Fermented food made from milk

The majority of fermented milk products rely on **lactic acid bacteria (LAB),** which include species belonging to the genera *Lactobacillus*, *Lactococcus*, *Leuconostoc*, and *Streptococcus* (figure 1). These firmicutes tolerate acidic conditions, are nonsporing, and are aerotolerant with a strictly fermentative metabolism. Louis Pasteur discovered lactic acid fermentation, which led to the development of pure LAB starter cultures and the industrialization of milk fermentation.

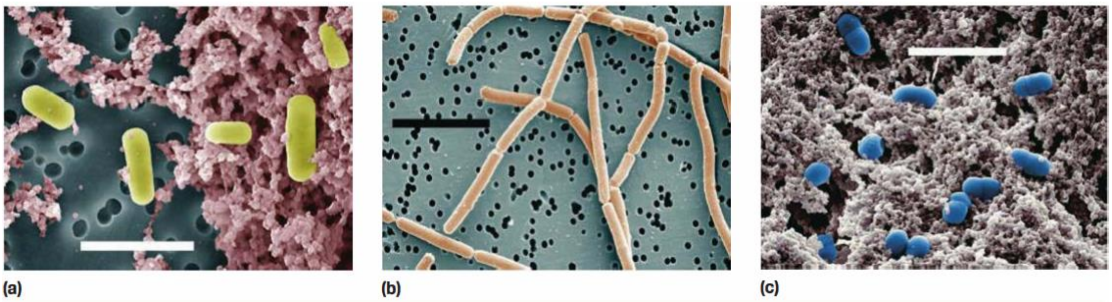

Figure 1. Lactic Acid Bacteria (LAB).

Mesophilic Fermentations

Mesophilic milk fermentation relies on protein denaturation by the acid produced through microbial activity. To carry out the process, milk is typically inoculated with the desired **starter culture**-a carefully selected group of microbes used to initiate the fermentation. It is then incubated at optimum temperature (approximately 20 to 30°C). Microbial growth is stopped by cooling, and *Lactobacillus* spp. and *Lactococcus lactis* cultures are used for aroma and acid production. *Lactococcus lactis* subspecies *diacetylactis* converts milk citrate to diacetyl, which gives a richer, buttery flavor to the finished product. The use of these microorganisms with skim milk produces cultured buttermilk, and when cream is used, sour cream is the result.

Thermophilic Fermentations

Thermophilic fermentations are carried out at temperatures around 45°C. An important example is yogurt production. In commercial production, nonfat or low-fat milk is pasteurized, cooled to 43°C or lower, and inoculated with a 1:1 ratio of *Streptococcus salivarius* subspecies

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thermophilus (*S. thermophilus*) that grows more rapidly at first and renders the milk anoxic and weakly acidic. *L. bulgaricus* then acidifies the milk even more. Acting together, the two species ferment almost all of the lactose to lactic acid and flavor the yogurt with diacetyl (*S. thermophilus*) and acetaldehyde (*L. bulgaricus*). Many yogurts now contain probiotic bacterial strains, but these do not necessarily contribute to the fermentation process.

Cheese Production

The milk protein casein curdles because of the action by lactic acid bacteria or the enzyme rennin.

Cheese is the curd separated from the liquid portion of milk, called **whey**. Hard cheeses are produced by lactic acid bacteria growing in the interior of the curd.

The growth of microbes in cheese is called ripening.

Semisoft cheeses are ripened by bacteria growing on the surface; soft cheeses are ripened by Penicillium growing on the surface.

Often cheeses are classified based on texture or hardness as soft cheeses, semisoft cheeses, hard cheeses, or very hard cheeses. All cheese results from a lactic acid fermentation of milk, which results in coagulation of milk proteins and formation of a curd. Rennin, an enzyme from calf stomachs but now produced by genetically engineered microorganisms, can also be used to promote curd formation. After the curd is formed, it is heated and pressed to remove the watery part of the milk (called the whey), salted, and then usually ripened. The cheese curd can be packaged for ripening with or without additional microorganisms. *Lactococcus lactis* is used as a starter culture for a number of cheeses. Starter culture density is often over 10^9 colony-forming units (CFU) per gram of cheese curd before ripening. However, the high salt, low pH, and the temperatures that characterize the cheese microenvironment quickly reduce these numbers. This enables other bacteria, sometimes called nonstarter lactic acid bacteria (NSLAB), to grow; their numbers can reach 10^7 to 10^9 CFU/g after several months of aging. Thus both starter and nonstarter LAB contribute to the final taste, texture, aroma, and appearance of the cheese.

In some cases, molds are used to further enhance the cheese. Obvious examples are Roquefort and blue cheese. For these cheeses, *Penicillium roqueforti* spores are added to the curds just before the final cheese processing.

Preparation of Wine and Liquors

Wine is traditionally considered any alcoholic beverage arising from the fermentation of grape juice, but practically any fruit can be rendered into wine. The essential starting point is the preparation of **must**, the juice given off by crushed fruit that is used as a substrate for fermentation. Major steps in making wine include **must** preparation (crushing), **fermentation**, **pasteurization**, **storage**, and **aging**. The right amount of sugar is essential for proper fermentation. The must should contain 12% to 25% glucose or fructose, so the art of wine making begins in the vineyard.

Other Fermented Plant Products

Fermentation provides an effective way of preserving vegetables, as well as enhancing flavor with lactic acid and salt. During pickling fermentations, vegetables are immersed in an anaerobic salty solution (brine) to extract sugar and nutrient-laden juices. The salt also disperses bacterial clumps, and its high osmotic pressure inhibits proteolytic bacteria and sporeformers that can spoil the product. Sauerkraut is the fermentation product of cabbage. Cabbage is washed, wilted, shredded, salted, and packed tightly into a fermentation vat. Weights cover the cabbage mass and squeeze out juices. The fermentation is achieved by natural cabbage microbiota or by an added culture. The initial agent of fermentation is *Leuconostoc mesenteroides*, which grows rapidly and produces lactic acid. It is followed by *Lactobacillus plantarum*, which continues to raise the acid content to as high as 2% (pH 3.5) by the end of fermentation. The high acid content restricts the growth of spoilage microbes.

Natural vinegar is produced when the ethyl alcohol in fermented plant juice is oxidized to acetic acid, which is responsible for the pungent odor and sour taste. Vinegar is actually produced in two stages.

The first stage is similar to wine or beer making, in which a plant juice is fermented to alcohol by Saccharomyces.

The second stage involves aerobic metabolism carried out by acetic acid bacteria in the genera *Acetobacter* and *Gluconobacter*. These bacteria oxidize the ethanol in a two-step process, as shown here:

$$2C_2H_5OH + \frac{1}{2} O_2 \rightarrow CH_3CHO + H_2O$$
Ethanol → Acetaldehyde

$$CH_3CHO + \frac{1}{2} O_2 \rightarrow CH_3COOH$$
Acetaldehyde → Acetic acid

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