Enzymatic Reactions

Enzyme + Substrate $\underset{K2}{\overset{K1}{\leftrightarrow}}$ Active Complex $\underset{K4}{\overset{K3}{\leftrightarrow}}$ Enzyme + Products

At equilibrium (steady state, where concentrations are not changing) can define the rate of enzyme-substrate complex formation by using the equilibrium constants:

K1[E] [S] + K4 [E] [P] = [ES] (K2+ K3)

At time zero, [S] >>>[P] then :

K1[E] [S] = [ES] (K2+ K3)

Can rearrange to:

E/ES = K2 + K3/ K1 **Km = K2+K3/ K1**

Km

$$K_m = \frac{K_2 + K_3}{K_1}$$

K1, K2 and K3 are constants

With proper substitutions and rearrangement of the rate equation we can obtain the Michaelis-Menton equation:

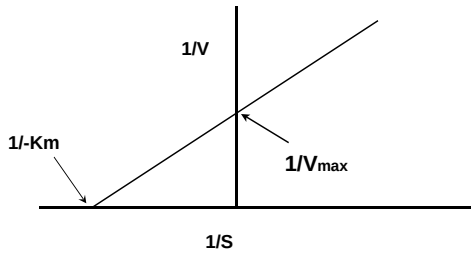
Michaelis - Menton

$$V = \frac{[S]V_{max}}{[S] + Km}$$

It can be shown that: V = 1/2 V_{max} , when Km = [S]

V = Velocity
S = Substrate Concentration
K_m = Michaelis Constant
V_{max} = Maximal Rate

Lineweaver-Burk



Enzyme Activity

Factors that affect enzyme activity:

- **pH**
- **Temperature**
- **Ionic strength**
- **Aw**
- **Substrate concentration**
- **Substrate location**

pH

Enzymes usually have a fairly narrow pH optimum, but they may show considerable activity 2 to 3 pH units away from the optimum. pH may alter:

- **Enzyme conformation**
- **Recognition site**
- **Active site**
- **Substrate conformation**

Temperature

Temperature effects may be multiple:

- **Reaction rates and Ea**
- **pH effects**
- **Denaturation effects**

Enzymes in Food Processing

Food Enzymes may be:

Associated with loss of product quality
Used to evaluate process induced changes
Used to enhance flavor quality
Used to alter physical properties
Used to modify protein functionality

Enzymes and Processing

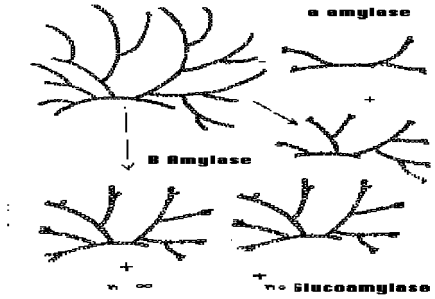
Enzymes are used because they are:

Selective for both substrate and product

Effective under mild conditions

Easy to control

Amylases

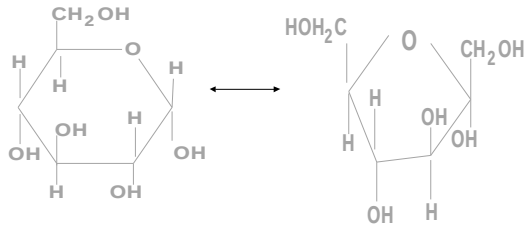


Amylases

Food uses:

- **Syrup manufacture**
- **Dextrose manufacture**
- **Baking**
- **Saccharification of fermented mashes**
- **Distillery and brewery**
- **Food dextrin manufacture**
- **Dry breakfast foods**
- **Chocolate syrups**
- **Starch removal from fruit juices**

Glucose Isomerase



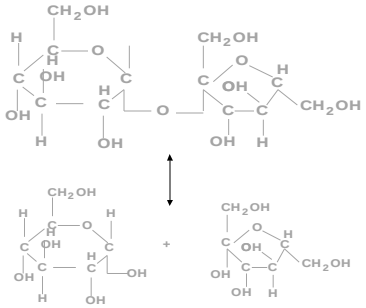
Invertase

The enzyme, invertase, converts sucrose into glucose and fructose.

Food uses include:

- **Production of artificial honey**
- **Production of invert sugar**
- **Manufacture of liquid center candies**

Invertase Reaction

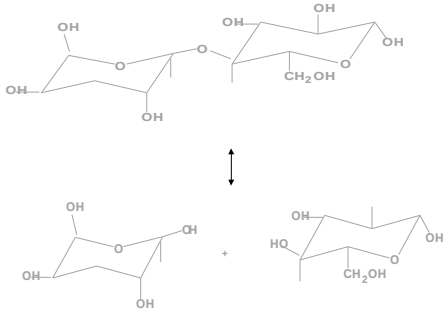


β–Galactosidase

This enzyme converts lactose into glucose and galactose. It has the following applications in foods:

- **Prevention of sandiness in ice cream**
- **Reduction of lactose intolerance**
- **Improving the freeze stability of milk proteins**
- **Decreased time for cheese manufacture**
- **Improved efficiency of lactosel utilization**

Lactase Reaction



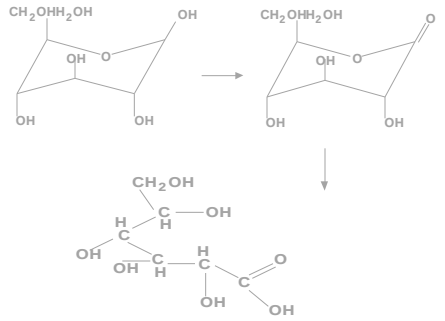
Glucose Oxidase - Catalase

D -Glucose + O_2 D-Gluconolactone + H_2O_2

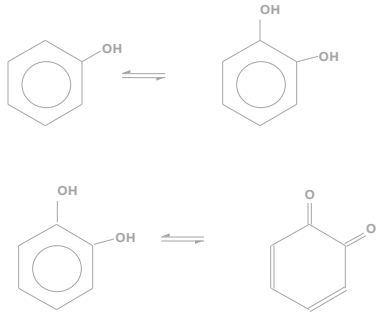
Removal of oxygen or glucose from products to prevent oxidation or browning including:

- **Beer**
- **Cheese**
- **Dried eggs**
- **Fruit Juices**
- **Meat and fish**
- **Milk powder**
- **Wine**

Glucose Oxidase - Reaction



Polyphenol Oxidase



Lipoxygenase

Converts a cis-cis methylene interrupted system of double bonds into one that is trans-cis conjugated. In the process a hydroperoxide is formed.

Effects of lipoxygenase can include:

- **Color changes**
- **Flavor changes**
- **Textural changes**
- **Loss of nutritional quality**

Lipoxygenase

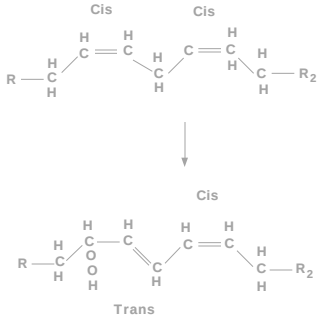
Positive Effects

- **Bleaching of flours**
- **Disulfide bond formation in gluten**

Negative effects

- **Destruction of chlorophyll and carotene**
- **Production of oxidized flavors**
- **Oxidative damage to vitamins and proteins**
- **Oxidative damage to essential fatty acids**

Lipoxygenase - Reaction



Lipase Reactions

Lipases catalyze the hydrolysis of glycerides to fatty acids and glycerides containing one fewer fatty acids:

Triglyceride ⟷ Fatty acid + Diglyceride

Diglyceride ⟷ Fatty acid + Monoglyceride

Monoglyceride ⟷ Fatty acid + Glycerol

Lipase

Uses of Lipases

Improvement of whipping quality of dried egg white

Flavor enhancement of milk chocolate and chocolate ice cream

Production of butter flavors

Essential for flavor of certain cheeses such as:

Blue Ramono Provolone

Proteases

Some proteases have been suggested as being useful in altering the functionality of food products. Some of the functions suggested include:

- Emulsifying property modification
- Improved properties of dough
- Improved whipping characteristics
- Improving nutritional quality
- Meat tenderization
- Milk coagulation
- Plastein reaction

Sources of Proteases

Enzyme	Source
Bromelain	Pineapple
Ficin	Fig
Papain	Papaya
Rennet	Calf Stomach

Pectic Enzymes

Types of pectic enzymes:

- Pectin methylesterases
- Polymethylgalacturonases
- Pectic lyases

METHYLESTERASE

Polygalacturonase

Pectate Lyase

Uses of Pectic Enzymes

Uses of pectic enzymes:

- Hydrolysis of pectic substances
- Assist in the fermentation of cocoa
- Hydrolysis of coating of coffee beans
- Softening of fruits
- Extraction of oil from olives
- Improved yield of fruit juices
- Prevent cloudiness in fruit juices
- Clarification of wine

Immobilized Enzymes

Covalent attachment to matrix
Inclusion within a matrix
Adsorption to a matrix
Cross-linking
Adsorption followed by cross-linking

Immobilization for Food Uses

Immobilized, Living Cells - use whole cells rather than isolated enzymes to catalyze the reaction.

- **Easier initially**
- **Must be certain that unwanted activities are eliminated**

Immobilization for Food Uses

Enclose enzyme, substrate or enzyme + Substrate in a capsule that is isolated from rest of food product

Can control when reaction will occur or when products will be released

Immobilization for Food Uses

Can use enzyme-substrate as an indicator of conditions:

- **Temperature**
- **pH**
- **Moisture**
- **Oxidation-Reduction Potential**
- **Substrate Concentration**