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FERMENTED FOODS

Fermented foods are among the oldest processed foods and have been eaten in almost all countries for millennia. They include fermented cereal products, alcoholic drinks, fermented dairy products and soybean products among many others. Details of the production of individual fermented foods are given in the following Technical Briefs:

- **Dairy products:** Cheese making; Ricotta Cheese Making; Soured Milk and Yoghurt; Yoghurt Incubator
- **Fruit and vegetable products:** Gundruk (Pickled Leafy Vegetable) Banana Beer; Grape Wine; Toddy and Palm Wine; Tofu and Soymilk Production; Dry Salted Lime Pickle; Dry Salted Pickled Cucumbers; Green Mango Pickle; Lime Pickle (Brined); Pickled Papaya; Pickled Vegetables; Fruit Vinegar; Pineapple Peel Vinegar; Coffee Processing.
- **Meat and fish products**: Fresh and Cured Sausages.

This technical brief gives an overview of food fermentations and examples of fermented foods that are not included in the other technical briefs.

Types of food fermentations

Fermentations rely on the controlled action of selected micro-organisms to change the quality of foods. Some fermentations are due to a single type of micro-organism (e.g. wines and beers fermented by a yeast named '*Saccharomyces cerevisiae*'), but many fermentations involve complex mixtures of micro-organisms or sequences of different micro-organisms. Fermented foods are preserved by the production of acids or alcohol by micro-organisms, and for some foods this may be supplemented by other methods (e.g. pasteurisation, baking, smoking or chilling). The subtle flavours and aromas, or modified textures produced by fermentations cannot be achieved by other methods of processing. These changes make fermentation one of the best methods to increase the value of raw materials. The process is particularly suitable for small-scale processing because the technologies are relatively simple and locally available equipment can have low capital and operating costs; the products usually have a high demand and added value; and processing has low energy consumption due to mild (often ambient) operating temperatures. There are many hundreds of types of fermented foods and a small selection is shown in Table 1.

Appam (or hoppers)	A type of pancake bread from South India and Sri Lanka made from rice batter with toddy (fermented palm, palmyrah or coconut sap) baked on a griddle.
Atchara	A pickle used in the Philippines, made from shredded unripe papaya, carrot, ginger, bell pepper, onion and garlic, mixed with vinegar, sugar and salt and fermented in airtight jars.
Bagoong	Fermented anchovy sauce used as an ingredient in curry and as an accompaniment to traditional food dishes in Philippines.
Brem	Fermented cake or beverage from Indonesia made from rice wine, white or black glutinous rice.
Chicha	A drink from yellow maize with a slightly milky appearance and mildly sour taste, containing 1-3% alcohol.

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technical brief

Cheonggukjang Dajiang, black bean sauce, Douchi, Sufu, Miso, Nattō, Tamari, Tauchu, Tempeh, Tofu, lufu	Different types of fermented soybeans and pastes in East and Southeast Asia used as condiments. Colours from light tan to dark brown due to different fermentation conditions, addition of wheat flour, rice, or sugar and different bacteria or moulds used in their production. Fermented bean pastes are starting materials for soy sauces, such as tamari.
Dhokla (or dhokra or khummun)	An Indian snack made from fermented chickpea batter and baking soda, spiced with chilli and ginger.
Dosa	A fermented crêpe or pancake made from rice and black lentils
Douban-jiang	A spicy, salty paste made from fermented broad beans, soybeans, salt, rice and various spices
Gari (or Garri)	West African dough made from peeled, grated cassava tubers, fermented for 1-2 days, sieved and roasted, and pounded to a fine flour.
Gochujang	A reddish paste with a rich flavour, made from fermented red chillies with glutinous rice powder, powdered fermented soybeans and salt.
Hákarl	Basking shark cured by fermentation and hung to dry for 4-5 months in Iceland and Greenland.
Hongeohoe	Fermented skate fish from Korea with a strong ammonia-like odour, used uncooked as a side dish.
Idli	A South Indian savoury cake made by steaming a batter of fermented black gram (lentils) and rice, eaten for breakfast or as a snack food.
Injera	A flatbread with a unique, spongy texture made from fermented tef flour in Ethiopia, Eritrea, Somalia and Yemen
Irú	Fermented locust beans used in Nigeria as a condiment and in soups.
Kefir	A fermented milk drink of the Caucasus region prepared by inoculating milk with kefir grains produced by lactic acid bacteria.
Kim chi	Fermented cabbage, radish, green onion or cucumber made in hundreds of varieties.
Kombucha	Fermented drink for medicinal purposes made using a kombucha culture 'mushroom' - a solid mass of yeast and bacteria (similar to tibicos).
Koumiss	A fermented dairy product made from mare's milk in Central Asia, similar to kefir but produced from liquid starter culture instead of kefir grains and having a higher alcohol content.
Lassi	A yoghurt drink in India and Pakistan, made by mixing yoghurt with water or milk, spices or sugar, fruits or honey.
Mageu	A South African non-alcoholic drink made from fermented maize paste with an acidic taste.
Miso	A thick paste used for seasoning and sauces in Japan, produced by fermenting soybeans, rice, and/or barley with salt.
Nata de coco	A chewy, translucent, jelly-like product produced by fermentation of coconut water and used as a dessert.
Nattō	Fermented soybeans with a powerful smell, strong flavour and a slippery texture, popular in Japan as a breakfast food.
Ogi	A fermented porridge from West Africa made by fermenting maize, sorghum or millet with lactic acid bacteria and yeasts until sour. Then boiled to make a stiff porridge.
Ogiri	A West African flavouring made from fermented sesame seeds or egusi seeds, smelling of cheese or miso.
Oncom	West Javan black or red fermented cake, similar to tempeh, made from by-products (e.g. soybean residue from tofu production, peanut or coconut presscake, cassava residue after starch extraction).
Tapai (or tapé)	A sweet or sour alcoholic paste made from cassava, white rice, or glutinous rice fermented by a variety of moulds, bacteria and yeasts
Sauerkraut	Finely shredded fermented cabbage with a distinctive sour flavour, fermented by *Lactobacilli*, then *Leuconostoc* sp., followed by various *Lactobacillus* sp. and *Pediococcus* sp. that further increase its acidity.

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Shiokara	Small pieces of strongly flavoured meat in a viscous brown paste, made from heavily salted, fermented seafood viscera (e.g. cuttlefish, squid, tuna, oyster, shrimp, crab or sea cucumber).
Soy sauce	A condiment produced by fermenting salted soybeans with *Aspergillus oryzae* and *Aspergillus soyae*. All types of soy sauce are salty, earthy, brownish liquids with a distinctive umami flavour.
Tempeh (or tempe)	A fermented soybean cake that has a firm texture and strong flavour.
Tian mian jiang	A thick, brown or black Chinese sauce made from wheat flour, sugar, salt and fermented soybean residue from soy sauce production.
Tibicos	A drink made by bacteria and yeasts in a matrix similar to kefir grains. The fermentation produces lactic acid, alcohol and carbon dioxide, which carbonates the drink.
Tương	Different types of Vietnamese salty dark brown pastes or liquids used as condiments, made from roasted soybeans fermented with *Aspergillus oryzae*.
Viili	A type of Nordic yoghurt with a ropy, gelatinous consistency and a sour taste produced by lactic acid bacteria. Traditional cultures also contain yeasts.
Zha cai (Sichuan vegetable)	A spicy, sour and salty Chinese pickle (similar to kimchi) made from salted, pressed and dried mustard stems rubbed with red chilli paste and fermented in earthenware jars. It is washed before use to remove the chilli paste and excess salt.

Table 1. Examples of fermented foods
(Adapted from multiple sources based at http://en.wikipedia.org/wiki/Fermentation_%28food%29)

Fermentations can be grouped into those that take place using solid foods and those that use liquid raw materials. Most solid food fermentations use micro-organisms that require air to grow and produce the characteristic flavours (i.e. 'aerobic' micro-organisms), whereas most submerged fermentations using liquid foods require anaerobic conditions in which air is excluded. This difference is reflected in the different production methods and equipment described below.

Solid fermentations

Most solid food fermentations involve the growth of moulds, yeasts and/or lactic acid bacteria on moist materials such as tubers, cereals, soybeans or meats, and also food-processing residues (e.g. wheat bran, or soya flakes remaining after oil extraction). Traditional products produced by mould fermentations include Indonesian tempeh and Indian ragi. Yeasts and moulds are used to produce tapé, and yeasts and/or lactic acid bacteria produce raised bread dough as well as fermented cassava and rice products.

The first stage is to prepare the food by shredding, grinding or flaking the material, and sometimes by heating it to remove any contaminating micro-organisms. It is then inoculated with the required micro-organism(s), either from bought cultures or using previously fermented material. It is incubated within a specific temperature range and moisture content to allow the micro-organism to grow into the food. Fermentations that are traditional to an area are successful at ambient temperatures, whereas fermentations that are introduced from other areas may require temperature control. This can be done by continuously mixing the food or by blowing cool air through the material. Depending on the product, the moisture content is usually maintained between 30-75% to allow maximum cell growth. The final product may be the fermented material itself, or liquid components that are drained or washed from the fermented material.

The simplest technologies for solid food fermentations such as kenkey, bread dough and gari are trays, bowls or other containers of food that are incubated in a room or a cabinet. Many types of sausage are also fermented in their casings (see Technical Brief: fresh and cured sausages). At a larger scale, equipment known as a 'bioreactor' is used. Different types of batch bioreactors include rotating or rocking drums, and stationary or stirred aerated beds. For

example, one design has a slowly rotating basket that is fitted with internal baffles to mix the substrate. The slow rotation equalises the temperature and aerates the food with air to provide oxygen for cell growth and to control moisture loss by evaporation.

Fermented cereals, legumes and root crops

Leavened breads are produced by first mixing the yeast, *Saccharomyces cerevisiae,* with flour, water and other ingredients to form a dough (see Technical Brief: Baking). This is then fermented in a proving cabinet to produce carbon dioxide, which leavens the dough. Ethanol is also produced in small amounts but it is evaporated when the dough is baked. In sour dough fermentations, lactic acid bacteria and yeasts are used to ferment different cereal/legume mixtures using similar equipment. The proving cabinet has a controlled temperature of 35-43°C and humidity of ≈ 85%. Commercial proving cabinets are made from stainless steel, with humidifiers and thermostatically controlled electric heaters to control the temperature and humidity. A simple low-cost prover can be made using a wooden or metal framework covered in polythene sheeting with a flap to gain entry (Fig. 1). Dough is placed on shelves inside the prover and the raised temperature and humidity are created by gently boiling a pan of water in the cabinet. A larger prover can be made from a steel container of the type that is used to carry goods aboard ships and on trucks. It is converted to a prover by fitting it with an insulated pipe to supply steam from an external boiler. This raises the temperature and humidity. The dough is loaded into the prover on wheeled trolleys and the container doors are closed while proving takes place.

Figure 1: Low-cost dough prover. Photo: Pete Fellows.

Batters made using a variety of cereal and legume floursare fermented by lactic acid bacteria without control of the temperature or humidity and heated on a griddle to produce leavened pancakes, including idli from lentils and rice in India, and injera from tef in Ethiopia (Table 1). In all products, the baking stage destroys the fermentation micro-organisms. Fermented porridges are made from milled maize, millet, sorghum, cassava and yam. Examples include gari, a creamy-white, granular flour, made in West Africa from fermented cassava. The tubers are washed, peeled and grated and the grated cassava is fermented by a mixture of naturally occurring bacteria by packing it into baskets and leaving it at ambient temperature for 5 days. The fermentation both removes toxic cyanide compounds and produces the desirable flavours. After fermentation, the cassava is pressed to remove water and then roasted using a hot pan. Roasting destroys enzymes and micro-organisms; drives off the cyanide gas; causes partial gelatinisation of the starch; and dries the product. Fufu is another West African fermented cassava product that is produced by soaking peeled whole or sliced cassava roots in vats for 3-4 days. During soaking, a natural fermentation increases the acidity, softens the tubers, and reduces the concentration of cyanide compounds. After fermentation, the softened tubers are grated to a paste and sieved to remove larger fibres. This is mixed with water, allowed to settle for 24 hours and the water is then poured off and the sediment pressed to dewater it. The resulting cake is sieved and dried. When properly packaged and stored, dried fufu and gari flours have a shelf life of six months or more.

In Ghana, kenkey is prepared from maize flour mixed with warm water to make a dough. A natural fermentation takes place for 2-3 days at ambient temperatures, and the fermented dough is then kneaded until it is slightly stiffened. It is divided into two equal parts: one part (named 'aflata') is partially boiled in water for ≈10 minutes, stirring constantly and vigorously. This is then mixed with the remaining uncooked dough and the aflata-dough mixture is divided into portions and wrapped tightly in banana leaves, cornhusks, or foil. These are steamed for

1-3 hours, depending on the size of the portions and the final product is consumed on the same day that it is produced.

Different types of light and dark soy sauce, tamari and similar products are made by a two-stage fermentation: in the first stage a mixture of cooked soybeans and roasted wheat flour is fermented by the moulds *Aspergillus oryzae* and *A. soyae* for 3 days at 30°C. The fungal enzymes break down starch and proteins, and these form the substrate for the second fermentation. The fermenting mixture (named 'koji') is transferred to 18-20% brine in deep tanks and lactic acid bacteria are inoculated. The fermenting mixture is kept at 15°C for the first month, allowing the pH to fall from 6.5 to 5.0. Then cultures of the yeasts *Zygosaccharomyces* sp. *and Candida* sp. are added and the temperature is increased slowly to 25-28°C to allow an alcoholic fermentation to take place for 3-6 months. During this time the sauce develops its characteristic flavour. The liquid is collected, filtered, pasteurised and bottled. The final product has a pH of 3.3-5.3 and is preserved by the salt and a low concentration (≈2.5%) of ethanol.

Tempeh is another fermented soybean product, made by soaking beans at 25°C, removing the seed coats and steaming the split beans for 0.5-2 hours. These are inoculated with spores of the fungus, *Rhizopus* sp., packed into trays or rolled in banana leaves, and incubated at 32°C for 20 hours. The fungus softens the beans and binds the bean mass to form a solid cake. The fermentation changes the texture and flavour of the soybeans but has little preservative effect. The product is sliced, dipped in salt water and fried within a few days, or preserved for longer periods by chilling or freezing. In Japan, sake is an alcoholic beverage with an alcohol content of 13-17%, produced by first growing *Aspergillus oryzae* on steamed rice mash to produce koji. This is then mixed with more rice mash and the starch is converted to sugars by enzymes in the koji. A mixture of yeasts produce an alcoholic fermentation and the liquor is separated from the fermented mash after 10-13 days and distilled. Other fermented cereal and legume products include dhokla (chickpeas), brem (rice), miso (rice and soybeans), dosa (rice) and idli (rice and black gram) in Table 1.

Fermentation is also used in the processing of coffee and cocoa beans: after removal of the outer skin, coffee berries are soaked in water and allowed to ferment. Bacteria first break down the berry pulp, followed by a lactic acid fermentation that increases the acidity and develops flavour compounds that contribute to the final coffee flavour after the beans have been dried and roasted. Similarly, in cocoa fermentation, yeasts and lactic acid bacteria break down the pulp around the beans and contribute to the aroma, flavour and colour of the cocoa.

Fermented vegetables

Important fermented vegetables include sauerkraut from cabbage, kimchi from cabbage, radish and green onion, atchara from mixed fruits and vegetables, gundruk from leafy vegetables, and zha cai from mustard plant stems (Table 1). These are produced by dry salting, in which alternate layers of chopped or shredded vegetables and salt are packed into sealed jars, barrels or tanks. Juice is extracted from the vegetables by the salt to form a sweet brine, which is then fermented by lactic acid bacteria. The natural fermentation involves a succession of different lactic acid bacteria, each more tolerant of the increasing acidity. Further details are given in the technical briefs listed in the introduction.

Fermented meat and fish products

Fermented sausages are described in Technical Brief: Fresh and Cured Sausages. There are a large number of fish or seafood sauces made from fermented whole raw fish, dried fish or shellfish, or from the blood or viscera of different species (e.g. shiokara and bagoong in Table 1). Some sauces contain only fish and salt, whereas others are flavoured with a variety of herbs and spices. A short fermentation results in a pronounced fishy taste, whereas longer fermentation times produce nuttier and cheesier flavours. These sauces are popular in Southeast Asian countries, where they are used as cooking ingredients, condiments, flavourings or dipping sauces. For example, sauce made from anchovies is produced by layering the fish and salt in wooden boxes. The fish are slowly pressed as they ferment, to

produce the liquid sauce. Semi-solid fish pastes (prahok in Cambodia, trasi in Indonesia and belacan in Malaysia) are other variations of the sauce. Also in Malaysia, fresh small prawns or krill are mixed with salt and rice and sealed in jars to ferment for three days and produce the condiment cincalok. In Europe, Worcester sauce is made from a fermented mixture of molasses, sugar, salt, anchovies, vinegar, tamarind extract, onions, garlic, spices, and other flavourings. The ingredients are sealed in barrels and allowed to ferment for several weeks and the liquor is drawn off to make the sauce.

Liquid (or submerged) fermentations

At a small scale, the most important fermentations using liquid substrates are:

- Alcohol production, including wines made from fruits, honey, tree saps, rice and vegetable pods. Beers are produced from malted (partly germinated) barley and other cereals, including wheat in temperate climates, and maize, sorghum and millet in tropical countries.
- Dairy fermentations, including lactic acid fermentations of milk to make acidified milks, yoghurts and cheeses.
- Pickled vegetables and
- Vinegar production, which is a two-stage process that involves an alcohol fermentation followed by a fermentation using acetic acid bacteria that convert the alcohol to vinegar (acetic acid).

For small-scale production, the equipment for fermentation of beers, pickles and fermented dairy products usually consists of a covered container, such as plastic, aluminium or stainless steel buckets, drums or tanks. Note: some producers use jerrycans that are intended to carry fuel or water, but this should be discouraged because they are more difficult to inspect to ensure that they are properly cleaned, and some types are made from plastics that are not food-grade. Likewise, re-used steel oil drums should be avoided due to the risk of contamination, or corrosion of the steel by acidic products. Stainless steel batch fermenters are commercially available in sizes that are suitable for small-scale operation, but they are relatively expensive, mostly because of the systems that are used to control the fermentation process (i.e. the temperature, acidity, dissolved oxygen, degree of agitation and foaming).

In outline, liquid fermentations involve preparing the liquid substrate, pasteurisation, inoculation with the required micro-organism(s), fermentation, followed for some products by sedimentation or filtration and separation of the fermented product. The following section gives an outline of fermentation processes used to make beers and wines. Processes for vinegar, dairy products and pickled vegetables are described in Technical Briefs listed in the introduction.

Beers and wines

Note: In some countries a special licence is needed to produce and sell any alcoholic products, whereas in others it is only distilled spirits that need a licence. Alcohol production is not permitted in some Muslim countries. Producers should ensure that they have the correct licences or permits to avoid the risk of prosecution.

Beer ‘wort’ is produced by boiling malted cereal grains to release sugars, which are then fermented by the yeast, *Saccharomyces cerevisiae.* Some have added hops to produce bitterness in the beer. Variations in the composition of the wort, the strains of yeast and the fermentation time and temperature, each result in the hundreds of different types of beers that are produced. ‘Top-fermenting’ yeast strains are used at temperatures from 12-25°C and rise to the surface during fermentation, creating a thick ‘head’. They produce high levels of flavour compounds that give the distinctive character to beers, ales, porters and stouts. For example, wheat beers have a lighter colour and more delicate flavour than beers made with barley and other grains, and many wheat beers are cloudy. Lager yeast (*S. carlesbergensis*) is a bottom-fermenting yeast that is used at temperatures from 7-15°C. This yeast grows less rapidly than top-fermenting yeast; produces less surface foam, and settles out to the bottom of

the fermentation vessel. The flavour of the lager depends on the ingredients, the strain of yeast and the fermentation temperature.

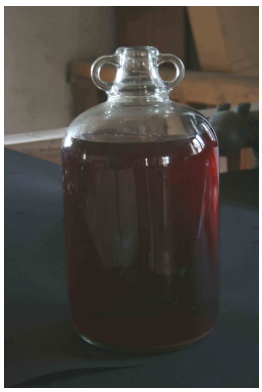
Other types of beer include maize beer (Chicha de jora) in Latin America and sorghum beer in Eastern and Southern Africa. This is brownish-pink with a fruity, sour taste and an alcohol content of 1-8%. It is not filtered and appears cloudy, and it may also contain small pieces of grain. It is produced using malted sorghum mash, which is first soured by lactic acid bacteria and then fermented by yeasts in a similar way to other beer fermentations. The lactic acid bacteria may be added from yoghurt or a sour dough, or the bacterial that occur naturally on the sorghum grain may be used. Commercial sorghum beer is packaged with the fermentation still active and for this reason, special containers with vents are used to allow the gas to escape.

After fermentation, most beers are allowed to clear, with the yeast and other materials settling out as sediment in the fermentation tank. At larger scales of production, the beer is filtered and/or centrifuged, often using filter aids to produce crystal-clear products. Beers may be filtered and bottled directly if they are to be consumed within a few days. For a longer shelf life, they may be pasteurised after filling into bottles, or at a larger scale they are pasteurised before filling into bottles, cans or kegs. The alcohol content of beers and lagers is typically 2-6%, measured using a hydrometer. If a standard alcohol content is required, beers from different batches are blended, based on the hydrometer readings.

Wines may be produced from almost any plant material that contains sufficient amounts of sugar, including most fruits and some types of tree sap (e.g. maple sap, or palm sap used to make palm wine or ‘toddy’ - see Technical Brief Toddy and Palm Wine). Some types of vegetables or young vegetable pods (e.g. pea pods) can also be fermented with added sugar. Worldwide, grapes are the preferred fruits to make high quality wines (see Technical Brief: Grape wine). The most popular non-grape wines in many countries are pineapple, papaya, passion fruit, banana, melon and strawberry. ‘Fortified’ wines, such as sherry, port, ginger wine etc., have alcohol contents of 15-20%.

The important factors for the production of good quality wines are: 1) a suitable wine yeast that is added in sufficient amounts (e.g. 1-2%) to rapidly start a vigorous fermentation; 2) strict attention to cleanliness and hygiene, with sterilisation of fermentation vessels and all other equipment using sodium metabisulphite solution; 3) exclusion of air with an airlock to prevent micro-organisms converting the alcohol to vinegar; 4) a fermentation temperature of ideally 20-25°C, but ambient temperature usually is satisfactory if it is not below ≈ 18°C; 5) sedimentation and filtration after the fermentation has finished to produce a crystal-clear wine.

Glass ‘demijohns’ (Figure 2a) are popular fermentation vessels for micro-scale production of wines because they are transparent to check that they are clean and to monitor the fermentation, but any container made from food-grade material is suitable. All fermentation vessels should be fitted with an airlock (Figure 2b) to prevent contamination by micro-organisms from the air and to ensure that carbon dioxide from the fermentation replaces the air above the fermenting liquor and so reduces the risk of oxidation of wine to vinegar.



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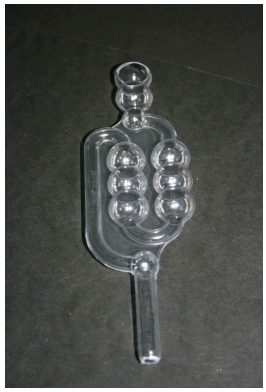

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Figure 2: Equipment for production of wine a) demijohn, b) airlock. Photos: Pete Fellows.

Wines should be stored in airtight containers until they are bottled to prevent contamination by acetic acid bacteria that would convert the alcohol to vinegar. Grape wine may be bottled directly, or it can be aged to reduce its acidity and develop a characteristic bouquet. The main acid in most grape wines is tartaric acid but in some red wines malic acid is present in a high concentration. A secondary 'malo-lactic' fermentation by lactic acid bacteria converts malic acid to lactic acid, which reduces the acidity and improves the flavour and aroma. Wines made from other raw materials are usually bottled directly after they have cleared.

Filter aids are used to ensure that most wines and beers are crystal clear. Typically, diatomaceous earth and perlite are used for beers. For wines, the filter aids are bentonite, which is added first to the wine, and then perlite and isinglass are stirred gently into the wine without disturbing the sediment. The wine should then be left for 30-60 minutes to clear. If a haze remains, this is due to pectin and it may be necessary to use a pectic enzyme to remove it (often named 'wine enzyme' or 'wine clearing enzyme').

Fermented dairy products

There are a large number of fermented milk products produced throughout the world using lactic acid bacteria (Table 1). The bacteria use milk sugar (lactose) to produce lactic acid and aroma chemicals that create the distinctive flavours found in products such as yoghurt and cheeses. The lactic acid in turn changes milk proteins to produce the characteristic textures of these products. The type of starter culture, incubation conditions and subsequent processing conditions each controls the texture and flavour of the fermented milk, and hence produces the many different fermented dairy products. Preservation is due to the increased acidity (in yoghurt and cultured milks), the reduced moisture content (in some cheeses) and by chilling. Further details of yoghurt and cheese production are given in technical briefs described in the introduction.

Fruit and vegetable pickles

A large number of pickled vegetables, including olives and cucumbers (gherkins) are produced by submerging them in brine, which inhibits the growth of spoilage bacteria and allows the growth of salt-tolerant lactic acid bacteria. In each type of vegetable pickle, preservation is achieved by the combination of lactic acid and salt, and products that are packed into jars may also be pasteurised. Either naturally occurring lactic acid bacteria are allowed to grow in the pickling brine or it is inoculated with a starter culture of different lactic acid bacteria (e.g. *Lactobacillus plantarum* with *Pediococcus cerevisiae*). The amount of added salt controls the type and rate of the fermentation: for example a brine containing 2-5% salt encourages the initial lactic acid bacteria that produce the lactic acid, and this may be increased to 10% salt to select salt-tolerant Lactobacilli. In some processes, sugar is added to increase the rate of fermentation or to make the product sweeter. Vegetables are fermented for ≈ 5 weeks in ceramic or earthenware jars at household- and micro-scales of production, or in fibreglass or tiled concrete tanks at a larger scale.

Yeasts and moulds that have a high tolerance to acid and/or salt may cause spoilage, which is seen as a white growth on the surface of vegetables that protrude from the surrounding liquor. The lid of the tank should therefore be weighted to hold down the vegetables so that they remain submerged. It is essential that pickle processors maintain good hygiene in a processing plant because acid-tolerant spoilage yeasts and moulds may adapt to conditions and colonise a production unit to cause serious outbreaks of product spoilage. Manufacturers should make sure that all surfaces, floors, machines and utensils are cleaned daily with hot water and chlorine-based sterilants. Further information on the production of individual pickles is given in separate technical briefs described in the introduction.

Further information

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