Programme: Bachelor of Science (First Year)

Subject: Microbiology

Course Code: MIC 102

Course Title: Microbiology and Biochemistry II

Unit 5 - Chemoheterotrophic metabolism - anaerobic respiration and fermentation

Module Name: Lactate fermentation (homofermentative & heterofermentative pathways), Concept of linear and branched fermentative pathways

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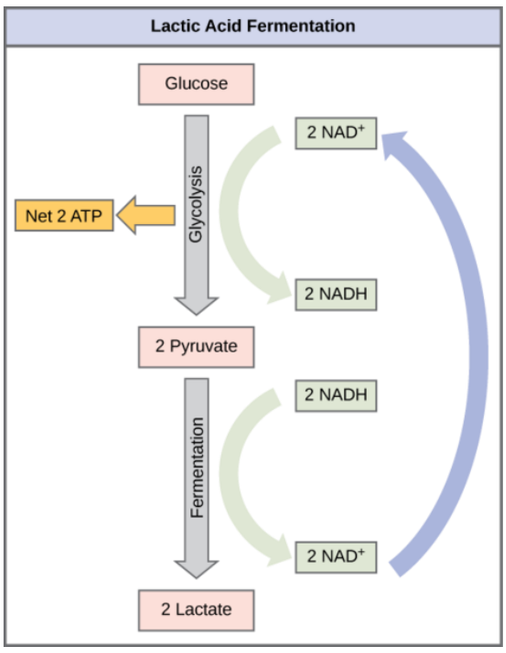
Lactate Fermentation

Fermentation is an anaerobic microbial metabolic process. Fermentation can be carried out by microbial cells such as yeast and bacteria to produce alcoholic beverages and by lactic acid bacteria to produce non-alcoholic foods and beverages.

Lactic acid bacteria, under anaerobic conditions, convert pyruvic acid to lactic acid. This is called lactic acid fermentation. The enzyme involved in this reaction is lactate dehydrogenase (LDH). NADH transfers its electrons directly to pyruvate, generating lactate. This process regenerates NAD^+ from NADH, since there is a limited supply of NAD^+, thus allowing glycolysis to continue to make ATP under low-oxygen conditions. Lactic acid is formed by the reduction of pyruvate.

$C_3H_3O_3$ (pyruvate) +NADH→ $C_3H_6O_3$ (lactic acid) +NAD^+



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Lactic Acid Bacteria (LAB) as a group exhibits an enormous capacity to metabolise different carbohydrates and related compounds. Generally, the predominant end product is lactic acid. However, LAB adapts to various conditions and changes their metabolism accordingly; this may lead to significantly different end-products.

Based on sugar fermentation patterns, two broad metabolic categories of LAB exist: homofermentative and heterofermentative pathways.

Homolactic Fermentation or homofermentative pathway

Homofermentative bacteria ferment glucose to yields lactic acid as the primary end metabolite.

$$\text{Glucose} + 2\ \text{ADP} + 2\ P_i \rightarrow 2\ \text{lactate} + 2\ \text{ATP}$$

Under conditions of high glucose and limited oxygen, homolactic LAB catabolize one mole of glucose in the Embden-Meyerhof pathway to yield two moles of pyruvate which is further reduced to lactic acid. This process yields two moles of ATP per glucose consumed. Representative homolactic LAB genera include *Lactobacillus, Lactococcus, Enterococcus, Streptococcus* and *Pediococcus* species.

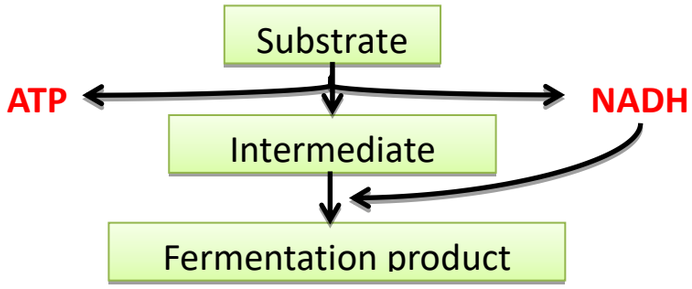
Heterolactic Fermentationor heterofermentative pathway

Heterofermentative bacteria consume glucose and the end products are lactic acid, ethanol, and carbon dioxide. Heterofermentative LAB utilizes the phosphoketolase pathway (heterolactic pathway) to dissimilate sugars. In this pathway, one mole of glucose-6-phosphate is dehydrogenated to 6-phosphogluconate and which is subsequently decarboxylated to yield one mole of xylulose-5-phopshate and CO_2. The resulting xylulose-5-phosphate is cleaved into one mole glyceraldehyde phosphate (GAP) and one mole acetyl phosphate. GAP is further metabolized to lactate, while the acetyl phosphate is reduced to ethanol via acetyl-CoA and acetaldehyde intermediates. This pathway yields one molecule of ATP per glucose consumed. Heterofermentative LAB includes species of *Leuconostoc, Oenococcus, Weissella*, and certain lactobacilli.

$$\text{Glucose} + \text{ADP} + P_i \rightarrow \text{lactate} + \text{ethanol} + CO_2 + \text{ATP}$$

CONCEPT OF LINEAR AND BRANCHED FERMENTATIVE PATHWAYS

Metabolic pathways can be cyclic, linear and branched. Fermentation processes with a constant ratio of ATP are referred to as linear pathways. Glycolysis is characterized as a linear metabolic pathway. Ethanol fermentation is another example of a linear fermentative pathway.



A biochemical pathway in which an intermediate substance serves as a precursor for more than one final product is known as a branched fermentation pathway. Branched fermentation pathways give different end product. It gives more oxidized products and more ATP than a linear pathway. Phosphoketolase pathway is an example of branched pathway.