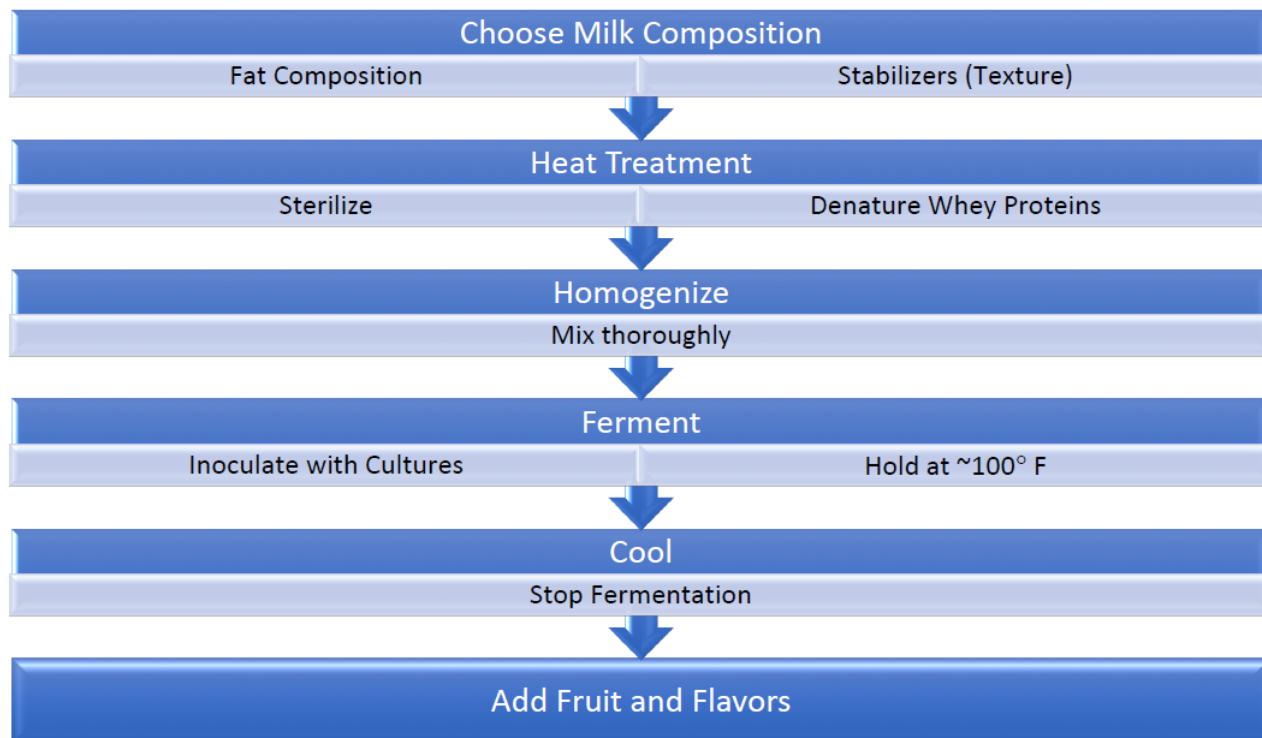


1.11: Yogurt

Yogurt Production

Yogurt has been around for several millennia. The mythological story about the discovery of yogurt suggests that shepherders stored their milk in bags made of the intestinal gut of the animals. The intestines contain natural enzymes that cause the milk to curdle and sour. This soured milk lasted longer so they continued making it. Today, the FDA defines yogurt as a milk product fermented by two bacterial strains: a lactic acid producing bacteria: *Lactobacillus bulgaricus* and *Streptococcus thermophiles*.

Yogurt Production Process:



? Exercise 1.11.1

- What is the purpose of the heat treatment in step 2? Think about the whey proteins.
- How does this process differ from cheese production? How does that affect the texture?

Biochemistry of Yogurt Fermentation

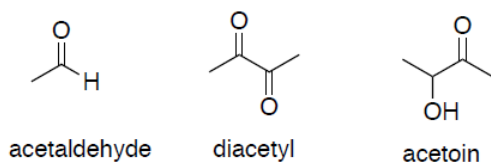
In step 4, yogurt cultures are added to milk. These bacteria are lactic acid fermenters; they use enzymes to produce energy (ATP) from lactose.

? Exercise 1.11.2

- Draw the structure of lactic acid.
- From the previous discussion of lactic acid fermentation, draw a quick pathway showing the production of lactic acid.
- What is the biochemical purpose of producing this lactic acid?
- Bacteria creating lactic acid as a side product which results in a _____ [**acidic** / **basic**] environment.
- When the pH drops, what changes occur to the casein micelles?

Biochemistry of Yogurt Flavors

Yogurt is often tart. This flavor is often attributed to the presence of lactic acid. However, there are also a number of carbonyl compounds like acetoin, diacetyl and acetaldehyde that also contribute to the tangy yogurt flavor.



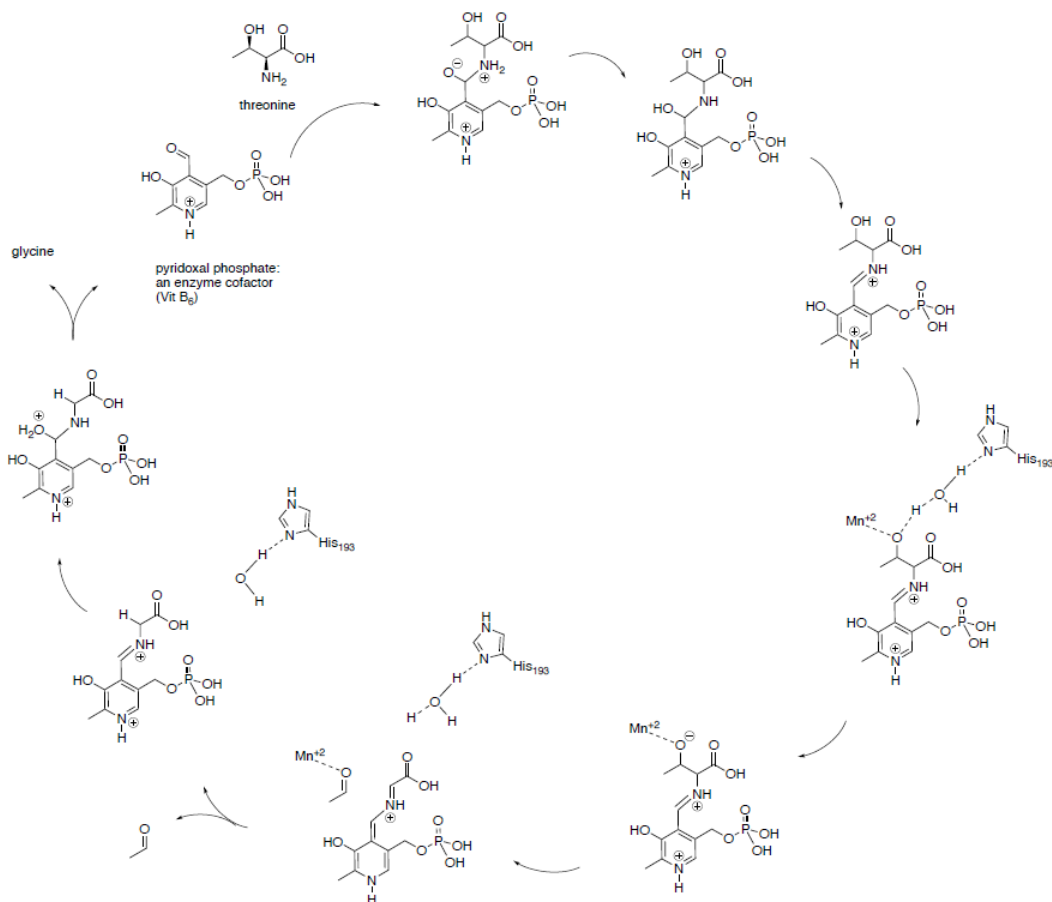
Acetaldehyde Production

During yogurt fermentation, acetaldehyde could be produced from lactose metabolism as a result of pyruvate decarboxylation. However, the primary source of acetaldehyde in these bacteria is from the conversion of threonine (amino acid) into acetaldehyde and glycine.



? Exercise 1.11.3

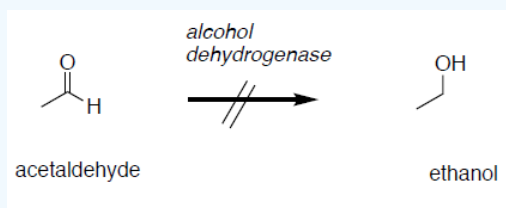
- Add arrows for the mechanism of acetaldehyde production shown below.



? Exercise 1.11.4

- Goat's milk is richer in glycine than cow's milk. In turn, the level of acetaldehyde is much lower in goat milk yogurt. Explain.

Many yogurt bacteria lack the enzyme, alcohol dehydrogenase.



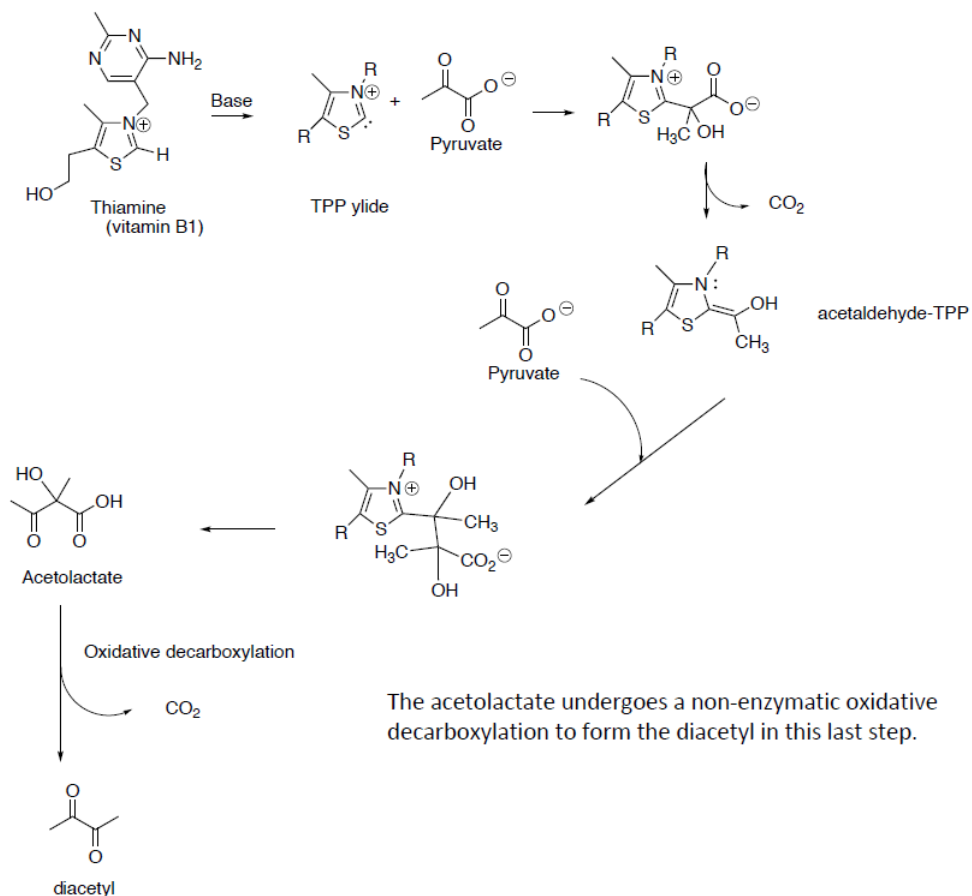
- How does the lack of the dehydrogenase enzyme impact the concentration of acetaldehyde?

Diacetyl and Acetoin Production

Both *Streptococcus thermophilus* and *Lactobacillus bulgaricus* produce diacetyl which provides a distinctive “buttery” flavor to yogurt (and other fermented milk products). Acetoin is the reduced form of diacetyl and it complements the diacetyl with a mild creamy flavor.

? Exercise 1.11.5

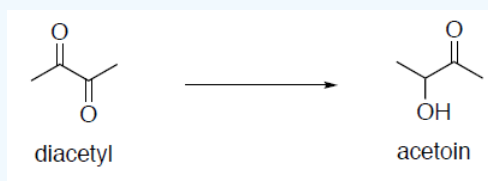
- Add arrows for the mechanism for the formation of acetolactate.



Diacetyl can be converted to acetoin.

? Exercise 1.11.6

Propose a mechanism.



Probiotics

Yogurt cultures in the intestinal tract have been shown to release the enzyme lactase which continues to break down lactose in the dairy product. This makes yogurt edible for people who are lactose-intolerant.

? Exercise 1.11.7

To give their products a longer shelf life, manufacturers often **heat-treat yogurt after** fermentation. This kills the live cultures. What will happen to lactase if the yogurt has been heat-treated after fermentation?

Lactobacillus bulgaricus and *Streptococcus thermophilus* are the two main bacteria used for creating yogurt. However, these strains do not survive the gastrointestinal tract. They are destroyed by the acidity of the stomach and the enzymes of the pancreas. It has become common to add 'probiotic' bacterial strains to yogurt such as *Lactobacillus acidophilus*, *Lactobacillus casei*, or *Bifidobacterium spp.* There is evidence that these bacteria will make it to the intestine intact.

✓ Example 1.11.8

- Read more about probiotics in foods: Scourboutakos, et. al. , *Nutrients*, **2017**, 9(4), 400; <https://doi.org/10.3390/nu9040400> and Bisanz & Reid, *Science: Translational Medicine*, **2011**, 3(106), 1-4 (in Canvas)
 - Describe their experiments and finding.
 - How are probiotics beneficial?
 - What are their concerns about the claims in probiotic foods on the market?

When probiotics are added to foods, the food industry often also adds ingredients known as prebiotics, such as inulin, which will, after digestion, aid in the growth of the probiotics in the colon.

? Exercise 1.11.9

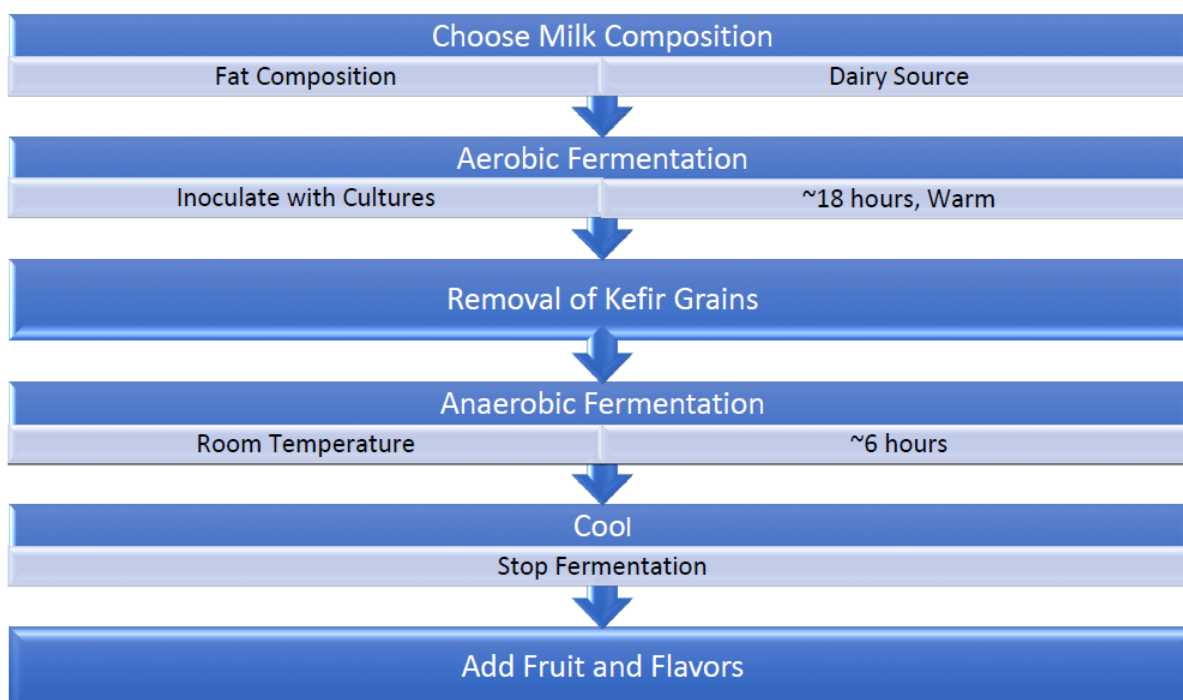
- Draw the structure of inulin.
- Can humans metabolize inulin?
- Why is it added to the yogurt?

Other Fermented Milk Beverages

Kefir

Kefir is a carbonated fermented milk drink. The microbes involved in the production of kefir are a symbiotic culture of lactic acid bacteria and yeasts embedded in a matrix of proteins, lipids, and polysaccharides, 'kefir grains'.

Kefir Production Process:



During the first fermentation, lactic acid bacteria are responsible for the conversion of the lactose present in milk into lactic acid, which results in a pH decrease and milk preservation.

? Exercise 1.11.10

- This step is similar to cheese and yogurt production. What is occurring to casein proteins?

Biochemistry of the Flavors of Kefir

Similar to yogurt, the flavor of kefir is often attributed to diacetyl and acetoin (both of which contribute a "buttery" flavor), acetaldehyde, and related carbonyl products.

? Exercise 1.11.11

- Draw the structure of diacetyl and acetoin.

Non-lactose fermenting yeast and acetic acid bacteria (AAB) also participate in the process. Propionibacteria further break down some of the lactic acid into propionic acid (these bacteria also carry out the same fermentation in Swiss cheese).

? Exercise 1.11.12

- Draw the structure of acetic acid and propionic acid. Review the pathways for these products.

Second Fermentation

Other kefir microbial constituents include lactose-fermenting yeasts such as *Kluyveromyces marxianus*, *Kluyveromyces lactis*, and *Saccharomyces fragilis*, as well as strains of yeast that do not metabolize lactose, including *Saccharomyces cerevisiae*, *Torulaspora delbrueckii*, and *Kazachstania unispora*.

The lactose-fermenting yeast break the lactose down into ethanol and carbon dioxide resulting in a carbonated taste. Ethanol concentration is typically low, usually 0.2-0.3%.

? Exercise 1.11.13

Review:

- Recap the pathway that leads to ethanol and carbon dioxide production.
- Why is this step anaerobic?

Summarize:

- Describe the biochemical difference between kefir and yogurt. Include structures and products

Sources

Zourari, Accolas, & Desmazeaud, Metabolism and Biochemical Characteristics of Yogurt Bacteria, A Review. *Le Lait, INRA Editions*, **1992**, 72 (1), pp.1-34. (Available in Canvas)

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