Taken from *Slayers, Saviors, Servants, and Sex: An Exposé of Kingdom Fungi* by David Moore; published by *Springer-Verlag, New York: 2001,* ISBN 0387950982.

Chapter 7 Let's party!

Well, we've done a good deal of work up to this point so why don't we have a break? I'm enjoying your company, let's go for a meal - my treat. I know a nice little place not far from here - *Valentino's* they call it; you'll like the place, it's small and quiet but serves an amazingly wide range of dishes.

Now, the first question is: what are you going to have to drink? Unless you choose a still fruit juice, the chances are that some fungus or other will have contributed to its production. All those fizzy drinks contain citric acid, and a fungal fermentation process makes most of it - a global production of around three hundred thousand metric tonnes each year. But the *really* important fermentation, of course, is the one that makes alcoholic drinks. It's a simple process. You start with something that's rich in sugar, like fruit juices, honey, or cereal grains or roots. Then add yeast (or rely on the yeasts already in the starting material) and allow the mixture to ferment. You'll end up with a liquid which contains up to sixteen percent alcohol! Drink it fresh or, if you have the patience, let it age for a while, and, if you really want to pickle the nerve endings, distil the stuff into a spirit.

It's such a simple process that all, even the most primitive, societies have one or more fermentation processes which they include in their rituals. There are some beautiful ancient Egyptian murals and tomb ornaments depicting bread and wine making. I suppose it says something about the human condition that alcohol (and caffeine, for that matter) have been incorporated into the way of life of every civilization. From the biological point of view it's remarkable that the organism responsible for fermentation is invariably the yeast called *Saccharomyces cerevisiae* (not surprisingly known as Brewers' yeast) or some closely related variant. The yeasts used for making ales tend to form a froth and grow on the top of the mix and such top fermenting yeasts are *Saccharomyces cerevisiae* itself. Lager yeasts do their fermenting at the bottom of the tank and they belong to the related *Saccharomyces carlsbergensis*. Wine yeasts are an elliptically-shaped variant of *Saccharomyces cerevisiae*. Cider yeast is called *Saccharomyces uvarum* and saki yeast is called *Saccharomyces sake*. As there are so many yeasts around, it's remarkable that the alcohol-producing ones belong to such a closely related little family. And they support massive industries, our annual global consumption of alcohol is currently thirty billion litres! That's a lot of yeast!

We don't drink it all. Alcohol is used as a raw material in the chemical and other industries and it's also used to make auto fuels, but we drink an awful lot of it. You can start your share now. Why not try something produced from the fermented juice of grapes? Wine making is now a global industry, although France and Italy still account for half the world's production. The classic wine grape has the scientific name *Vitis vinifera*. The important cultivars include Sauvignon (red Bordeaux); Pinot Noir (the main red Burgundy grape); Riesling and Silvaner (for German white wines); Barbera and Freisa (northern Italian wines); and Palomero, the main sherry grape. The whole of the black grape is crushed to make red wine; it's the grape skin pigment that makes it red. Black or white grapes can be used to make white wines but only the pressed juice is used and extraction of skin pigments is avoided. Of course, the quality of the wine depends on the grape used (and what the growing season was like that produced it), on production techniques, and on fine points like the type of soil type and whether the vineyard is on the north slope or a south-facing slope, and the colour of the owner's socks.

Experts really can identify all these features from the taste and aroma of the final product. (OK, I admit it, not *all*, I was lying about the socks). But the crucial feature is the controlled fermentation by that one specific yeast, *Saccharomyces ellipsoideus* which may come from natural sources (the grapes or the preparation machinery) or from a starter yeast culture. After the yeast fermentation, quality wines take one to four years to age in wooden casks. For some wines a bacterial fermentation is encouraged during aging to mellow the taste by reducing acidity. To make sparkling wines sugar, a little tannin and a special strain of *Saccharomyces ellipsoideus* that can form a granular sediment are added when the wine is bottled. A secondary fermentation in the bottle produces carbon dioxide and results in formation of an unstable compound with alcohol (called ethyl pyrocarbonatene) which gives the characteristic lingering sparkle of naturally-produced sparkling wines (compared with the brief sparkle of those that have only had carbon dioxide injected into them under pressure.

You might like a glass of a fortified wine (one which has had up to twenty percent brandy added to it) as an aperitif or even at the end of your meal. Sherry is one of these. Made from a particular grape and a secondary growth of yeasts in the maturing vats which create the characteristic sherry flavour compounds. Vermouths are wines flavoured with herbs, like wormwood, and with extra alcohol added. Port is a red wine in which the primary fermentation was stopped by adding alcohol or brandy while some sugar still remained. The special flavour of Madeira results from a heat treatment of the fermented wine before extra alcohol is added.

Personally, I like wine, particularly red wine, well enough, but I do prefer a glass of beer to start a leisurely meal. All ales, beers and lagers are made from malted barley. The process starts by encouraging barley grains to germinate. In two to four days the sprouting seeds start the digestion of their stored starch, producing more soluble sugars. Then the sprouted grain is killed by slow heating and mashed into hot water with other cereals like maize, wheat or rice. Finally, the sweet mix is boiled with hops to add bitter flavours to the beer. The boiled liquid is cooled and passed to the fermentation vessels for fermenting. After fermentation, the beer is stored (‘conditioned’) to remove harsh flavours. Ale is conditioned for a few weeks, but lagers are left at close to zero degrees for several months before being filtered, carbonated, and bottled.

While we sip our drinks and look at the menu, the waiter will bring some bread rolls for us to toy with. Leavened bread is another product of the fermentation of sugars from cereal grains by *Saccharomyces cerevisiae*. Its structure also depends on the gooey-gluey properties of the wheat gluten protein. It’s another ‘easy’ technology which has been with us for thousands of years. Mix wheat flour with water, yeast, salt, sugar and some fat and the dough will stick to anything - it’s the gluten that does the sticking. Put the dough in a warm place for at least an hour, ideally two, and the yeast produces carbon dioxide and alcohol. The carbon dioxide gas is trapped into bubbles by the gluten and as more and more bubbles are formed in the dough they make it ‘rise’. After this fermentation period the dough is cooked, the alcohol evaporates (shame!) and the bubbly structure of the dough is turned into the open structure of bread.

OK, so let’s look at that menu. I think fungi will feature prominently in my choices, but I guess you expected that! Fungi are an ideal food because they have a fairly high content of protein (typically twenty to thirty percent crude protein as a percentage of dry weight) and it contains all the amino acids which are essential to human health - and several of the vitamins, too. Fungal tissue is easily digested and the walls of fungal cells provide a good source of dietary fibre. Possibly the most important attribute of all fungal food, though, is that it is virtually free of cholesterol. Fungi just don’t use cholesterol in their membranes to the extent that animals do (fungi use a different sterol which doesn’t accumulate in humans). Consequently, fungal foods compare very favourably with meats on health grounds as well as on grounds of nutritional value. I believe they also compare well on grounds of taste. So I think I’ll go for a ‘fruits of the forest’ style mushroom starter - just a selection of wild mushrooms lightly tossed in a hot pan with melted butter and a pinch of sugar and served with really fresh crusty bread and a wedge of lemon.

Collecting mushrooms for food is an age-old tradition, on a par with collection of berries and other forest fruits. In several forests in the USA and Europe commercial mushroom picking has become big business now. Chanterelles, morels and truffles probably represent the best expression of this in the popular imagination because of the history and mystique associated with the industries in Europe, particularly France and Italy. Their histories include festivals and markets which associate folk events and heighten interest in and appreciation of the qualities of the products themselves. Those qualities contribute to the mystique, prompting discussion of how tasty and flavourful competing collections might be. The truffle probably has more mystique than most because this subterranean delicacy is still hard to find and harvest so there is the added mystery of detecting the presence of a truffle ten or twenty centimetres underground with the help of forest lore, flies, or trained pigs and dogs. There are about seventy different truffle species. The most highly prized in French cuisine is the black truffle of the Périgord, *Tuber melanosporum*, but in Italy it is the white truffle of Alba which is considered the true delicacy. Deciding these matters creates lots of fun and innocent enjoyment. And makes lots of money. The world market for chanterelles (collected, not cultivated) was estimated recently at more than one and a half billion US-dollars. Add the value of tourism and peripheral matters like cookery programs on TV and recipe books and magazine articles and the collection and appreciation of these fungi becomes a very big industry indeed. The demand for wild mushrooms has grown sharply since about the early 1980s. Speciality mushrooms have always been harvested and shipped to distant markets. There is a story that as early as 1872 New Zealand had a fungus-based industry earning, eventually, hundreds of thousands of pounds annually (at 19th century values!) by collecting the wood ear fungus for sale in China. The then Colonial Secretary of Hong Kong, in answer to an inquiry from the New Zealand Colonial Secretary in 1871, reported that the fungus was used as a medicine '...much prized by the Chinese community...' The local entrepreneur, a Chinaman called Chong, paid colonial farmers four pence per pound weight of sun-dried fungus and is said to have purchased an average amount on each market day worth sixty-five pounds sterling. Now, if you calculate what that's equivalent to at the 'four pence per pound' rate, then it turns out that Mr Chong was collecting just less than two metric tonnes each market day! This trade was killed off when commercial cultivation of the fungus made collection from nature uncompetitive. This story emphasizes the rural ideal of collection of a cash crop by local residents for sale elsewhere. Generally small and scattered enterprises where pickers sell and ship most of their own harvest. The trade may be seasonal, and the volume of mushrooms picked may be relatively small.

All of this changed during the late 1980s, mainly in the amount and manner in which mushrooms were harvested, sold, and handled. The commercial picking industry has now expanded to a system of harvesters, buyers, processors, and brokers. Harvesters locate and pick the mushrooms. Buyers, typically associated with a specific processor, set up buying stations near wooded areas known to produce mushrooms and advertise their willingness to buy. Processors grade, clean, pack, and ship the product while providing the cash directly to the field workers. Brokers market the mushrooms around the world. This is a model which has become common in Europe and the United States. One of the things that makes it viable is the easy access to rapid trans- and intercontinental transport. As transport and communications continue to improve, the commercial picking industry is bound to continue to expand. Even remote areas may experience commercial picking of especially valuable species. Apparently, helicopters are routinely used to transport matsutake collected (mostly for export to Japan) in roadless areas of interior British Columbia! There is significant international competition and international markets and prices can fluctuate wildly from year to year, and even within a season, as global weather patterns produce good or poor crops in various locations.

When prices are high, large numbers of pickers may congregate in small areas and then the operation is seen as a 'problem', though the exact perception of what the problem consists of depends very much on the standpoint of the observer. The *Daily Telegraph* newspaper had a report on July 1, 1993 headlined 'Mushroom rustlers shoot it out' that told of heavily-armed mushroom rustlers taking part in mushroom wars in Oregon's forests as they battle for rare mushrooms. A Morrow County Sheriff's Deputy was quoted as saying that '... nearly all the mushroom pickers are armed and it's real scary...' Apparently, two people had died in the shootings and several others had been mugged for their mushrooms. Now, that's a problem! But it's not a problem with the mushrooms.

In any one region there may be thousands of pickers harvesting fungi for commercial purposes from both private and public lands. The knowledge we have about the ecology of wild edible mushrooms is incomplete and this ignorance is at the centre of the (un-armed!) conflicts which are arising between commercial pickers and conservationists and local residents. The three parties do not always align as might be expected. A successful commercial picking job can see a region of woodland completely denuded of marketable mushrooms in just a few hours. Local residents see this as destruction of a natural resource which 'belongs to the people' and expect the support of conservation-minded mycologists in the campaigns which result. Unfortunately, ownership of the resource is not always entirely transparent. 'The people' may be allowed to enjoy woodland for what it is by a generous landowner who subsequently is enlightened to the cash value of ***his*** mushroom crop. Similarly, it is not at all clear that ***picking*** mushrooms does any damage that a conservationist would be concerned about. In the UK the activities of commercial pickers have been likened to the activities of factory fishing boats which take fish of all ages and consequently damage the breeding stock of the fishery to the point where the fish population declines drastically. This is an emotive comparison for the United Kingdom, which has experienced a catastrophic decline in its own fishing industry, but it has almost no biological relevance to commercial mushroom picking. Mushrooms are not individuals, but simply the fruiting structures arising on underground fungal growth - more like apples on a tree than fish in the sea. Removing one generation of fruit bodies will probably *encourage* a new generation to emerge - like pruning. Certainly, continued productivity of mushroom farms is enhanced by regular harvesting. Try to explain that to an irate resident who's just seen 'their' mushrooms disappear down the road on the back of a truck and their respect for academic mycologists evaporates!

The growth in commercial mushroom picking of recent years is unlikely to have generated so much concern had it not coincided with the growing debate about conservation and the damage done to natural biodiversity by commercial pressures. Revelations of the extent of commercial picking, or indeed the arrival of commercial pickers in a woodland, fuel concern that both timber and mushroom harvesting adversely affect the sustainability of wild mushroom populations. You don't have to be an expert to recognize that the woods and forests are being changed by commercial pressures of all sorts; from pressure to use the land for other purposes to pressure to grow a more profitable tree crop. Couple this with the known adverse effects of atmospheric pollution (especially severe in northern Europe) and it's easy to see how commercial mushroom picking might be viewed as one step too far.

Some US agencies are restricting mushroom harvest in particular forest areas because of these uncertainties and additional regulation and legislation will no doubt be called for. Data from Europe, however, has not blamed decline in populations of fungi in the last thirty years to collection of mushrooms by commercial pickers. Rather, an alteration in forest habitats by agriculture and urban development has led to changes in fungus composition. Importantly, though, decline in mushroom populations over these years has outpaced the loss or alteration of habitat, changes in forest age, change in tree composition, and change in forest structure. Make small change to the forest and you cause a big change in the fungi. The key response to all this seems to be effective management of the forest resource as a whole - fungi included. It may make more (economic) sense to cultivate trees for the sake of the fungi with which they are associated. So that the forest becomes the mushroom farm. A sustainable resource which the public can enjoy while the mushroom harvester profits from it. Truffle cultivation is a successful model of what might be done. The truffle is the underground fruit body of a mycorrhiza of oak, so it is dependent on its host tree. Truffle 'cultivation' was first achieved early in the nineteenth century when it was found that when seedlings adjacent to truffle-producing trees were transplanted, they too began producing truffles in their new location. 'Truffières' or truffle groves have been established throughout France in the past hundred years and the value of the crop is such that the practice is now extending around the world. Truffières are started by planting oak seedlings in areas known to be infested with truffle fungi. The truffles begin to appear under such trees seven to fifteen years after planting and cropping will continue for twenty to thirty years. Most plants infected with the black truffle are now raised in greenhouses although pure cultures of this truffle cannot be used yet to inoculate the roots of oak seedlings. Recently, methods have been developed to colonize plant roots with one of the white truffles, encouraging the hope that the same might be done with other truffle species.

Conventional mushroom cultivation produces a total crop of around five million metric tonnes each year. At averaged-out prices this has a retail value of about fifty billion US dollars. In the mid-1970s the button mushroom (called *Agaricus*) accounted for over seventy percent of total global mushroom production. Today, it accounts for something closer to thirty percent even though production tonnage has more than doubled in the intervening years. The biggest change during the last quarter of the twentieth century has been the increasing interest shown in a wider variety of mushrooms. Even in the most conservative of markets (like the United Kingdom) so-called 'exotic' mushrooms have now penetrated the market and supplies of fresh shiitake (*Lentinula*) and oyster mushroom (*Pleurotus*) are routinely to be found alongside *Agaricus* in local supermarkets. Most of these mushrooms are cultivated fairly close to the point of sale. For example, most UK mushrooms originate locally or from the Netherlands or Ireland. The industry is truly international, however, and a small supermarket local to my home in south Manchester regularly displays punnets of fresh enoki (*Flammulina*) which are grown in Chile. This indicates that intercontinental air transport makes the twelve thousand kilometre distance irrelevant, ***and*** that the production costs are sufficiently low to enable reasonable pricing in such a distant market.

Mushroom cultivation is the next-biggest biotechnology industry after alcohol production, and the mushroom industries of the world all depend on some form of solid state fermentation. In the European tradition this has come to mean cultivation of a mushroom crop on compost. Similar approaches were developed for Oyster and Paddy straw mushrooms in the Orient, though in the Chinese tradition the typical approach is to cultivate the crop of choice (*Lentinula*) on wood logs.

Good compost is the essential prerequisite for successful farming of the *Agaricus* mushroom, but compost preparation is a smelly process, and even the most modern installations have a severe impact on their neighbours! The basic raw material for mushroom compost in Europe is wheat straw, although straws of other cereals are sometimes used. Ideally, the straw is obtained after it has been used as stable bedding and is already mixed with horse manure. On commercial scale this is not possible and other animal wastes, like chicken manure, are mixed with the straw, together with gypsum and large quantities of water. The European mushroom industry is said to have originated in the caves beneath Paris at the end of the nineteenth century. It probably emerged from the food provisioning functions of the kitchen gardens on the estates of the European aristocracy. Some of the surviving records of such estates refer to manured and composted plots set aside for mushroom production. The compost used, and its preparation, would very definitely be familiar to the very competent gardeners of the day. The current industry depends on compost which is very selective for the crop species. Although widely distributed in nature, the *Agaricus bisporus* fungus is rarely encountered because it produces relatively few mushrooms in the wild and them only infrequently. The industry we know today seems, therefore, to be the result of a remarkable 'joint evolution' during which otherwise ordinary horticultural compost was developed that achieves high cropping densities with an otherwise unremarkable and not very abundant mushroom. And all without a genetic engineer in sight!

The beginnings of mushroom fruit bodies, 'pins' or 'pinheads' which are more or less spherical and have a smooth surface, will be seen about three to four weeks after the compost is first 'seeded' (it's actually called spawning) and about one to two weeks later marketable mushrooms can be harvested. Successions of mushrooms then develop in a series of flushes about eight days apart, each taking about five days to clear from the beds. Growers expect to harvest between three and five flushes from each spawning cycle, with a total yield of around twenty-five kilogram from every square meter of growing tray. After the final pick (seven to ten weeks after spawning) the compost is spent, and the cropping room is emptied, cleaned, sterilized and filled with the next crop. On most farms a new crop is filled every one or two weeks throughout the year. So a mushroom farmer is likely to see more crops in one year than a cereal farmer will see in a lifetime!

It's different in China, of course. The main crop is the black-oak or shiitake mushroom (official name *Lentinula edodes*) which is traditionally grown on deciduous hardwood logs (oak, chestnut, hornbeam) and is still very widely grown like this in the central highlands in China. To put this statement into perspective, the traditional log-pile approach is still the most frequently used method in China over a growing region which covers an area about equal to the entire land area of the European Union. China is big! The logs considered suitable for shiitake production are about thirty centimetres diameter and one and a half to two meters long, and normally cut in spring or autumn of each year to minimize pre-infestation by wild fungi or insects. Holes drilled in the logs (or saw- or axe-cuts) are packed with spawn, and the spawn-filled hole then sealed with wax or other sealant to protect the spawn from weather, insects and competitor fungi. The logs are stacked in laying yards on the open hillside in arrangements which permit good air circulation and easy drainage and warm temperatures (twenty-four to twenty-eight degrees Celsius). The logs remain here for the five to eight months it takes for the fungus to grow completely through the log. Finally, the logs are transferred to the raising yard to promote fruit body formation. This is usually done in winter to ensure the lower temperature (around twelve degrees) and increased moisture which are required for fruit bodies to start. The first crops of mushrooms appear in the first spring after being moved to the raising yard. Each log will produce about two kilogram of mushrooms, each spring and autumn, for five to seven years. This traditional approach to shiitake production is expensive and demanding in its use of both land and trees. Some commentators estimate that there are ten million mushroom farmers in China; if true, the traditional use of locally-cut logs is likely to devastate the hill forests. This is a good reason why more industrial approaches are being applied to shiitake growing. Hardwood chips and sawdust packed into polythene bags as 'artificial logs' provide a highly productive alternative to the traditional technique, and the cultivation can be done in houses (which may only be plastic-covered enclosures) in which climate control allows year-round production.

The Chinese straw mushroom *(Volvariella volvacea)* is grown mainly on rice straw, although several other agricultural wastes make suitable substrates. Preparation of the substrate is limited to tying the straw into bundles which are soaked in water for twenty-four to forty-eight hours. The soaked straw is piled into heaps about one meter high which are inoculated with spent straw from a previous crop. An important reason for the remarkable increases seen in production of certain mushrooms has been the use of substrates which are waste products from other industries. For example, although the Chinese straw mushroom is traditionally grown in South-East Asia on rice straw, it can be grown on cotton waste. Cotton waste gives higher yields and is also more widely available than is rice straw so it is a far cheaper substrate (the higher cost of rice straw does not indicate any intrinsic value but rather the price of transporting it to a non-rice-growing region). Oyster mushrooms are also easily grown on a wide range of agricultural wastes.

There are quite a few other cultivated mushrooms, something approaching fifteen or more, but we have quite enough for a starter already and its time to think about a main course. Main course, yes that usually means a large lump of protein like a steak or something else that used to run around going moo, baa, oink or cluck.... but it doesn't have to be meat. Have you considered single-cell protein? Understandably, it doesn't appear under that name in the menu and I've got to admit that the emphasis given in the 1950s to the 1970s to the production of single-cell protein is now almost forgotten. In those days the hope was born that microbes could provide a means of solving the world's food shortage by industrial production of cheap protein alternatives to meat protein. Several fortunes were invested in the idea, and were duly lost when it turned out that the people who were short of food didn't want to eat industrially-produced single cell protein, thank you very much. Solution of problems on that scale has more to do with politics and economics than with biotechnology. Today, the emphasis has moved towards the use of single cell protein for animal feed, and the only successful fungal product currently on the market is the myco-protein Quorn. Myco-protein is the term coined by the United Kingdom Government's Foods Standards Committee to serve as the general name for a food product resulting from the growth of a selected strain of the filamentous soil-fungus *Fusarium*. This is grown in a very large (it's forty-five meters tall) air-lift fermenter. This is a high-technology product which took a long time (and a lot of money) to develop and even longer to get official approval to use it as human food. Quorn is marketed as 'The tasty, healthy, alternative to meat ...' because its filamentous structure enables it to be processed to simulate the fibrous nature of meat. Coupled with the inherent nutritional value of fungal tissue, this permits the product to be sold as a low-fat, low-calorie, cholesterol-free health food to consumers who can afford to choose Quorn as a meat substitute. At a price. The retail prices of Quorn exceed those of most meats and are two to three times greater than retail prices of mushrooms. Quorn mince and Quorn pieces can be used in cooking recipes in much the same way as meat products. If you talk nicely to the chef I'm sure he'll be delighted to prepare you a choice Quorn burger or Quorn fillet steak.

Me? No thanks, I'll write about it but I don't need to eat it. I'll settle for a mushroom stroganoff. Why eat substitute meat when you can eat real mushrooms for half the price? You can feed four with this recipe: heat about thirty millilitres of good olive oil in a large frying pan with three hundred and fifty grams of chopped onion, cook until the onion goes translucent (about five minutes) then add seven hundred grams of chopped mushrooms (assorted - and equal amounts of oyster, shiitake and brown-cap *Agaricus* mushrooms are recommendable - or all of one sort according to your preferences) with a crushed clove of garlic or two (to taste) and cook over a moderate heat for five to ten minutes. The oyster mushroom stems will take longest to cook; if a fork will go through them easily then they're done. Stir in three hundred millilitres of a stock made up from stock cubes (vegetable if you want a vegetarian dish, chicken otherwise) together with fifteen to twenty grams of corn flour as a thickening agent. Bring to the boil and simmer for five to ten minutes. Remove from the heat and season with pepper and salt, lemon juice and/or tabasco sauce to taste. Finally, stir in three hundred millilitres of fromage frais (you can use sour cream if you don't care about either your waistline or the cholesterol) and heat through until piping hot, but do not allow to boil. Serve immediately onto a bed of rice or pasta. That goes down well with a nice red wine from Chile!

As well as being used directly as food, fungi are also used in the processing of various food products. In these the fungus is mainly responsible for the production of some characteristic odour, flavour, or texture and may or may not become part of the final edible product. Growing fungi on water-soaked seeds of plants is a popular way to produce several foods in Asia, including soy sauce and various other fermented foods. In soy sauce production soybeans are soaked, cooked, mashed and fermented with two moulds called *Aspergillus oryzae* and *Aspergillus sojae*. Depending on the size of the factory, the soybeans may be fermented in fist-sized balls (the traditional method) or on trays. When the soybean substrate has become overgrown with the fungus the material is mixed with salt and water and the fermentation is completed in the brine. The biggest industrial units today use a continuous process in which defatted soybean flakes, moistened and steam-sterilized are mixed with ground, roasted wheat. The mixture is turned mechanically to ensure even growth of the two moulds for two to three days; then it is transferred to brine and inoculated with a bacterium and a yeast. The brine fermentation takes six to nine months to complete, after which the soy sauce is pressure-filtered, pasteurized and bottled.

As an example of a fermented food, rather than a flavouring condiment like soy sauce, the Indonesians make tempeh - a white cake produced by fermentation of partially cooked germinated soybeans with a different mould (called *Rhizopus oligosporus*). The fungus binds the soybean mass into a protein-rich cake that can be used as a meat substitute. This is being increasingly widely sold into the vegetarian market. There are a variety of other fermented products of this sort. Ang-kak is a rice product popular in China and the Philippines which is fermented using a fungus called *Monascus purpureus*. This fungus produces red pigments as well as alcohol which are used for red rice wine and food colouring.

These exotic products have their place, but cheese is a very good way of ending a meal. If you look in the dictionary you'll find that cheese is a solid or semisolid protein food product manufactured from milk. Before the advent of modern methods of food processing, like refrigeration, pasteurization and canning, cheese manufacture was the only method of preserving milk. Although basic cheese making is a bacterial fermentation, there are two important processes to which fungi contribute; these are the provision of enzymes for milk coagulation and mould-ripening. Cheese production relies on the action of enzymes which coagulate the proteins in milk, forming solid curds (from which the cheese is made) and liquid whey. Traditional cheese-making uses animal enzymes (called chymosin or rennet) extracted from the stomach membranes of unweaned ruminants. Rapid expansion of the cheese-making industry caused attention to shift to alternative sources of such enzymes and moulds like *Aspergillus* and *Mucor* have supplied these to the extent that around eighty percent of cheese making now uses coagulants from non-animal sources. Recently, animal enzymes produced by genetically-modified microbes have entered the market. Indeed, chymosin was the first enzyme from a genetically-modified source to gain approval for use in food manufacture, in 1988. Today, about ninety percent of hard cheese production depends on enzymes from genetically-modified microbes (mostly yeasts) for the coagulation step.

Mould ripening is a different matter. It is a traditional method of flavouring cheeses which has been in use for at least two thousand years. Blue cheeses, like Roquefort, Gorgonzola, Stilton, Danish Blue, and Blue Cheshire, all use *Penicillium roquefortii* which is inoculated into the cheese prior to storage at controlled temperature and humidity. The fungus grows throughout the cheese, producing flavour and odour compounds. Camembert and Brie are ripened by a mould called *Penicillium camembertii*, which changes the texture of the cheese rather than its flavour. This fungus grows on the surface of the cheese extruding enzymes which digest the cheese to a softer consistency from the outside towards the centre.

You know, if we finish off the last few crumbs of cheese on that plate with just one more ***tiny*** glass of Frangelico liqueur (that hazel nut flavor complements Roquefort so well), we could go quietly to sleep in the corner until the next chapter ... and ***nobody*** will notice ...