Methods of processing and preservation of meat

Meat was originally processed to preserve it, but since the various procedures cause so many changes in texture and flavour it is also a means of adding variety to the diet. Processing also provides scope to mix the less desirable parts of the carcass with lean meat and in addition is a means of extending meat supplies by including other foodstuffs such as cereal in the product.

Meat is a highly perishable products and soon becomes unfit to eat and possibly dangerous to health through microbial growth, chemical change and breakdown by endogenous enzymes.

These processes can be curtailed by reducing the temperature sufficiently to slow down or inhibit the growth of micro-organisms, by heating to destroy organisms and enzymes (cooking, canning), or by removal of water by drying or osmotic control (binding the water with salt or other substances so that it becomes unavailable to the organisms). It is also possible to use chemicals to inhibit growth and, very recently, ionising radiation (however, the last is not allowed in some countries).

Traditional methods that have been used for thousands of years involve drying in wind and sun, salting and smoking. Canning dates from early in the 19th century and allows food to be stored for many years since it is sterilised and protected from recontamination.

Chilling and Freezing

While mechanical refrigeration is a modern process it is known that the ancient Romans kept food cool with ice. "Chilled" meat is usually stored at temperatures around 1C to +4C when it keeps well for several days. Provided that the meat is kept very cool(1C to 0C) and that slaughter and meat cutting are carried out under strict hygienic conditions, modern packaging techniques including storage under carbon dioxide or nitrogen or in vacuum can extend this period to about 10 weeks.

Chilling at temperatures very close to the freezing point of meat, -15C, diminishes the dangers of most pathogens and slows the growth of spoilage organisms; growth of some organisms, moulds, virtually ceases at -10C.

Most pathogens (Salmonella, Staphylococcus species and Clostridium perfringens) are inhibited by cooling but Listeria monocytogenes can grow at + 2C, some Salmonella species at +5C and Campylobaner at +7C.

Non-pathogens include Pseudomonas species which predominate on the exposed surface of chilled meat and Laaobacilli on vacuum-packed meat.

Freezing - commercially at -29C and domestically at -18C - is now a standard method of preserving for periods of 1-2 years but there is some deterioration of eating quality compared with fresh or chilled meat.

However, there are problems in chilling and freezing meat. If it is cooled too rapidly below 10C before the pH of the muscle has fallen below a value of about 6, the muscle fibres contract (cold shortening) and the meat is tough when cooked. This problem applies more to small animals, such as lamb, which cool down rapidly. The modern procedure is to cool the carcass to 10-15C ("conditioning") and to hold that temperature for a few hours until the pH has fallen to 6. Beef carcasses can be suspended in such a way as to exert a pull on certain muscles to prevent contraction. Another method is to apply electrical stimulation to the carcass after slaughter (low volt) or after evisceration (high volt) for 2-4 minutes to bring down the pH rapidly.

Another problem can arise during thawing of pre-rigor frozen meat when the muscle contracts and exudes a substantial part of its weight as tissue fluids (thaw rigor) (Lawrie 1991). Clearly, freezing of meat is not a straightforward procedure and calls for certain expertise. Only post-rigor meat should be frozen.

Nutritional Changes by Freezing

Meat is frozen without any prior treatment, unlike vegetables which have to undergo a preliminary blanching process to destroy enzymes involving considerable loss of water-soluble nutrients. So there is little or no loss of nutrients during the freezing procedure, nor, so far as there is reliable evidence, during frozen storage - apart from vitamin E.

Proteins are unchanged during frozen storage but fats are susceptible to rancidity. Pork and poultry meat are more susceptible since they are richer in unsaturated fatty acids than other meats, and comminuted meat is also very susceptible to rancidity because of the large surface area which is accessible to oxygen.

The vitamin E is damaged because the first products of fat rancidity, hydroperoxides, are stable at the low temperature and oxidise the vitamin. At room temperature they break down to harmless peroxides, aldehydes and ketones, so that vitamin E is more stable at room temperature than during frozen storage.

The losses incurred in frozen meat mostly take place when the meat is thawed, and juices are exuded containing soluble proteins, vitamins and minerals. This is termed "dripthaw" and the amount depends on the length of time of ageing (time between slaughter and freezing), whether frozen as carcass or meat cuts, conditions of freezing and speed of thawing; it varies between 1% and 10% of the weight of the meat and is usually about 5%.

There is some loss of nutrients when the meat is cooked after thawing; results published in the scientific literature tend to measure the combined losses from the original fresh meat to the final cooked product. Unfortunately the results vary so much that it is not possible to draw conclusions.

It must be emphasised that the variations are largely due to difficulties in analysis of the B vitamins, and to differences in conditions and methodology - even results from the same laboratories are inconsistent. This is illustrated very clearly by results published from one group of investigators who examined pork loin after freezing and storage at -12C and 24C and subsequent cooking at regular intervals over one year for changes in thiamin, riboflavin and pyridoxine (Mikkelsen, Rasmussen and Zinck 1984). Despite constant experimental conditions analyses at two monthly intervals showed wide fluctuations, especially for thiamin, which were attributed by the authors to difficulties in analytical methods.

It was tentatively concluded after storage at -12C and cooking that about 90% of the thiamin was retained but no firm conclusions could be drawn about other vitamins. No conclusions could be drawn about storage at the lower temperature!

For riboflavin about 90% was retained at -12C and 100% after storage at -24C and cooking, although these results were also variable.

For pyridoxine 80% was retained when stored at -12C and cooked but the results were erratic.

In the same report ground beef was examined only after 1 year storage and showed 80% retention of thiamine, 85% of riboflavin and 100% of pyridoxine at both temperatures.

A summary of earlier work (Fennema 1975) suggested that losses during freezing and storage of meat and poultry for 6 - 12 months at -18C but excluding subsequent cooking, ranged between zero and 30% for thiamin, riboflavin, niacin and pyridoxine. A survey of frozen meals analysed after freezing, storage and cooking reported losses of up to 85% of thiamin, 55% of vitamin A, 33% vitamin E, 25% niacin and pyridoxine (De Ritter et al 1974).

Little research in this area has been reported in recent years and this limited number of reports illustrates the difficulty of making even generalisations about the stability of vitamins in frozen meat products.

Processing - General Aspects

Processed meats are products in which the properties of fresh meat have been modified by the use of procedures such as mincing, grinding or chopping, salting and curing, addition of seasonings and other food materials, and, in many instances heat treatment. Most of these processes extend the shelf life of meat. Their manufacture, in most instances, depends on the ability of the mixture to retain water since they are emulsions of protein, fat and water.

Meat Content of Processed Meats

Where there is a demand for consumer protection it is often necessary to legislate to control the meat content of products that include other food ingredients.

Even if no additives are included meat products can contain variable amounts of lean muscle tissue, fat and connective tissue. A method of assessing the apparent meat content of a raw product is by determination of the total nitrogen content on a fat-free basis and multiplying by an average conversion factor, corrections being applied for the contributions from cereals or other nitrogen-containing ingredients e.g. 3.45 for pork products, 3.55 for beef, 3.7 for chicken (3.9 for breast of chicken and 3.6 for dark meat), 3.45 for ox liver, 3.65 for pig liver (3.55 for liver of unknown origin), 2.7 for kidney, 3.2 for blood and 3.0 for tongue. There are no agreed factors for conversion of nitrogen for cooked, cured or processed meat and the apparent meat content of such products is expressed approximately in terms of "raw meat equivalents" (Egan, Kirk and Sawyer 1981).

Other methods used for legal control purposes refer the composition of meat products directly to the nitrogen or protein content of the dry, fat-free product or to the water: nitrogen ratio. Lean meat can be determined directly by measurement of 3-methyl histidine which is characteristic of meat protein but if large amounts of fillers and binders are present the method is unreliable.

The proximate composition of some processed meat products is given in Tables 216, United Kingdom products, and 2-18, United States products; in both instances the composition is regulated so these data are not universally applicable and serve only as examples.

Curing

Curing was originally a term applied to preservation in general but is now restricted to preservation with salt (sodium chloride) and sodium or potassium nitrite or nitrate or a mixture of these two salts. The nitrate serves as a reservoir for nitrite - the active compound - since bacteria in the curing solution form it from the nitrate.

The use of salt is one of the oldest methods of preserving meat since at concentrations greater than 4% in the aqueous phase it inhibits the growth of most spoilage organisms. To function as a complete preservative the salt concentration would need to be around 17%, at which levels the product would be unpalatable. In most cured meat products the salt concentration is between 2.5 and 5% and the nitrite inhibits the growth of other organisms. Nitrite also reacts with proteins when heated to form compounds (called Perigotype factors) that inhibit the development of spores of Clostridium botulinum, the cause of botulism, the most serious type of food poisoning.

Additionally, nitrite is broken down to nitric oxide, which reacts with the red colouring matter in muscle, myoglobin to form deep-red nitrosomyoglobin. As the protein is denatured, this is converted, rapidly when heated and more slowly otherwise, into a pink compound which is responsible for the typical colour of cooked ham, canned luncheon meat, franfurters and raw ham, dry sausage, etc.

The early curing procedures were lengthy and recent developments have led to a reduction in the time required. For example instead of simply immersing the meat in brine it is first injected with the curing solution and the process can be completed in 1 - 2 weeks. Thin slices of meat such as bacon can be cured in a few hours, and the processing time can be reduced to a few minutes if heated and if the cure is completed in the final package.

Animal experiments have shown potential risk from nitrosamines formed from nitrite but, as discussed in Chapter 3, the amounts present do not appear to be harmful to human beings.

The addition of sodium ascorbate to the pickling brine accelerates the curing process because of its reducing capacity and allows smaller amounts of nitrite to be used, so there is less residual nitrite in the meat which reduces the possibilities of the formation of nitrosamines. Residual ascorbic acid has an antioxidant effect in stabilising the colour and preventing rancidity.

Tumbling and Massaging

A new technique was developed in the 1960's to accelerate the penetration of salt. Pieces of meat are injected with the curing salt solution or chopped meat immersed in it and then mechanically shaken - "tumbled". Solutions of 2-8% salt are used, sometimes with the addition of polyphosphate, when there is some extraction of water-soluble protein, mainly myosin. The effect is to improve the water-holding capacity of the meat by reaction between the salt and the structural proteins, aided by the polyphosphate. The extracted proteins set to a strong gel on heating and so bind together the pieces of meat, which can then be shaped or sliced.

The term "massaging" is applied to a relatively gentle mechanical treatment while "tumbling" is a more vigorous action.

Smoking

Meat has been treated with smoke from the earliest days - traditionally over a wood fire and more recently by producing smoke from wood sawdust in a generator and conducting the smoke over the meat.

The substances deposited on the meat contribute to the flavour and appearance but with ordinary, light smoking the preservative effect is limited and the product has to be stored refrigerated.

Intensive smoking does prolong shelf life both by heavier deposition of preservatives and by the drying effect of the hot air but it has a detrimental effect on flavour. Consequently preservation by smoking is regarded as an emergency measure when other methods cannot be used.

A modern development making use of the flavouring effect is to use an aqueous solution of the constituents of smoke which reduces the amount of strongly flavoured and other unwanted substances.

Processed meat products

Common Cured Meat Products

The commonest cured products are sausages, bacon, pork shoulder, ham, luncheon meat; any type of meat can be cured either as whole cuts or after comminution.

Bacon is cured pork, in various countries traditionally made from specified parts of the pig but it can be made from any part. There are modifications of the process including so called sweet cure with added sugar (0.25%) and mild cure with less salt.

Bacon can vary greatly in the amount of fat and there are considerable differences between the various published figures; those shown in Table 2-16 are from the same source and so are comparable with one another.

Ham is the cured product of the upper leg and buttock of the pig and differs from gammon only in that the latter is cut from the side of bacon after it has been cured. It is stable when raw after a certain period of maturation but is often cooked to pasteurisation temperature, 70C, or it may be canned at pasteurising temperature. It may be smoked as an additional means of preservation and flavouring.

Typical analysis of canned ham per 100 g: 65-72 g water, 18 g protein, 5-12 g fat, 0.5-0.8 MJ, 1100-1250 mg sodium, 1.2-2.7 mg iron, 0.2 mg copper, 2 mg zinc, 0.5 mg thiamin, 0.2-0.25 mg riboflavin, 4 mg niacin, 0.2 mg vitamin B6, and may have residual ascorbic acid 10-60 ma.

Sausages

There are some 800 types of sausage made of comminuted or chopped meat of various kinds, seasoned with salt and spices, often mixed with cereal and packed into natural casings (consisting of the connective and muscle tissue of animal intestines) or made of cellulose, collagen or synthetic materials. There are six main types of sausage - fresh, smoked, cooked, smoked and cooked, semi-dry and dry.

Frankfurters, Bologna, Polish and Berliner sausages are generally made from beef, pork and pork fat comminuted with the addition of curing salts and are smoked and cooked. Thuringer, soft salami, mortadella, and soft cervelat are cooked and semi-dry; pepperoni, chorizos, dry salami and dry cervelat are slowly dried to a hard texture without cooking. The nutrient content of a number of products is given in Table 2-18. There are several variants of each type of sausage; for example, a US table of food composition (Watt and Merrill 1975) includes six types of Frankfurters, namely all meat, with non-fat dried milk with cereal and with both these additions, also raw and canned.

Table 2-18 includes two figures from Great Britain which differ considerably from the US figures.

These differences can be attributed to variations in composition and method of analysis, and serve to illustrate the approximate nature of any tables of nutrient contents of processed meat products. A major reason for the difference in thiamin content in some comminuted meat products between US and UK tables, is the use of a preservative in UK, namely sulphur dioxide, which destroys most of the thiamin.

Liver sausage contains 10-20% liver and in many cases other edible offals. Blood sausage contains 10-20% whole blood with nitrite salt (not precooked). Other components are precooked meat, edible offals, fatty tissue (cooked sufficiently to separate fat with a low melting point) and pigskin. This type of sausage has a firm consistency due to swollen connective tissue and gelatinized collagen.

Fermented sausages are dry sausages including salami, dry pork and beef sausages and summer sausages, that have been subjected to bacterial fermentation. Meat from a variety of animals may be used, including camel, donkey and horse but rarely mutton, goat or venison. Only well-chilled or frozen meat is used and a temperature of -2 to +5C maintained during chopping to facilitate comminuting of lean and fatty tissues to the particle size desired and to avoid deposition of fat drops in the batter. Added salt prevents the growth of unwanted micro-organisms and extracts salt-soluble proteins to form a protein gel which binds the pieces of meat together. The bacteria originate from the natural flora of the meat and the environment although starter cultures of Micrococcus, Pediococcus cerevisiae, etc., are sometimes used.

During the slow, prolonged fermentation the pH falls to between 4.8 and 5.4 then the product is dried and may be smoked. Fermented sausage is not cooked and preservation depends on the high acidity and high salt content toegther with the low water content.

Additives

Comminuted products such as sausages and luncheon meats are based on lean meat, which, technologically, provides water-holding and meat-binding capacity, with the addition of fatty meats and, sometimes, organ meats. The amount of these is limited otherwise the products have an unattractive soft texture and high shrinkage on cooking.

The ingredients include cereals and potato starch, termed fillers, which also serve to bulk out the supply of meat products ("meat extenders"). Other ingredients include a number of substances which have considerable water-holding and binding capacity ("binders"). These include egg or egg yolk blood plasma, skim milk powder, caseinates, soya isolates, wheat gluten, whey protein and dehydrated products derived from various vegetable proteins (soybean, safflower, corn, peanut and pea protein) and their binding properties depend on their ability to form irreversible gels on mild heating which serve to hold together the small pieces of meat.

It is not posssible to generalise about the nutritional value of products of such variable composition.

Other Comminuted Products

These are made from chopped (minced, ground) meat and fat and usually include meat from various parts of the animal including trimmings. In specific products organ meats are also used

(Table 2 - 17). Some tissues can be included only in restricted amounts because their texture can adversely affect the product.

Other ingredients are included for the purposes of ekeing out meat supplies or for their capacity to bind the minced pieces (See Additives later) and seasoning.

Seasoning is a comprehensive term for ingredients intended to improve flavour such as salt, pepper, spices, herbs and vegetables. Spices commonly used include cinnamon, cassia, clove, ginger, mace, nutmeg, paprika, cardamom, coriander and mustard; herbs include sage, savory, bay leaves, thyme and rosemary; onions and garlic are also used.

Liver and blood have a pronounced colour and flavour and can be included in comminuted meat products only in limited amounts (15-50% of the total) depending on the local acceptability or may be used in specific liver or blood sausages.

Pates can be included with comminuted products since they are made from coarsely or finely chopped meats, precooked and seasoned, and some are cured with salt, nitrite and phosphate.

Luncheon Meat

This is the name given to several products made from finely chopped meat and fat with the addition of cereal and water, preserved by the addition of salt and nitrite and by heating.

Although the nutrient content is very variable a typical analysis of a canned product of this type, per 100 g is:- 5 g water, 13 g protein, 27 g fat (10 g saturated, 12g monounsturated, 3 g polyunsaturated, 70 g cholesterol), 1.3 MJ, 1000 mg sodium, 1 mg iron, 0.3 mg copper, 2 mg zinc, 0.07 mg B1, 1.8 mg nicotinic acid, 1 mg B12.

Corned Beef

This was originally a by-product from the manufacture of meat extract when it was the only meat product that could be shipped from South America before the introduction of refrigerated transport. The latter is made by hot water extraction of the low quality meat from animals that have taken several years on relatively poor pasture to reach suitable size so is relatively rich in connective tissue (as well as in muscle extractives). The meat is coarsely chopped and immersed in hot water to extract the solubles; the exhausted meat is cured by the addition of coarse grains of salt ("corns") and nitrite and canned, often with the addition of fat. It has an extremely long shelf-life and used to play a major role in military rations and in expeditions.

Other meats such as mutton can be treated similarly and some modern processes use unextracted beef.

In the United States the term "corned beef" is applied to what is elsewhere termed "salt beef" i.e. cured whole beef.

Since corned beef is made from extracted meat it is low in water-soluble vitamins, containing per 100 g only a trace of thiamin, 2.5 mg nicotinic acid, 0.2 mg riboflavin, 2 mg B12, 3 mg iron, 0.25 mg copper, 6 mg zinc, together with 950 mg sodium and 60 g water, 26 g protein, 12 g fat and supplying 0.9 Ml (220 kcal).

Burgers

Patties made from minced meat have become popular world-wide through the agency of international fast-food outlets. These were originally hamburgers made from beef with the name derived from the Hamburger sausage but may be made from any meat and "muttonburgers" are marketed in regions where beef is not eaten.

The meat content varies from 100% including about 20% fat, to 80% or less with various additions of cereals, onion and water. Since the pattie is raw it is stored frozen.

Typical composition per 100 g raw hamburgers made from 90% meat is;- 56 g water, 15 g protein, 20 g fat (10 g saturated, 9 g monounsaturated, 1 g polyunsaturated, 100 mg cholesterol), 1.1 Ml, 600 mg sodium, 2.5 mg iron, 0.25 mg copper, 3 mg zinc, 0.04 mg B1, 0.2 mg B2, 4 mg nicotinic acid, 0.2 mg B6, 1 ug B12, 1 mg folate, 0.4 mg pantothenate.

Frying causes a small loss of water, about 5%, and a greater loss of fat depending on the method used - whether under a grill, on a heated surface or over a direct flame. Other nutrients, including protein, are proportionately increased.

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Drying

Micro-organisms cannot grow unless there is sufficient moisture available to them and drying meat under conditions of natural temperatures and humidity with circulation of air and the assistance of sunshine is the oldest method of preservation (FAO 1990 c).

The free water in a food product, i.e. excluding the water bound to proteins, is termed the water activity (aw). Free water is that part that can be removed as water vapour (and is not the same as the total moisture content). "Water activity" is defined as the ratio of water vapour pressure measured in the product to the pressure of a saturated water vapour atmosphere at the same temperature.

The minimum moisture content necessary for bacterial growth varies with the type of organism. The lowest value for normal bacteria is water activity 0.91; for normal yeasts it is 0.88; for normal moulds 0.80; and for salt-tolerant (halophilic) bacteria it is 0.77.So water activity must be reduced below these levels to preserve the food.

Muscle meat of almost any kind can be dried but it is necessary to use lean meat since fat becomes rancid during the drying process. Drying involves the removal of moisture from the outer layers and the migration of moisture from the inside to the outside, so the pieces of food must be thin. The meat is cut into long thin strips or flat thin pieces and preferably salted, either dry or by dipping into salt solution, to inhibit bacterial growth and to protect from insects.

The pieces are suspended in racks in freely circulating air under hygienic conditions and protected from dirt and dust for the several days required. If the air is warm and of low humidity with relatively small temperature fluctuations between day and night the time needed will be shorter. Slow drying allows deterioration since micro-organisms can multiply in the early stages while the moisture content is still high enough. Another problem arises from the practice in developing countries of using meat from unchilled carcasses and while the temperature is still high the meat ripens rapidly so changing the flavour. At the same time there is some oxidation of the fat so further lowering the quality of the finished product.

There are a number of traditional dried products in various regions. For example biltong in South Africa, which is made from beef or antelope meat cut into strips 1 - 2 cm thick, salted, with the addition of nitrate or nitrite , spiced and dried in air for 1 - 2 weeks.

The outer layer of biltong is hard and brown with a soft, inner, red inside, and is eaten raw. It will keep for a year if stored in airtight packaging.

Typical analysis per 100 g: 11.5 g water, 1.9 g fat, 12.5 g ash, 65 g protein, 1.3 MJ (300 kcal).

Jerked beef or charque is the product used in South America which may be made from beef, llama, sheep, alpaca. The fresh meat is cut into large pieces no more than 5 cm thick, salted, pressed for several days and dried - but it still contains moisture which is allowed to drain freely from the product. It keeps for months at ambient temperatures and is resistant to insect infestation and mould growth.

Pemmican is dried meat that has been powdered or shredded and mixed with fat to form a solid product. Typical analysis per 100 g:- 3 g water, 40 g protein, 45 g fat, 2.4 MJ. Pemmican was almost a routine food taken on earlier expeditions until replaced by modern types of dried meat products.

Other traditional dried products include pastirma (Turkey, Egypt and Armenia), odka (Somalia and other countries of East Africa), qwanta (Ethiopia and East Africa) and kilishi (Nigeria and West Africa). There is a variable loss of vitamins from such products due to the long drying times which can be shortened by the use of modern drying techniques.

Such a procedure is freeze-drying which causes little or no loss of vitamins and results in products which are readily rehydrated and much closer in texture and flavour to fresh meat than the traditional dried product but calls for specialised equipment.

Partial Drying/Intermediate-Moisture Foods

In dried meats the water activity is below levels needed for microbial growth so the product is shelf-stable but there will still be chemical and physical changes due to rancidity and discolouration which call for adequate packaging. Some products such as "dry" sausages and hams cannot be dried adequately without spoiling the product - they are termed "semi-dry" - so it is necessary to combine an incomplete reduction in water activity with other methods such as lowering of pH or the addition of nitrate.

In an attempt to avoid the relatively poor texture and flavour of most dried meat products a modern development is partial drying to a moisture content of 15 to 50% and then reduction of free water to the required low levels by adding humectants such as glycerol, sorbitol or other polyhydric alcohols which combine with the free water so that it cannot be used by the micro-organisms.

The meat is cut into small pieces and treated with a mild salt solution, and the humectant and an antimycotic (anti-mould agent) are added and the meat cooked to 70C before packaging. It will keep for several months even at 38C but there are changes in texture, colour and flavour (Lawrie 1991).

Products preserved in this way are called intermediate-moisture foods and they are more succulent than dried foods but the humectants spoil the palatability and the process has been limited to animal foods in industrialised communities and for military purposes.

<u>Canning</u>

Micro-organisms can be completely destroyed by heat (sterilisation) but a sterile product can be readily recontaminated unless it is protected. This is achieved by heating in an air-tight can or bottle, or, more recently, in a heat-resistant or aluminium foil-laminated plastic pouch. Sausages can be filled into retortable synthetic casings sealed with aluminium clips.

The procedure is to seal the food into the container and then heat it under pressure in an autoclave (retort) to the required temperature for the required length of time and to cool rapidly to avoid overheating. Overheating results in too soft a consistency and a burnt taste. It is not always possible to destroy all the organisms without excessive heat which would spoil the product so the objective is to destroy the greater proportion of the organisms when the remaining few pose no hazard so long as the container is cooled rapidly and stored below 20-25C. This condition is termed "commercially sterile". The established standard is equivalent to a reduction in the number of micro-organisms by a factor of 10 to the power of 12 so it is clear that the higher the initial load of organisms the more will survive a standard heat treatment.

The intensity of heat treatment necessary depends on the nature of the product, its pH, and the amount of salt and other curing agents present as well as on the bacterial load. The time required at a given temperature will vary with the rate of heat penetration to the centre and so with the size of the container.

The intensity of heat treatment is defined in physical terms called F-value, which means that the product received heat treatment with the same effect on micro-organisms as exposure to a temperature of 121C for 1 minute. The standard is based on the time required at a temperature of 121C to destroy all spores of Clostridium botulinum, the most dangerous of all toxin-producing organisms. This is termed "the botulinum cook" and such treatment destroys practically all spoilage and other organisms. It takes 2.45 minutes at 121C to destroy all C. botulinum spores;

this is an F-value of 2.45. Spores of other organisms are less or more heat-resistant. F-value 1 is the lethal effect on micro-organisms after 1 minute at 121C; F-value 2 (3,4) is the lethal effect after 2 (3,4) minutes.

At temperatures greater than 121C a shorter time is needed to achieve the F-value of 1, thus at 130C the time is 0.13 min. Correspondingly the time is longer at lower temperatures, thus at 115C the time is 4 min at 105C it is 40 min.

These conditions apply to foods of low acidity (pH above a value of 5) and medium acidity (pH 4.5 - 5); with more acid foods the spores of micro-organisms are less heatresistant. Meat products are mostly low-acid, while meat and vegetable mixtures are medium -acid. In practice once the F-value has been determined for a batch of food according to the size of the container the heat treatment required to treat subsequent batches is the same. Generally it has been shown that F-value 4 will usually ensure commercial sterility. Larger canned products may require F-values up to 20-25 owing to the longer periods required for heat penetration.

A fully-treated product of this type will keep for up to 4 years at ambient temperatures but even fully-preserved meat can contain a very heat-stable spore former, Clostridium sporogenes, which poses a hazard only when stored under extreme climatic conditions, namely at temperatures above about 40C If canned meat is to be stored under such conditions then it must be treated more intensively, F-value 12 or more ("tropical preservation") and then has a shelf life up to 4 years.

Virtually every type of meat product made from chopped, cured meat can be canned, as well as stewed meat, dishes in jelly, soups with meat ingredients, and pastas and sausages in brine.

Products such as luncheon meats, liver sausage, blood sausage and jellied products are adversely affected by high temperatures and are "three-quarters preserved" at F-values 0.6 to 0.8. The temperature reached at the centre of the pack is between 108 and 112C and the product is stable for up to 1 year if stored at temperatures no higher than 15C.

Cooked preserved products are simply boiled until the central temperature reaches near to 100C and they can be stored (protected from contamination) for 1 year at temperatures no higher than 10C.

Smaller size containers are most suitable for meat products because heat penetration is mostly by conduction so larger containers would require severe heat treatment involving overcooking. Large pieces of meat products such as hams, shoulders, etc., are pasteurised. Pasteurisation is a more gentle process intended to destroy only pathogenic organisms and the treatment limits the central temperature to about 80C (Fvalue almost zero). This destroys only vegetative cells and refrigeration is necessary to prevent germination of spores. Pasteurised products must be stored between 2 and 4C when they have a shelf life up to 6 months.

The temperatures quoted must be reached in the centre of the pack to ensure that the entire contents are adequately heated but protein and fat are poor heat conductors. If there is enough liquid in the can, such as meat cooked in gravy, Frankfurters in brine, or through release of liquid from the meat and liquefaction of the fat, heat can penetrate by convection as well as conduction if the can is rotated during the process. This allows a shorter heating time with less damage to flavour, texture and nutrients, and the outer layer of the food is not overheated.

Canning operations must be performed only by fully-trained personnel (FAO 1990c; Hershom and Hulland 1980).

High-temperature Short-time Processing (HTST)

Since the effect of heat in speeding up biological reactions (in this instance destruction of micro-organisms) is greater than the acceleration of chemical reactions (in this instance damage to protein and other nutrients) heating to a higher temperature for a shorter time is an effective means of preservation. Sterilisationis achieved in a shorter time with less damage to the product. The process is termed high-temperature short-time heating (HTST) and has been particularly applied to milk but can be applied to meat if there is sufficient liquid present to allow mixing of the contents by rotating the cans in the autoclave. The cans must be cooled immediately after the temperature of sterilisation has been reached to avoid overheating.

Nutritional Damage

Most of the investigations of nutritional changes in canning have involved fullypreserved foods. There are large differences reported in the literature due to differences in raw materials and conditions of processing.

Thiamin is the most labile of the vitamins and reported losses range between 20 and 40%. This is heat destruction since any water-soluble nutrient that is leached out of the meat will be retained in the can and is usually consumed together with the meat. Losses of niacin and riboflavin are about 10%, 20% of biotin, 20-30% of pantothenate.

If more accurate figures are required they would need to be determined on the specific procedure in the factory in question on the particular product.

In principle losses in canning are somewhat higher than in wet cooking since the temperature is higher, and for the parallel reason less than losses in dry cooking methods such as roasting, grilling and frying where the temperature at the surface can be between 180 and 350C So far as proteins are concerned there is some small reduction in biological value due to reduced availability of methionine and cystine. Semi-preserved meat products heated to temperatures not exceeding 100C do not suffer this damage.

The heat applied causes partial hydrolysis of the collagen so that tough meat, rich in collagen, is rendered more palatable by being canned.

During storage after canning there can be a loss of thiamin of as much as 30% depending on the length of time, and at higher storage temperatures there can be a reduction in protein quality.

Fat Embedding

A traditional process that is parallel to canning is that of cooking the meat in a vessel that can be sealed under a layer of melted fat and so protected from recontamination.

An example of such a product is mixiria of the Amazon region where the meat is roasted, sliced and sealed in jars. The layer of fat not only protects the meat from contamination but excludes oxygen, however, organisms can survive so the method is not dependable.

The process of fat embedding was tested by the Australian meat trade in the 19th century - beef was packed into barrels and covered with fat heated to 150C - but superseded by refrigeration.

It is used to a very limited extent in some industrialised countries, in particular for a product called "potted shrimps", which have been cooked in butter and sealed into jars.

Ionising Irradiation

Micro-organisms can be destroyed by subjecting a food to ionising radiation produced from radioactive or electromagnetic sources. High doses (50 kiloGrays - kGy) are required for sterilisation of meat while recommendations of WHO and legislation in most, if not all, countries limit the dose at present to 10 kGy, simply because safety has been established up to this level.

The 10 kGy dose does not sterilise the product but substantially reduces the bacterial load and is effective in destroying many pathogens including Salmonellae. A dose of 2 - 5 kGy will extend the shelf life of poultry stored at 1-3C by 8-14 days. Irradiation is of no value as a means of "cleaning up". heavily contaminated food since it would still carry a considerable microbial load, nor does it destroy toxins once they have been produced. Indeed, in some countries where irradiation is permitted microbiological standards are specified for foods to be treated. Irradiation of spices to be used for meat products has proved to be an effective way of lowering their microbial content and so increasing the shelf life of the products.

Although the preservation of food by irradiation has been intensively studied for many years its commercial application is still in its infancy. There are many problems involved since the process calls for heavy investment in factory plant and is regarded with some suspicion by consumers. Moreover irradiation does not destroy enzymes so the meat softens during storage.

Since the radiation penetrates into the product it also penetrates packaging so the food can be protected from recontamination by adequate wrapping before irradiation.

In general irradiation has some deleterious effect on vitamins but the amount of damage is not considered nutritionally significant (Codex 1984A).

Recent developments in meat processing

Mechanically Recovered Meat (MRM)

Also termed mechanically deboned and mechanically separated meat.

When bones are trimmed of adhering meat by hand some of the meat is left attached to the bones. It is said that some 2 million tonnes of meat world -wide are discarded with the bone. This can be recovered by a mechanical scraping process in which bones with adhering meat are generally broken into small pieces and the soft components, meat, fat etc., forced through perforated screens and recovered as a finely comminuted product consisting of a gel of meat, fat and sometimes marrow from the inside of the bones together with fine particles of bone. The bone content should be reduced to a minimum; it has been recommended that the calcium content of MRM expressed on a dry matter basis should not exceed 1.5% (Codex 1983).

MRM can increase the overall profitability of meat production not only by increasing meat yield but also by providing a product with emulsifying properties useful in preparing comminuted meat products. Generally MRM is less acceptable than ordinary muscle meat because it is darker in colour due to its high content of haeme protein, and more readily oxidised because of the high fat content.

Because of its physical state and the longer process MRM is subject to heavy microbial contamination; if not used immediately it needs freezing to prevent decomposition.

Reformed Meat Products

Apart from the high regard for certain cuts of meat in some areas there is a growing demand for lean rather than fatty cuts. The high cost of such products has led to the use of other, less expensive cuts of meat which are higher in content of connective tissue but can have some of this tissue, together with skin and gristle, removed in a process of comminution and reformation.

The pieces of meat are treated in a tumbling device with brine which penetrates the tissues and extracts some of the myofibrillar protein to form a gel (as descibed earlier).

At a low temperature the product can be compressed into thin flakes which bind together when the meat is heated, sometimes with the addition of binding agents such as wheat gluten, egg albumin and soya; the final product can be shaped or sliced.

The nutritive value of reformed meat products depends on the tissue used and the added ingredients, and approximates to that of comminuted products.

Protein Extraction

A recently discovered but highly technical process for recovering edible foodstuffs from by-products of low acceptability (such as lungs and stomachs) is extraction of the proteins.

The procedure is similar to that of preparing textured vegetable proteins usually made to simulate meat. The proteins are extracted in alkali and reprecipitated from solution by acidifying. If the alkaline solution is forced through fine tubes (spinnerets) into the acid solution it is precipitated in the form of long fibres which can be pressed and texturised to a solid form. High temperature extrusion is also used. Other materials such as soya can be incorporated.

There is an added advantage in that the number of micro-organisms is greatly reduced during the process.

A recent method of using low quality meats is the application of the Japanese fish surimi process to meat and poultry by-products. This consists of mechanically deboning and washing to remove water-soluble proteins, enzymes, minerals and fat to leave a product that is stable and with a high concentration of salt-soluble myofibrillar proteins that have the capacity to form strong elastic gels when gently heated. Fish surimi is used to make a range of products by extrusion and shaping and it seems possible to apply the procedure to meat. Low-quality meat is rich in fat and the process is intended to remove the greater part of the fat and to make novel meat products or to add to traditional meat products such as sausages, sliced cooked meat and burgers or other foods.

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Chapter 3 - Meat and health

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Meat consumption role of meat in the diets

Meat consumption

Meat consumption is based largely on availability, price and tradition. Meat production is a very complex operation depending not only on demand (which is usually based on price and income) but on many social and economic influences such as official policy, price support mechanisms, and interrelations such as the interaction between beef and milk production, the availability of animal feedstuffs and competition for food between man and animals.

It is difficult to make accurate comparisons of meat consumption between countries because different methods are used to estimate consumption. Figures may be derived from total supplies available at wholesale level, or from records of household purchases, with or without estimates of what is consumed away from home; the estimate of waste, both in preparation of the food and by the individual adds to the uncertainty. Some national estimates fail to include imports, and some surveys include the weight of non-meat components of the products (for example the amount of meat in a product can range between 100% in some burgers to 10% in some pizzas). FAO Food Balance Sheets are prepared from figures for production, imports, stock changes and exports with allowances for feed, processing and "other uses" and the same methods are applied to all regions so that the figures, as in Table 1-1A, are comparable.

Up to a certain level of income the amount of meat eaten varies with income, in the relatively affluent western world where the proportion of available income spent on food has been steadily falling over the past generation, there is now little if any difference between the amounts of meat eaten by the different income groups. This contrasts with the Third World countries (FAO 1990a).

The amount of meat consumed in different countries varies enormously with social, economic and political influences, religious beliefs and geographical differences. It is very large in meat-producing areas such as Uruguay, Argentina, Australia and New Zealand, at 300 g per head per day compared with an average of 10 g in India Indonesia and Sri Lanka Table 1-1A shows the contrast between total meat supplies in developed and developing countries, allowing for exports, imports and stock changes, and Table 3-1 shows that the production per capita in the former is five times as much as in the developing countries. These tables also show the relative size of production of the different types of animals involved.

Role of meat in the diet of developed and developing countries

Meat is held in high esteem in most communities. It has prestige value, it is often regarded as the central food round which meals are planned, various types of meat are sometimes made the basis of festive and celebratory occasions, and from the popular as well as the scientific point of view, it is regarded as a food of high nutritive value.

While it is clear that meat is not essential in the diet, as witness the large number of vegetarians who have a nutritionally adequate diet, the inclusion of animal products makes it easier to ensure a good diet.

There is a marked difference at the present time in attitudes towards meat between the people of the developing and industrialised communities In the former where meat is in short supply it can be taken as a measure of the nutritional quality of the diet as a whole. Where a typical diet is heavily dependent on one type of cereal or root crop, meat, even in small amounts, complements the staple food. It provides a relatively rich source of wellabsorbed iron and also improves the absorption of iron from other foods, its amino acid composition complements that of many plant foods, and it is a concentrated source of B vitamins, including vitamin B12 which is absent from plant foods. Consequently there is pressure to increase the availability of meat products.

In the industrialised countries where food of all kinds is plentiful and cheap there is concern, whether or not misplaced, about the potentially harmful effects of a high intake of saturated fat from animal foods (discussed later), emphasis on continuous development of regulations dealing with hygiene in slaughter houses and during subsequent handling, concern about hormones administered to cattle, what is perceived as excessive addition of water to some processed products - concerns that can scarcely be afforded in developing countries when balanced against food supplies.

With increasing mechanisation in industrialised communities the steady fall in human energy expenditure and consequently in per capita food consumption poses a potential problem in achieving an adequate intake of nutrients even where there is an abundance of food available. With the variety of food available a diet of 8 Ml (2000 kcal) or more per day is likely to supply enough of all the nutrients, but when the intake is 6.5 to 7 MJ (1600-1800 kcal) per day the consumer needs to make an informed choice of foods to ensure an adequate intake of nutrients.

In western Europe the daily average energy intake of women is about 6.5 Ml and that of men 8 MJ (excluding alcohol) and there are reports of biochemical signs of deficiencies of several B vitamins and iron. It is not clear whether this is accompanied by functional defects.

In industrialised countries there have been slow but continuous changes over the years in the relative amounts of different types of meat consumed (beef, pork, lamb, poultry) depending partly on price and influenced by fashion, advertising, etc. In more recent years health aspects, more correctly, perceived health aspects, have become a factor.

The concerns about public health in industrialised countries where coronary heart disease and other "diseases of affluence. are common have led to recommendations to the public to modify their diet, popularised as Dietary Guidelines. These particularly recommend a reduction in fat consumption, especially saturated fatty acids and consequently, even if incorrectly, in red meat (discussed later). This has led in some sections of their populations to a relative increase in the consumption of poultry and fish at the expense of red meat.

In addition there is concern, whether or not misplaced, about the presence in meat of pesticides, residues of hormones and growth promoters used to increase yields, and concern about human diseases thought to be transmitted by beef, together with an increase, for many reasons, in vegetarianism.

Meat as a source of protein

Human Protein Requirements

Human requirements for protein have been thoroughly investigated over the years (FAD/WHO 1985) and are currently estimated to be 55 g per day for adult man and 45 g for woman. (There is a higher requirement in various disease states and conditions of stress).

These amounts refer to protein of what is termed "good quality" and highly digestible, otherwise the amount ingested must be increased proportionately to compensate for lower quality and lower digestibility.

Protein Quality

The quality of a protein is a measure of its ability to satisfy human requirements for the amino acids. All proteins, both dietary and tissue proteins, consist of two groups of amino acids - those that must be ingested ready-made, i.e. are essential in the diet, and those that can be synthesised in the body in adequate amounts from the essential amino acids. Eight of the 20 food amino acids are essential for adults and ten for children.

The quality of dietary protein can be measured in various ways (FAD/WHO 1991) but basically it is the ratio of the available amino acids in the food or diet compared with needs. In the earlier literature this was expressed on a percentage scale but with the adoption of the S.I. system of nomenclature it is expressed as a ratio. Thus a ratio of 1.0 (100 per cent) means that the amino acids available from the dietary proteins are in the exact proportions needed to satisfy human needs; a ratio of 05 means that the amount of one (or more) of the essential amino acids present is only half of that required. If one essential amino acid is completely absent (a circumstance that can occur only experimentally with isolated proteins since any food, let alone a whole diet, consists of a mixture of many proteins) the protein quality would be zero.

There is a popular impression, originating at one time from nutrition textbooks, that the qualities of proteins from animal sources are greatly superior to those from plant sources. This is true only to the extent that many animal sources have Net Protein Utilisation, NPU, (a measure of the usefulness of the protein to the body) around 0.75 while that of many, but not all plant foods is 0.5-0.6. However, after infancy people consume a wide variety of proteins from different foods and a shortfall in any essential amino acids in one food is usually made good, at least in part, by a relative surplus from another food - this is termed complementation. As a result the protein quality of whole diets even in developing countries rarely falls below NPU of 0.7, a value that can be compared with the average of 0.8 in industrialised countries (FAD/WHO 1985).

The value of meat in this respect is that it is a relatively concentrated source of protein, of high quality (NPU 0.75-0.8), highly digestible, about 0.95 compared with 0.8-0.9 for many plant foods, and it supplies a relative surplus of one essential amino acid, lysine which is in relatively short supply in most cereals.

Effect of Cooking on Protein Quality

Apart from the inherent quality of the various proteins a reduction in quality takes place if there is damage to amino acids when the food is cooked. At a temperature below 100C when proteins are coagulated, there is no change in nutritional quality.

The first changes take place when food is heated to temperatures around 100C in the presence of moisture and reducing sugars, present naturally or added to the food. There is a chemical reaction between part of one essential amino acid, lysine and a sugar to form a bond that cannot be broken during digestion, and so part of the lysine is rendered unavailable.

When proteins are analysed in order to determine their amino acid composition the procedure involves a preliminary hydrolysis with strong acid which does break the lysinesugar bond, so chemical analysis does not reveal this type of damage and special methods are needed. At a higher temperature or with more prolonged heating, the lysine in the food protein can react with other chemical groupings within the protein itself and more becomes unavailable. In addition the sulphur amino acids (cystine which is not essential and methionine which is) are rendered partly unavailable.

The lysine-sugar reaction results in a brown-coloured compound (the so-called browning or Maillard reaction) which produces an attractive flavour in food and is the main cause of the colour of bread crust and roast meat. While such severe heating reduces the amount of lysine available in these foods the loss is nutritionally insignificant since it affects only a very small fraction of the total amount present.

At the temperature needed to cook meat there is little loss of available lysine or the sulphur amino acids but there can be some loss if the meat is heated together with reducing substances, as may be present when meat is canned with the addition of starch-containing gravy or other ingredients.

Overall the damage to protein caused by cooking is of little practical significance and it can be argued that if there is meat in the diet it is likely that the quantity of protein would compensate for any shortfall in quality.

The nutritional quality of the proteins of meat rich in connective tissue is low since collagen and elastin are poor in the sulphur amino acids - there is only 0.8 g of each per 100 g of total protein compared with values of 2.6 and 1.3 of each respectively in "good meat. Meat is tough to eat when it is rich in connective tissue and such meat is often used for canning since the relatively high temperature involved in the sterilisation process partly hydrolyses the collagen so making the product more palatable. However, it still results in a product with NPU as low as 0.5 compared with a value of 0.75 - 0.8 for good quality meat (Bender and Zia 1976).

Adequacy of Dietary Protein

The protein requirement of an individual is defined as the lowest level of protein intake that will balance the loss of nitrogen from the body in persons maintaining energy balance at modest levels of physical activity (FAD/WHO 1985). The "requirement" must allow for desirable rates of deposition of protein during growth and pregnancy. When energy intake is inadequate some of the dietary protein is diverted from tissue synthesis to supply energy for general physical activity - this occurs at times of food shortage and also in disease states where food is incompletely absorbed and utilised.

A diet adequate in energy is almost always adequate in protein - both in quantity and quality. For example, an adult needs an amount of protein that is equivalent to 7 - 8% of the total energy intake, and since most cereals contain 8 - 12% protein even a diet composed entirely of cereal would, if enough were available and could be consumed to satisfy energy needs, satisfy protein needs at the same time. Growing children and pregnant and nursing mothers have higher protein requirements as do people suffering from infections, intestinal parasites and conditions in which protein catabolism is enhanced. During the stress that accompanies fevers, broken bones, burns and other traumas there is considerable loss of protein from the tissues which has to be restored during convalescence and so high intakes of protein are needed at this time together with an adequate intake of energy.

The digestibility of the proteins of various diets varies considerably. For example, the digestibility of typical Western diets and Chinese diets is 0.95 (i.e. 95% digested). That of the Indian rice diet and Brazilian mixed diet is 0.8 (FAD/WHO 1985). Digestibility is high in diets that include milk and meat and low when maize and beans predominate.

An increase in the amount of protein eaten beyond "requirement" figures compensates for any shortfall in digestibility and protein quality.

Meat as a source of vitamins and minerals

Meat and meat products are important sources of all the B-complex vitamins including thiamin, riboflavin, niacin, biotin, vitamins B6 and B12, pantothenic acid and folacin. The last two are especially abundant in liver which, together with certain other organs is rich in vitamin A and supplies appreciable amounts of vitamins D, E and K.

Meats are excellent sources of some of the minerals, such as iron, copper, zinc and manganese, and play an important role in the prevention of zinc deficiency, and particularly of iron deficiency which is widespread.

Meat Iron

The amount of iron absorbed from the diet depends on a variety of factors including its chemical form, the simultaneous presence of other food ingredients that can enhance or inhibit absorption, and various physiological factors of the individual including his/her iron status. Overall, in setting Recommended Daily Intakes of nutrients the proportion of iron absorbed from a mixed diet is usually taken as 10%.

Half of the iron in meat is present as haeme iron (in haemoglobin). This is well absorbed, about 15-35%, a figure that can be contrasted with other forms of iron, such as that from plant foods, at 1-10%.

Not only is the iron of meat well absorbed but it enhances the absorption of iron from other sources - e.g. the addition of meat to a legume/cereal diet can double the amount of iron absorbed and so contribute significantly to the prevention of anaemia, which is so widespread in developing countries.

Zinc is present in all tissues of the body and is a component of more than fifty enzymes.

Meat is the richest source of zinc in the diet and supplies one third to one half of the total zinc intake of meat-eaters. A dietary deficiency is uncommon but has been found in adolescent boys in the Middle East eating a poor diet based largely on unleavened bread.

Health concerns associated with the consumption of meat

<u>Coronary or Ischaemic Heart Disease</u>

A major cause of death in some parts of the industrialised world is coronary heart disease (CHD) and saturated fatty acids have been implicated as an important dietary risk factor. Since about a quarter of the saturated fatty acids in the diet is supplied by meat fat, the consumption of meat itself has come under fire.

The first stage of development of the disease is a narrowing of the coronary arteries by deposition of a complex fatty mixture on the walls - a process termed atherosclerosis. The fatal stage is the formation of a blood clot that blocks the narrowed artery thrombosis. Even if the thrombosis is not fatal the reduced blood flow to the heart muscle deprives it of oxygen and can lead to extensive damage - myocardial infarction.

Despite many years of intensive investigation the real cause of CHD is not known but a large number of what are termed risk factors have been identified, including a family history of CHD, smoking, lack of exercise, various types of stress and certain disease states together with a number of dietary factors. The saturated fatty acids, myristic and palmitic, have been established as the most important of the dietary risk factors in coronary heart disease.

There are three types of lipoproteins (protein-lipid complexes) in the blood; low density lipoproteins (LDL) in which 46% of the molecule is cholesterol; high density lipoproteins (HDL) which include 20% as cholesterol; and very low density lipoproteins (VLDL) which have 8% cholesterol. High levels of total blood cholesterol are associated with the incidence of CHD and high intakes of saturated fatty acids elevate blood cholesterol levels: hence the association between dietary saturated fatty acids and CHD. It is the LDL that appear to be the main problem and HDL appear to be protective.

This lipid hypothesis of causation of CHD has led to the adoption in many countries of dietary guidelines which, among other objectives, are intended to reduce the intake of saturated fatty acids as compared with unsaturated fatty acids and so reduce blood levels of LDL.

Types of Fatty Acids

Saturated Fatty Acids (SFA)

Two of the saturated fatty acids, myristic and palmitic acids, appear to be the principal dietary factors that increase the blood cholesterol and do so by increasing LDL The other main SFA in the diet, stearic acid, does not have the same effect (apparently because it is converted to oleic acid which is monounsaturated - see below); fatty acids of shorter chain length appear to have no effect.

In order to explain the terms saturated and unsaturated fatty acids to the consumer, SFA have been equated with animal fats so meat fat is perceived as being saturated, but, in fact, this is only relative. For example pork lard is 40% SFA, beef tallow is 43-50% SFA, depending on the part of the body from which it is derived. These figures can be compared with 20 - 25% SFA in vegetable oils which are perceived as unsaturated. Table 3-2 shows that except for lamb fat the proportion of SFA is about 40% or less. In four of the six samples of meat listed there is a higher proportion of monounsaturates than SFA.

This perception of meat fat as being saturated has led to the belief that meat, particularly red meat, should be avoided. In fact it has been shown that a reduction of total fat intake while still including in the diet 180 g of lean meat containing 8.5% fat can result in a reduction in blood cholesterol levels (Watts et al 1988). The relation between diet and coronary heart disease is not only a subject of considerable misunderstanding in the minds of consumers but also a subject of some controversy among medical scientists.

Monounsaturated Fatty Acids (MUFA)

The fatty acid of main interest is oleic acid (plentiful in olive, rape seed and higholeic safflower oils). The relatively high intake of olive oil and consequently the proportionately low intake of SFA are believed to be important dietary factors in the low incidence of CHD in Mediterranean countries compared with northern Europe. It is not clear whether oleic acid confers direct protection or simply replaces SFA in the diet. Table 3-2 shows the contribution of meat fat to the intake of MUFA.

Polyunsaturated Fatty Acids (PUFA)

These are fatty acids with between 2 and 6 double bonds and long carbon chains of 18 to 22 carbon atoms (Table 3-3). Linoleic acid (18 carbon atoms and 2 double bonds) and linolenic acid (18 carbon atoms and 3 double bonds) are plentiful in many vegetable oils. The very long chain fatty acids, eicosatetraenoic (20C, 4 double bonds) and docosapentaenoic (22 C, 5 double bonds) are plentiful in fish oils and smaller amounts are present in some meat fats.

These very long chain PUFA appear to offer direct protection against "heart disease", particularly against thrombosis, but it is not clear whether the other PUFA in the diet (from vegetable oils) offer protection or simply displace SFA. Consequently it is often recommended that vegetable oils (rich in PUFA) should not simply be added to a diet but should be used to replace other fats when there is a need for fat in formulating food products.

Linoleic and linolenic acids are essential in the diet (they were at one time termed vitamin F) and the very long chain FA are formed from them in the body. It is possible that the rate of their formation may not be adequate under all circumstances and so there may be benefit from consuming some of these very long chain PUFA ready-made in the diet.

Trans Fatty Acids

PUFA exist in nature in two structural forms, termed cis and bans forms. It is the cis forms that are used in the production of fatty products such as special margarines. The other forms, bans, are formed when oils are hydrogenated to make hard fats for some margarines, and small amounts are found in the fats of ruminants where they are formed by bacterial hydrogenation in the rumen.

Experimentally bans fatty acids have been shown to have an adverse effect on both LDL and HDL and so are considered potentially harmful. When calculating the ratio of PUFA and SFA in diets, the bans fatty acids are often included with SFA.

Cholesterol

Cholesterol is a fatty compound involved in the transport of fat in the blood stream and is also part of the structure of cell membranes of tissues of the body. It is not a dietary essential since adequate amounts are synthesised in the body from other dietary ingredients.

Confusion has arisen between the terms blood cholesterol and dietary cholesterol. For most individuals dietary cholesterol has little or no effect on blood cholesterol levels because reduced synthesis in the body compensates for increased dietary intake. However, there are individuals who are sensitive to dietary cholesterol (Reiser and Shorland 1990) and most authorities advise a general reduction in cholesterol intake for everyone.

Meat supplies about one third of the dietary cholesterol in many western diets with the remainder from eggs and dairy products. Since all these foods are valuable sources of nutrients there could be some nutritional risk in restricting their intake. The cholesterol content of meat and other foods is listed in Chapter 2, Table 2-7.

In addition to playing an important role in CHD dietary saturated fats have been implicated in hypertension, stroke, diabetes and certain forms of cancer, so all dietary guidelines include recommendations to reduce total fat intake and especially that of saturated fats.

Some 20 national authorities have issued dietary guidelines which differ mainly in the amounts of the various foods advised (James 1988). Generally it is recommended that total fat should be reduced to 20-30% of the total energy intake, with not more than 10% from saturates, 10-15% from MUFA and with PUFA at 3% or more; this results in a P/S ratio of 1.0.

Most authorities, but not all, recommend a reduction in dietary cholesterol to around 300 mg or less per day.

Poultry Meat versus Read Meat

Dietary guidelines sometimes include advice to substitute, at least in part, chicken for red meat. Chicken meat including its skin contains about the same amount of fat as does medium-fat red meat, 20%; it is necessary to remove the skin with the adhering subcutaneous fat, to reduce the fat content to around 5% - which is no lower than the figure for lean meat.

However, chicken flesh has less saturated fatty acids (33% of the total) and more PUFA (14%) than lean meat with 45% and 4% respectively.

Duck flesh is very fat, containing about 10% fat - 45% when the skin and subcutaneous fat are included; only 27% of duck fat is saturated.

Meat from game birds, grouse, partridge, pheasant and pigeon, contains about 5, 7, 9, and 13% fat respectively, of which about one quarter is saturated.

Apart from differences in the amounts and types of fatty acids in the various kinds of meat, poultry and game their nutrient compositions are similar.

Toxic compounds formed during processing and cooking

While cooking is necessary to develop the desirable flavours in meat (as well as to destroy harmful organisms) the oxidation of fats, especially at frying temperatures, can give rise to compounds that decompose to aldehydes, esters, alcohols and short chain carboxylic acids with undesirable flavours.

Meats are particularly susceptible because of the unsaturated lipids present which are more readily oxidised and because of catalysis by haeme and non-haeme iron.

The more PUFA present the greater the likelihood of oxidation, and pork (3.6 g PUFA/100 g when grilled), duck (meat and skin, cooked, 3.5 g) and chicken (roast meat and skin, 2.5 g) are the most susceptible. Other types of meat are less susceptible, e.g. lamb (grilled cutlets, 1.5 g PUFA), turkey (meat with skin, 1.3), and beef (fried steak, 0.6 g per 100 g).

The adverse effect of these oxidation products on eating quality is well recognised but more recently it has been suggested that some of them may be carcinogenic, and also may be involved in the ageing process and CHD. However, it is possible or even likely that the unpleasant flavours would cause rejection of the food at levels below harmful ranges.

Cholesterol can also be oxidised and the oxidation product has been suggested as a possible factor in CHD (Addis 1986).

<u>Carcinogens</u>

A number of epidemiological studies have suggested a link between the intake of animal protein and predisposition to cancers at various sites -pancreas, breast, colon, prostate and endometrium

- but there are many contradictory reports. A summary of eleven case-controlled studies of colon cancer, three of stomach cancer and one of breast cancer concluded that the available data do not provide convincing evidence that removal of meat from the diet would substantially reduce the cancer risk (Phillips et al 1983; Kritchevsky 1990).

The products of pyrolysis of organic material (by overheating and charring), polycyclic hydrocarbons, are believed to be carcinogenic. The most thoroughly investigated of these is 3,4-benzpyrene which is formed on the surface of barbecued and broiled (grilled) and smoked meat products (including broiled fish and roasted coffee).

The main source of these compounds is the flame itself, especially from charcoal, and indirect cooking where the flame is not in contact with the food greatly reduced the amount present.

Nitrosamines

Nitrites, used in curing salts can react with amines commonly present in food, to form nitrosamines.

These have been shown to be carcinogenic in all species of animals examined but it is not clear, despite years of intensive research, whether the amounts present in cured meats affect human beings. The problem is particularly difficult because nitrosamines have been found in human gastric juice, possibly formed from nitrites and amines naturally present in the diet. As a precaution, legally enforced in some countries, there is a tendency to reduce the amount of nitrite used in the curing mixture and to add vitamin C which inhibits the formation of nitrosamines.

Erythorbic acid and tocopherol are also effective in reducing nitrosamine formation. The problem is complex since the process of curing is designed to prevent the growth of Clostridium botulinum which is responsible for botulism, and the risk of botulism is increased if the concentration of nitrate-nitrite is reduced too far. (Moreover, cigarettes contribute far greater amounts of nitrosamines, up to one hundred times as much as cured meats).

Other potential problems

Bovine Spongiform Encephalopathies (BSE)

There is a group of diseases called prion disease, also known as spongiform encephalopathies or transmissable dementias, which include some very rare human diseases, scrapie in animals and BSE. It is not clear whether these all represent the same disease but they have in common the presence of an aberrant form of a normal cell protein called prion protein.

In some countries there have been recent outbreaks of BSE in cattle with the suspicion that it might be transmitted to human beings through affected meat.

This is difficult to prove or disprove and the risk may be remote but it has added to other popular suspicions about meat and may be partly responsible for the reduction in beef consumption in some countries.

Excessive Amounts of Vitamin A in Liver

There are reports in the scientific literature of harmful effects of acute and chronic excessive intakes of vitamin A, mostly from pharmaceutical preparations. Recently, however, concern has been expressed at unusually high levels of vitamin A found in some, few, samples of animal liver, which, if eaten during the early stages of pregnancy, might possibly affect the human foetus.

Residues of Drugs. Pesticides. etc.

Residues of drugs, pesticides and agricultural chemicals can be found in small amounts in meat and meat products. Pesticides, for example, may be applied specifically to the animals to control insects or intestinal parasites but may also be present in meat as a result of exposure of the animals to chemicals used on buildings, grazing areas and crops. While there is no clear evidence that these small amounts cause harm to the consumer they are perceived as a risk. For this reason there is widespread legislation to test for and control a range of chemical substances that may be present in meat (Codex 1991A).

The problem is complicated because several hundred substances are used to treat animals, to preserve animal health and to improve animal production. These include antimicrobial agents, beta-adrenoreceptor blocking agents (used to prevent sudden death in pigs due to stress during transport) anti-helminthics, tranquillizers, anti-coccidial agents, vasodilators and anaesthetics.

Potential safety problems arise from the possibility of residues of these drugs and their metabolites remaining in the tissues (and milk) consumed by human beings. Some tranquillizers, for example, are used in pigs in the immediate pre-slaughter period when there is no time for their removal through the normal metabolic processes . They can persist in the human body so that repeated intakes could possibly result in accumulation of the drugs.

In order to protect the consumers from such risks the Codex Alimentarius Commission publishes Draft Codes of Practice for control of the use of veterinary drugs (Codex 1991A). These provide guidelines for the prescription, application, distribution and control of drugs.

Where there is sufficient scientific information available about the drug in question the Codex Commission defines the following:- Acceptable Daily Intake (ADI) as a measure of the amount of a veterinary drug, expressed on a body weight basis, that can be ingested over a life-time without appreciable health risk (the same term and definition as used for food additives). This is set at one hundredth of the maximum no-observed-effect level (NOEL) determined in experimental animals, on the assumption that human beings may be ten times as sensitive as the test animals used to determine NOEL and that there may be a tenfold range of sensitivity within the human population. When data are incomplete the safety factor may be set at a much higher multiple.

The maximum amount of residue of a drug - maximum residue limit (MRL) - is the maximum concentration per kg fresh weight of food that is recommended by the Codex Commission as being legally acceptable. This is based on the amount considered to be without any toxicological hazard to human health and takes account of other relevant public health risks as well as food technological aspects.

A point is made in the 1991 report that the principal problem is not only the safety of the substances and their residues but the public perception of their safety.

There is no doubt that administration of drugs to animals (and birds) is always a potential risk to human health and so there is a need to control the use of these drugs and to measure the extent of any residues left in the food intended for human beings.

Conclusion

Meat is not an essential part of the diet but without animal products it is necessary to have some reasonable knowledge of nutrition in order to select an adequate diet. Even small quantities of animal products supplement and complement a diet based on plant foods so that it is nutritionally adequate, whether or not there is informed selection of foods.

Side by side with these known benefits of including meat and meat products in the diet are problems associated with excessive intakes of saturated fats, risks of food poisoning from improperly processed products, residues of chemicals used in agriculture and animal production and other potentially adverse aspects discussed.

Within these concepts is the major problem of meat production under conditions that avoid food poisoning and satisfy the economic demands of profitability with the traditional, cultural and religious concerns of the community in question.

There is a steadily increasing demand for meat in the developing countries which can be satisfied by increased domestic consumption and/or increased imports. It is thought that the major increase in domestic production will come from small producers rather than from creating large production units but these lack the essential facilities for producing safe and wholesome products.

If there is to be a significant increase in meat production it will require clear policy decisions with the necessary financial, legislative and technical support. There is considerable potential for increased supplies through better management, selection of animals, avoidance of waste and making use of indigenous species.

If exports are to be considered then attention has to be paid to the strict hygienic and safety requirements involved, whatever the domestic market might tolerate.

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Glossary

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actin	protein muscle
aerobes	bacteria that require oxygen
amino acids	components of proteins (essential amino acids those that cannot be made in the body and so are essential in the diet)
anaerobes	bacteria that can grow in the absence of oxygen
anti-mycotic	anti-mould agent
ascorbic acid	vitamin C
autoclave	sterilising device involving heat destruction of microorganisms

botulism	severe form of food poisoning from toxins produced by Clostridium botulinum
carotene	precursor to retinol
collagen	protein in connective tissue of muscle
complementation	filling a gap; with reference to proteins a shortage of an amino acid in one protein is made good by a relative surplus of another
curing salts	mixture of sodium or potassium nitrite and nitrate
elastin	protein in connective tissue of muscle
folate	unnumbered member of B group of vitamins
glycogen	body (liver and muscle) reserve carbohydrate
HTST	high-temperature short-time heating to destroy microorganisms
indigenous	native born
lipids	group name for all types of fat
Maillard reaction	reaction between the lysine in a protein with a reducing sugar to form a brown compound
mesophilic organism	those that grow best at temperatures of 10-40C

metmyoglobin	brown, oxidised form of myoglobin
microorganisms	bacteria, moulds and yeasts
MUFA	monounsaturated fatty acids
myoglobin	purple-red colouring matter of muscle (2% of total muscle protein)
myosin	major protein of contractile mechanism of muscle
niacin	unnumbered member of B group of vitamins
nitrogen	effectively (but not precisely) alternative term for proteins
oxymyoglobin	bright red oxygenated form of myoglobin
pantothenate	unnumbered member of B group of vitamins
pasteurisation	heat treatment sufficient to destroy pathogenic organisms
pathogens	bacteria that cause disease
phospholipids	structural lipids containing phosphate
P/S ratio	ratio of polyunsaturates to saturates
psychotrophic organisms	those that grow best at temperatures of -2 to + 7C
PUFA	polyunsaturated fatty acids
pyridoxine	vitamin B6
retinol	vitamin A

riboflavin	vitamin B2
rigor mortis	stiffening of muscles after slaughter

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Tables (part I)

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TABLE 1-1A - World Meat Supplies (million tons)

	1970	**1980**	**1990**
World Total	100	136	176
Bovine Meat	39.5	46	53
Sheep & goat meat	6.9	7.5	9.6
Pig meat	35	53	69
Poultry meat	15	26	40

Other meat	3.1	3.5	3.7
Developing countries Total	29.5	46	72
Bovine meat	11	14	19
Sheep & goat meat	3	4	5.7
Pig meat	10	17.7	31
Poultry meat	3.9	8.5	14.5
Other meat	1.3	1.5	2
Developed countries Total	70	90	103.5
Bovine meat	28	31.5	34
Sheep & goat meat	3.7	3.4	3.9
Pig meat	25	35	38.5
Poultry meat	11	17.6	25
Other meat	1.8	1.9	1.7

Source: FAO (1991)

TABLE 1-1B - Protein and Fat Available from Meat Products - grams/caput/day (ranges in brackets) 1990

	Developing countries		Developed countries	
	Protein	**Fat**	**Protein**	**Fat**
Total	6.1	10.4	27.4	33.9
	(4.5 - 14.7)	(3.8 - 16.9)	(13.1 - 38.3)	(13.9 - 54.4)
Bovine meat	1.8	1.9	10.1	12.5
Sheep & goat meat	0.5	0.6	1.0	1.4
Pig meat	2.3	6.8	8.1	15.3
Poultry meat	1.2	1.0	7.6	4.6

Table 1-2 - Estimated numbers (in millions of units) of draught animals and tractors. 1980-2000

Region	**1980**		**1990**		**2000**	

	Draught animals	Tractors	Draught animals	Tractors	Draught animals	Tractors
90 Developing countries	165	2.6	175	5.8	185	14.2
Africa	14	0.2	16	0.5	17	1.3
Far East	126	0.6	135	1.6	145	4.9
Latin America	17	1.3	17	2.9	16	6.2
Near East	7	0.5	7	0.9	6	1.8
Low-income countries	130	0.5	140	1.3	150	4.4

Source: Ramaswamy (1981)

Table 1-3

Yield of vegetable and animal foods (million kcal per hectare)			
Grain	5	Beef	0.4
Rice	7	Eggs	0.5
Potatoes	12	Milk	1.8

Cassava	12		
Banana	13		
Sugar	25		
Land (in ha) needed to produce 20 kg protein per year (sufficient for one adult)			
Beans	0.25	Dairy cows	1 - 3
Grass	0.3 - 0.6	Chickens	3
Cereals	0.6	Sheep	2 - 5
Potatoes	0.7	Pigs	5
		Beef	3 - 6

Table 1-4 - Income elasticities of demand for livestock products and cereals, 1975

Country Group/Region	**Meat**	**Milk**	**Eggs**	**Cereals**
Developed economies	0.25	0.05	0.27	0.22
Developing economies	0.63	0.57	1.00	0.16
Africa	0.79	0.68	1.05	0.21
Asia and the Far East	0.97	0.52	1.07	0.22

Near East	0.72	0.53	0.83	0.13
Latin America	0.37	0.49	0.60	0.16

Source: Food and Agriculture Organization of the United Nations, Rome, 1978.

Table 1-5 - Approximate yield of various items obtained from meat animals

Item	**Steer**	**Lamb**	**Pig**
Live weight, kg	455	45	100
Dressed carcass, kg	273	23	70
Retail cuts, kg	190	16	56
By-products, kg			
Hide or pelt	36	7	-
Edible fats	50	4	16
Variety meats	17	1	4
Blood	18	2	4
Inedible fats, bone and meat scrap	80	10	8

Unaccounted items (stomach contents, shrink, etc.)	64	5	12

Source: Principle of Meat Science; Eds. Forrest et al. (1975).

Table 1-6 - 'Normal' performance levels and attributes

Species	**Mature size (kg liveweight)**			**Reproductive rate (No. of young/year)**	**Ratio of males to females for breeding**	**Yield/progeny (kg carcass weight)**
	Male		**Female**			
Cattle	700-800		450-700	0.9	1:30-50	200-300
Buffalo	665-718		509-548	144-279		
Musk oxen		365		0.5-1.0		
Yak	230-360		180-320			
Sheep	30-150		20-100	1-2+	1:30-40	18-24
Goats	48-58		45-54	1-3	1:40	4.3-8.4

Deer (rod)	124		75-82	1	1:1.6-6.6	20-64
Horses	1000		700-900	1	1:70-100	360
Camels	450-840		595	0.5	1:10-70	210-250
Alpaca		80				
Llama		80-110				
Rabbits	4.0-7.2		4.5-7.6	30-50	1:15-20	1-2
Guinea pigs			0.6-1.0	20-30		0.7
Capybara	60		45	8.7		15.3
Pigs	350		220	20	1:20	45-67
Dogs		12-15				
Hens	4		3	108	1:10	1.45
Ducks	4.5		4.0	110-175	1:5-8	2
Geese	5-10		4.5-9	25-50	1:2-6	4-5
Turkeys	13-23		8-12	40-100	1:10-15	3-9

Source: Spedding and Hoxey (1975)

Table 1-7 - Products other than meat

Species	Products				
	Milk	**Skin**	**Fibre**	**Feathers/down**	**Faeces**
Cattle	+	+	+		+
Buffalo	+	+			+
Musk oxen			+		
Yak	+	+	+		
Sheep	+	+	+		+
Goats	+	+	+		+
Deer (red)		+			
Horses	+	+	+		+
Camels	+	+	+		+
Alpaca			+		
Llama			+		
Rabbits		+	+		+
Guinea pigs			+		
Capybars		+			
Pigs		+	+		+

Dogs					
Chickens / Hens				+	+
Ducks				+	+
Geese				+	+
Turkeys				+	+
Game animals and birds				+	

Source: Spedding and Hoxey (1975)

Table 1-8

Storage conditions for chilled animal products			
Commodity	**Temperature (C)**	**Relative humidity (%)**	**Practical storage life**
Beef	-1.5 to 0	90	3-5 weeks
Beef (10% CO_2)	-1.5 to -1	90-95	max. 9 weeks
Lamb	-1 to 0	90-95	10-15 days
Pork	-1.5 to 0	90-95	1-2 weeks

Veal	-1 to 0	90	1-3 weeks
Chicken	-1 to 0	>95	7-10 days
Rabbit	-1 to 0	90-95	max. 5 days
From: Recommended conditions for cold storage of perishable products, International Institute of Refrigeration, Paris, 1967 & 1971			

Practical storage life of meat and meat products

Products	Practical storage life in months		
	-18C	-25C	-30C
Beef carcass	12	18	24
Roasts, steaks, packaged	12	18	24
Ground meat, packaged (unsalted)	10	>12	>12
Veal carcass	9	12	24
Roasts, chops	9	10-12	12
Lamb carcass	9	12	24
Roasts, chops	10	12	24
Pork carcass	6	12	15
Roasts, chops	6	12	15

Ground sausage	6	10	
Bacon (green, unsmoked)	2-4	6	12
Lard	9	12	12
Poultry, chicken and turkeys,			
eviscerated, well packaged	12	24	24
Fried chicken	6	9	12
Offal, edible	4		
From: Recommendations for the processing and handling of frozen foods, International Institute of Retrigeration, Paris, 1972.			

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Tables (part II)

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Table 2-1 - Approximate composition of mammalian skeletal muscle (percent fresh weight basis)

	Percent		Percent
WATER (range 65 to 80)	75.0	NON-PROTEIN NITROGENOUS SUBSTANCES	1.5
		Creatine and Creatine phosphate	0.5
PROTEIN (range 16 to 22)	18.5	Nucleotides (Adenosine triphosphate (ATP), adenosine tiphosphate (ADP), etc.)	0.3
Myofibrillar	9.5	Free amino acids	0.3
Myosin	5.0	Peptides (anserine, carnosine etc.)	0.3
Actin	2.0		
Tropomyosin	0.8		
Troponin	0.8	Other nonprotein substances (creatinine, urea, inosine monophosphate (IMP), nicotinamide adenine dinucleotide (NAD), nicotinamide adenine dinucleotide phosphate (NADP))	0.1
		CARBOHYDRATES AND NON-	

M protein	0.4	NITROGENOUS SUBSTANCES (range 0.5 to 1.5)	1.0
C protein	0.2	Glycogen (variable range 0.5 to 1.3)	0.8
a-actinin	0.2	Glucose	0.1
b-actinin	0.1	Intermediates and products of cell metabolism (hexose and triose phosphates, lactic acid, citric acid, fumaric acid, succinic acid, acetoacetic acid, etc.)	0.1
Sarcoplasmic	6.0	INORGANIC CONSTITUENTS	1.0
Soluble sacroplasmic and mitochondrial enzymes	5.5	Potassium Total phosphorus	0.3
Myoglobin	0.3	(phosphates and inorganic phosphorus)	0.2
Hemoglobin	0.1	Sulfur (including sulfate)	0.2
Cytochromes and flavoprotein	0.1	Chlorine	0.1
		Sodium	0.1
		Others (including magnesium,	

Stroma	3.0	calcium, iron, cobalt, copper, zinc, nickel, manganese etc.)	0.1
Collagen and recticulin	1.5		
Elastin	0.1		
Other insoluble proteins	1.4		
LIPIDS (variable range: 1.5 to 13.0)	3.0		
Neutral lipids (range: 0.5 to 1.5)	1.0		
Phospholipids	1.0		
Cerebrosides	0.5		
Cholesterol	0.5		

Source: Principles of Meat Science by Forrest et al. (1975) W.H. Freeman & Co.

Table 2-2 - Composition of fat and lean (per 100 g wet weight)

					Fat*

					Fat			
	Water	**Protein**	**Pat**	**Energy**	**Sat.**	**Mono**	**Poly**	**Chol**
	(g)	**(g)**	**(g)**	**(MJ)**	**(g)**	**(g)**	**(g)**	**(mg)**
Beef fat, raw	24	9	67	2.6	29	32	3	90
lean	74	20	5	0.5	2	2	0.2	60
Lamb, fat	21	6	72	2.8	36	28	3	75
lean	70	21	9	0.7	4	3	0.4	80
Pork, fat	21	7	71	2.8	26	29	11	75
lean	72	21	7	0.6	2.5	3	1	70

Fat*: - saturated, monosaturated, polyunsaturated, cholesterol.

Table 2-2 (continued) - VITAMINS AND MINERALS

	Fe	**Cu**	**Zn**	**A**	**D**	**E**	**B1**	**B2**	**Niacin**	**B6**	**B12**	**Folate**	**Pantothenate**	**Biotin**
	mg	**mg**	**mg**			**mg**	**mg**	**mg**	**mg**	**mg**	**µg**	**µg**	**µg**	**µg**
Beef, fat, raw	1.0	0.1	1.0	-	-	0.3	-	-	-	-	tr	-	-	tr

lean, saw	2.1	0.14	4	tr	tr	0.15	0.07	0.25	5	0.3	2	10	0.7	tr
Lamb, fat	0.7	0.15	0.8	-	-	0.3	-	-	-	-	tr	-	-	tr
lean	1.6	0.17	4	tr	tr	0.1	0.14	0.3	6	0.25	2	5	0.7	2
Pork, fat	0.7	0.1	0.4	tr	tr	0.03	-	-	-	-	tr	-	-	tr
lean	0.9	0. 15	2.4	tr	tr	0	0.9	0.25	6	0.45	3	5	1	3

(McCance and Widdowson 1991)

Table 2-3 - TYPICAL ANALYSES OF VARIOUS TYPES OF MEAT

Source	**Protein**	**Fat**	**Na**	**K**	**Ca**	**Mg**	**P**	**Fe**	**Cu**	**Zn**	**Cl**
	(X wet wt.)	**(% wet wt.)**	**(mg/100g wet wt.)**								
Ox lean,											

av	20.3	4.6	61	350	7	20	180	2.1	0.14	4.3	59
Sheep lean, av	20.8	8.8	88	350	7	24	190	1.6	0.17	4.0	76
Pig lean, av	20.7	7.1	76	370	8	22	200	0.9	0.15	2.4	71
Calf, filet	21.1	2.7	110	360	8	25	260	1.2	-	-	68
Rabbit lean, av	21.9	4.0	67	360	22	25	220	1.0	0.54	1.4	74
Chicken, light meat, av	21.8	3.2	72	330	10	22	180	0.9	0.25	1.6	86
dark meat, av	19.1	5.5	89	300	11	25	190	1.2	0.20	2.0	90

Source	**Thiamin**	**Riboflavin**	**Nicotinic Acid**	**B6**	**B12**	**Folic Acid**	**Biotin**	**E**
	(mg)	(mg)	(mg)	(mg)	(µg)	(µg)	(µg)	(mg)
Ox lean, av	0.07	0.24	5.2	0.32	2	10	Tr	0.19

Sheep lean, av	0.14	0.78	6.0	0.25	2	5	2	0.10
Pig lean, av	0.89	0.25	6.2	0.45	3	5	3	-
Beef, fillet	0.10	0.25	7.0	0.30	1	5	Tr	-
Rabbit lean, av	0.10	0.19	8.4	0.50	10	5	1	0.13
Chicken, light meat, av	0.10	0.10	9.9	0.53	Tr	12	2	0.08
dark meat, av	0.11	0.22	5.4	0.30	1	12	3	0.14

(Lawrie 1981)

TABLE 24 - AMINO ACID COMPOSITION (ma AMINO ACID PER g PROTEIN) OF MUSCLE PROTEINS, CONNECTIVE TISSUE COMPONENTS AND SELECTED MEAT PRODUCTS

	Beef	**Pork**	**Lamb**	**Cured Processed**	**MDM***	**Actin**	**Myosin**	**Tropomyosin**	**Bovine Collagen**	**Bovine elastin**

Meats

Aspartic acid	88	89	85	91	88	107	115	117	43	9
Threonine	40	51	49	49	32	77	54	31	18	9
Serine	38	40	39	42	38	58	41	40	35	7
Glumatic acid	144	145	144	129	142	140	229	320	99	19
Proline	54	46	48	52	61	50	25	6	114	106
Glycine	71	61	67	80	82	43	26	9	187	189
Alanine	64	63	63	64	67	58	59	89	74	158
Valine	57	50	50	52	61	49	47	29	23	140
Methionine	23	25	23	22	28	42	33	25	8	Tr
Cystine	14	13	13	15	15	12	11	9	-	-
Total SAA	37	38	36	37	43	43	54	44	34	8
Isoleucino	51	49	48	49	39	84	55	39	15	31
Leucine	84	75	74	74	80	82	108	121	28	72
Tyrosine	32	30	32	29	25	67	33	29	67	13
Phenylalanino	40	41	39	40	43	48	47	9	21	52
Total aromatic	72	71	71	69	68	115	80	38	88	65

amino acidsHistidine	29	32	27	28	30	27	24	10	8	1
Lysine	84	78	76	74	78	70	146	184	30	4
Arginine	66	64	69	66	77	74	79	75	75	11
Tryptophan	11	13	13	10	5	20	9	-	-	-

***MDM - mechanically deboned meat**
(Pellet and Young 1990)

Table 2-5 - Composition of different cuts of meat

	Cut of meat	**Protein**	**Moisture**	**Pat**	**Ash**	**Cal/100 g**
		(%)	**(%)**	**(%)**	**(%)**	
BEEF	Chuck	18.6	65	16	0.9	220
	Flank	19.9	61	18	0.9	250
	Loin	16.7	57	25	0.8	290
	Rib	17.4	59	23	0.8	280
	Topside	19.5	69	11	1.0	180

	Rump	16.2	55	28	0.8	320
PORK	Ham	15.2	53	31	0.8	340
	Loin	16.4	58	25	0.9	300
	Shoulder	13.5	49	37	0.7	390
	Spare rib	14.6	53	32	0.8	350
LAMB	Breast	12.8	48	37	0.7	380
	Leg	18.0	64	18	0.9	240
	Loin	18.6	65	16	0.7	220
	Rib	14.9	52	32	0.8	360
	Shoulder	15.6	58	25	0.8	300

(Sawyer 1975)

Table 2-6 - Composition of Fats

	Total fat (%)	**Per cent of total fat**		
		SFA	**MUFA**	**PUFA**
Beef fat	67	43%	48%	4%

Lamb fat	72	50%	39%	5%
Pork fat	71	37%	41%	15%
Chicken, meat and skin	18	33%	42%	19%
Duck, meat and skin	43	27%	54%	12%
Calf liver	7	30%	18%	26%

SFA - Saturated Fatty Acids
MUFA - Monounsaturated Fatty Acids
PUFA - Polyunsaturated Fatty Acids

Table 2-7 - Cholesterol content of various foods (mg/100 g)

Milk	14
Butter	230
Hard cheese	70-100
Eggs	450
Egg yolk	1 260

Meat and poultry	60-120
Heart	140-260
Brain	2 000 - 3 000
Liver	300 - 350
Fish	50 - 60
Crustacea	100 - 200

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Table 2-8

Constituents of meat from some free living animals					
Species	**Composition of meat**				
			Solid		

	Ash	Fat	nutrient	Calories /100g
	(g/100 g fresh weight)			
Eland	1.1	1.9	23	125
Hartebeest	1.2	2.1	24	130
Topi	1.3	2.3	23	126
Giraffe	1.4	2.2	22	123
Buffalo	1.1	1.8	22	120
Warthog	1.2	2.3	25	132
Free range cattle	1.1	2.0	22	120
Intensive fat stock	0.9	15.0	18	230

A comparison of the fatty acids in muscle total lipids, triglycerides and ethanolamine phosphoglycerides1

Fatty acid designation	Bos taurus2 (Beef)			Taurotragus oryx (Eland)		Syncerus caffer (Buffalo)		Bos Indicus3 (African beef)		
	Total	Trigly ceride	EPG	Total	EPG	Total	EPG	Total	Triglyceride	EPG
16:0	29.0	33.0	12.0	19.0	9.0	16.0	11.0	17.0	29.0	15.0

18:0	18.0	16.0	36.0	20.0	33.0	22.0	32.0	18.0	16.0	33.0
18:1	47.0	45.0	16.0	17.0	9.0	23.0	14.0	28.0	48.0	18.0
18:2,n-6	1.2	1.0	1.6	22.0	8.5	16.0	4.5	14.0	3.6	3.7
18:3,n-3	0.9	0.5	0.8	4.1	3.8	5.0	3.0	3.5	2.1	2.0
20:3,n-6	0.3	0.1	3.0	0.8	0.4	0.3	0.9	1.1	0.1	1.1
20:4,n-6	1.2	0.2	12.0	6.4	15.0	7.1	12.0	7.0	-	13.0
20:5,n-3	0.2	-	2.9	1.0	1.9	1.1	2.5	1.8	-	1.9
22:5,n-3	0.5	-	8.0	3.8	9.3	3.0	9.0	4.0	-	11.0
22:6,n-3	0.2	-	1.4	0.8	3.4	0.2	0.9	0.8	-	1.2

1The results are expressed as the percentage (by weight) of the total fatty acids. These results illustrate that whole tissue fatty-acid analyses need not reflect the fatty-acid composition of cell structural lipids.

2Intensive reared for the London market

3Non-intensive obtained from the Siroti market, Uganda

(Crawford. 1975)

Table 2-9 - Composition of offals (per 100 g raw)

Table 2-10A - PROPORTIONAL VALUE DERIVED FROM CARCASS MEAT AND DIFFERENT BY-PRODUCTS FROM CATTLE, HOGS AND LAMBS

	Cattle	**Pig**	**Lamb**
	(%)	**(%)**	**(%)**
Carcass meat	34	52	32
Bones	16	17	18
Organs	16	7	10
Skin and attached fat	6	6	15
Blood	3	3	4
Fatty tissues	4	3	3
Horns, hoofs, feet and skull	5	6	7
Abdominal and intestinal contents	16	6	11

(Goldstrand 1988)

Table 2-10B - NOMENCLATURE OF OFFAL (VARIETY MEATS, SIDE MEATS, ORGAN MEATS)

Tissue	
Stomach	Pork- maw
	Sheep - paunch
	Cow - tripe
Rumen	Blanket tripe
Reticulum	Honeycomb tripe
Omasum	Bible
Abomasum	Reed
Weasand	Gullet meat surrounding oesophagus; throat meat in lamb and veal
Giblets	Neck, gizzard, heart and liver of poultry
Small intestines of pigs	Chitterlings

Fat	(1) Lard - surrounding stomach and kidneys mainly of pigs (2) Tallow (hard fat or dripping) beef and mutton fat from parts other than kidney
Suet	From kidneys of oxen and sheep

Table 2-11 - Change in composition from cooking meat and meat products (per 100 g)

	Water	Protein	Fat	Energy		Thiamin	Niacin
	(%)	(%)	(%)	kcal	MJ	(mg)	(mg)
Bacon, collar joint lean & fat, raw	51	15	29	320	1.3	0.4	2.7
boiled	49	20	27	325	1.3	0.3	2.6
Beef brisket, raw	62	17	21	250	1.4	0.05	3.7
boiled	48	28	24	290	1.2	0.04	4.3
Rump steak, raw	67	19	14	200	0.8	0.08	4.2
fried	56	29	15	250	1.0	0.08	5.5
grilled	59	27	12	220	0.9	0.08	5.7
Lamb cutlets, raw	49	15	36	390	1.6	0.09	4

grilled	45	23	31	370	1.5	0.10	5
Veal fillet, raw	75	21	3	110	0.5	0.1	7
roast	55	32	12	230	1.0	0.06	7
Chicken meat, raw	74	21	4	120	0.5	0.1	8
boiled	63	29	7	180	0.8	0.06	7
roast	68	25	5	150	0.6	0.08	8
Rabbit meat, raw	75	22	4	120	0.5	0.1	8.4
stewed	64	27	8	180	0.7	0.07	8.5
Ox liver, raw	69	21	8	160	0.7	0.25	13
stewed	63	25	10	200	0.8	0.2	10
Beefburgers, raw, frozen	56	15	21	265	1.1	0.04	3.7
fried	53	20	17	265	1.1	0.02	4.2
Beef sausage, raw	50	10	24	300	1.2	0.03	5
fried	48	13	18	270	1.1	0	7
grilled	48	13	17	270	1.1	0	5

(McCance and Widdowson, 1991)

Table 2-12 - Per Cent Composition Raw and Cooked Meats (Coefficient of Variation) (From Massachusetts Nutrient Data Bank)

Product		**Protein**	**Fat**
Beef steak (with bone)	Raw	18.7 (15)	19.4 (65)
	Cooked	26.4 (16)	21.4 (63)
without bone	Raw	19.2 (14)	16.9 (74)
	Cooked	27.4 (15)	17.6 (75)
Pork chops	Raw	19.3 (11)	15.1(61)
	Cooked	27.0 (14)	20.9 (36)
Bacon	Raw	6.3 (58)	69.7 (30)
	Cooked	18.0 (59)	52.9 (59)
Lamb	Raw	17.1 (13)	18.5 (60)
	Cooked	24.7 (14)	19.2 (62)

(Pellett and Young, 1990)

Table 2-13 - Macronutrients in Chicken (in %)

Product	**Water**	**Protein**	**as % DM***	**Fat**	**as % DM***
Light	74.4	21.8		3.2	
Dark	74.5	19.1		5.5	
Total with skin	64.4	17.6		17.7	
Total meat raw	74.4	20.5	82.7%	4.3	17.3%
Boiled	63.4	29.2	80%	7.3	20%
Roast	68.4	24.8	82.1%	5.4	17.9%

***DM = Protein + Fat**
(McCance and Widdowson, 1991)

Table 2-14 - Retention of vitamins B_1 and B_2 in different cuts of braised meat

	Weight	**Time of cooking**	**Vitamin B_1**	**Vitamin B_2**
	(lb)	**(min/lb)**	**(% retention)**	**(% retention)**
BEEF				
Short ribs	4.5	30	25	58
Chuck	6	35	23	74
Flank steak	1.75	28	30	72
Round (roast)		27	40	73
Round (steak)		18	40	65
VEAL				
Chops	1.75	28	38	73
Round steak	1.75	27	48	76
PORK		Total time of cooking		
Chops		50 min	44	64
Spare ribs		2 h	26	72
Tenderloin		40 min	57	83

(Noble, 1965)

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Table 2-15 - Vitamins B_6, B_{12} and Folate

Vitamin B_6, Vitamin B_{12}, and Folate content of cooked lean beef			
Item	**Vitamin B6**	**Vitamin B12**	**Folate**
	(µg/100 g)	**(µg/100 g)**	**(µg/100 g)**
Round			
Top, broiled	0 56	2 48	12
Eye, roasted	0 38	2 17	7
Loin, broiled			

Top loin	0 42	2 00	8
Tenderloin	0 44	2.57	7
Rib			
Small end, broiled	0 40	3 32	8
Large end, roasted	0 26	2 61	9
Chuck, braised			
Blade	0 29	2 47	6
Brisket, braised			
Flat portion	0 28	2.58	8
Ground (85% lean)			
Broiled (medium)	0 27	2 71	9
Pan-fried (medium)	0 28	2.45	9

Percent retention of Vitamin B_6, Vitamin B_{12} and Folate in cooked lean fresh beet or pork			
% retention			
Item	Vitamin B_6	Vitamin B_{12}	Folate
Beet, fresh, lean			
Braised	46	67	72

Broiled	74	75	87
Roasted	66	72	88
Pork, fresh, lean			
Braised	52	60	65
Broiled	0	91	86
Roasted	64	82	95
(Watt and Merrill, 1975)			

Retention of Vitamin B_6 in Roast fleer

Roast beef	Vitamin B_6	Vitamin B_6 retained
	(mg/100 g)	(%)
Initial	0.470.12	-
Reheated	0.260.11	55.3
Held 1 h (66C)	0.220.10	46.8
Held 2 h (66C)	0.200.10	42.6
Held 3 h (66C)	0.150.07	31.9
(Reiter and Driskell, 1985)		

Table 2-16 - Composition of Cured Meats per 100 g (in %)

	Water	Protein	Total Fat	SFA	MUFA	PUFA	Chol	Energy
							(mg)	(MJ)
Bacon, fat only, raw	13	5	80	31	36	9	200	3.0
Lean only	67	20	7	3	3	1	20	0.6
Collar, joint lean & fat boiled	50	20	27	11	12	3	100	1.3
Gammon, joint, lean& fat, boiled	54	25	19	7	9	2	70	1.1
Gammon rashers, grilled	52	30	12	5	6	1	45	0.9
Rashers, lean & fat, fried	30	25	40	16	18	4	140	1.9
"streaky" fried	28	23	45	18	20	5	160	2.0
"streaky" grilled	35	25	36	14	16	4	130	1.7
Beef, salted,	55	29	14	6	7	0.6	80	1.0

silverside, boiled								
Ham, canned	73	18	5	2	2	0.6	70	0.5
US data	65	18	12					0.8

SFA Saturated Fatty Acids
MUFA Monounsaturated Fatty Acids
PUFA Polyunsaturated fatty acids - as per cent total fat
Chol Cholesterol (ma per 100 g meat)
(McCance and Widdowson, 1991 - figures rounded off)

Table 2-16 (continued) - Composition of cured meats per 100 g

					VITAMINS						
	Na	**Fe**	**Cu**	**Zn**	**E**	**B1**	**B2**	**Niacin**	**B6**	**B12**	**Pantothenate**
	(mg)	**(mg)**	**(mg)**	**(mg)**	**(mg)**	**(mg)**	**(mg)**	**(mg)**	**(mg)**	**(µg)**	**(mg)**
Bacon, fat only	560	0.7	0.06	0.6	0.1	-	-	-	-	tr	-
lean only, raw	900	1.2	0.1	2.5	0.06	0.7	0.3	4.7	0.5	tr	0.6

collar joint lean and fat, boiled	1100	1.6	0.2	4	0.1	0.3	0.2	2.6	0.2	tr	0.4
Gammon joint lean and fat boiled	1000	1.3	0.2	3	0.1	0.3	0.2	2.6	0.2	tr	0.4
gammon rashers grilled	2100	1.4	0.2	3	0.1	0.9	0.2	6	0.3	tr	0.6
Rashers, lean and fat, fried	1900	1.3	0.1	3	0.2	0.4	0.2	5	0.3	tr	0.3
"streaky" fried	1800	1.2	0.1	2	0.2	0.4	0.2	5	0.3	tr	0.3
"streaky" grilled	2000	1.5	0.15	3	0.1	0.4	0.2	4	0.3	tr	0.5
Beef salted silverside boiled	900	3	0.25	6	0.3	0.03	0.3	3	0.3	2	0.8

Ham, canned	1250	1	0.2	2	0.1	0.5	0.25	4	0.2	tr	0.6
US data	1100	3				0.5	0.2	4			

Table 2-17 - Typical composition of cooked sausages made of precooked raw materials

Component	Type							
	Liver paste		Liver sausage		Cooked sausage with high collagen content		Blood sausage	
	1	2	1	2	1	2	1	2
(%)								
Liver	10	10	15	10	10	5	5	-
Fatty tissue	30	30	20	20	10	25	30	20
Head meat	20	30	20	30	40	33	15	5
Lean meat trimmings	5	-	5	-	5	-	-	5
Other organs	5	10	10	15	5	10	10	13
Pigskin/beef								

tendons	-	10	5	13	15	20	30	-
Broth	14	15	15	15	15	10	-	15
Caseinate	3	3	2	3	-	-	-	-
Seasonings	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Nitrite salt	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Fried onions	1	-	1	-	-	-	-	-
Cured blood	-	-	-	-	-	-	20	10

Table 2-18 - Composition of sausages of various types (US values except for two UK figures) Per 100 g

	Water	Energy	Protein	Fat	Iron	Vitamins (mg)		
	(%)	MJ	(%)	(%)	(mg)	B1	B2	Niacin
Blood sausage	46	1.6	14	37				
Bock worst	62	1.0	11	24				
Bologna	56	1.2	12	30	1.8	0.16	0.22	2.6

Capicola	26	2.0	20	45				
Dry Cervelat	29	1.8	25	38	2.7	0.3	0.2	5.5
Frankfurter, raw	56	1.2	13	28	1.9	0.16	0.2	2.7
Knock worst	58	1.1	14	23	2.1	0.17	0.2	2.6
Liver worst fresh	54	1.2	16	26	5.4	0.2	1.3	6
Mortadella	50	1.3	20	25	3			
Pork sausage	35	1.9	18	44	2.4	0.8	0.3	4
cooked								
UK figures, fried	45	1.3	14	25	1.5	0.01*	0.25	4
Salami, cooked	51	1.2	18	26	2.6	0.25	0.25	4
UK figures	28	2.0	19	45	1.0	0.2	0.2	5
Thuringer	49	1.2	19	25	2.8	0.1	0.25	4

*** Preserved with SO_2 which destroys thiamin**

(Watt and Merrill, 1975)

Table 3-1 - World population and meat production in various regions

Countries	Population 1985 (millions)	Meat production					
		Total Million (metric tons)	Per capita (kg)	Approximate percentages			
				Cattle	Sheep	Pigs	Poultry
Developed							
North America	264.2 (1.0)	28.2 (1.4)	106.8	43	1	25	30
Western Europe	377.4 (0.4)	31.0 (2.4)	82.0	32	4	46	20
Oceania	19.0 (1.4)	3.7 (1.2)	196.0	50	31	9	10
Eastern Europe and USSR	392.4 (0.8)	27.1 (2.5)	69.0	36	5	44	15
Developing							
Africa	449.0 (3.0)	5.0 (2.4)	11.2	48	15*	9	28
Far East	1 379.4 (2.3)	6.3 (3.9)	4.6	15**	13*	57	16
Latin America	406.2 (2.4)	15.3 (2.8)	37.6	56	3	19	22

Near East	240.2 (2.8)	4.4 (4.2)	18.2	37	28	<1	35
Developing countries	3 632.8 (2.2)	52.1 (4.0)	14.3	44	12	22	23
Developed countries	1 210.5 (0.8)	94.8 (2.2)	78.3	37	4	37	21

Source: FAO (1986), USDA (1988)
***Includes goat**
****Includes buffalo**
Note: Values in parentheses for population and production data are the annual rates of change

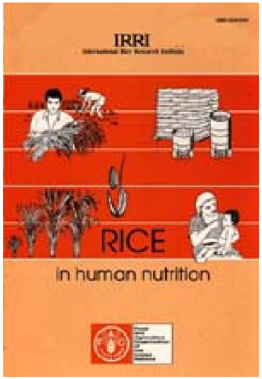
Table 3-2 - Polyunsaturated Fatty Acids and Cholesterol Fatty Acid (% total fatty acids)

Source	**C18:2**	**C18:3**	**C20:3**	**C20:4**	**C20:5**	**C22:5**	**C22:1**	**C22:4**	**C22:6**	**Cholesterol (mg/100 g)**
Ox, lean	2.0	1.3	Tr	1.0	Tr	Tr	-	-	-	59
Sheep, lean	2.5	2.5	-	-	Tr	Tr	-	-	-	79
Pig, lean	7.4	0.9	-	Tr	Tr	Tr	-	-	1.0	69

Rabbit, lean	13.5	0.7	Tr	0.7	0.7	Tr	-	-	-	71
Chicken, lean	20.9	9.9	Tr	1.9	1.9	1.3	-	-	-	90
Brain, sheep	0.4	-	1.5	4.2	0.7	3.4	0.6	0.8	9.5	2200
Heart, ox	2.5	0.5	Tr	0.7	0.7	Tr	-	-	-	140
sheep	7.3	2.7	Tr	2.1	2.1	Tr	-	-	-	140
Kidney, ox	4.8	0.5	Tr	2.6	Tr	Tr	-	-	-	400
sheep	8.1	4.0	0.5	7.1	Tr	Tr	-	-	-	400
pig	11.7	0.5	0.6	6.7	Tr	Tr	-	-	-	410
Liver, ox	7.4	2.5	4.6	6.4	0.7	5.6	-	-	1.2	270
sheep	5.0	3.8	0.6	5.1	-	3.0	-	-	2.4	430
pig	14.7	0.5	1.3	14.3	-	2.3	-	-	3.8	260
calf	15.0	1.4	2.1	9.0	0.3	4.0	-	-	2.5	370
Sweetbread, sheep	2.1	2.2	-	1.3	Tr	-	-	-	-	260
Tongue, sheep	4.0	3.4	-	Tr	Tr	-	-	-	-	180

Tripe, ox, dressed	1.5	0.6	-	Tr	Tr	-	-	-	-	95

(McCance and Widdowson's "The Composition of Foods" 4th Ed. 1978 A.A. Paul and D.A.T. Southgate HMSO)



Rice in human nutrition

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Preface

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Rice in human nutrition has been written to serve a wide range of readers in government, universities and industry as a general source on most aspects of rice production, processing, trade and consumption. We hope that this book, as well as complementary trade information on rice published by FAO, will successfully address many readers' questions about this important food and assist in development and training activities in all countries.

John R. Lupien

Director

Food Policy and Nutrition Division

Chapter 1 - Introduction

Rice (Oryza sativa is the most important cereal crop in the developing world and is the staple food of over half the world's population. It is generally considered a semi-aquatic annual grass plant. About 20 species of the genus Oryza are recognized, but nearly all cultivated rice is O. sativa L. A small amount of Oryza glaberrima, a perennial species, is grown in Africa. So-called "wild rice" (Zizania aquatica), grown in the Great Lakes region of the United States, is more closely related to oats than to rice.

Because of its long history of cultivation and selection under diverse environments, O. sativa has acquired a broad range of adaptability and tolerance so that it can be grown in a wide range of water/soil regimens from deeply flooded land to dry hilly slopes (Lu and Chang, 1980). In Asia, cultivars with resistance to aluminum toxicity and with tolerance to submergence by flood water (IRRI, 1975), (Figure 1), high salinity and cool temperatures at the seedling or ripening stage have been developed (Chang, 1983). In Africa, cultivars with tolerance to iron toxicity and heatconstraints have also been developed and cultivated. Rice is now grown in over 100 countries

on every continent except Antarctica, extending from 50 north latitude to 40 south latitude and from sea level to an altitude of 3 000 m.

Origin and spread of rice

The geographical site of the origin of rice domestication is not yet definitely known. The general consensus is that rice domestication occurred independently in China, India and Indonesia, thereby giving rise to three races of rice: sinica (also known as japonica), indica and javanica (also known as bulu in Indonesia). There are indications that rice was cultivated in India between 1500 and 2000 B.C. and in Indonesia around 1648 B.C. Archaeological findings have shown that tropical or indica rice was being cultivated in Ho-mu-tu, Chekiang Province, China at least 7 000 years ago (Chang, 1983). Recently, remains of the temperate or sinica (japonica) rice of the same age were found at Lou-jia-jiao, also in Chekiang Province (Chang, 1985). Rice was rapidly dispersed from its tropical (southern and southeastern Asia) and subtropical (southwestern and southern China) habitats to much higher altitudes and latitudes in Asia, reaching Japan as recently as 2 300 years ago (Chang, 1983). It was introduced to points as far as West Africa, North America and Australia within the last six centuries.

FIGURE 1 The world's rice land classified by water regimes and predominant rice type

Rice growing became firmly established in South Carolina in the United States in about 1690 (Adair, 1972). Rice was cultivated in Europe from the eighth century in Portugal and Spain and by the ninth to the tenth century in southern Italy (Lu and Chang, 1980).

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World rice production compared to other cereals

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The world annual cereal production for 1989 is shown in Table 1 . About 95 percent of the world's rice is produced in developing countries and 92 percent of it in Asia. In contrast only about 42 percent of the wheat produced is grown in developing countries. Production of rice, exports and imports and estimated irrigated areas of major rice producing countries are shown in Table 2. In 1988, China was the principal rice producer (35 percent) followed by India (22 percent), Indonesia (8.5 percent), Bangladesh (4.7 percent), Thailand (4.3 percent) and Viet Nam (3.4 percent). Of the major rice producers only Pakistan, the United States and Egypt had 100 percent irrigated rice land (IRRI, 1991 a). Non-irrigated rice cultivation predominates in many countries, such as Thailand and Brazil.

Among the cereals, rice production uses the highest proportion of land area. Of the 147.5 million ha of land devoted to rice production worldwide in 1989, developing countries contributed 141.4 million ha, or 96 percent. Asia accounted for 90 percent of the world's land area cultivated to rice; in this region, 132.1 million ha are used for this crop (FAO, 1990a).

Mean yields of cereal crops in various regions of the world in 1989 were lower in developing countries than in developed countries (FAO, 1990a), (Table 3). Rough rice yields were highest in Oceania, mainly Australia, followed by Europe and North and Central America, and were lowest in Africa and South America.

When the yields of the various cereals were adjusted using conversion factors based on extraction rates, rice was shown to have the highest food yield among the cereals (Table 4). Food energy yields were approximately proportional to food yields, since energy contents of the cereals are similar. Food protein yield, however, was higher in white wheat flour than in milled rice because the protein content of wheat flour is higher than that of milled rice.

TABLE 1 - Annual production of cereal crops, total tubers and roots and pulses by region, 1989 (million tonnes)

Region	Wheat	Rough rice	Maize	Sorghum	Millet	Barley	Rye	Oats	Total cereals	Total tubers and roots	Soybean, peanut and pulses
Africa	12.7	10.7	37.0	13.7	9.3	5.6	0.01	0.2	90.5	102.6	11.7
North and Central America	84.2	9.5	212.0	22.0	0.2	20.9	1.2	9.1	360.6	23.8	59.9

South America	19.0	17.1	36.6	3.1	0.05	1.2	0.1	1.1	78.4	43.7	36.3
Asia	192.0	469.9	113.7	19.1	15.2	15.3	1.2	0.9	830.0	242.0	55.4
Europe	127.5	2.2	55.5	0.6	0.03	71.6	13.5	11.7	290.9	103.0	10.1
Oceania	14.3	0.8	0.3	1.2	0.02	4.4	0.02	1.7	23.0	2.9	1.8
Soviet Union	92.3	2.6	15.3	0.2	4.1	48.5	20.1	16.8	201.3	72.0	12.5
World	542.0	512.7	470.5	59.9	28.9	167.6	36.1	41.6	1 874.7	590.2	185.6
Developed countries	317.2	25.5	280.8	18.1	4.3	145.7	34.8	39.3	877.1	203.6	80.4
Developing countries	224.7	487.2	189.7	41.8	24.6	21.9	1.3	2.3	997.6	386.6	105.2

Sources: FAO, 1990a, 1990b.

TABLE 2 - Rough rice production and rice imports and exports, 1988, and estimated irrigated rice area, 1987

Region or country	Rough rice production	Rice imports[a] (million tonnes)	Rice exports[a] (% of rice area)	Irrigated area

(million tonnes)	(million tonnes)			
World	492 137	11 408	12 185	53
Asia	449 252	5 309	8 099	
Bangladesh	23 097	674	-	19
China	173 515	314	802	93
Hong Kong	-	364	12	
India	106 385	684	350	44
Indonesia	41676	33	-	81
Iraq	141	603	-	-
Japan	12419	16	-	99
Korea, DPR	5400	-	200	67
Korea, Rep. of	8260	1	1	99
Malaysia	1 783	284	5	54
Myanmar	13 164	-	64	18
Pakistan	4 800	-	1 210	100
Philippines	8 971	119	-	58
Saudi Arabia	-	363		

Singapore	-	213	3	
Sri Lanka	2 477	194	-	77
Thailand	21263	-	5 267	27
Viet Nam	17 000	176	97	46
North and Central America	9 509	699	2 261	
United States	7 253	0	2 260	100
Africa	9 785	2 589	87	
Egypt	2 132	-	71	100
Madagascar	2 149	37	0	31
Nigeria	1400	200	0	1 6
South America	17 741	255	467	
Brazil	11 806	108	26	18
Europe	2 211	1827	950	
Italy	1093	95	510	
Australia	740	0	297	
Soviet Union	2866	498	22	

[a] Milled rice basis. Conversion factor from rough rice to milled rice is 0.7.

Sources: FAO, 1990a: IRRI, 1991a.

TABLE 3 - Mean yield of cereal crops by region, 1989 (t/ha)

Region	Wheat	Rough	Maize	Sorghum	Millet	Barley	Rye	Oats	Total cereals
Africa	1.47	1.95	1.77	0.81	0.65	1.12	0.13	0.21	1.22
North and Central America	2.10	5.09	5.92	3.37	1.20	2.52	1.79	1.83	3.65
South America	1.90	2.50	2.10	2.23	1.11	1.71	1.02	1.45	2.09
Asia	2.32	3.56	2.90	1.04	0.77	1.41	1.44	1.51	2.71
Europe	4.60	5.35	4.96	3.74	1.22	4.04	3.03	2.89	4.26
Oceania	1.59	7.40	4.93	1.86	0.89	1.80	0.54	1.48	1.69
Soviet Union	1.94	3.90	3.72	1.22	1.48	1.76	1.87	1.56	1.90
World	2.40	3.48	3.66	1.35	0.78	2.31	2.14	1.79	2.66
Developed countries	2.53	5.86	6.05	3.17	1.46	2.60	2.18	1.83	3.10
Developing	2.24	3.40	2.31	1.08	0.72	1.32	1.40	1.36	2.37

countries									

Source: FAO, 1990a.

TABLE 4 - Comparison of grain yield, food energy yield and protein yield of cereals based on energy and protein contents and conversion factor (extraction rate)

Cereal	Mean yield (t/ha)	Conversion factor	Conversion factor derivation	Adjusted yield (t/ha)	Energy content (kcal/g)	Food energy yield (10^{-6} kcal/g)	Protein content[a] (%)	Adjusted protein (%Nx6.25)	Food protein yield (t/ha)
Wheat	2.40	0.73	white flour	1.8	3.85	6.9	11.2	12.3	0.22
Rough rice	3.48	0.70	milled rice	2.4	3.75	9.0	7.5	7.9	0.19
Maize	3.66	0.56	corn meal	2.0	3.97	7.9	7.5	7.5	0.15
Sorghum	1.35	0.80	white flour	1.1	3.85	4.2	8.3	8.3	0.09
Millet	0.78	1.0	whole grain	0.78	3.94	3.1	5.6	5.6	0.04
Barley	2.31	0.55	white flour	1.3	3.90	5.1	8.2	8.2	0.11

Rye	2.14	0.83	white flour	1.8	3.75	6.8	7.3	8.0	0.14
Oats	1.79	0.58	white oats	1.0	3.92	3.9	14.2	14.2	0.14

[a] N factor was 6.25, except 5.7 for wheat and rye and 5.95 for rice.

Sources: FAO, 1990a; Lu & Chang, 1980; Eggum, 1969, 1977, 1979.

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Methods of rice production

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Irrigated rice

Review of rice production methods has shown that practices range from very primitive to highly mechanized (De Datta, 1981; Luh, 1980; Yoshida, 1981). Tractors and two-wheeled power tillers are the most important agricultural machines used for rice production (Barker, Herdt and Rose, 1985). In 1980 the number of power tillers used per 1 000 ha was from 0.1 to 26 in tropical Asia,

56 in China, 73 in Taiwan (province of China), 198 in the Republic of Korea and 1158 in Japan. In Asia, animals (buffalo and water buffalo, carabao) are still used for ploughing and harrowing. Land preparation may be carried out while the soil is dry or wet, depending on the water supply. For irrigated rice, the soil is prepared wet or puddled in Asia, but puddling is not generally practiced in America, Europe and Africa. In areas without a hard pan, where animals and tractors sink in the mud, the soil is prepared with hand hoes. Regardless of whether the land is prepared wet or dry, the water is always held on the lowland fields by bunds.

Most irrigated rice is transplanted, although direct seeding is becoming more extensive. The seeds are pregerminated and grown in wet seed-beds for 9 to 14, 20 to 25 or 40 to 50 days after sowing and are then transplanted either by hand or by mechanical transplanters. The number of seedlings per hill may vary from one to eight. Direct seeding is done by broadcasting the pregerminated grain by hand in Asia or by water-seeding by airplane in the United States and Australia. The seeds may also be machine-drilled in puddled soil or drill-seeded into dry soil. Deep-water rice is commonly dryseeded, but it is occasionally transplanted or double transplanted.

Ideally, water is maintained in the rice field to suppress weed growth during the growing season. Hand weeding and mechanical or rotary weeders are popular. Herbicides are also economical and effective. Fertilization is normally practiced for increased yield, particularly with the modern, semi-dwarf or high-yielding varieties which respond well to fertilizer without lodging. Both inorganic and organic fertilizers are used, including green manures such as the leguminous shrub Sesbania spp. and the water plants Azolla and Anabaena spp. Modern rice varieties increase in

grain yield by 6 kg per kg of applied fertilizer in the wet season and by 9 kg per kg of applied fertilizer in the dry season. Total fertilizer nutrients range from 10 to 100 kg/ha in tropical Asia and from 200 to 350 kg/ha in Japan, Taiwan and the Republic of Korea (Barker, Herdt and Rose, 1985).

Other rice ecosystems

Rain-fed lowland rice is grown on puddled soil in fields bounded by dykes that can pond water to depths of 0 to 25 cm (shallow) and 25 to 50 cm (medium), depths seldom exceeded in such areas (Huke and Huke, 1990). The irrigation water is not received from river diversions, storage reservoirs or deep wells, but from rainfall or runoff from a local catchment area. The prevailing climatic and soil conditions in shallow rain-fed rice areas are extremely variable. In deep-water (50 to 100 cm) rain-fed lowland rice, modern semi-dwarf varieties cannot be used. Fertilizer use is low, stand establishment difficult and pest control almost impossible, and yields are poor. Rain-fed lowland rice is next to irrigated rice in importance in terms of harvested area and production of rice (Table 5).

Upland rice is grown in fields that are not bunded but are prepared and seeded under dry conditions and depend on rainfall for moisture (Huke and Huke, 1990). In Brazil, a major part of the rice crop is upland. In India and throughout Southeast Asia, upland cultivation is common along river banks as waters recede at the end of the rainy season. Soils are commonly heavy and residual moisture alone sustains growth. Upland rice farming ranges from shifting cultivation of forested hilly or mountainous areas that are cleared and burned to large-scale mechanized operations. Between these two extremes is farming of sloping hill regions that are subject to

serious erosion and frequent drought, by hundreds of thousands of the poorest of rice farmers. The environmental damage here is very serious. In South and Southeast Asia some 13 percent of the total rice area is upland, but in some countries in Africa and Latin America upland rice exceeds 50 percent of the national total rice area. Yields are lowest in upland rice (Table 5).

TABLE 5 - Harvested area, yield and rough rice production in 37 major rice" producing developing countries, by ecosystem, 1985

Ecosystem	**Area**		**Yield (t/ha)**	**Production**	
	(million ha)	(%)		(million t)	(%)
Irrigated	67	49	4.7	313	72
Rain-fed lowland	40	29	2.1	84	19
Upland	18	13	11	21	5
Deep-water/tidal wetland	13	9	1.5	19	4
Total	138	100	3.2[a]	437	100

[a] Weighted average. Source: IRRI, 1989.

In deep-water rice, water depth is at least 1 m during a significant portion of the growing season. In large parts of Bangladesh as well as in portions of the Mekong and the Chao Praya Deltas, water depth may exceed 5 m, but it is normally between 1 and 3 m in other regions (Huke and Huke, 1990). Where water rises rapidly after the start of the monsoon rains, rice is commonly broadcast in unpuddled fields that are seldom bounded by dykes of any sort. The varieties planted are tall and leafy, with few tillers. They are photoperiod sensitive and mature only after the rainy season. They can elongate and float as the water level rises. Major dyking and flood control projects in the last two decades have upgraded many former deep-water rice areas into the rain-fed or irrigated category in Bangladesh, India, Thailand and southern Viet Nam.

Harvesting

Tropical rice is usually harvested at 20 percent or more moisture about 30 days after 50 percent flowering, when grains will provide optimum total and head rice yields. Moisture content at harvest is lower during the dry season than in the wet season because of sun-drying while the grains are in the intact plant. The actual period of dry-matter production is no more than 14 to 18 days, after which the grain undergoes drying.

Harvesting is carried out by cutting the stem, sun-drying and then threshing by hand by beating the rice heads on a slotted bamboo platform, by having animals or people tread on the crop or by the use of mechanical threshers. Combine harvesters are used in large areas such as the Muda estate in Malaysia and in the United States, Australia, Europe and Latin America.

Sun-drying to 14 percent moisture is a common practice but is unreliable during the wet season. Many mechanical dryers have been designed but have not been popular with farmers and processors. After drying, the rough rice is winnowed to remove the chaff using either a hand winnower or a manually operated wooden winnower.

Labour use

More labour may be used by Asian farmers growing modern varieties than by those growing traditional varieties (Barker, Herdt & Rose, 1985). The contribution of family labour and hired labour is quite variable with location.

The various steps in rice cultivation include seed selection, seed-bed and land preparation, transplanting, weeding, fertilizing, pest management, harvesting, threshing, drying and marketing. Huke and Huke (1990) estimated that the labour requirements for one hectare of low-intensity rice production relying on rainfall for water and using improved IR36 seed and 50 kg of urea fertilizer are about 84 person-days and 14 animal-days to yield 2.5 tonnes of rough rice. In obtaining the 2.5 tonne yield, harvesting with a sickle and hand threshing against a log will consume at least 22 person-days. By contrast, labour input in high-technology California rice production of about 350 ha is 40 person-days (Herds, 1986).

Huke and Huke (1990) calculated the energy efficiency of low-intensity rice production at a specific site in the Philippines to be 12 calories per calorie expended. Under medium and high inputs, output ratios were 7 to 8 calories per calorie expended.

While women make up 25 to 70 percent of the labour in rice farming systems in Asia, their role has not been recognized until recently and their needs have remained unaddressed in technology development (Feldstein and Poats, 1990). They participate in rice and rice-related production, marketing and processing activities. It is now widely appreciated that women are often active in agricultural production and that they, as well as men, are potential users and beneficiaries of new technology. Gender analysis is now integrated into research projects and priority is given to technologies that reduce the burden of rural women without displacing their income-generating capacities. These technologies include integrated pest management, seed management and post-harvest rice utilization and processing (Unnevehr and Stanford, 1985).

Production costs

The total cost of producing one tonne of rough rice in 1987-89 is compared for irrigated upland and rain-fed rice in Table 6. Total cost per hectare and grain yield were highest for irrigated rice and lowest for upland rice.

Modern high-yield varieties

In the 1950s, growth in rice production in most Asian countries was due to expansion of the area planted, but in the 1960s and 1970s yield increase was more important (Barker, Herdt and Rose, 1985). Contributing factors were the introduction of semi-dwarf varieties and higher fertilizer inputs.

The semi-dwarf varieties developed at the International Rice Research Institute (IRRI) have a plant type that contrasts with that of the tall, traditional, photoperiod-sensitive varieties. They have erect leaves, are heavy tillering and have low photoperiod sensitivity. Their plant architecture allows them to absorb nutrients without lodging and allows sunlight to penetrate the leaf canopy. Growth duration is shorter in the modern varieties and is close to 100 days from seeding, which allow three crops per year. At low input levels, they yield comparably to traditional varieties. However, in all cases, modern varieties outperform traditional varieties, given additional inputs of energy, insecticides and fertilizers.

TABLE 6 - Cost of producing one tonne of rough rice, 1987-89 (US$)

Country	Irrigated	Upland	Rain-fed
Argentina	870	-	-
Colombia	204	-	194
Ecuador	441	196	295
India	-	-	303
Indonesia	82	141	104
Italy	543	-	-
Japan	3 676	-	-
Korea, Republic of	939	-	-

Nepal	96	-	108
Philippines	1 24	-	-
Portugal	376	-	-
Thailand	98	-	-
United States	481	-	-

Source: FAO. 1991.

By 1981-84, modern varieties covered 13 percent of the total rice area in Thailand, 34 percent in the Republic of Korea, 25 percent in China, 25 percent in Bangladesh, 36 percent in Nepal, 54 percent in Malaysia, 46 percent in Pakistan, 49 percent in Myanmar, 54 percent in India, 82 percent in Indonesia, 85 percent in the Philippines and 87 percent in Sri Lanka (Dalrymple, 1986). The low adoption rate in Thailand is due to the requirement in that country for long-grain varieties (brown rice length greater than 7 mm) for export. More than 60 percent of the world's rice area is now planted to varieties of improved plant type.

The yield potentials of the new modern varieties are no better than those of the first modern variety, IR8, but they show improved resistance to insect pests and diseases and increased tolerance to environmental stresses. However, their increased resistances are single-gene characteristics which are overcome by the pests in a few years. insect resurgence has been documented in which insecticide spraying increased the insect population instead of reducing it (Chelliah and Heinrichs, 1984). Alternative approaches of horizontal or multiline resistance are

considered necessary, as there is a rapid breakdown of resistance to the brown planthopper because of the appearance of new insect biotypes. No source of resistance to tungro virus disease has been identified in cultivated rice, O. saliva. However, resistance sources have been identified in wild species and are being introduced through wide crosses to O. saliva.

Farm units

The mean size of the rice farm is less than 1 ha in Bangladesh, Japan, the Republic of Korea and Sri Lanka, over 1 ha in Indonesia and Nepal, about 2 ha in Malaysia, Pakistan and the Philippines and about 3 ha in Thailand (IRRI, 1991a). The most common types of tenure are share-cropping and fixed rent (Barker, Herdt and Rose, 1985). Share-cropping is widely practiced in Bangladesh, India, Pakistan and Indonesia. Fixed-rent systems exist in all countries of the region, but are less common than share rents. In land reform in China, North Korea, Viet Nam and Myanmar, land has been expropriated by governments and held in public ownership; in Japan and Taiwan, former tenants were deemed owners. In the Philippines, the 1972 land reform for fixed-rent tenants was rapidly implemented, but land ownership transfer has been slow.

Rice trade

About 4 percent of the world's rice production enters international trade. The major exporters in 1988 were Thailand, the United States and Pakistan, while the major importers were Iraq, the Soviet Union, Hong Kong, Saudi Arabia, Malaysia, Singapore, Sri Lanka, Nigeria, Bangladesh and

Brazil (FAO, 1990a, Table 2). Viet Nam became the third largest rice exporter in the world in 1989, with 1.38 million metric tons of milled rice (IRRI, 1991a).

Pests and diseases

Pests and diseases are major problems in the tropics, particularly with rice monoculture, since hosts are continuously present in the environment. Rodents, birds and golden snails all reduce rice yields. The major insect pests are the yellow stem borer, the green leafhopper, which is the vector of the tungro virus, and brown planthoppers, which cause hopperburn. Insect control has been attempted by breeding varieties with improved resistance to the pests. Integrated pest management is becoming more popular in view of the problem of insect resurgence from the excessive use of insecticides.

The major diseases of rice plants in tropical Asia remain the rice blast fungus and bacterial leaf blight. The existence of many races of the blast fungus makes control difficult. Blast is a particular problem in upland rice. The major virus disease is the tungro virus, transmitted by the green leafhopper. The rice weevil and hoja blanca are the main problems in Latin America, while yellow mottle virus and diopsis predominate in Africa.

The incorporation of resistance into rice varieties is complicated by the presence of many races of diseases, as in blast, and the existence of biotypes of pests, as in the brown planthopper.

Conclusion

The great production gains in the 1960s and 1970s occurred in the irrigated and favourable rain-fed lowland areas, where short-duration, semi-dwarf varieties could express their high yield potential. Mean farm yields of irrigated rice in many countries are still about 3 to 5 tonnes per ha, but some farmers can obtain twice that. Irrigated land now comprises about half of total harvested area, but it contributes more than two-thirds of total production and is expected to continue to dominate the sector (Table 5). The less favourable environments (unfavourable rain-fed lowland, upland, and deep-water and tidal wetland) produce 20 to 25 percent of the world's rice. These rice ecosystems must sustain farmers and consumers who so far have received little benefit from modern advances in rice technology.

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Chapter 2 - Rice consumption and nutrition problems in riceconsuming countries

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In 39 countries rice is the staple diet, but the dependence on rice for food energy is much higher in Asia than in other regions (FAO, 1984), (Table 7). The energy dependence on rice in South and

Southeast Asia is higher than the energy dependence on any other staples in other regions. South Asia also has the lowest energy intake. Rice provides 35 to 59 percent of energy consumed for 2 700 million people in Asia (FAO, 1984). A mean of 8 percent of food energy is supplied by rice for 1 000 million people in Africa and Latin America.

FAO statistics for 1987-89 showed that rice availability per caput could supply from 19 to over 76 percent of total food energy in different Asian countries (Table 8). This range is equivalent to a milled rice availability ranging from 40 to 161 kg per caput annually.

The contribution of rice to protein in the diet, based on FAO Food, balance sheets for 1979-81, was 69.2 percent in South Asia and 51.4 percent in Southeast Asia (FAO, 1984), (Table 7). These percentages are higher than the contribution of any other cereal protein in any region of the world.

With the exception of the highest income countries in Asia, per caput rice consumption has remained stable or has increased moderately over the past 30 years. Total consumption continues to increase in close association with population and income growth. Rice supply, personal income and the availability and price of dietary substitutes are key determinants of the diversity in Asian diets, in addition to the quality of the rice being consumed. The greatest factor affecting demand, however, continues to be the unabated except China, which is 1984-86 average. population growth, particularly in the poorest countries wherein rice constitutes the most important component of the diet (Huang, 1987).

TABLE 7 - Energy and protein contribution to diets in developing-country regions by commodity,

1979-81

Region	Energy contribution (% of regional total)						Total energy (kcal/day)	Protein contribution (% of regional total)		
	Rice	Wheat	Maize	Barley	Sorghum and millet	Roots, tubers and plantain		Rice	Other cereals	Roots, tubers and plantain
Temperate South America[a]	1.3	30.7	1.4	0.2	0	4.7	3178	1.0	20.4	2.4
Tropical	14.9	12.8	9.3	0.3	0	11.9	2514	12.9	19.7	3.6
Central America[b]	5.1	11.4	35.0	0	0.6	4.0	2655	5.0	37.4	0
East/Southern Africa[c]	3.0	5.7	33.6	0	4.6	23.0	2047	2.9	48.1	5.9
Equatorial Africa[e]	9.5	2.3	8.4	0.1	5.9	46.4	2153	1 1.8	30.0	12.9

Humid West Africa[f]	18.3	4.5	10.6	-	4.1	35.2	2120	20.3	20.2	15.9
Semi-arid West Africa[g]	6.8	4.6	5.6	0.1	31.1	20.9	2290	6.9	42.7	9.7
North Africa/ Near East[h]	6.0	39.6	5.8	2.6	4.5	1.7	2594	5.1	53.0	0.9
India	33.2	18.5	3.1	0.7	11.0	2.5	2056	32.3	35.4	0
South Asia[i]	68.0	9.9	2.5	0.1	0.4	3.7	1898	69.2	13.1	0
Southeast Asia[j]	56.1	4.7	6.1	0.6	0.4	7.6	2414	51.4	10.1	1.4
China	35.4	18.4	7.7	0.6	2.9	12.1	2428	28.6	26.9	5.0
All developing countries	29.3	17.5	7.6	0.8	4.9	9.1	2349	25.3	29.1	2.7

[a] Argentina, Chile, Uruguay.

[b] Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru Suriname, Venezuela

[c] Costa Rica, Cuba, the Dominican Republic, El Salvador, Guatemala. Haiti, Honduras, Mexico,

Nicaragua.

[d] Angola, Botswana, Kenya, Lesotho, Malawi, Mozambique, Swaziland, United Republic of Tanzania, Zambia. Zimbabwe.

[e] Burundi, Cameroon, the Central African Republic, the Congo, Gabon, Madagascar, Rwanda, Uganda, Zaire.

[f] Benin, Cte d'lvoire. Ghana, Guinea, Liberia, Sierra Leone, Togo.

[g] Burkina Faso, Chad, the Gambia, Guinea-Bissau, Mali, Mauritania. the Niger, Nigeria Senegal.

[h] Afghanistan, Algeria, Cyprus, Egypt, Ethiopia. Islamic Republic of Iran, Iraq, Jordan, Lebanon, the Libyan Arab Jamahiriya, Morocco, Pakistan, Saudi Arabia

Somalia, the Sudan, the Syrian Arab Republic, Tunisia, Turkey, Yemen AR, Yemen PDR.

[i] Bangladesh, Nepal, Sri Lanka.

[j] Bhutan, Cambodia, Indonesia, Democratic People's Republic of Korea, Republic of Korea, Laos, Malaysia, Myanmar.,the Philippines, Thailand, Viet Nam.

Source: FAO, 1984.

TABLE 8 - Per caput availability of milled rice and contribution of rice to dietary energy and protein in selected rice-eating countries

Country	Availability of milled rice (kg/caput/year)	% Contribution of rice	
		Energy	Protein
Bangladesh	142	73	63
Belize	25	9	7
Brazil	41	16	14
Brunei	94	36	23
Cambodia	173	80	71
China	104	38	27
Colombia	36	25	13
Comoros	78	42	37
Cte d'lvoire	63	23	22
Dominican Republic	44	19	18
Gambia	98	40	32

Guinea	59	28	26
Guinea-Bissau	116	48	45
Guyana	86	33	29
Hong Kong	59	21	12
India	68	31	24
Indonesia	140	59	49
Japan	64	25	14
Korea, DPR	125	48	29
Korea, Republic of	98	38	25
Liberia	110	43	49
Madagascar	111	53	50
Malaysia	84	31	26
Maldives	60	26	14
Mauritius	71	26	16
Myanmar	187	76	68
Nepal	94	44	35
Papua New Guinea	39	16	14

Philippines	92	40	31
Seychelles	68	30	21
Sierra Leone	89	44	41
Singapore	58	19	12
Sri Lanka	92	42	39
Suriname	103	35	30
Thailand	132	58	48
Vanuatu	43	17	12
Viet Nam	147	68	62

Source: FAO (Statistics Division) 1987-89 average.

Within a country, rice consumption is higher in the rural than in the urban areas. While income elasticity for rice will undoubtedly decline as income increases, only Japan, Malaysia, Singapore, Taiwan and Thailand have income levels that support negative estimates of income elasticities for rice (Huang, David and Duff, 1991), (Table 9). However, the population and rice consumption of these five countries account for less than 10 percent of totals for Asia. In most Asian countries, therefore, rice is not an inferior food and income elasticities for rice will likely remain positive throughout the 1990s.

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Nutritional problems in rice-consuming countries

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The nutritional situation in rice-consuming countries varies substantially depending on a web of interacting socio-economic, developmental, cultural, environmental and dietary factors. Regardless of the region, most rice-dependent economies have high population growth rates, low rice yields (except for China, Korea and Indonesia) and low gross national product (IRRI, 1989), (Table 9). Landholdings are small, low percentages of the population are economically active and literacy rates are variable in tropical Asia (Asian Development Bank, 1989), (Table 9).

TABLE 9 - Key indicators of developing Asian countries, rough rice yield and income elasticity for rice

Country	Economically active population, 1985 (%)	Percent agriculture in economically active population, 1985	Cropped land per caput, 1985 (ha)	Literacy rate 1985 (%)(yr)	Life expectancy at birth, 1985	Per caput GNP, 1987 (US$)	Rough rice yield 1988 (t/ha)	Income elasticity for rice 1988a

Afghanistan	30.1	57.9	0.49	23	(37)	-	2.29	
Bangladesh	28.5	71.8	0.09	33	51	160	2.36	0.125
Bhutan	44.6	91.6	0.07	(10)b	44	-	1.66	
Cambodia	49.5	72.3	0.42	(66)	-	-	1.33	
China	-	-	-	(59)	69	300	5.35	0.299
Hong Kong	51.7	1.6	0.00	88	76	8260		
India	38.6	68.1	0.22	43	57	300	2.54	0.237
Indonesia	38.1	52.8	0.13	74	55	450	4.11	0.446
Korea								
Republic of	40.7	30.1	0.05	(96)	69	2 690	6.56	0.174
Laos	48.9	73.7	0.22	84	45	-	1.91	
Malaysia	39.7	36.7	0.28	73	70	1 800	2.68	-0.349
Myanmar	44.9	50.0	0.27	81	59	-	2.26	0.524
Nepal	41.7	92.4	0.14	25	47	160	2.26	0.435
Pakistan	29.7	52.1	0.20	29	51	350	2.35	
Philippines	36.5	49.2	0.14	86	63	590	2.64	0.324
Singapore	47.9	1.3 0	.00	86	73	7 940	-	0.522

Sri Lanka	36.5	52.5	0.14	87	70	400	3.04	
Taiwan,Province of China	-	-	-	92	73	-	4.86	-0.591
Thailand	51.9	67.7	0.38	91	64	840	2.15	-0.328
Viet Nam	48.2	64.1	0.11	(84)	65	-	2.97	

a Japan, 0.530.

b Figures in parentheses are 1980 values.

Sources: Asian Development Bank, 1989: IRRI, 1991a (rough rice yield); Huang, David and Duff, 1991 (income elasticity).

Malnutrition is not just a problem of food availability; it is also a problem of income and food and income distribution (Flinn and Unnevehr, 1984). Because rice is a major source of income in rural Asia as well as a key component of private expenditure, increased productivity can reduce malnutrition both by increasing the incomes of the poorest rice producers and by increasing the availability of rice and the stability of rice prices.

A summary of nutritional problems prevalent in rice-consuming countries is presented. As 90 percent of the rice is produced and eaten by populations in Southeast Asia, the description is biased toward that region.

Among the major nutritional problems prevalent in rice-consuming countries, inadequate and unbalanced dietary intake is the most important one. In combination with other compounding factors, it leads to widespread prevalence of protein-energy malnutrition (PEM), nutritional anaemia (particularly from iron deficiency), vitamin A deficiency and iodine deficiency disorders (Chong, 1979; Scrimshaw, 1988; Khor, Tee and Kandiah, 1990). In addition, dietary deficiencies of thiamine, riboflavin, calcium, vitamin C and zinc are prevalent in many areas but often are not manifested in overt clinical syndromes.

These nutritional problems are not caused directly by the consumption of rice per se but reflect an overall impact of multiple causative factors similar to those of other developing countries where rice is not a major staple.

Food availability and dietary intake

Data on availability of food and nutrients are derived from FAO Food balance sheets and from nutrition surveys and studies on food consumption.

Food balance sheet data provide estimates of per caput food and nutrient availability taking into consideration food production, imports, exports, non-food uses, manufactured foods and wastage at the retail level. A comparison of daily nutrient supply for developed and developing countries (FAO, 1990b), (Table 10) shows that the Far East has the lowest availability of fat, retinol, thiamine, riboflavin and ascorbic acid. Individual data pertaining to rice-eating countries (Table 11) show that in addition to dietary energy many rice-consuming countries have unsatisfactory levels of fat, calcium, iron, riboflavin and ascorbic acid. When wastage at the

household level, including cooking loss, is taken into account the supply situation becomes more precarious.

Available data from nutrition surveys are often fragmentary and do not pertain to all countries. Even when data are available they may not always be representative and are often out of date. Table 12 presents examples of available data on average consumption of energy and protein from selected countries. Overall this consumption is unsatisfactory when compared with availability of these nutrients, except in China and Mauritius (Table 11). There appears to be a large gap between availability of food and actual consumption, which indicates a significant influence of factors related to food access and utilization. However, these intake values strongly suggest the possibility of widespread prevalence of protein-energy malnutrition in young children. There is also enough indication from available consumption studies to suggest that special groups such as young children and pregnant mothers have dietary intakes that are low in energy, protein, vitamin A, iron, riboflavin and calcium.

TABLE 10 - Comparative daily provisional supply of nutrients per caput in developing and developed countries, 1986-88

Region	Energy (kcal)	Protein (g)	Fat (g)	Calcium (mg)	Iron (mg)	Vitamin A (g retinol equivalents)	Thiamine (mg)	Ribo-flavin (mg)	Niacin (mg)	Ascorbic acid (mg)
World	2 671	70.0	65.8	472	14.4	900	1.39	1.01	15.4	94
Developed	3 398	102.7	128.7	860	16.1	1329	1.61	1.68	20.9	138

countries										
Developing countries	2 434	59.4	45.4	346	13.9	760	1.31	0.79	13.5	80
Africa	2 119	51.1	37.4	363	17.8	859	1.37	0.80	13.8	89
Latin America	2732	69.1	68.6	499	13.5	712	1.32	1.14	14.6	103
Near East	2 914	77.2	68.7	498	18.9	854	1.87	1.12	15.9	103
Far East	2 220	53.2	39.2	352	13.3	588	1.22	0.70	13.2	55
Others	2 379	51.3	61.8	402	14.3	1342	1.16	1.06	15.4	202

Source: FAO, 1990b.

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TABLE 11 - Daily per caput nutrient supply in 36 countries with rice as staple

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Country	Energy (kcal)	Protein (g)	Fat (g)	Calcium (mg)	Iron (mg)	Retinol (g)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid (mg)
Bangladesh	1 996	43.0	17.5	134	7.49	40	7.41	0.37	1.02	16
Belize	2 660	73.7	75.7	683	14.33	310	13.37	1.25	1.57	142
Brazil	2722	60.4	76.0	479	11.23	330	10.17	1.02	1.18	134
Brunei	2824	77.6	72.9	486	18.75	290	11.29	1.16	2.07	67
Cambodia	2 155	50.8	19.2	176	9.51	60	7.84	0.51	1.13	61
Colombia	2571	57.0	60.6	487	14.59	290	11.00	1.10	1.48	96
Comoros	1 896	41.6	32.6	233	9.78	50	6.95	0.65	0.95	80
Cte d'lvoire	2580	54.4	54.0	333	13.28	120	13.90	0.80	1.75	201
Dominican Republic	2 342	47.1	61.9	382	10.03	160	8.48	0.94	1.25	88
Gambia	2 351	56.2	56.3	251	10.72	90	10.31	0.55	1.46	15
Guinea	2 192	51.2	45.8	262	11.86	60	11.57	0.65	1.29	247
Guinea-Bissau	2 471	50.8	55.2	189	9.94	80	9.55	0.64	1.27	43

Guyana	2 739	68.6	46.9	319	10.32	160	9.71	0.89	1.67	47
Hong Kong	2 817	85.4	109.1	389	15.04	420	12.99	1.12	1.73	83
India	2 197	53.2	38.9	417	14.93	70	14.27	0.79	1.41	55
Indonesia	2709	59.7	39.1	226	11.94	50	10.15	0.53	1.40	58
Japan	2909	94.2	78.9	610	15.86	480	13.38	1.21	1.67	114
Korea, DPR	2 798	80.3	36.6	352	16.43	80	15.70	0.99	1.82	136
Korea, Rep. of	2 853	76.8	59.0	501	16.88	160	14.04	0.97	1.59	168
Liberia	2404	42.8	52.8	272	13.01	30	11.70	0.66	1.56	147
Madagascar	2 176	50.9	28.2	230	12.92	150	11.12	0.67	1.50	121
Malaysia	2755	57.9	87.5	323	11.18	140	9.25	0.81	1.40	51
Maldives	2 375	89.2	39.7	387	17.64	60	11.95	1.09	2.80	72
Mauritius	2 823	67.3	58.0	505	13.06	250	10.59	1.02	1.29	29
Myanmar	2 474	63.9	40.4	219	10.27	60	8.70	0.51	1.16	39
Nepal	2 074	52.5	28.5	300	11.29	120	12.92	0.65	1.25	24
Papua New Guinea	2 410	48.8	41.4	403	14.56	90	13.37	1.26	1.64	309
Philippines	2 342	53.1	36.4	211	8.64	90	7.79	0.65	1.20	44

Seychelles	2 340	63.	57.3	410	11.29	160	7.90	0.93	1.39	39
Sierra Leone	1 840	38.1	54.8	222	10.02	40	9.59	0.55	1.20	68
Singapore	3 248	91.1	78.5	533	15.62	280	16.89	1.28	2.09	92
Sri Lanka	2 298	46.3	43.0	334	12.45	50	7.11	0.58	0.96	67
Suriname	2 908	70.1	53.0	447	10.76	140	9.72	0.97	1.55	64
Thailand	2 312	49.0	39.0	198	9.23	90	8.22	0.56	1.15	56
Vanuatu	2 552	65.8	89.7	464	20.08	280	14.18	0.97	1.94	121
Viet Nam	2 232	50.5	28.2	170	8.62	70	7.65	0.54	1.09	74

Source: FAO Statistics Division, 1987-89 average.

General nutritional status

Table 13 provides information on some important indicators of overall nutritional status for 34 rice-consuming countries (UNICEF, 1991). It clearly indicates that in most of these countries the incidence of low birth weight, infant mortality and mortality under five is high and the prevalence of moderately and severely underweight children is alarmingly higher. The life expectancy is also low. About half the people in South Asia and sub-Saharan Africa receive inadequate energy for an active working life. Some 470 million undernourished people live in South Asia. All these data are

a reflection of the poor general nutritional status of the population.

Protein-energy malnutrition

Protein-energy malnutrition still prevails widely in many rice-consuming countries. The low-income developing countries among the group are primarily and seriously affected. PEM is manifested by widespread growth retardation among preschool children. For example, nutrition surveys have shown combined prevalence rates of 71 and 17 percent for moderate and severe underweight among preschool children in Bangladesh and the Philippines, respectively. In many other rice-consuming countries, particularly India, Laos, Madagascar, Nepal, Sierra Leone, Sri Lanka and Viet Nam, PEM is a major factor directly or indirectly contributing to high under-five mortality.

TABLE 12 - Average daily energy and protein intake in selected riceconsuming countries

Country collection	**Year of data (kcal/caput/day)**	**Energy intake (g/caput/day)**	**Protein intake**
Bangladesh	1980/81	1 943	48.0
China	1982	2 485	67.0
Colombia	1981	2 223	55.3
Cte d'lvoire	1979	2 140	55.7

Guyana	1976	2 054	55.5
Indonesia	1980	1 800	43.0
Madagascar	1962	2 223	55.3
Mauritius	1983	3 043	79.4
Nepal	1985	2 440	66.0
Philippines	1987	1 753	49.7
Sri Lanka	1980/81	2 030	49.9
Viet Nam	1988	2 142	59.1

Source: FAO country profiles and national nutrition surveys.

Vitamin A deficiency

Vitamin A deficiency is widespread in rice-consuming populations of tropical Asia (DeMaeyer, 1986). The most severely affected countries include Bangladesh, India, Indonesia, Myanmar, Nepal, the Philippines, Sri Lanka end Viet Nam. Vitamin A deficiency is also a problem in northeastern Brazil.

TABLE 13 - Nutrition indicators for selected rice-consuming countries

Country[a]	Under-five	Infant	Percent low	Percent moderate	Life	Daily per caput

	mortality[b] 1989	mortality[c] 1989	birth-weight[d] 1980-88	and severe underweight, children 0-4 yr[e] 1 980-89	expectancy[f] 1989	energy supply as percent of requirement 1984-86
Sierra Leone	261	151	17	21	42	81
Guinea	241	142	-	-	43	77
Bhutan	193	125	-	38	49	
Bangladesh	184	116	28	71	51	83
Madagascar	179	117	10	33	54	106
Pakistan	162	106	25	52	57	95
Laos	156	106	39	37	49	104
indict	145	96	30	41	59	100
Cte d'lvoire	139	93	14	12	53	110
Indonesia	100	73	14	51	61	116
Guatemala	97	56	14	34	63	105
Myanmar	91	67	16	38	61	119
Brazil	85	61	8	5	65	111

Viet Nam	84	61	18	42	62	105
Dominican Republic	80	63	16	35	66	96
Philippines	72	44	18	33	64	104
Colombia	50	39	8	12	69	110
China	43	31	9	21	70	111
Korea, DPR	36	27	-	-	70	135
Sri Lanka	36	27	28	38	71	110
Thailand	35	21	12	26	66	105
Panama	33	23	8	16	72	107
Korea, Republic of	31	24	9	-	70	122
Malaysia	30	23	10	-	72	121
Mauritius	29	22	9	24	70	121
Singapore	12	8	7	14	74	124
Hong Kong	9	7	5	-	77	121
Japan	6	4	5	-	79	122

[a] Listed in descending order of under-five mortality rate.

[b] Annual number of deaths of children under five years of age per 1000 live births.

[c] Annual number of deaths of children under one year of age per I 000 live births.

[d] 2 500 g or less.

[e] Below minus two standard deviations from median weight for age of reference population.

[f] The number of years new-born children would live if subject to the mortality risks prevailing for the cross-section of population at the time of their birth.

Source: UNICEF, 1991.

Although it is difficult to determine the exact number of new cases of vitamin A deficiency and xerophthalmia occurring globally each year, available data from Indonesia indicated an annual rate of 2.7 per 1 000 children, leading to an estimate of 63 000 new cases annually for Indonesia. If a similar rate is applied to Bangladesh, India and the Philippines some 400 000 preschool children in these countries are likely to develop active corneal lesions resulting in total or partial blindness. It has been further estimated that worldwide some 3 million children under 10 years of age are currently suffering from blindness from xerophthalmia, about I million of whom are in India. In addition, countless children not presenting active signs of xerophthalmia are vitamin A

depleted, a condition associated with decreased resistance to infectious diseases and increased mortality and morbidity.

Nutritional anaemias

Nutritional anaemias, mostly from iron deficiency, are widespread among rice-consuming countries. The causes are low dietary intake of iron, low biological availability of iron from food (Hallberg et al., 1977), blood loss caused by intestinal parasites, particularly hookworm, and unfulfilled increased demand associated with rapid growth and pregnancy.

Anaemia is a condition diagnosed when haemoglobin level is below a set level suggested by the World Health Organization (WHO), depending on the age, sex and physiological condition (with adjustments necessary for high altitudes). AWHO estimate for 1980 (DeMaeyer and Adiels-Tegman, 1985) indicated that about 1 300 million of the 4 400 million people in the world suffer from anaemia and 1 200 million of these are from developing countries. Young children and pregnant women are most affected, with global prevalence rates estimated at 43 percent and 51 percent respectively, followed by school age children (37 percent), women of reproductive age (35 percent) and male adults (17 percent).

The highest overall prevalence of anaemia in the developing countries occurs in South Asia and Africa. The prevalence rate of anaemia in South Asia (DeMaeyer and Adiels-Tegman, 1985) was estimated to be 56 percent in children up to 4 years of aye, 50 percent in 5- to 12-year-old children and 32 percent in men and 58 percent in women 15 to 59 years old. A higher rate (65 percent) was reported for pregnant women. Slightly lower rates were reported for East Asia,

excluding China.

Estimates of anaemia from folate and vitamin B12 deficiency are not known, but this type of anaemia is reported to occur, particularly in India. Dietary patterns suggest increased risk in parts of Southeast Asia, but data are inadequate to confirm this.

Anaemia is an important cause of maternal mortality associated with childbirth. In addition, in adults it lowers work performance and has been linked with reduced immune competence and resistance to infection. Mild anaemia may also have far-reaching effects on psychological function and cognitive development.

Iodine deficiency disorders

Iodine deficiency disorder (IDD) is prevalent in many rice-eating populations, particularly in mountainous regions in Brazil, China, India, Indonesia and Malaysia, where the iodine content of soil, water and food is generally low

(Chong, 1979; Khor, Tee and Kandiah, 1990). IDD is also prevalent in Bangladesh because frequent flooding washes the iodine from the soil. It has been estimated that about 800 million people worldwide are at risk of IDD (United Nations, 1987). Nearly a quarter of those at risk have goitre and over 3 million are estimated to show overt cretinism. Most people at risk are in Asia, including 300 million in China and 200 million in India.

In areas with very high prevalence of iodine deficiency goitre may affect over 50 percent of the

population and occurrence of cretinism may vary from I to 5 percent. An additional 25 percent may suffer from measurable impairment of mental and motor function. In some remote areas of the Himalayas IDD prevalence of 30 percent has been recorded.

Iodine is essential for normal growth and foetal development and for normal physical and mental activities in adults. Apart from overt signs of IDD, iodinedeficient populations may suffer from a variety of consequences that include reduced mental functions, widespread lethargy, increased stillbirths and increased infant mortality.

Thiamine and riboflavin deficiency

Thiamine and riboflavin deficiencies still exist in many parts of Asia. Beriberi is a characteristic disease of rice-eating communities, particularly when polished rice is consumed. It is rarely seen in communities where rice is eaten parboiled or undermilled. The replacement of hand pounding by machine mills in rural areas has aggravated the problem (Chong, 1979). Thiamine and riboflavin availabilities are lowest in Far Eastern diets (FAO, 1990b), (Table 10).

Clinical and experimental studies have suggested that the development of clinical manifestations of beriberi requires a thiamine intake below 0.2 mg per 1 000 kcal. Biochemical signs may be present at intakes as high as 0.3 mg per 1 000 kcal.

Over the years beriberi has tended to disappear as economic conditions have improved and diet has become more varied. Although the prevalence of clinical cases of apparent beriberi in adults has fallen, in many places beriberi in breastfed infants is seen sporadically in some populations.

For example, some rural lactating Thai mothers who only eat rice and salt post partum and who restrict nutritious food are prone to develop thiamine deficiency. The low thiamine content in their breast milk predisposes their breast-fed infants to beriberi.

Angular stomatitis, a clinical sign often attributed to riboflavin deficiency, is also frequently seen in young children, pregnant women and lactating mothers in rice-eating populations in Bangladesh, India and Thailand. In Thai villages riboflavin deficiency has been reported to coexist with thiamine deficiency (Tanphaichitr, 1985).

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