Fermented Foods of the World

A Dictionary and Guide

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Preface

My interest in fermented foods of the world was stimulated by my own and students' researches into fermented foods in Ghana. In the Department of Nutrition and Food Science of the University of Ghana we were concerned with teaching the principles of nutrition, food science and technology to students who would graduate and help ensure the production of safe nutritious food products. Many of these products, including *bread* and *beer*, are fermented and are known throughout the world. In addition, though, there are many staple foods, often made in traditional ways by small-scale processors, which include a wide variety of fermented foods. These products play an important part in local diets, and whilst their production and composition varies from place to place, there is an underlying unity running throughout the world. This was demonstrated to me personally when I was in Chaing Mai in northern Thailand discussing my own researches in West Africa into *dawadawa*, made from the tree legume, *Parkia* species. Fellow food scientists listened and then showed me *thua-nao*, produced from soybeans in northern Thailand, and used similarly to flavour soups and stews.

This dictionary is an attempt to bring together fermented foods from all parts of the world, into a cohesive whole. They are listed in the dictionary as some 3500 individual foods, classified into some 250 groups.

The book is intended for use as a reference sourcebook for students, researchers, food scientists, technologists, nutritionists, biotechnologists, microbiologists, information scientists, product developers, people involved in food inspection and control, food importers, and all those who come across a food unfamiliar to them and who need further information.

I owe much to the years spent in Ghana, to my colleagues, students and friends throughout the world, too numerous to mention, who have helped fill gaps in my knowledge. For help in obtaining literature on fermented foods I am indebted to many librarians, particularly to Michael Walpole, of the Balme library, University of Ghana. I am also indebted to my former colleague Robert Mitchell who has read the text and made much useful constructive criticism, to Anthony Williams for contributing thoughts and ideas, and to Marilyn West for typing the manuscript. I am indebted most of all to Kiran, my wife, who has contributed her own wide international knowledge, and has provided constant encouragement and support.

The classification of the fermented foods, the grouping of the individual types of foods, and any errors and omissions are my own. With so much diversity and local variation within this broad world framework, the work is necessarily incomplete. I would welcome hearing from anyone with knowledge of fermented foods to help improve and extend the work and its usefulness in future.

Geoffrey Campbell-Platt

How to use the dictionary

Types of fermented foods are listed alphabetically. Individual types, shown in bold typeface, indicate the geographical region of production, class of food, and the group entry to refer to.

Group entries, shown in larger bold typeface, are asterisked to indicate their importance: minor ★, medium ★★ or major ★★★. Information is given on regions of production, class of food, consumption, types, production, microbiology and biochemistry, composition and nutritive value, references, and some other similar foods are listed for cross reference.

Where the name of a type of fermented food is protected by a registered trade-mark or has a reserved source of origin, it is indicated by the letters ™. The production methods described are general, and will differ in detail from one type of product to another, and from one producer to another. For beverages where water is normally the major component, compositions are given generally on a wet-weight or 'as consumed' basis. For all other fermented foods, which may be dried or served at different moisture contents, normal moisture content ranges are given, and all other compositional data and energy values are given on a dry matter basis (DM). This allows valid comparisons to be made between foods of different moisture contents. Figures are given as ranges or average values, and variation will exist between different types and individual samples. To convert these figures to a particular sample of food as eaten, they should be multiplied by the factor DM/100, which is equivalent to (100−moisture content)/100.

The introduction gives an overview of the nine classes of fermented foods, with references for further information. Throughout the dictionary, under each fermented food group, references are given. Generally references are given to authoritative composition sources, to production methods and to the microbiology and biochemistry of the fermentation. At the end of the dictionary, all fermented foods are listed alphabetically, both by region of production and by class of food, to allow searches to be made for other fermented foods. Group entries are shown in bold type.

Introduction

Fermented foods may be defined as those foods which have been subjected to the action of micro-organisms or enzymes so that desirable biochemical changes cause significant modification to the food. By fermentation the food may be made more nutritious, more digestible, safer or have better flavour. Fermentation is a relatively efficient low-energy preservation process which can increase product life and reduce the need for refrigeration or other energy-intensive operations in food preservation.

The classes of fermented foods produced in different regions of the world reflect the diet in each region. Fermented foods provide a major contribution to the diet in all parts of the world. Their importance is indicated by world annual production estimates of 700 million hectolitres of *beer*, 12 million tonnes of *cheese* and 1 million tonnes of *mushrooms*. Other groups of fermented foods include *bread*, *yoghurt*, *soy sauce*, *fish sauce*, *peperoni*, *kimchi* and *gari*.

Fermented beverages include alcoholic *wine*, *beer*, *saké*, *brandy*, *whisky* and non-alcoholic *tea*, *coffee* and *cocoa*. These are of major importance throughout the world, particularly so where safe drinking water supplies cannot be guaranteed.

The terms solid substrate fermentation or biotechnology are new but the art of food fermentation is old. The production of many of the fermented foods described in this dictionary lies at the boundary between traditional art and modern science. Knowledge and understanding of what has already been achieved is essential in order to gain maximum benefit from future developments.

History of food fermentations

The transition from hunting and gathering food to organized food cultivation and production is believed to have taken place some 10 000–15 000 years ago, in the Middle East. To store food, three main forms of preservation were developed: drying, salting and fermentation. They were used either singly, or in combination, and are still used today as major methods of food preservation. Descriptions of fermented foods go back as far in time as inscriptions are available.

The Egyptians, Sumarians, Babylonians and Assyrians knew about the use of barley to produce alcoholic beverages; a cuneiform inscription on a Babylonian brick from 2800 BC gave a recipe for the production of *barley wine*, a type of *ale* (Borgstrom, 1968). Early Europeans were known to be making flat *sour-dough bread* from rye in 800 BC, while it is estimated that around 100 BC there were 250 *bread* bakeries operating in Ancient Rome (Pederson, 1979). The drinking of *wine* was common in the Roman Empire throughout Europe and North Africa. Records of *soy sauce* and *miso* production in China go back to around 1000 BC, with the transfer of knowledge of these production processes to Japan occurring around AD 600 (Yokotsuka, 1985). Accounts of production of fermented dairy products can be found in early Sanskrit and Christian works, while recipes of both sweet and savoury fermented milks were given in Roman times around AD 200 (Oberman, 1985).

The Romans were known to be processing fish and making *fish sauce* around this time in Europe and North Africa. Today, South-East and East Asia are the main regions of its production.

Microbiology and biochemistry

Food left uneaten, particularly in warmer climates, spoils due to the growth of micro-organisms. It is known that some bacteria, such as *Salmonella* species, or bacterial toxins, such as those from *Clostridium botulinum* and *Staphylococcus aureus* can cause food poisoning. Since the 1960s it has also been realized that some strains of moulds belonging, for example, to *Aspergillus*, *Penicillium* and *Fusarium* can also

produce toxic metabolites, or mycotoxins, particularly in hot humid conditions.

However, the growth and activity of micro-organisms play an essential role in controlling the whole environment and ecosystem, of which our food supply is only a part. Micro-organisms and their enzymes are responsible for the biochemical changes which occur during food fermentations. The types of organisms which develop in any particular food system depend on the water activity, the pH, the temperature, the composition of the food, and also on the presence of buffering compounds. The practices of using the same containers for successive batches of food, or the addition of starter cultures (Gilliland, 1985), help to direct the fermentation, and to establish dominance. Lactic acid bacteria are perhaps the most widespread of desirable micro-organisms in food fermentations, found in fermented cereal products, milks, cheeses and fermented meats.

Typically, the lactic acid bacteria convert available carbohydrate to lactic acid, so lowering the pH, and, if the fermentation is prolonged, changing the environment to one more suitable for yeast growth. They also produce flavour compounds including diacetyl, acetaldehyde and acetoin. Carbohydrate metabolism by lactic acid bacteria has been reviewed by Kandler (1983), and their role in proteolysis and flavour production during maturation of foods such as cheeses is discussed by Law and Kolstad (1983). The production of the antibiotic penicillin by some species of *Penicillium* mould is well known, but less understood are the mechanisms by which particular bacteria gain dominance. The metabolism of lactic acid bacteria is controlled by their plasmids. They are able to suppress competitive organisms, for example *Lactobacillus plantarum* appears in many 'natural' fermentations, and may be particularly active in suppressing competitors, perhaps by acetate production. The application of modern science to the traditional art of food fermentation has however led to some over-simplification. Although yeast of *Saccharomyces cerevisiae* is the dominant organism in *beer* and *bread* fermentations, lactic acid bacteria are normally also present, in symbiotic relationship. Moulds are found in the environment playing a major role in the rotting or breakdown of vegetation, and the fruiting bodies of moulds are eaten directly as *mushrooms*. In food fermentations in Asia, moulds of *Rhizopus* and *Aspergillus* species are important in many legume product fermentations, while elsewhere *Penicillium* moulds are responsible for the blue veining of *blue cheese* and the white coat of *camembert* cheese.

Nutritive values

In East and South-East Asia moulds play a major part in food fermentations. The microbiology of the Indonesian *tempe* process was explained by scientific investigation as a *Rhizopus* mould fermentation. More recently, on investigation of the increase in cobalamin or vitamin B_{12} levels found as the soybeans were fermented to *tempe*, the bacterium *Klebsiella pneumoniae* has been found to be responsible (Steinkraus, 1985). This synthesis of vitamin B_{12} is vital to people on vegetarian diets, as the vitamin is normally found only in meats and milks, and its absence leads to pernicious anaemia. The author has also found *Klebsiella pneumoniae* and *Enterobacter* species to be active in West Africa *dawadawa* fermentation, from legume beans of *Parkia* species. *Dawadawa* is a good source of riboflavin, which is generally deficient in West African diets (Campbell-Platt, 1980). Food choice is generally conservative, but lack of variety is more critical in poorer regions. In Southern Africa it has been found that *sorghum beer* consumption prevented pellagra, due to B vitamin deficiency, in people living predominantly on a maize-based diet. The term biological ennoblement has been coined by Platt (1964) to describe this vital role of food fermentations in Africa.

The conversion of lactose to lactic acid in *yoghurt*, and the breakdown of the toxic glucoside linamarin in casava in *gari* production, and the breakdown of antinutrients and improved digestibility in fermented legume products are illustrations of the nutritive importance of fermented foods.

While fermentation can improve the nutritive value of foods, excessive fermentation can lead to the loss of nutrients, as happens in the production of ammonia from amino acids.

The acceptability and quantity of food consumed generally decreases where particularly strong flavours or odours are generated. Whereas fermentation was originally necessary in many cases to give a fully-preserved food, the modern preference for milder flavours and the combination with other widely-available technologies, such as refrigeration, has led to the production of less-fermented or non-fermented foods. Examples of these include *bacon*, *pickled fruit*, *pickled vegetables* and *butter*. Combination treatments promise to become more important in the future. Whether used alone or together with other methods of preservation, fermentation has the major advantage of providing flavour and variety to the diet. The key to good nutrition is the consumption of a well-balanced, nutritious and varied diet.

Literature on fermented foods

The increasing interest in fermented foods recently has been reflected in the range of reviews and multi-author works which have been published, covering various food fermentations. These include: Hesseltine's *Millenium of food fermentations* (1965); Smith and Palumbo's *Micro-organisms as food additives* (1981); the 4th edition of *Prescott and Dunn's Indus-*

trial Microbiology (edited by Reed, 1982a); Jay's *Modern Food Microbiology*, 2nd edition (1979); National Academy of Sciences *Microbial Processes: Promising Technologies for Developing Countries* (1979); Pederson's *Microbiology of Food Fermentations*, 2nd edition (1979); *Fermented Food Beverages in Nutrition*, edited by Gastineau, Darby and Turner (1979); *Microbial Technology*, 2nd edition, edited by Peppler and Perlman (1979); *Handbook of Indigenous Fermented Foods*, edited by Steinkraus (1983). *Economic Microbiology, Vol 7, Fermented Foods*, edited by Rose (1982); and *Microbiology of Fermented Foods*, edited by Wood (1985).

These works should be consulted to give more background or information on fermented foods presented in this dictionary.

Classification of fermented foods

Fermented foods can be divided into nine classes:

1. Beverages
2. Cereal products
3. Dairy products
4. Fish products
5. Fruit and vegetable products
6. Legumes
7. Meat products
8. Starch crop products
9. Miscellaneous products

The largest number of types of fermented foods are dairy products, reflecting the great interest worldwide in processing nutritious, but highly perishable, fresh milk. The other two major classes of fermented foods in the world are cereal products and beverages.

The major component of diets worldwide is cereals, whether consumed directly, indirectly via animals, or used as the basis for beverages such as *beers* and distilled *spirits*.

The class miscellaneous foods includes *mushrooms*, the fruiting bodies of edible fungi.

Starch crop products made from cassava, potatoes, sweet potatoes, yams, cocoyams and bananas are treated separately because of their role as staple foods in some parts of the world, notably Africa.

The world has been divided into ten geographical regions as shown on the map (*Figure 1*). Regions of major and minor fermented food class production are shown in *Table 1*.

Europe is the world's most important fermented food producer, and the most significant producer of fermented dairy products, cereals, beverages and meat products, but only a minor producer of fermented legume and starch crop products. North America, populated chiefly by European immigrants, is the second most important producer of fermented foods, although only minor quantities of fermented legumes, starch crops and fish products are produced.

Africa South of the Sahara, is the third largest fermented food producer. Because Africa has a much hotter climate, its traditional foods are different; it is the world's major producer of fermented starch crops, many of which are tropical crops, but it is only an insignificant producer of fermented dairy products, because of low milk production. Then comes South America, including Central America, which produces many beverages and dairy products and reasonable quantities of most fermented foods.

Production of different types of fermented foods in the other four medium-level producing regions reflects their climates and types of food consumed. In the Middle East, larger quantities of fermented dairy products are made; in the Indian subcontinent cereal and legume fermentations are dominant, while in East and South East Asia legume and fish fermentations are particularly important, and indeed are the major protein sources.

Oceania and North Africa are less important producers of fermented foods, but this is as much a reflection of their relatively low populations as it is of any lack of interest in fermenting food.

Relatively few fermented foods are produced in all regions of the world. Those which are include the meat product *sausage*, dairy products *cheese*, *butter* and *yoghurt*; and from fruit and vegetable products *pickled fruit* and *vegetables*. The cereal products *bread*, *brown bread*, *brown roll*, *buns*, *doughnuts*, *flat bread*, *french bread*, *malt*, *mash*, *nan*, *pancakes*, *rolls*, *tea bread*, *white bread*, *wholemeal bread* and *wort* are produced everywhere. Beverages produced in all regions include *beer*, *brandy*, *digestive*, *fruit liqueur*, *herb liqueur*, *lager*, *liqueur*, *red wine*, *rosé wine*, *rum*, *sparkling wine*, *spirit*, *white wine* and *wine*. Miscellaneous fermented foods produced worldwide are *mushroom*, *pickle*, *vinegar* and *yeast*, including the types *bakers' yeast*, *brewers' yeast* and *leaven*.

Beverages

Beverages are produced in large quantities in all regions of the world, and a large proportion of these involve fermentation. The fermentation may be the major part of the process as in *beer* and *wine* production, or these beverages may then be further processed by distillation to produce *spirits* such as *whisky*, *gin*, *brandy* or *liqueurs*.

Non-alcoholic beverages such as *coffee*, *cocoa* and *tea* all involve fermentation in conversion of the harvested crops to the flavoursome base for the beverage as consumed.

The groups of beverages produced in any particular region or country reflect the crops grown locally. The combined effects of crop production, costs of transportation and the application of different duty levels on beverage consumption can be illustrated in Europe. The colder northern countries of Europe, including Britain, Scandinavia, Netherlands and Poland

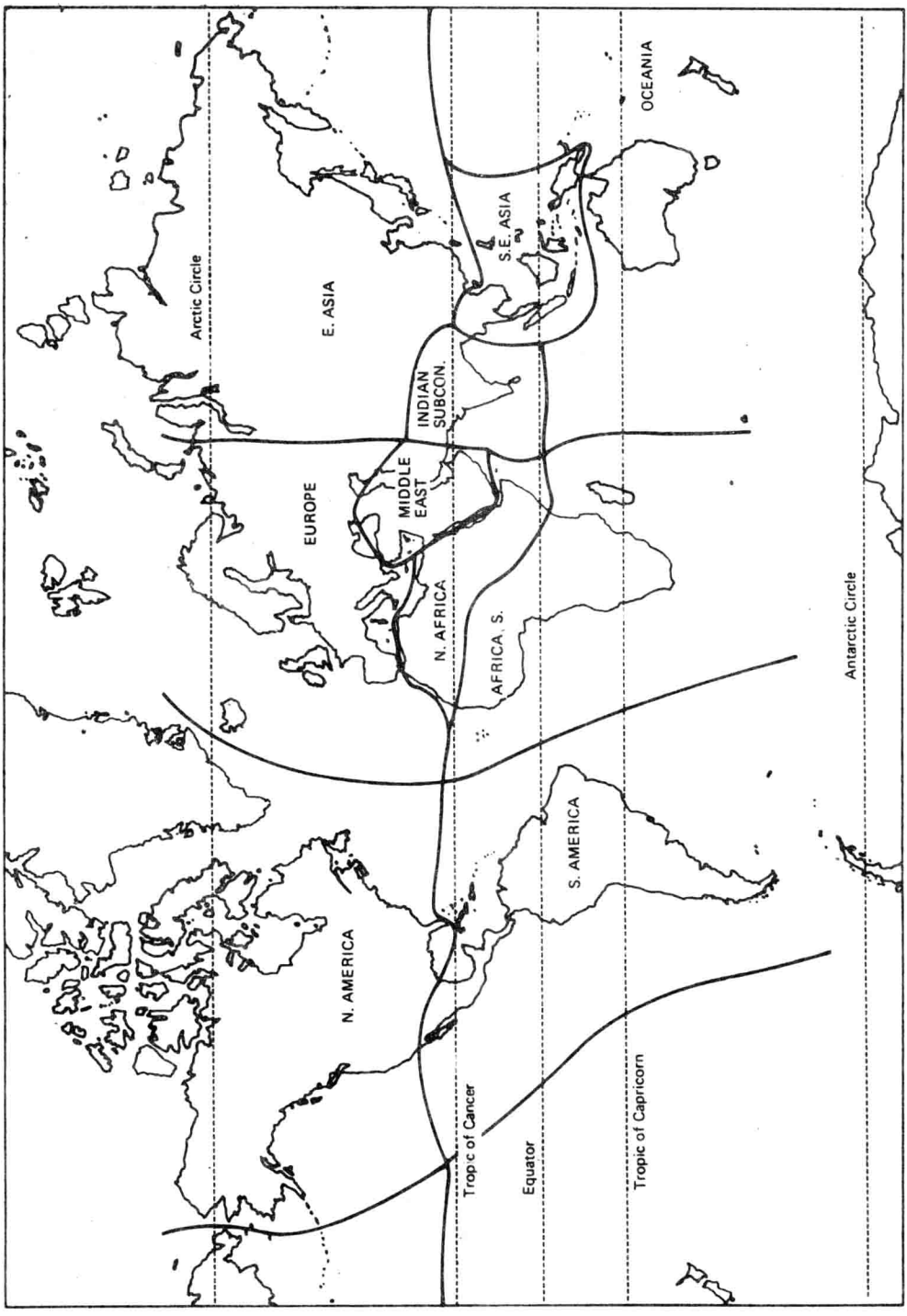

Figure 1 World map showing regions of production of fermented foods

Table 1 Production of classes of fermented foods by geographical region

World production	*Region*	*Importance*	
		Major	*Minor*
High	Europe	Dairy; beverages; cereals; meat	Legumes; starch crops
	N. America	Beverages; dairy; meat	Fish; legumes, starch crops
	Africa S.	Starch crops; cereals; beverages	Dairy
Medium	S. America	Beverages; dairy	Legumes
	Middle East	Dairy	Legumes; meat
	Indian subcon.	Cereals; legumes	Meat
	E. Asia	Fish; legumes	Dairy
	S. E. Asia	Fish; legumes	Dairy
Low	Oceania	Dairy	Legumes
	N. Africa	Dairy	Legumes

produce and consume chiefly *beer* or *lager* from cereals, principally barley, while the warmer southern countries of Spain, France, Italy and Greece produce and consume chiefly *wine* made from grapes.

To produce alcoholic beverages from cereals, the starches in the grains have to be converted to fermentable sugars. This is normally done in a two-stage process, first malting in which protease and amylase enzymes are active, as the grains germinate in the presence of water. This process is then halted by kilning or drying, and when one wants to produce the beverage, the *malt* is ground and mixed with warm water, at 55–65°C. This is the mashing process in which amylases continue the breakdown to produce soluble sugars which are extracted in the *wort*. On the continent of Europe, the most popular process is the use of bottom-fermenting yeast *Saccharomyces uvarum* to ferment the *wort* at cool temperatures, 10–15°C to *lager*. In Britain, top-fermenting strains of the yeast *Saccharomyces cerevisiae* are used in warmer fermentations at 20–25°C to produce *beer*, *ale* and *stout*. Whereas barley is the major cereal used in Europe to produce most beverages, *lambic* uses wheat as its main substrate and involves a lactic acid bacterial fermentation as well as the alcoholic yeast fermentation. The taste for European lagers and beers has spread throughout the world, but traditionally in Asia and the Indian subcontinent *rice beer* is produced, and in Africa *sorghum beer* and *seven-day beer* from maize are important. *Sorghum beer* is cloudy, containing suspended solids and is a useful source of B vitamins in otherwise deficient diets. Clarified beers from sorghum and millets, called *amgba* are less common. In Southern Africa, the sour, non-alcoholic *aliha* is found, whilst *iced-kenkey* is another thick, sour maize beverage found in Ghana, in West Africa. Across in South America, the thick alcoholic beverages made usually from maize belong to the *chicha* group, in which the first stage of amylase activity to break down the starch is traditionally achieved by chewing the grains to release amylase-containing saliva onto the grains.

Most beers contain only 4–8% alcohol. In the Indian subcontinent and South-East and East Asia rice is fermented by a longer process to make *saké*, which contains 14–20% ethanol. Instead of malt, a *koji* process is used in which the mould *Aspergillus oryzae* releases the amylases to break down the rice starch. Fresh rice, *koji* and water are then added to the *moto*, and a secondary fermentation by *Saccharomyces saké*, a yeast closely related to *S. cerevisiae* produces the larger amount of alcohol, which makes the stronger beverage.

In contrast to the high starch content of cereal grains, grapes when mature contain 15–25% sugar, which can be used directly by yeasts, chiefly of *Saccharomyces cerevisiae var. ellipsoideus*, to produce ethanol and *wine*, which typically has an alcoholic content of 10–16%. Lactic acid bacteria, of *Leuconostoc oenos*, are also involved in the conversion of the malic acid to lactic acid in *wine* fermentation. Grapes, which are the world's twelfth major crop, with yields around 60 million tonnes per annum, are mainly used for *wine* production. If black grapes are crushed and fermented whole, *red wine* is formed, whereas if the skins are removed, or white grapes used, *white wine* is produced. There are a large number of different white and red wines found around the world, of which over 100 of the more important types of each are listed in this dictionary. If some contact with the dark grape skins is allowed, *rosé wine* can be produced. Where all the sugar in the grapes is fully utilized, dry wine is produced, while sweet wines contain some residual sugar. Secondary fermentation of these residual sugars in bottle leads to the formation of mildly gassy *pearl wine*, or more strongly gassy *sparkling wine*. Higher-alcohol *sherry* and *dessert wine* are produced from grapes of higher sugar content, fortified normally with *brandy* and this wine may be left in partially filled barrels to develop particular bouquets

and flavours. Other materials can be fermented to give alcoholic beverages. In Europe and North America, apples are converted to *cider*, while in hotter countries, in Africa, Asia, Oceania, the Indian subcontinent and South America, the sweet liquid sap of various palm trees is fermented to produce *palm wine*, which varies from a fresh cloudy sweet drink, to a potent alcoholic beverage when left to ferment for a few days.

The alcohol content of most alcoholic beverages can be increased from its original range of 5–18% by distillation to give *spirits* of alcohol content 35–55%. For example, palm wine can be distilled to *local gin*, wine is distilled to *brandy*, beer to *whisky* or *schnapps* and fermented sugar cane to *rum*. In some products, including *whisky* and *rum*, ageing for several years in wooden barrels is an important part of the process, after distillation. Distillation must be carried out under carefully controlled conditions to concentrate the ethanol fraction, to allow only a limited quantity of higher or fusel alcohols, which contribute extra flavour notes and to ensure that no significant level of methanol, which is poisonous, is allowed into the final product. Consumption of excessive amounts of alcoholic beverages is known to lead to intoxication and loss of control in people. In some, particularly strict Muslim countries, alcoholic beverage consumption is forbidden, while in others it is controlled by the application of licensing regulations. By contrast, small amounts of *spirits* are used medicinally, to relieve colds, reduce nausea and to aid digestion. Beneficial effects are thought to be gained by drinking *liqueurs*, which contain a combination of a high-alcohol *spirit*, sweetening and other flavourings from fruits, nuts, spices or herbs. The production of many of these liqueurs originated in religious institutions such as monasteries and their exact compositions remain closely-guarded secrets. The great diversity of liqueurs, many produced in particular places or countries, is shown by the 200 or so types found in the dictionary.

In contrast to the large number of locally-produced alcoholic beverages, the three non-alcoholic beverage materials *cocoa*, *coffee* and *tea* are produced chiefly in the hotter regions of Asia, the Indian subcontinent, Africa and South America, and are exported to all corners of the world as cash crops. In the case of *tea*, it is the leaves which are fermented by the release of their own enzymes on crushing. In the case of both *coffee* and *cocoa*, the pulp found in the fruit case surrounding the beans is removed by complex fermentation processes in the countries of origin, and the flavour and aroma of the hard kernels or beans which remain is improved in the process. The fermented beans are then transported and are eventually roasted to further improve their flavour before consumption. These high-value commodities can be transported large distances economically because the water to make the final beverage is not added until the point of consumption. The exact value of any crop can depend on the fermentation process; the simpler heap method of fermentation on the farms in Ghana produced a superior quality *cocoa* to that produced on a larger scale in boxes at fermentation units in Malaysia. Bacteria, yeasts and moulds are all involved in *cocoa* fermentation, with the environment determining the exact nature and sequence of micro-organisms through bacteria, then yeasts and then acetic acid bacteria. Given the huge quantities of cocoa, chocolate and coffee which are consumed worldwide, the lack of detailed understanding of their fermentation is surprising. Perhaps the developing interest in biotechnology will lead to a better understanding of fermented beverages and foods.

For further information on fermented beverages the reviews by Benda (1982), Brandt (1982), Carr (1985), Steinkraus (1979) and Yates (1979) should be consulted.

Cereal products

Cereals are the largest class of foods eaten by man. In the world today, around 500 million tonnes each of the three major cereals are produced each year; wheat in the temperate regions and maize and rice in subtropical and tropical regions. Cereals are the major staple food in all regions of the world, except for Africa, south of the Sahara, and a substantial proportion of the cereals produced are fermented.

The fermented cereal product found most widely is *bread*, which was known to be produced in Roman times, and is now produced in all regions of the world. It is made by fermenting principally wheat doughs with the yeast *Saccharomyces cerevisiae*, often in conjunction with small amounts of lactic acid bacteria. Flour amylases and yeast convert starch to sugars and ferment them to carbon dioxide, which expands and stretches the unique extensible and elastic protein gluten, found in wheat, triticale and to a lesser extent in rye, causing the bread to rise in volume, and retain its shape on oven-baking. *Rolls* are essentially small-sized pieces of bread, with a higher ratio of crust to crumb, and *buns* are sweetened versions, which may also contain dried fruit and spices. Sweeter larger loaves are called *tea bread*, and all these groups are produced widely. *Savarins* are rich in both fat and eggs, while *brioches* contain a high proportion of eggs. Europe, which also uses significant quantities of rye, which may be used alone or mixed with wheat, is the original home of *sourdough bread*, which is particularly popular in north and east Europe. In this, the yeast *Candida milleri*, a non-sporing form closely related to *Saccharomyces* is active together with acid-producing lactobacilli, particularly *Lactobacillus sanfrancisco*. European immigrants carried their practice of keeping their own sourdough starter to North America, which is now the second main producing region. Other products originating from Europe include the lower-moisture

crisper baked *rusk, crispbread, cracker, grissini* and *pizza* base.

Moving southwards and eastwards from Europe into Arab countries, North Africa, the Middle East and the Indian subcontinent, flat breads belonging to the *lavash* and *nan* groups are more common. These are fermented, flattened then baked very rapidly directly on the surfaces of very hot ovens, giving flat loaves.

Pancakes are made throughout the world by dropping cereal batters onto hot metal surfaces, and *doughnuts* by frying batter in hot oil; both these are often fermented, although alternatively chemical raising agents such as sodium bicarbonate may be used to give their open texture.

The Indian subcontinent, with its large population, depends heavily on many fermented cereal products; many products are also made from combinations of cereal and legume flours. This gives a higher protein content, and provides a better balanced ratio of amino acids, overcoming the danger of lysine deficiency from cereals alone, or sulphur-containing amino acid deficiency from legumes alone. These cereal/legume products include *hopper, idli, dosa, adai, vada* and *papadam*. Lactic acid bacteria of *Streptococcus*, and *Pediococcus* species are important in these fermentations. The heterofermentative *Leuconostoc* bacteria produce carbon dioxide, which aerates the products, in an alternative way to yeast fermentation.

Cereals are also used with legumes in South-East Asia and East Asia, where wheat may be fermented together with soy beans in the production of *miso, soy sauce, natto* and *hama-natto*.

Rice is also used in combination products in these regions, this time together with fish in producing *paak* and *fish sauce*. Rice alone is fermented to give the rather sweet, slightly alcoholic *lao-chao*, which is used as a dessert in South-East Asia and East Asia, particularly at celebrations or on festive occasions. Further north, in cooler China, wheat gluten is allowed to ferment, then salted and dried to produce thin strips of *mien chien*.

Africa is dependent on many fermented cereal products, some of which may be made with starch crops as an alternative, or in combination. *Akpiti* is produced, *chindanda* is a steamed maize-based bread, while *kenkey* is a steamed maize dumpling made by the *aflata* process in West Africa, where *maasa* is made on hotplates from millet or sorghum. Maize, sorghum, millet and, to a lesser extent, rice are the main cereal crops of Africa, and if left to stand in water a natural lactic acid bacterial fermentation takes place which produces an acidic flavour. This has become popular and is now regarded as essential, whether in thicker, boiled gelatinized products such as balls of *fula*, dumplings of *banku* or *agidi*, or in the universal porridges and thick *tuo zaafi* or thinner *koko*. These dumplings, pasta and porridges are the major staple component of African stews and soups which are the traditional meals eaten. In North Africa, *ka-ak, kisra* and *injera*, which is made from the Ethiopian cereal teff, are found. The influence of French colonization of Africa has left its mark in the importance of the freshly-baked long thin loaves of *french bread* in French-speaking and Arabic countries today.

In South America *arroz fermentado*, made by fermenting rice, is used as a staple food in the Andes. Maize is otherwise the major cereal in the region, and is used in the production of *corn bread*. In the northern parts of South America, and in the West Indies, Indian and European immigrants have introduced respectively the *jalebi* and *muffin*. Large quantities of directly-consumed cereal products are major suppliers of carbohydrate, protein, minerals and B vitamins to the diet. In addition, major amounts of cereals are fermented for use in beverages. The first step is the enzyme fermentation of cereals to *malt*, in which amylases break down the starch to smaller dextran and sugar units, which form the substrates for beverage production discussed in the previous section. Barley is one of the world's major cereal crops, but most is used indirectly in making *beer*.

Further information on cereal fermentations can be found in the reviews by Hanneman (1980), Muller (1970), Ponte and Reed (1982), Stanton and Wallbridge (1969) and Sugihara (1985).

Dairy products

Fermented dairy products account for about 20% of all fermented food production. They reflect the regions where most milk is produced. Europe is the world's major region of production, with the Middle East, North America, South America, North Africa and Oceania also being important producers. By contrast, Africa South, South-East Asia and East Asia, where little milk is produced, are only minor producers of fermented dairy products. In the Indian subcontinent fermented dairy products are produced, but a large proportion of the milk is preserved with sugar and consumed as milk-based confectionery.

The largest number of groups of fermented foods are *cheeses*, of which some 50 groups are found in the dictionary, covering a total of more than 900 individual types. This large number of types reflects both the cultural and food product diversity found within heavily-populated and developed Europe. Total annual production in the world is estimated to be around 12 million tonnes, which is increasing at 3–4% per year. The major components of *cheese* are protein and fat, and it is a major source of calcium, sodium, potassium, magnesium and phosphorus in the diet, and provides useful amounts of B vitamins, and vitamins A and D; it contains only trace amounts of carbohydrates, no fibre and no vitamin C.

The basis of *cheese* production is the coagulation of

the main milk protein, casein, as the pH drops to around 4.6 as acid is produced. The coagulation is often aided by the addition of proteolytic enzymes from rennet obtained from young animals' stomachs. The milk may be cows', sheep's, goats', or buffaloes'. It may be enriched with extra cream for high-fat cheese production, as in 'treble cream' cheeses such as *bavaria blu* and *excelsior*, with over 70% fat in the dry matter, or 'double cream' cheeses such as *Neufchâtel*™ and *caprice des dieux*, with around 60% fat in the dry matter, or *cream-cheese*. Cheeses, e.g. cows' milk *cheddar* and *Saint Paulin* and sheep's milk *manchego* are made from whole milk and contain 40–55% fat in the dry matter. These cheeses range from the hard *Swiss cheese*, through semi-hard humid-cured *raclette* and *tilsit* cheese to soft, surface-washed *liederkrantz*, filamentous *mozzarella*, and low or full-fat *ricotta* cheese.

At the other end of the spectrum are hard *grana* cheeses made from partially-skimmed milk, containing 30–40% fat in the dry matter, and soft *rocroi* cheese, made from skimmed milk, and containing 20–35% fat in the dry matter, *quark* with 1–20% fat, and nearly fat-free *sapsago* and *whey cheese*.

The micro-organisms which are principally responsible for the acid production in cheese-making are lactic acid bacteria which convert the lactose in the milk to lactic acid. These lactic acid bacteria belong chiefly to genus *Streptococcus*, often *Strep. lactis* su' sp. *diacetylactis*. The organisms survive the mild heat treatment or scalding which is often applied at the end of the curd coagulation period. The cheese may then be eaten fresh, as is *joncheé*, the acid-coagulated *cottage cheese*, *bakers' cheese* and *panir*, or it may be pressed to different degrees to give textures which are semi-soft, semi-hard or hard. The cheese can then be subjected to relatively short maturation periods, of a few weeks, e.g. *tomme de savoie*, *provola*, *Bel Paese*™ and *queso blanco*, medium maturation of a few months, e.g. *Cantal*™, goats' milk *valençay*, cows' milk *gouda*, or sheep's milk *esbareich*, or to long maturation of many months, e.g. low-fat *Handkäse*, or years such as *sbrinz*. Protease enzymes from the lactic acid bacteria continue their activity during maturation, and help produce the many subtle and characteristic flavours of different cheeses. The maturation changes can be modified by briefly soaking the cheese in salt brine, as in sheep milk's *villalón* or filamentous-curd *provolone*, or by curing the cheese in brine, as with *maroilles* and *white brined cheese* or by the use of washings and maturing under humid conditions, which allows surface bacteria, principally *Brevibacterium linens* to develop and ripen the cheese from the outside, as occurs with *munster* and *Limburger*. Moulds, of *Penicillium* species can grow and produce proteases and lipases and produce a white surface mycelium, as with *camembert*, blue surface mould in *olivet*, or be inoculated into the cheese to produce the characteristic blue veins of *blue cheese*. These various different processes give an idea of the wide variety encountered in cheese production.

If prepared from pasteurized milk, cheese is a safe nutritious food, but if it is made from unpasteurized milk, under poor hygienic conditions, the high moisture soft cheeses can act as nutritious substrates for the growth of food-poisoning strains of *Staphylococcus aureus*, *Salmonella*, *Campylobacter*, Enteropathogenic *Escherichia coli* or *Listeria*.

The second major groups of dairy products are the high-moisture liquid or semi-solid fermented milks of which *yoghurt* is the largest group. They contain 0.5–1% lactic acid, which is produced by lactic acid bacteria, often the combination of the rod *Lactobacillus bulgaricus* and the coccus *Streptococcus thermophilus*. Yoghurt is a major food, and is both produced and consumed in all regions of the world. In Scandinavia, the slime-forming bacteria of *Leuconostoc* species ferment milk, together with *Streptococcus* species into the distinctive thicker, ropy *filmjölk*. In the Middle East and the USSR, *kefir* is produced, as well as *kumiss*, which is also made in East Asia. *Kumiss*, which is traditionally made from horses' milk, differs in being alcoholic, from yeast growth, in addition to being acidic from the lactic acid bacteria. *Bulgarian buttermilk* is produced in Europe and *buttermilk, cultured* is found more widely. The conversion of the milk sugar lactose, to lactic acid aids absorption of these fermented milks in the body, and they are generally thought to aid digestion. Several claims have been made that these fermented milks benefit digestion by the establishment of lactic acid bacteria in the human gut flora, but only in the case of *Lactobacillus acidophilus* from Eastern European *acidophilus-milk* has this been firmly established. Fermented milks, are often low fat, while at the high-fat end of the spectrum are *crème fraiche* and *sour cream*. All can be eaten, usually with a spoon, as dressings or components of savoury starters, main dishes or sweet or fruit desserts. In addition to these uses, there is increasing interest in diluting fermented milks with water and drinking as savoury or sweet products of the *lassi* group.

In the Middle East, and south-eastern Europe, the keeping life of soured milks is prolonged from weeks to years by drying to *kurut* or by adding cereals, shaping into balls and sun-drying to *kishk*. These can be reconstituted as needed, even after long periods of hot weather in the region, particularly useful in dry desert areas.

For further information on fermented dairy products, reference should be made to the reviews by Chandan (1982), Chapman and Sharpe (1981), Kosikowski (1977), Marshall (1984), Robinson and Tamime (1981) and Scott (1981).

Fish products

Fish muscle has a pH just below neutral at 6.2–6.5,

and no glycogen reserves to help lower pH after death. This means that this high protein food is even more susceptible to rapid attack by micro-organisms than is meat.

Methods of preservation were therefore developed in South-East and East Asia to retain the food value of the large quantities of fish caught, and to preserve the fish in the hot ambient temperatures. Some fermented fish products have also arisen from Europe, the Middle East, the Indian subcontinent and Africa. Relatively few are found in the Americas, where meat products are more important.

Most fermentation methods involve the addition of salt. Where large quantities of salt are added, generally 30% or more of the raw fish weight, fermentation by micro-organisms is largely suppressed, and enzymes from the fish flesh and gut cause proteolysis of the fish by autolysis. The Asian fish paste *bagoong*, and *fish sauce* are produced in this way, from low-fat marine or river fish, or shrimps.

In North Africa, the Middle East and Europe, *surströmming* is produced from fatty fish, often herring. *Rakørret* and *tarama* are also produced from fatty fish, or fish-roe, respectively. Fatty fish are also usually used to produce *pickled fish* in many parts of the world. For *pickled fish*, sugars and spices are used in addition to salt, but autolysis by fish enzymes is still the dominant form of change.

To allow microbial fermentation to gain more importance, a source of carbohydrate can be added to the fish. Throughout East and South-East Asia, a range of fish pastes of the *paak* type are produced, usually by adding rice to the small fish. In these products, in addition to the salt-tolerant *Micrococcus*, *Staphylococcus* and *Bacillus* bacteria, lactic acid bacteria belonging to *Pediococcus* and *Lactobacillus* species ferment the carbohydrate to organic acids, which help lower the pH, aiding preservation, and producing a more tangy flavour. Carbohydrate is occasionally added in making *fish sauce*.

Dehydration is often used in conjunction with fermentation and chemical preservation or salting. If salt is added immediately after landing the fish, its preservation is controlled, with the mixture of autolysis, microbial fermentation, and reduction in water activity. *Dried fish* is produced with an average of 35–45% moisture content, but it can range from as high as 64%, down to as low as 17%. The lower moisture content is needed where the fish is expected to keep for a long time at tropical temperatures. If salting is delayed for a few hours after catching, rapid autolytic and microbial attack is initiated; strong-smelling *momoni* is produced by this method in West Africa.

Fermented fish products are generally high in protein, and amino compounds. The consumption of most of the products is limited by their high salt contents. Where extensive breakdown of the protein right through to amines such as trimethylamine, and ammonia has been allowed to take place, as in *momoni* and *surströmming*, the strong flavours and odours restrict the number of people who find them acceptable, and the quantity consumed, but they make a positive flavour contribution to dishes. It is interesting to note that *fish sauce* was found as a useful flavouring by colonizers and visitors to South-East and East Asia, and it is now exported in significant quantities for consumption in North America and Europe, particularly France.

Being a high protein food, particular care must be taken in fermenting fish to prevent the growth of toxin-producing food poisoning organisms. Botulism, caused by growth of *Clostridium botulinum* has occurred by consumption of *pindang*, the cooked then fermented fish product of Indonesia and of Japanese *izushi*, a pickle made from raw fish, rice and vegetables. A hazard may arise if mycotoxin-producing *Aspergillus ochraceus* strains grow in *katsuobushi*, which is unusual in being a fish product fermented by the mould *Aspergillus repens*, in Japan and the Maldive Islands. The high levels of salt used in most fish fermentations, whilst limiting consumption levels, do provide the major safeguard against the growth and toxin production of food poisoning organisms.

In the cooler and more industrialized world, fish is normally preserved nowadays by freezing, chilling and controlled-atmosphere packing. However, in hotter countries, particularly in rural areas, fermented fish products continue to play a vital role in adding protein, flavour and variety to rice-based diets.

Reviews of fermented fish products of the world include those by Adams, Cooke and Pongpen Rattagool (1985), Beddows (1985), Clucas and Sutcliffe (1981), Magno-Orejano (1983) and Van Veen (1965).

Fruit and vegetable products

Fermentation is used throughout the world, often in conjunction with chemical preservation, using salt and acid, to preserve fruits and vegetables from and vegetables are the major contributors of vitamin C and fibre to the diet.

Pickled vegetables and *pickled fruits* are produced in all regions. The particular fruits or vegetables used depend on the crops available locally, although in some countries particular crops may be dominant in pickle production, such as onions in Britain and cucumbers in the USA. Usually slightly under-ripe firm fruits and vegetables are harvested and then salted, either with dry salt or brine. In the fermentations, salt-resistant lactic acid bacteria, initially of heterofermentative *Leuconostoc* species and *Lactobacillus brevis*, are gradually replaced with homofermentative *Lac. plantarum* and *Pediococcus* species. Coliform bacteria, of *Enterobacter* and *Klebsiella* species, are also involved. As acids, particularly lactic acid, are produced and the pH drops, yeasts become more important. In few of these fruit and vegetable fermen-

tations are starter cultures used; the establishment of the desired microflora depends more on environmental conditions.

In the hotter, southern parts of Europe, the Middle East, North Africa and California in the USA, the fermentation of *olives* is important. This process differs in the use of a preliminary alkali treatment to destroy the bitter glucoside oleuropein before fermentation. As with *pickled fruit* and *pickled vegetables*, some of the crop immediately after harvest may be processed more quickly, with exposure to salt and acid but with little or no fermentation involved. Originating in Germany and Eastern Europe, and carried by immigrants to the USA, the fermentation of shredded cabbage to produce *sauerkraut* is a major industry.

In Southern Europe, particularly Italy, unripe, hard fruits of *Citron medica*, closely related to lemons, are cut, salted and fermented to produce *citron*. The rinds are washed, cooked and soaked in sugar syrup of stepwise increasing strengths to produce the candied peels used in baked and other foods. On tropical islands in various regions of the world, pods of the orchids belonging to genus *Vanilla* are collected when the pod colour begins to change from green to yellow. The bean pods are laid out in the sun, or wilted in hot water, and are then fermented in sweat boxes, when their better-known dark brown colour develops. Cured *vanilla* is used throughout the world as a flavouring of baked goods, dairy products and other foods.

In the northern parts of East Asia, with Korea as main producer, *kimchi* is the important provider of vitamin C in the long winter months. In its production, various vegetables, separately or together are fermented in brine in sealed containers in nearly every household. They are then consumed daily and their quality and variety are an important component of traditional family life. *Hum-choy*, a Chinese pickled vegetable product, is found in East and South-East Asia, where *bai-ming* from fermented tea-leaves and *tempoyak*, from durian fruit *Durio zibethinus*, are also found. The region has in common with South, Central and North America the production of *hot pepper sauce*, which gives flavour to many otherwise rather bland dishes.

In Africa South, the seeds of various trees or plants are fermented, and the products then partially or fully dried, for later use as pungent flavouring components of soups and stews. These *oilseeds, fermented* include *kantong*, made by fermenting seeds of kapok (*Ceiba pentandra*) or baobab (*Adansonia digitata*), *ogili* (castor oil, *Ricinus communis*) and *ogiri* (melon, *Citrullus vulgaris*).

Fruits and vegetables are eaten generally in combination with other foods. It is not surprising therefore to find them as just one component of mixed fermented foods, where they may be involved in the fermentation to a greater or lesser extent. Examples include *pickles*, *kushuk* (2), *injera*, *pizza* and *wähe*.

Fruit and vegetable fermentations have been reviewed by Etchells, Fleming and Bell (1979), Fleming (1982) and Vaughn (1985).

Legume products

Fermented legume products are particularly important in diets in East Asia, South-East Asia and the Indian subcontinent. By contrast, their role in Oceanian, North American, European, Middle Eastern and North African diets is minimal. In regions where little meat, fish or dairy products are consumed, legumes are the highest protein-containing food, although cereals may contribute more protein in total. It is because of the importance of legumes in vegetarian diets that the consumption of legumes is likely to increase in more developed regions as the search for less rich, saturated-fat containing foods increases. Because meat has been a major source of B vitamins in diets in these regions, the importance of increasing levels of B vitamins by the fermentation of legumes, where they are to be used as meat substitutes, can be appreciated.

Legumes contain three major components: protein, oil and carbohydrate. Much of the carbohydrate is in the form of oligosaccharides, such as stachyose and verbascose, which are not readily digestible and can cause flatus in the intestine. Other antinutritional factors, such as trypsin inhibitors are also present in raw legumes. Fermentation improves digestibility by breaking down antinutritional factors, and by proteolytic conversion of proteins to the more digestible peptides and amino acids. This is useful particularly for weaning children, the elderly and infirm people.

The only legume which features as a major world crop is the soybean, *Glycine max*, which is the world's tenth food crop, with an increasing annual production currently around 90 million tonnes.

Soybean protein can be coagulated into a curd, the Asian equivalent of *cheese*. The curd is allowed to ferment or mature, with the growth of *Actinomucor elegans* mould to products belonging to the group *sufu*. Alternatively, a beverage is produced, *soymilk, fermented*. In both cases, fresh, non-fermented products are also consumed. In Indonesia, *tempe* is made by the fermentation of cooked soybeans for 1–2 days, in which *Rhizopus oligosporus* mould as well as *Klebsiella* bacteria are involved. The *tempe* is then fried in oil and eaten as a snack or in soups. This is one of the fermented legume products now attracting interest in the West, and it is now also produced in the USA.

Whilst these products are made from soybeans alone, other Asian fermented legume products involve the combination of soybeans with varying amounts of cereals, either wheat or rice flour, or occasionally as with *soy sauce*, made in Indonesia

with the starch crop, cassava. *Soy sauce* production is believed to have started in China, and only much later did Japan become a major producer. Japanese *soy sauce* differs in using larger quantities of wheat in addition to the soybeans. The production process which is somewhat similar to *beer* brewing, involves three stages, the *koji*, *moromi* and maturation stages. Soy sauce is used as a major flavouring ingredient of much Chinese and Japanese food, and so is in demand wherever these foods are prepared around the world. Because of this large demand, and the many months' long maturation process, lower quality chemically-hydrolysed sauces are now produced in Japan, although this practice is forbidden by law in China. This increasing demand for soy sauce worldwide is also now being met by the establishment of factories in Britain and the USA.

The thicker soybean paste, *miso* which is principally a yeast fermentation, is also used to flavour foods, particularly soups. *Hama-natto* fermentation is carried out by the mould *Aspergillus oryzae*. The production of *natto* is unusual for Asian legume fermentations in being a bacterial fermentation, due to *Bacillus subtilis var. natto*. It is used mainly as a strongly-flavoured side dish in parts of Japan, China and Thailand. Being stronger in aroma and flavour, because of the powerful proteolytic action of the *Bacillus* enzymes, it has less appeal to younger people, and a milder version is now produced for their consumption.

Another legume, groundnut or peanut, *Arachis hypogeae*, is fermented after the oil has been extracted, to produce *oncom* in Indonesia. Cassava may be mixed with the groundnut to accelerate the fermentation. *Hoppers* are fermented legume/cereal products which are made in East and South-East Asia, to where they have been introduced by southern Indian and Sri Lankan peoples.

The Indian subcontinent is the home of many fermented products made from legumes, which in the region may be called pulses, grams or beans. For example, *idli* is made by fermenting three parts of parboiled rice with one part of dehulled black gram or mung beans, *Phaseolus mungo*, *dosa* is made from equal parts of rice and black gram, and *dhokla* from a mixture of rice, and dehulled black gram and ginger seed. Black gram can be fermented and then deep fried to make *vadas*. Most of these products originate from the south of India where rice is the major staple food. From central and northern India, where the staple changes from rice to wheat and potato, *Solanum tuberosum*, comes *papadam*, which is a large thin crisp wafer made from fermenting doughs of legumes, with or without potato or cereal flours, and is becoming a popular accompaniment to Indian food served around the world. *Kenima* is a much less well-known fermented legume product from Nepal and Sikkhim in the far north of the region.

Increasingly hitherto 'unknown' fermented foods from various regions are gaining popularity internationally. Decolonization and subsequent immigration of people to the colonizers' countries have aided the process. The introduction of Chinese and Indian food originally to Britain, of Indonesian food to the Netherlands, of Laotian and Vietnamese food to France are illustrations of these processes. Africa has remained as the exception, with colonizing Europeans, and some governments paying less attention to traditional local food production in favour of importing foreign foods. Where a food is not traded via normal international channels its significance can be missed altogether. An interesting example is *dawadawa*, which is produced by bacterial fermentation of the beans of the leguminous African locust bean tree, *Parkia* species. It is then dried and stored in every household in the drier, northern parts of every country in West Africa, from Senegal and Gambia, in the west, through to Cameroun and Chad in the east. It is important because, as has been dramatically demonstrated in recent drought years, annual planted crops with their shallow roots fail when the rains fail, while the deeper-rooted established trees continue to provide food crops, as well as holding the precarious topsoil against desert encroachment. *Dawadawa* is a high protein food which is extensively hydrolysed by the bacterial protease enzymes, mainly *Bacillus* species, and has a strong, slightly ammoniacal odour. This reduced European settlers interest, but the importance of the food has long been recognized by the local people and the chiefs of each area claim a harvesting fee, or tax, on each tree, the equivalent of duty on alcohol elsewhere. *Ugba*, from the legume tree *Pentaclethra macrophylla* is also found in Africa South.

In South America, *lupin seeds*, *Lupinus mutabilis*, are fermented as a foodstuff.

For further information on fermented legume products, reference should be made to the articles by Batra and Millner (1976), Wang and Hesseltine (1979), and Yokotsuka (1985).

Meat products

Fermented meat products can be divided into two broad groups: those made from whole meat pieces or slices, such as *dried meat* and *jerky*, and those made by chopping or comminuting the meat, usually called *sausage*, which may be sliced before eating.

Fresh meat has a moisture content normally between 55 and 70%. Cured, fermented meat products can be further divided into semi-dry, with moisture content 30–45%, which keep for days or weeks, particularly where refrigeration is applied, and dry products, of moisture less than 30%, which generally keep for months, even without refrigeration. Drying may be achieved using the sun, warm

air or may be helped by cool or hot smoking, when deposited smoke compounds also help preservation.

In practice, there is a continuous spectrum of reduced moisture contents, between different products, with the drier products, of water activity down to about 0.8 keeping better. This is a great advantage in hotter regions of the world.

The majority of the meat products are eaten without cooking, neither during processing, nor in the home. It is the combination of chemical curing, microbial fermentation and drying which together give stable, safe, ready-to-eat products.

Southern and Central Europe, dating back to Roman times, is the original home of many of these cured, fermented meat products, most made from pork or beef, separately or together. The name *salami* is thought to come from the city of Salamis in Cyprus, which was destroyed over 2000 years ago. Emigrants carried knowledge of these processes and practices to North America, and Australia. These regions now share a range of whole-meat *bacon*, to be cooked before eating, ready-to-eat *country ham*, and chopped semi-dry *cervelat*, dry *German salami* and *peperoni*, which are smoked, and dry *Italian salame* and *chorizo*, which are not. Cooked fermented meat products such as *mortadello*, *Kochsalami* and *Thüringer* are less common. In North America, the Inuits produce *mikiyuk* from whale and *iqunaq* from duck.

The hotter regions of Africa and Asia are the home of relatively few fermented meat products, although whole-meat dry uncooked *jerky* is produced in Africa as well as in the Americas; *nham* is produced from chopped meat in South-East and East Asia. From whole meat, *pickled meat* is produced in the Americas and East and South-East Asia.

Meat flesh is rich in protein and fat. It is a nutritious food for man. After death of the animal, the glycogen reserves in the muscle are broken down to glucose. This is used preferentially by micro-organisms, but when depleted, food spoilage and food poisoning bacteria are able to attack the meat protein and amino acids producing strong spoilage odours, and possible hazards, particularly at warm temperatures. Man learnt early on that by cooling and adding salt, which was often impure rock salt and contained some saltpetre or potassium nitrate, the growth of spoilage bacteria such as *Pseudomonas* and *Alcaligenes* and food poisoning by *Clostridium botulinum* could be prevented. Instead, salt-tolerant bacteria of *Micrococcus* and *Staphylococcus* species grow, and can convert the nitrate to nitrite, leading to the formation of nitrosomyoglobin, so fixing the pink colour of cured meats, and increasing safety. Lactic acid bacteria, cocci belonging to *Pediococcus* and *Streptococcus* and rods to *Lactobacillus* also grow, and produce lactic acid, which helps lower the meat pH, and make conditions unfavourable for other Gram-negative rod bacteria.

Meat is heterogeneous and is not sterile at the start of its fermentation. Complete control is therefore difficult. In modern processes, known quantities of sodium chloride, potassium or sodium nitrate, sodium nitrite, sugars, ascorbic acid or sodium ascorbate and desired seasonings are added. Starter cultures, usually of *Pediococcus pentosaceus* or *Ped. acidilactici*, sometimes with *Staphylococcus carnosus*, *St. xylosus* or *Lactobacillus plantarum* can be used. Cool temperatures are used initially and then the temperature is raised to allow fermentation at high relative humidity. The humidity of the surrounding air is then reduced to allow drying of the meat product. This is accompanied by changes of the protein structure in the acidic salty conditions, and development of flavour components, giving characteristic flavour and texture to cured, fermented meat products.

The production of fermented meat products has been reviewed by Bacus (1984), Coretti (1975a,b), Klettner and Baumgartner (1980), and Lücke (1985).

Starch crop products

Starch crops form a major part of the world population's requirement for energy from eating food. The potato, *Solanum tuberosum*, is the world's sixth largest food crop, with production around 270 million tonnes per year, with nearly half being grown in Europe. However, because of its good keeping qualities, it is not used in Europe for any significant fermented food production, although some is fermented and distilled to make the beverage *vodka*.

The picture is different in subtropical and tropical parts of the world. Three major starch crops are found: cassava, *Manihot* species, yields around 120 million tonnes annually, with Africa as the main producing region; sweet potato, *Ipomoea batatas*, 100 million tonnes, mostly from Asia; and bananas and plantains, *Musa* species, with world production around 55 million tonnes, one third in Africa. Other, less important starch crops include yams of *Dioscorea* species, cocoyams or taro, *Xanthosoma* or *Colocasia* species, the sago palm and breadfruit.

Africa South dominates the world in fermented starch crop products, a reflection of the importance of starch crops as staple foods in the African diet. It is the one region where, especially in poorer communities, starch crops are more important than cereals as the staple food. This is unfortunate in that starch crops contain only 1–4% protein, compared with 8–12% in cereals. Starch crops are so named because they are composed of 20–30% starch; they also contain large quantities of water, typically 60–70%, making them bulky to eat. This bulk, and low protein content, are major factors in the high incidence of protein-calorie malnutrition or marasmus, and kwashiorkor in poorer African children, and helps reinforce the importance of adding protein-rich ingredients such as the legume *dawadawa* or fermented fish *momoni* to the soups and stews in Africa.

Cassava is both perishable and contains the toxic cyanogenic glucoside linamarin. Fermentation has the beneficial effects of preservation and hydrolysing the linamanin and making the cassava safer to eat. Most starch crop fermentations are due to bacteria. Lactic acid bacteria, chiefly of *Lactobacillus* and *Streptococcus* species are the major fermentative organisms, which make the taste of the food sour, by lactic acid production. This sour taste has become the preferred flavour, and is now desired in fermented yam or plantain products, where there may be no toxic glucoside problem. Sun-dried flours, *lafun*, are produced chiefly in West Africa. Thicker pastes, such as *chicouangue* are popular, and starch crops may be mixed with cereals in production of the African fermented foods *banku*, *abolo*, *akpiti* and the bread-like *chindanda*. South America is the other region where fermented starch crops are important, *cassava bread* is made, and types of the popular West African food *gari* are also found in South America. Potatoes are grown in the higher, cooler parts of South America, and the Andes are the home of the two fermented potato products *chuño*, made after freezing, and *papa seca*, made after boiling the potatoes. In the Pacific islands of Hawaii, cocoyam, taro or breadfruit are fermented for 3 to 6 days to produce *poi*, and in Oceania fermented dough *bwiru* is made from breadfruit, *Artocarpus* species. In East and South-East Asia, starch crops are only seen as ingredients in a limited number of types of *tapé*, *soy sauce* and *oncom* fermentations.

More details of fermented starch crop products can be found in articles by Odunfa (1985), Stanton and Wallbridge (1969) and Woolfe and Woolfe (1984).

Miscellaneous fermented foods

Without the aid of a microscope, the bacteria or yeasts which produce fermented foods, cannot generally be seen, but the hyphae of mould mycelium is visible where it grows on the surfaces of fermented foods. In all regions of the world, certain basidiomycete moulds, particularly of *Agaricus*, *Lentinus*, *Pleurotus* or *Volvariella* species are cultivated, encouraged to fruit, and the fruiting bodies, or *mushrooms*, are eaten.

There is active cultivation of high concentrations of the micro-organisms which are used subsequently as starters for various food fermentation. After the realization that fermentations could be steered successfully in desired directions by using previously-utilized environments, such as caves, vessels or utensils, the next major technological advance was the deliberate use of starter cultures. Different forms are in use around the world: *yeast* is used for cereal and beverage fermentations and *ragi* in Asia, the Indian subcontinent and some parts of Africa South for legume and cereal fermentations.

In addition to the use of starters, some fermentations are carried out in stages to help direct the fermentation down the desired path in an efficient process. *Koji* and *moromi* are stages in production of *soy sauce*, brewing of *saké* and other Asian food fermentations.

The use of fermentation as a process is not found in the production of oil and fat products in a major way, and does not warrant a separate class. However, fermentation is involved in the manufacture of some *butter*, classified as a dairy product, in production of some *ghee*, in the Indian subcontinent, the Middle East and Africa South, and some *red palm oil*, which is important in diets in West Africa. Another minor group is *fermented eggs*, produced only in East and South-East Asia. Of wider use in the world is *vinegar*, produced by acetic acid bacterial fermentation of many materials including *wine* and *cider*. Another flavouring agent *Worcestershire sauce* is made in Europe. In South-East Asia, *bongkrek* is made from coconut presscake, *dagé* is made from the residues of several seeds, and the acetic acid bacterial fermentation is found again in the production of *nata*.

Some aspects of these miscellaneous fermented foods are covered by the reviews of Adams (1985), Hayes (1985), Hesseltine (1965) and Reed (1982b).

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