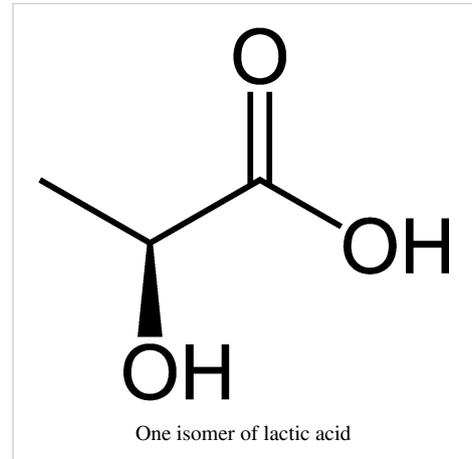


Lactic acid fermentation

This is presented to you by **TATSA WAMBEA LANDRY** www.futurelabtechnologist.weebly.com ^[1] Lactic acid fermentation is a biological process by which sugars such as glucose, fructose, and sucrose, are converted into cellular energy and the metabolic byproduct lactate. It is an anaerobic fermentation reaction that occurs in some bacteria and animal cells, such as muscle cells.^{[2][3][4]} If oxygen is present in the cell, many organisms will bypass fermentation and undergo cellular respiration; however, facultative anaerobic organisms will both ferment and undergo respiration in the presence of oxygen.^[4] Lactate dehydrogenase catalyzes the interconversion of pyruvate and lactate with concomitant interconversion of NADH and NAD⁺.



In *homolactic fermentation*, one molecule of glucose is ultimately converted to two molecules of lactic acid. *Heterolactic fermentation*, in contrast, yields carbon dioxide and ethanol in addition to lactic acid, in a process called the phosphoketolase pathway.^[2]

Chemical process

The process of lactic acid fermentation using glucose is summarized below. In homolactic fermentation, one molecule of glucose is converted to two molecules of lactic acid:^[4]



In heterolactic fermentation, the reaction proceeds as follows, with one molecule of glucose converted to one molecule of lactic acid, one molecule of ethanol, and one molecule of carbon dioxide:



Before lactic acid fermentation can occur, the molecule of glucose must be split into two molecules of pyruvate. This process is called glycolysis.^[4]

Glycolysis

To extract chemical energy from glucose, the glucose molecule must be split up into two molecules of pyruvate. This process also generates two molecules of adenosine triphosphate as an immediate energy yield and two molecules of NADH.^{[3][4]}



In aerobic respiration, the pyruvate is further oxidized completely, generating additional ATP and NADH in the citric acid cycle and by oxidative phosphorylation. However, this can occur only in the presence of oxygen. Oxygen is toxic to organisms that are obligate anaerobes, and is not required by facultative anaerobic organisms. In the absence of oxygen, one of the fermentation pathways occurs in order to regenerate NAD⁺; lactic acid fermentation is one of these pathways.^[4]

Fermentation

Lactic acid fermentation is the simplest type of fermentation.^[3] In essence, it is a redox reaction. In anaerobic conditions, the cell's primary mechanism of ATP production is glycolysis. Glycolysis reduces – that is, transfers electrons to – NAD^+ , forming NADH. However, there is only a limited supply of NAD^+ available in a cell. For glycolysis to continue, NADH must be oxidized – that is, have electrons taken away – to regenerate the NAD^+ . This is usually done through an electron transport chain in a process called oxidative phosphorylation; however, this mechanism is not available without oxygen.^{[3][4]}

Instead, the NADH donates its extra electrons to the pyruvate molecules formed during glycolysis. Since the NADH has lost electrons, NAD^+ regenerates and is again available for glycolysis. Lactic acid, for which this process is named, is formed by the reduction of pyruvate.^[4]

In homolactic acid fermentation, both molecules of pyruvate are converted to lactate. In heterolactic acid fermentation, one molecule of pyruvate is converted to lactate; the other is converted to ethanol and carbon dioxide. Homolactic acid fermentation is unique in that it is one of the only respiration processes that do not produce a gas as a byproduct.^[4]

Purpose

Some bacteria and yeasts organisms are unable to cope with the presence of oxygen. These organisms use fermentation as a method of obtaining energy in the form of ATP. Because the production of lactic acid frees up NAD^+ , the process of glycolysis can continue.^[4]

Lactic acid fermentation also occurs in animal muscle cells under conditions when oxygen is low. Extreme exercise would be an example of this. In this situation, the lactate is carried away by the circulatory system to the liver, where it is converted back to pyruvate through the Cori cycle.^[3]

Fermentation, however, is far less effective than cellular respiration, producing only two ATP molecules per glucose molecule consumed. The typical yield from cellular respiration is anywhere from 34-38 molecules of ATP. Thus, it is typically seen only in small organisms, such as bacteria and yeast, that can survive on this low energy yield.^[4]

Applications

Lactic acid fermentation is used in many areas of the world to produce foods that cannot be produced through other methods.^{[5][6]} The most commercially important genus of lactic acid-fermenting bacteria is *Lactobacillus*, though other bacteria and even yeast are sometimes used.^[5] Two of the most common applications of lactic acid fermentation are in the production of yogurt and sauerkraut.

Yogurt production

The main method of producing yogurt is through the lactic acid fermentation of milk with harmless bacteria.^{[5][7]} The primary bacteria used are typically *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, and US law requires all yogurts to contain these two cultures (though others may be added as probiotic cultures).^[7] These bacteria produce lactic acid in the milk culture, decreasing its pH and causing it to congeal. The bacteria also produce compounds that give yogurt its distinctive flavor. An additional effect of the lowered pH is the incompatibility of the acidic environment with many other types of harmful bacteria.^{[5][7]}

For a probiotic yogurt, additional types of bacteria such as *Lactobacillus acidophilus* are also added to the culture.^[7]

Sauerkraut

Lactic acid fermentation is also used in the production of sauerkraut. The main type of bacteria used in the production of sauerkraut is of the genus *Leuconostoc*.^{[8][2]}

As in yogurt, when the acidity rises due to lactic acid-fermenting organisms, many other pathogenic microorganisms are killed. The bacteria produce lactic acid, as well as simple alcohols and other hydrocarbons. These may then combine to form esters, contributing to the unique flavor of sauerkraut.^[2]

Kimchi

Kimchi also uses lactic acid fermentation.^[9]

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