Fermentations of Importance to Humans

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For millenia humans have taken advantage of the fermentations microbes perform. Over the years we have learned to control and optimize theses fermentations through trial and error. It was only in the last 100 years that the biochemistry behind fermentation has become clear.

In this section we take a little time off from the serious study of metabolism to look at the production of products we're all familiar with.

Several of the fermented products we consume depend upon yeast fermentation of glucose to ethanol as we just discussed in the section of fermentation.

Brewing Beer

Beer is a fermentation of barley and hops by yeast. The starch in barley is broken down into glucose and then fermented to ethanol by yeast. The finish product is aged and then packaged for distribution and consumption. It is an involved six stage process, beginning with the formation of malt from barley.

1. **Malt** - Barley is first soaked in water for 5 to 7 days. At this time the grain germinates and produces amylases (enzymes that degrade starch to glucose) and proteases (enzymes that break down proteins). These enzymes are essential to the brewing process. Amylase provides sugar for the yeast fermentation and the proteases solubilize compounds in the grain and hops important for the quality of the beer. The germinated malt is then dried and crushed.

2. **Mash** - Mashing solubilizes the starch and other flavors in the grain and extracts flavors and preservatives for the beer. The prepared malt is suspended in water mixed with boiled malt adjuncts (other grains, carbohydrates and sugars that provide a source of starch to be converted to sugar). This mash is then incubated at 65-70°C for a short time to allow the amylase to break down the starch to glucose. The temperature is raised to 75°C to inactivate the enzymes and then allowed to settle. Insoluble matter sinks to the bottom and serves as a filter as the liquid (now called wort) is taken from the container.
3. **Boiling with Hops** - Hops and wort are combined and boiled for 2.5 hours. The liquid is removed and ready for fermentation. Boiling with hops serves several purposes -

- Concentration
- Sterilization, killing many microbes that might spoil the beer
- Further inactivation of enzymes in the mash.
- Solubilization of important compounds in the hops and mash. Some of these add to the flavor of the beer while others, especially from the hops, have antiseptic qualities and help preserve the beer.

4. **Fermentation** - Fermentation begins by adding the brewers yeast *Saccharomyces carlsbergensis* to the wort. The starter culture is usually obtained from a previous batch of beer and is added at a very high concentration (500 grams per 120 liters). Fermentation is at a low temperature between 3.3 and 14°C for 8 to 14 days. At this time the glucose in wort is converted to ethanol and CO\textsubscript{2}. Other compounds in the wort are also fermented to add to the characteristic flavor of beer.

5. **Aging** - The fermented wort (green beer) is aged at 0 °C for a period of weeks or months depending on the brewer. At this time the yeast settle to the bottom of the vessel, bitter flavors are mellowed and other compounds are formed that enhance flavor.

6. **Finishing** - The beer is now prepped for packaging. This can involve filtering, pasteurization, carbonation to 0.45 to 0.52% CO\textsubscript{2}, and clarification. All of these processes depend upon the beer being made and each brewery will specialize the fermentation, aging and finishing of their beer. This is often the inspiration for various advertising done by the brewery.

The beer is then put in containers and distributed to customers. Beer normally has a shelf life of about 6 months and after that starts to take on undesirable flavors.

**Bread**

Bread is a simple fermentation of sugar to CO\textsubscript{2} and alcohol. The baker first combines flour, sugar, milk and other ingredients with a microorganism, usually a bread yeast such as *Saccharomyces cerevisiae*, but not always. The ingredients are mixed and then allowed to incubate at 27°C for a few hours. During this time the yeast convert the sugar present to ethanol and CO\textsubscript{2}. Most incubations are for less than 4 hours not leaving enough time for the yeast to increase in number. The CO\textsubscript{2} produced causes the bread to rise (leaven) and become porous. The success of leavening is dependent upon the rate of gas production. This can be increased by adding more yeast, more sugar, or dough.
conditioners (various salts that the yeast need). Tweaking a recipe by manipulating these factors can speed CO₂ production, within reasonable limits. Adding too much of anything can either kill the yeast or cause the bread to rise too quickly. The temperature of incubation is another critical consideration. *Saccharomyces* grows best at 26 to 28°C and deviations from that temperature will usually result in slow or complete lack of leavening. Failure as a baker can normally be attributed to either not adding the exact amounts of ingredients or inappropriate incubation temperatures during leavening.

**Yogurt**

Yogurt is a product of fermented milk. Lactic acid bacteria are the major microbes in many milk based fermented products. These bacteria are finicky having many growth requirements all of which can fortunately be satisfied by a milk mixture. Lactose in milk is fermented to lactic acid either via the homofermentative or heterofermentative pathway.

Production of yogurt starts by conditioning the milk. The water content of milk is first lowered 25% by vacuum evaporation and 5% milk solids are added. As a final conditioning step, the milk is heated to 86 to 93°C for 30-60 minutes. This causes some breakdown of proteins and other molecules and kills contaminating microbes that may compete with the starter culture. After cooling to 45°C a 1:1 mixture of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* is added. Fermentation is at 45°C until the desired degree of acidity is reached. This usually occurs in 3-5 hours. The finished product may have other ingredients added (such as mold inhibitors or dye) and is packages with fruit. Yogurt is stored at 0-4°C until consumed to prevent spoilage.

There is some evidence that consumption of products containing active cultures of lactic acid bacteria can be beneficial. However, the health claims by proponents of this idea have yet to withstand serious scientific scrutiny. It is reasonable to assume that ingesting lactic acid bacteria may help deter other more severe pathogens such as *E. coli* or *Salmonella typhimurium*.

**Cheese**

Cheese is also a milk fermentation, but its production is more complex. Different bacteria come into play and production periods are much longer than yogurt. Despite there being 20 classes and hundreds of varieties of cheeses the initial manufacturing process is surprisingly similar.

1. **Curd Formation** - Milk is first pasteurized and then fermented by a starter culture. This is usually a lactic acid bacteria with the specific species in use dependent upon the cheese being produced.

   Rennet (a protease) is added to the fermentation and along with the lactic acid made by the added starter, causes the milk to form curds.

2. **Curd Concentration** - depending upon the cheese being made, the curds may
be concentrated in some manner. The goal here is to remove the appropriate
amount of whey (liquid left from curd formation). For fresh cheeses (cottage or
mozzarella) no concentration takes place. For soft cheeses the curds are cut into
large cubes and then ripened with a fungus or mold. Hard and semi-hard cheeses
are cooked and then cut into small pieces to release more whey.

3. **Ripening** - prepared curd is then pressed into molds, salted and ripened for
weeks to years. This process if different for each cheese.

The finished product is sold either as a complete mold (a wheel of cheese) or cut into
smaller pieces. Most cheeses are stored at refrigerator temperatures.

**Other Products**

We have only touched on a few foods that are made with the help of microbes, there are
many more. To give you an idea of the array of products, here is a list of fermented
foods and the microbes that are involved in their formation.

<table>
<thead>
<tr>
<th>Foods and Products</th>
<th>Raw Ingredients</th>
<th>Fermenting Organisms</th>
<th>Country Commonly Produced in</th>
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<tr>
<td><strong>Dairy Products</strong></td>
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<td></td>
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<tr>
<td>Kefir</td>
<td>Milk</td>
<td><em>Streptococcus lactis</em>, <em>Lactobacillus bulgaricus</em>, <em>Torula</em> sp.</td>
<td>Southwestern Asia</td>
</tr>
<tr>
<td>Taette</td>
<td>Milk</td>
<td><em>S. lactis</em> var. <em>taette</em></td>
<td>Scandinavian peninsula</td>
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<tr>
<td>Tarhana</td>
<td>Wheat meal and yogurt</td>
<td>Lactics</td>
<td>Turkey</td>
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<td><strong>Meat and fish products</strong></td>
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<tr>
<td>Country-cured ham</td>
<td>Pork hams</td>
<td><em>Aspergillus</em>, <em>Penicillium</em> spp./</td>
<td>Southern U. S.</td>
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<tr>
<td>Lebanon bologna</td>
<td>Beef</td>
<td><em>Pediococcus cerevisiae</em></td>
<td>Europe, U.S.</td>
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<td>Fish sauces</td>
<td>Small fish</td>
<td>halophilic <em>Bacillus</em> spp.</td>
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<tr>
<td>Katsuobushi</td>
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<td>Japan</td>
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<td><strong>Nonbeverage plant products</strong></td>
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<tr>
<td>Cocoa</td>
<td>Cacao fruits</td>
<td><em>Candida krusei</em>, <em>Geotrichum</em></td>
<td>Africa, South America</td>
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<tr>
<td>beans</td>
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<td>spp.</td>
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</tr>
</tbody>
</table>
Coffee beans  Coffee cherries  *Erwinia dissolvens,*  
*Saccharomyces* spp.  Brazil, Congo,  
Hawaii, India

Kimchi  Cabbage and other vegetables  Lactic acid bacteria  Korea

Olives  Green Olives  *Leuconostoc mesenteroides,*  
*Lactobacillus plantarum*  Worldwide

Pickles  Cucumbers  *Pediococcus cerevisiae,*  
*Lactobacillus plantarum*  Worldwide

**Beverages**

Bourbon whisky  Corn, rye  *Saccharomyces cerevisiae*  U. S.

Cider  Apples, other  *Saccharomyces* spp.  Worldwide

Mezcal  Century plant  Yeasts  Mexico

Sake  Rice  *Saccharomyces saki*  Japan

Vinegar  Cider, wine  *Acetobacter* spp.  Worldwide

Wine  Grapes, other fruits  *Saccharomyces ellipsoideus* strains  Worldwide

Fermentation of organic substrates is one way to make a living, but it is a poor choice. Energy yields are low and microbes have to ferment large amounts of substrate to get enough energy for cellular processes. Anaerobes were probably the first microbes to evolve billions of years ago, but once oxygen became prevalent in the atmosphere, a better method of catabolism evolved, respiration.
Fermented Foods are Our Friends

The right nutrition can help your body not only heal itself, but possibly even reverse chronic disease. One or two servings a day of fermented foods will get you started down a healthier path.

But what is fermentation?

Technically speaking, fermentation is the addition—deliberately or by chance—of lactobacillus bacteria, such as Lactobacillus bulgaricus or Lactobacillus acidophilus, to milk or other foods to convert the carbohydrates to an organic acid.

It’s how we get yogurt—the bacteria convert lactose into lactic acid, which curdles the casein to make yogurt. It’s also how we get beer and wine. Sugars are fermented into alcohol with the help of yeast rather than bacteria, so they are a different kind of fermented food.

Fermentation has a long history. It was used in pre-modern times primarily to preserve food. Yet over the years, science has learned that the process of fermentation yields powerful health benefits. Fermented foods...

- improve gut health
- enhance digestibility
- enhance nutrient content.

You can easily get the benefits of fermentation in your diet by enjoying delicious foods like yogurt, kefir, marinated vegetables and miso.

The people who live in the Longevity Hot Spots like to eat certain foods which are teeming with friendly bacteria. Put another way, they are expert zymologists, meaning they know all about the science of fermentation.

Whether it’s an aged lump of pungent cheese, a piquant caper in a jar, a square of melt-in-the-mouth tofu, or a marinated olive, they know how to make it, they love eating it, and it brings them good health.

Then and Now

People began fermenting foods and drinks long ago to keep them from rotting. If you dip a stick in the ground or run your finger along some tree bark in Bulgaria, it will emerge covered in the beneficial fermentative bacteria Lactobacillus bulgaricus. Add those bacteria to milk, and the milk ferments.
The Thracians of ancient Bulgaria found they could preserve their milk this way by putting it in lambskin bags and carrying the bag around their waists to keep it warm. In fact, it’s thought that the word yogurt comes from the Thracian yog (“thick”) and urt (“milk”).

The Bulgarians weren’t the first, of course. There’s evidence the ancient Babylonians drank fermented milk circa 3000 BC, and its use probably dates long before that. Miso, sauerkraut, yogurt, and many other fermented foods are ancient culinary traditions all around the world.

And they are still popular in areas where modern cooking methods have not yet taken over — places like the Longevity Hot Spots.

Great for the Gut

Fermenting foods gives them a stronger flavor and enriches their nutrient content. Plus, fermentation begins the breakdown of proteins, carbohydrates, and fats, making the foods easier to digest.

For instance, when milk is turned into yogurt or cheese, much of the lactose is broken down. That’s why lactose-intolerant people can usually eat yogurt.

When you eat fermented foods, you introduce friendly bacteria, or probiotics (“for life”), into your digestive system. What they do in food, they also do in the gut — they repel pathogenic bacteria and help break down nutrients so you can absorb them more easily.

Friendly bacteria are fundamental to good health in so many ways. They...

- Protect the integrity of the intestinal lining.
- Maintain immunity, since around half of the body’s immune cells are in the intestines.
- Manufacture B vitamins (useful for vegans).
- Manufacture essential fatty acids.
- Extract calcium from dairy products.
- Aid absorption of vitamins and minerals.
- Produce enzymes to break down foods.
- Produce butyric acid, required for building colon cells.
- Produce anti-tumour substances.
- Produce antiviral substances.
- Produce anti-fungal substances.
- Prevent candida overgrowth.
- Destroy e coli, shigella, and salmonella by making the intestinal tract more acidic and by releasing substances such as lactic acid, hydrogen peroxide, and selective antibiotics.
- Neutralize endotoxins produced in the body.
- Neutralize potentially carcinogenic nitrates in the digestive tract.
- Aid peristalsis (the movement of the gut muscles for stool elimination) to prevent constipation.
- Get rid of excess cholesterol by breaking down bile.
- Regulate cytokines so as to reduce inflammation.
- Produce anti-cancer isothiocyanates, such as sulforaphane and indol-3-carbinol from foods. (These beneficial compounds are also found in fermented foods.)

Get more flora

The modern diet lacks beneficial bacteria — and is high in factors which prevent it from colonizing in our guts as it should. Dysbiosis, a bacterial imbalance, is common in Western society thanks to diets high in sugar and meat, but low in probiotics.
Dysbiosis encourages yeasts and putrefactive bacteria to flourish, instead of fermentative beneficial bacteria. In turn, toxins build up and damage the sensitive microvilli brush border that lines our intestinal wall. When it’s healthy, that area helps assimilate nutrients and prevent toxins from passing through the gut wall into the bloodstream.

The modern diet also causes inflammation of the gut and excessive intestinal permeability (leaky gut syndrome), leading to conditions such as Crohn’s disease, ulcerative colitis, and irritable bowel syndrome. Allergies, systemic candida, eczema, autoimmune disease, arthritis, and even mental illness have all been linked to dysbiosis. If your stool smells unpleasant, it is a good sign of too much putrefaction and an imbalance of gut flora.

So how can you get more of the good stuff?

Making sure you get enough probiotics from fermented foods or probiotic supplements can protect you from these illnesses and help you attain optimum health. Another tip: By eating plant foods rich in plant fibers, you also provide fructo-oligosaccharides (FOS), the food beneficial bacteria feed off, thus helping them thrive in your system. Avocados, bananas, and Jerusalem artichokes are high in FOS.

When researchers analyzed the stool of people aged 80-109 years old in Bama, a Longevity Hot Spot in China, they found that it contained from 53 to 87 percent bifidobacterium—significantly more than elderly Chinese from other districts. This finding was attributed to their diets rich in FOS and their intake of fermented foods. It’s likely the findings would be the same for people in the other longevity communities, given their intake of FOS and probiotics.

Here’s how to increase your levels of friendly flora:

- Eat more fermented foods, including live yogurt. See the list below.
- Take probiotics.
- Avoid excessive sugar and animal fats.
- Avoid stress, which can kill friendly flora.

To add probiotics to your diet, choose from among these fermented foods:

**Yogurt**

Yogurt is milk which has been fermented by live cultures so as to enhance its nutritional value and digestibility. The best yogurt is low fat with a creamy, slightly sweet texture which has been fermented with one part *L. bulgaricus* to seven parts *S. thermophilus*, these being the best yogurt cultures. Yogurt which has been pasteurized after the addition of probiotics will not contain live cultures and will not provide the same benefits. Pasteurizing live yogurt is forbidden in some states including New York.

To test whether or not the ‘live’ yogurt you buy is really live, mix a tablespoonful with a cupful of milk which has been heated but not boiled. Leave overnight in a warm place. If the mixture has thickened by morning, you have live cultures present.

**Kefir**

*Kefir* is a fermented milk product originating in the Caucasus. The word kefir (which rhymes with ‘see-her’) means ‘pleasure’. Kefir is tangy like yogurt, and contains a mix of cultures such as Saccaromyces kefir, Torula kefir, Lactobacillus brevis and Streptococcus lactis, amongst others. True kefir has a slightly alcoholic content due to the presence of yeast, which gives it its unique flavor (and presumably its name).

**Aged cheese**

Symiots, Hunzakuts, Sardinians, and Campodimelani all eat traditionally fermented cheese made from sheep’s, goat’s, or cow’s milk. Hunzakuts also enjoy maltash, a fermented butter which is wrapped in birch bark and buried underground for years or even decades and
If you want to eat cheese, choose high-quality matured cheeses which have been made in a traditional way, rather than processed cheese.

Crème fraîche

Crème fraîche is cream which has been soured with bacterial culture. It is thick with a slightly tangy taste and is popular for making sauces in French cuisine.

Traditionally fermented soy products

miso, tempeh, traditionally brewed soy sauce

Fermenting soy products raises their levels of isoflavones, the beneficial plant estrogens thought to protect against breast cancer and osteoporosis. It also makes them much more digestible than modern processed soy products, which are an invention of the West and are not eaten by long-lived Japanese or Chinese populations such as the Okinawans or people of Bama.

Sauerkraut

This pickled cabbage dish is popular in Eastern Europe. Its origins trace as far back as the 13th century, when Genghis Khan fed fermented vegetables to his plundering hordes. Captain Cook also used sauerkraut to prevent scurvy in sailors.

Traditionally fermented pickled vegetables

capers, olives, pickles

Capers are traditionally preserved by the Symiots and used as a relish and for stomach ailments. Modern pickled foods such as capers and olives are mass-produced and do not contain beneficial bacteria. However, traditionally marinated and fermented vegetables such as olives, artichokes, peppers and mushrooms can be obtained in specialist delicatessens.

Sprouted foods

Soaking a bean, grain, or seed in water causes the outer hull to be broken down by probiotics—fermented—which enables the sprouting process. Foods treated in this way have higher, more easily absorbed nutrient contents. Sprouting also reduces the content of antinutrients, such as phytic acid, which inhibits the absorption of minerals such as iron and zinc from these grains.

Sprouted wheat or rye bread can be obtained from good health food shops. Some delicatessens make sourdough rye bread from dough which has been fermented with lactic acid. These breads are much more digestible than ordinary bread.

You can make porridge by buying organic whole oats and soaking them overnight, then adding yogurt after cooking for a creamy texture. This will make a filling breakfast which is far more digestible than packaged cereals which are processed in a modern way and contain anti-nutrients such as phytates.

Umeboshi plums

These are small, reddish-purple, wrinkled, salty and very tangy pickled plums which are sometimes eaten in Japan after a meal as they are thought to aid digestion. Good umeboshi plums are left for six months to ferment in a mixture of salt and shiso leaves. They are sometimes referred to as 'The King of Alkaline Foods.' Japanese scientists studying umeboshi plums have found them to contain probiotics with powerful antibiotic properties and they are also thought to be beneficial for hangovers and bad breath. They are very potent (and salty) and two or three a week is enough!
Thai fish sauce

Known as Nam Pla in Thailand, it is a fish sauce made from fish (often anchovies, but sometimes whatever comes up in the net) which have been allowed to ferment and is popular in Asia as a dipping sauce and for use in cooking. Nam Pla which has been allowed to ferment for a long period has a slightly nutty, cheesy flavor whereas sauce which has fermented for only a short time tastes more fishy.

Tofuyo (fermented tofu)

Also called “the cheese of the east,” it’s an Okinawan delicacy made from tofu which has been fermented for three to four months in awamori (rice wine) and malted rice. It is prized for its medicinal properties, mellow flavor, and succulent texture. Okinawans will eat a single cube while sipping awamori and watching songs or dances; they describe this as Nuchi-gusui—“the medicine of life.”

When tofuyo was given to hypertensive rats, it was found to significantly lower blood pressure and cholesterol due to its angiotensin I-converting enzyme (ACE) inhibitory activity (1).

Contraindications

1. If you have candida, you may want to use caution. Fermented foods contain yeasts and molds that are unlikely to cause candida—but your body might be sensitive to them.
2. Fermented foods such as capers, olives, and umeboshi plums can be very high in salt. If you are on a low-salt diet, keep these to a minimum.
3. Cheese and wine are high in histamines. Avoid or limit them if you are intolerant.

Download a printable list of fermented foods here.

Fermented Foods References