

## Lesson Sheet 2 — Fermentation

Terminology. fermentation, ferment; *also zymurgy (zymology — applied science on fermentation):* brewing, winemaking, distilling\*, milk fermenting, and fermenting foods.

\* *Note. Most distillation processes, i.e., to produce alcoholic beverages, require that the medium—a liquid mixture, usually a mash (e.g., of wheat, corn, rice, etc.)—first go through one or more fermentation process(es). Distillation, by either evaporation or condensation, then separates out the alcohol from other substances that were produced during fermentation.*

Definition. **fermentation**: where microbes break down complex molecules into simpler ones — example: sugars broken down and converted to alcohol (ethanol) and carbon dioxide (CO<sub>2</sub>).

**Probiotic** — live microbes that are consumed by humans and animals to add or maintain/replenish bacteria and yeast in the body that help with digestion and other bodily functions.

**Prebiotic** — substances that promote microbial activity and growth in the human or animal body (prebiotics are usually non-digestible food substances, such as, plant fibers and indigestible carbohydrates).

**Metabolites** — substances used during metabolism and substances produced due to metabolic activities. The metabolites produced during fermentation by microorganisms can include enzymes, co-enzymes, bacteriocins, organic acids, amino acids, antioxidants, and natural antibiotics. Also, the metabolites, or the metabolites' functions, or consequences of the microbes' metabolic activities, can include the released nutrients, as well as, make nutrients more bioavailable (i.e., more soluble and therefore more absorbable and useful by other organisms; more easy uptake by plant roots). Nutrients may include vitamins, micronutrients, macronutrients, and trace minerals.

**Different kinds of fermentation** (the terms below may go by other names, see note below):

**Methane fermentation** (anaerobic digesters, bio-digesters) — where methanogens (methane (CH<sub>4</sub>) producing microbes, which are archaea) are the main actors in producing methane (a flammable, odorless gas [odor in utility/natural gas is added; odors from cows and humans/flatulence are from other substances, particularly hydrogen sulfide (H<sub>2</sub>S) which smells like rotten eggs]). In some anaerobic digesters, while food waste can produce methane, it may not be enough for commercial purposes. Therefore, slurry from wastewater treatment plants, which will have higher concentration of methanogens, are also added to the digesters.

**Lacto-fermentation** (lactic acid fermentation) — mainly using species of the *Lactobacillus* genus (lactic acid bacteria group) to produce fermented foods, such as, sauerkraut, yogurt, kimchi, etc.

**Yeast fermentation** (alcoholic fermentation\*\*, ethanol fermentation) — using species of the *Saccharomyces* genus, as well as *Brettanomyces* genus, to produce alcoholic beverages, such as, beer, wine, and mead, and to make bread (using the carbon dioxide). In bread making, if alcohol is produced, it's less than 1% which evaporates quickly after baking. Yeast are fungi and are about 1% of all known fungi; 1,500 yeasts species identified, but maybe about 30 yeast species used in fermenting foods and beverages. Yeast infection is due to a different species (*Candida* genus).

\*\* *alcoholic fermentation can also be done by certain bacteria other than yeast.*

**Lacto-yeast fermentation** — using both lactic acid bacteria and yeast to produce, for example, sour beers, sourdough, and kombucha.

**Lacto-yeast-phototrophic fermentation** (one way to make bokashi) — using lactic acid bacteria, yeast, and phototrophic bacteria which can then ferment a wider variety of organic matter for applications in farming, gardening, wastewater treatment, solid waste treatment (including food waste), and soil and water bioremediation. E.g., produces more types of enzymes affecting a wider range of materials.

*Note. Other terms and fermentation types: homofermentation (homolactic fermentation) and heterofermentation (heterolactic fermentation) — methods to produce lactic acid for preserving foods, flavoring, curing, etc.; propionic acid fermentation (Swiss cheese), acetone-butanol-ethanol (ABE) fermentation (to produce substances in its name, but also esters for fragrances); slow fermentation (from a few months to years), fast fermentation (in 1–3 days).*

**Fermentation of foods and beverages** — We've been fermenting foods and beverages since ancient times. Before refrigeration (early 20th century; and early 19th century, from 1830's, with cut ice transported and stored in icehouses), fermentation (besides preserving methods and curing/smoking meats) was an important way to have food available all year round, especially winter and early spring.

**Benefits** of fermented food and beverages — Fermented foods serve as probiotics and can also provide higher amounts of bioavailable nutrients. As with other things, it is not good to consume too much of the same thing. Having a wider variety of fermented foods and beverages would provide more microbial diversity and different nutrients. Fermentation can enhance flavors, texture, and aroma.

**Fermented foods** (short example list): pickles†, sauerkraut, yogurt (raw milk yogurt)§, kefir, cheeses, dark chocolate (the cacao bean first goes through a fermentation process before being used in making raw or roasted chocolates), vanilla extract (from the vanilla beans), kimchi, soy sauce, miso, green olives, breads, fermented meats (salami/fermented sausages), etc.

† *Some types of pickles may not be fermented or only partially fermented, and they may just have been immersed in vinegar or a brine (water with salt at 3.5% [similar to sea water] to as high as 26%), but this pickling solution will likely contain fermentative microorganisms (e.g., Lactobacillus) which may have even these pickles go through a low level fermentation.*

§ *Commercial yogurt is only fermented at the very end when microbes are added since the milk is pasteurized in the beginning, killing the original microbes.*

**Fermented beverages** (short example list): beer, wine, mead (alcoholic beverage from fermented honey), perry (alcoholic beverage from fermented pears), vinegar (apple cider vinegar, white vinegar, wine vinegar, etc.—by acetic acid bacteria), hard cider (alcoholic beverage by fermenting apple), kombucha (made with bacteria and yeast cultures, also called SCOBY: Symbiotic Culture Of Bacteria and Yeast; alcohol less than 1%, but may increase over time). Nearly all cultures throughout the world have fermented foods and beverages.

**Fermentation in farming**: silage; bokashi. **Silage** is fermented plant matter (grasses/cereals, corn) used as livestock feed (fodder), or as feedstock (biofuel) for anaerobic digesters.

**Bokashi** means fermented organic matter. Bokashi can be made using different fermentative microbes. Bokashi was originally used in farming to ferment organic waste, such as, post-harvest plant residue. It later became used in fermenting food waste as a pre-treatment before adding it to soil (as a soil amendment) or to be added to compost as a green and microbial inoculant.