

MODULE-2: APPLICATION OF BIOMOLECULES

Carbohydrates in Cellulose-Based Water Filters Production

- Cellulose is also the most abundant carbohydrate present in nature. It is insoluble in water. It is a crystalline solid having a white powdery appearance. It has high tensile strength due to firm hydrogen bonds between the individual chains in cellulose microfibrils. Because of these, they find immense applications in our day-to-day life.

(i) Cellulose- based water filters

- Filtration is a common way to obtain pure drinking water by removing particles and microorganisms based on size exclusion.
- The interest in the use of bio-based filters for water purification has increased in recent years, as such filters have the potential to be affordable, lightweight and biodegradable.
- Cellulose-based filters are affordable and bio based option for the removal of particles.
- Wood-based cellulose pulp fibres are used in disposable everyday filters, such as coffee filters and air filters, and some of the first membranes for *microfiltration* were produced from *cellulose nitrate* and *cellophane*.
- Microfiltration uses membranes with a pore size less than 0.5 μm to physically remove bacteria from water, such as faecal bacteria *e.g.*, *Escherichia coli* and *Vibrio cholera*, which are approximately 1–2 μm in length.
- Lately, research has been focused on creating biobased membranes for micro- and ultra filtration from *cellulose nano fibrils* (CNFs). *Electro-spun ultrafine nano fibers* made from cellulose to create a barrier layer on petroleum-based membranes to achieve a pore size of approximately 20 nm and are used for ultra filtration.
- The drawbacks of membrane filtration are that the small pores impair the water flow, so that electrical pumps are often required to obtain a sufficient flow through the filter, and that the small pores in the membranes can easily become clogged by organic matter in water.

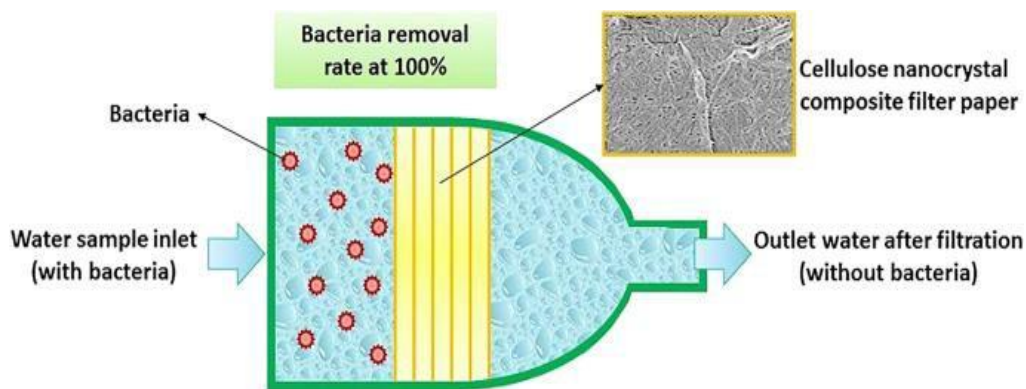


Figure: Cellulose based water filters

- Another interesting approach is to use charged particles (while keeping the filter pore size larger than bacteria). In this method, positively charged filters are used to *adsorb* negatively charged bacteria onto the surfaces of the filters. This allows negatively charged particles much smaller than the filter pore size to be efficiently removed from water.
- The use of fibres modified with the cationic polyelectrolyte polyvinyl amine polymer in single layers (1 L) or in multilayers together with the anionic polyelectrolyte poly acrylic acid (3 L or 5 L) using a water-based process at room temperatures, can physically remove more than 99.9% of *E. coli* from water and that the 3 L modified filters can remove more than 97% of cultivatable bacteria from natural water samples.

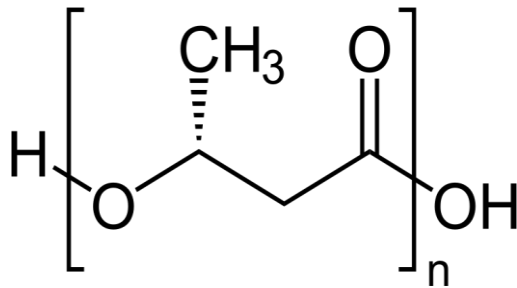
Bio Plastics

- Petroleum-derived plastics are linked to a variety of growing environmental issues throughout their lifecycle, including emission of greenhouse gases, accumulation in terrestrial and marine habitats, pollution, among others. There has been a lot of attention over the last decade in industrial and research communities in developing and producing eco-friendly polymers to deal with the current environmental issues.
- Bioplastics preferably are a fast-developing family of polymeric substances that are frequently promoted as substitutes to petroleum-derived plastics. Egs: PHA and PLA.

(i) Poly Hydroxy Alkanoates (PHA)

- PHAs are polyesters produced in nature by numerous microorganisms, including through

bacterial fermentation of sugars or lipids. These plastics are biodegradable and are used in the production of bioplastics.



Structure of PHA



- PHAs can be used either as a direct replacement of petroleum- derived plastics or as a blend with elements derived from natural origin.
- Among the most promising PHAs, polyhydroxybutyrates (PHBs) are the most well-known and have a significant potential to replace traditional plastics.
- These biodegradable plastics decompose faster after decomposing into carbon dioxide, water, and inorganic chemicals.

Properties

- PHA polymers are thermoplastic; they become liquid at their melting point.
- They are UV stable and have a low permeation of water.
- Processability, impact strength and flexibility can be improved with a higher percentage of valerate in the material.
- PHAs are soluble in halogenated solvents such chloroform, dichloromethane or dichloromethane.

Uses

- Bioplastics have been extensively utilized in several sectors such as food-processing industry, medical, agriculture, automobile industry, etc.

(ii) Polylactic Acid (PLA)

- Polylactide (PLA) is polyester (polymer containing the ester group) derived from renewable biomass, typically from fermented plant starch, such as corn, cassava, sugarcane or sugar beet pulp.
- PLA is made with two monomers- lactic acid and lactide.
- Lactic acid can be produced by the bacterial fermentation of a carbohydrate source

under the controlled conditions.

- In addition, crop residues such as stems, straw, husks, and leaves, can be processed and used as alternative carbohydrate sources.
- PLA is biodegradable and will breakdown within twelve weeks.
- According to research, the carbon emissions associated with PLA production are 80% lower than that of traditional plastic.

Properties

- They are thermoplastic.
- Stable to UV radiation.
- The crystallinity found up to 70%
- Good resistance to moisture.
- Good elasticity properties.
- The glass transition temperature (600 - 650°C)
- PLA possess melting points 173-178°C.

Applications

- a) PLA used orthopaedic device.
- b) PLA Widely used as a material for drug delivery system.
- c) PLA used in tissue engineering or regenerative medicine.
- d) PLA used in cardio vascular implants and dental.
- e) PLA used in cancer therapy.
- f) PLA used in skin and tendon healing.

Nucleic acids in Vaccines and Diagnosis

- Scientists have developed DNA vaccines to control the spread of Rabies disease.

(i) DNA vaccine for rabies

- Healthcare provider gives the infected person four shots of medicine over 14 days.
- If the person has already been vaccinated before exposure, he needs only two shots of medicine.

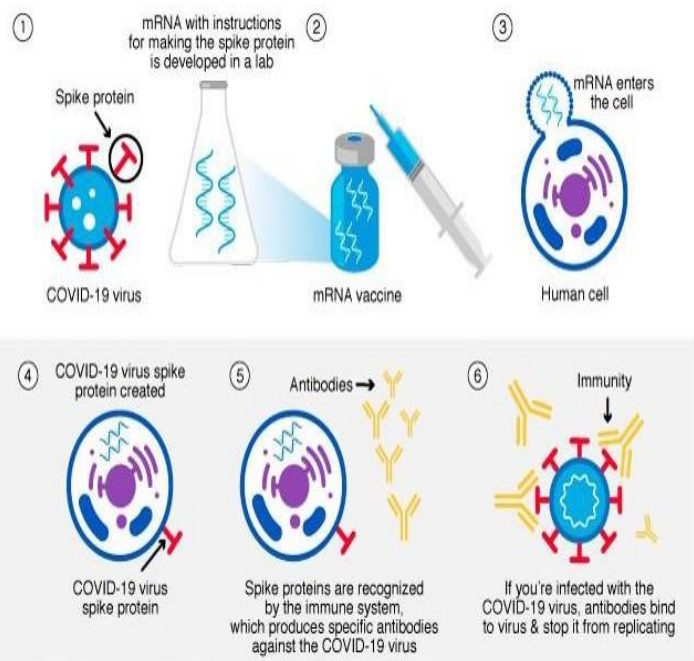
- The vaccine teaches the infected person's body to destroy the rabies virus before it enters the brain.
- *It comprises of plasmid (like vector) collected from bacteria, having the virus to sensitize immune against rabies (100 µg).*
- *Its surface of the plasmid is cut with endonuclease enzyme and its surface is introduced with virus surface glycoprotein and purified as per WHO/US FDA guidelines.*
- DRV is dissolved in saline and stored at -20° C.

(ii) RNA Vaccine for Covid 19

- Examples: Pfizer-BioNTech and the Moderna COVID-19 vaccines use mRNA.

Working of Vaccine

- Messenger ribonucleic acid (mRNA) is a molecule that provides cells with instructions for making proteins.
- *mRNA vaccines contain the instructions for making the SARS-CoV-2 spike protein.*
- This protein is found on the surface of the virus that causes COVID-19.
- After the protein piece is made, the cell breaks down the instructions and gets rid of virus.



The mRNA never enters the central part (nucleus) of the cell, which is where our DNA (genetic material) is found. DNA can't be altered by mRNA vaccines.

- *The cell then displays the protein piece on its surface. Our immune system recognizes that the protein doesn't belong there and begins building an immune response and making antibodies.*

Proteins in Food Production

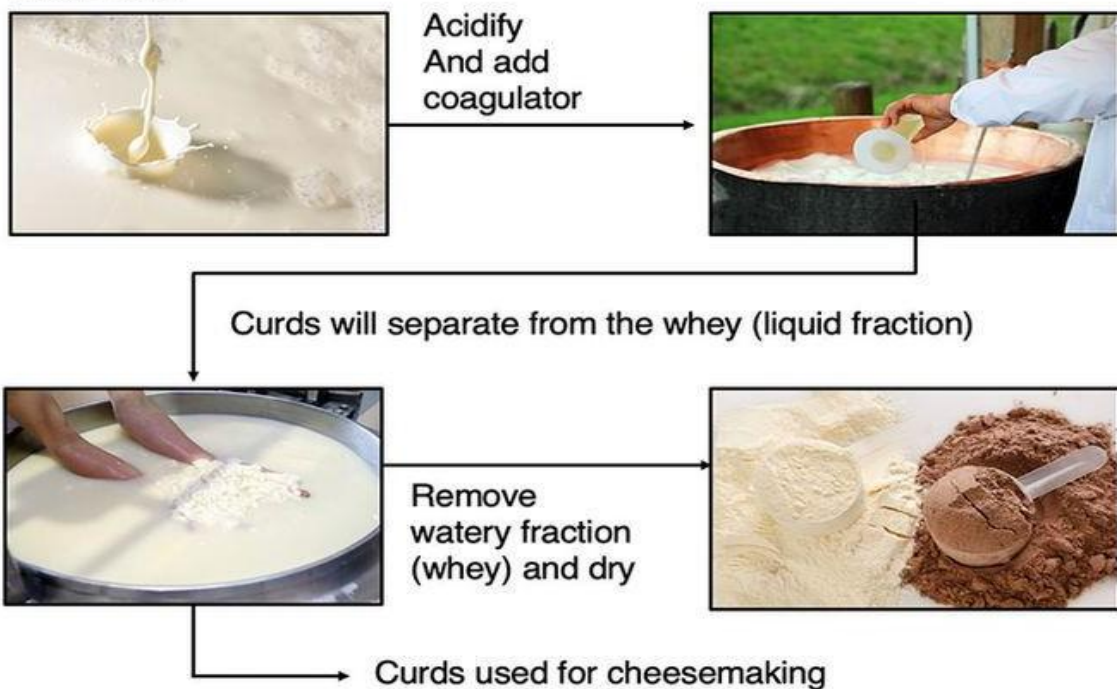
Whey protein

- Whey protein is a mixture of proteins isolated from whey, the liquid material created as a by-product of cheese production. Whey protein is commonly marketed as a protein supplement, and various health claims have been attributed to it.



How is whey protein made?

Fresh milk

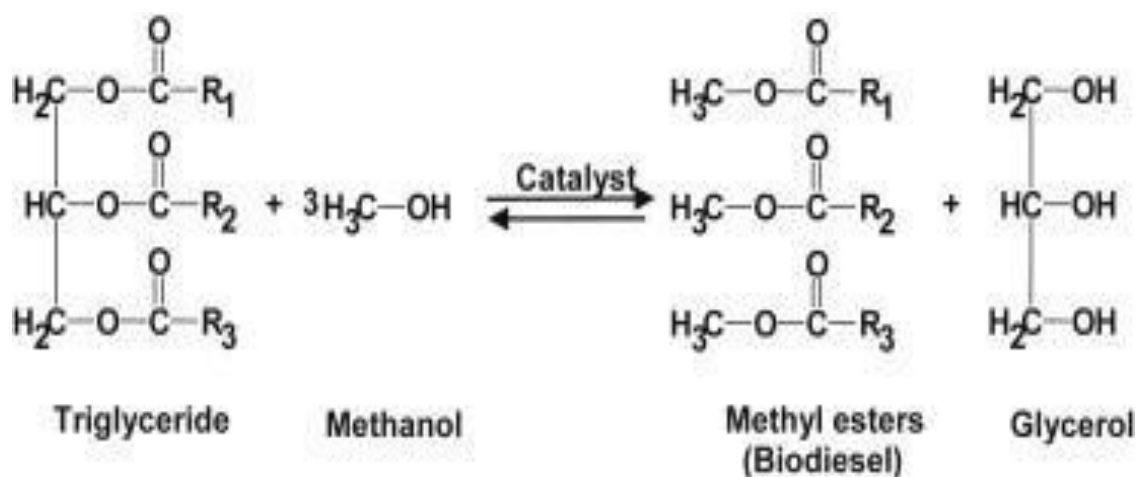


- Whey is left over when milk is coagulated during the process of cheese production. (pH is dropped to 4.6 during the coagulation process).
- Whey can be denatured by heat. High heat (such as the sustained high temperatures above 72°C associated with the pasteurization process) denatures whey proteins.

Lipids in Biodiesel And Detergents Production

Production of Biodiesel

- Biodiesel is a source of energy obtained from renewable sources of plant origin. It is produced from vegetable oils such as soyabean, jatropha, corn, sunflower, cotton seed, rice bran and rubber seed oil. It can be used as an alternative fuel to diesel in automobiles.
- The oils are triglyceride esters of fatty acids and their use in diesel engines require extensive engine modifications. However, it is possible to convert these triglycerides into substances of diesel quality by transesterification.
- Transesterification is alcoholysis of the triglyceride oil in the presence of a base. The resulting mixture of monoalkyl esters of fatty acids is referred to as biodiesel. Thus, biodiesel is a mixture of monoalkyl esters of long chain fatty acids.



where, R₁, R₂ and R₃ are the long chain fatty acids in the oil. Glycerol is soluble in water and can be separated from the reaction mixture.

Production of Cleaning Agents/ Detergents

- Cleaning agents or hard-surface cleaners are substances (usually liquids, powders, sprays, or granules) used to remove dirt, including dust, stains, foul odours, and clutter on surfaces.
- Lipids are used to produce detergents
- Detergents are a group of compounds with an amphiphilic structure, where each molecule has a hydrophilic (polar) head and a long hydrophobic (non-polar) tail. The hydrophobic portion

of these molecules may be straight- or branched-chain hydrocarbons, or it may have a steroid structure.

- The hydrophilic portion is more varied, they may be ionic or non-ionic, and can range from a simple or a relatively elaborate structure.
- Detergents are surfactants since they can decrease the surface tension of water. Their dual nature facilitates the mixture of hydrophobic compounds (like oil and grease) with water. Because air is not hydrophilic, detergents are also foaming agents to varying degrees.
- Detergent molecules aggregate to form micelles, which makes them soluble in water. The micelle can remove grease, protein or soiling particles.

Enzymes In Biosensors Fabrication

- Due to their high specificity, simplicity, and scalability, enzyme-based biosensors represent a fast, precise, and continuous monitoring of analytes. Additionally, the high specificity of enzymes enhances the ability to detect lower analyte concentration limits. So enzymes are used in biosensors.

Glucose-Oxidase in biosensors

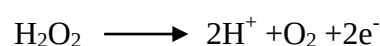
- A biosensor is a device that measures biological or chemical reactions by generating signals proportional to the concentration of an analyte in the reaction.
- Biosensors are employed in applications such as disease monitoring, drug discovery, and detection of pollutants, disease-causing micro-organisms and markers that are indicators of a disease in bodily fluids (blood, urine, saliva, sweat).

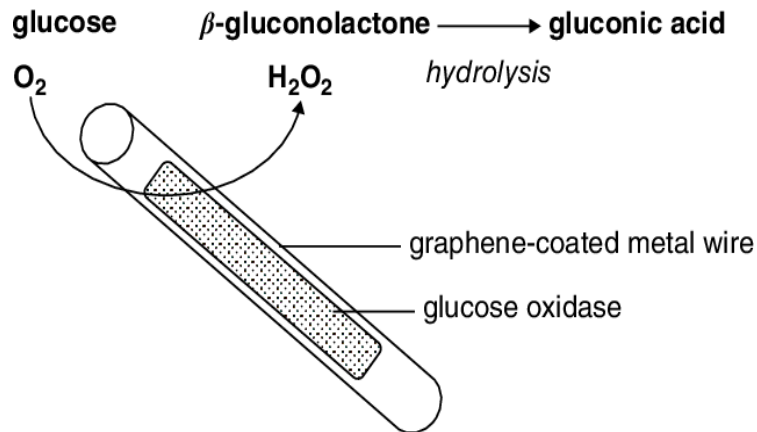
Principle

- Molecular oxygen aids in the oxidation reaction of β -D-glucose found in the blood sugar and this reaction is catalyzed by an immobilized enzyme GO_x .
- Gluconic acid and hydrogen peroxide (H_2O_2) are the end products of this reaction.



- Further, at the platinum electrode anode, the oxidation H_2O_2 of takes place. The electrode recognizes the number of electron transfer and the flow of electron is in direct relationship to the number of glucose molecules in the blood.





Enzymes in Food Processing

- Enzymes play a crucial role in food processing, where they are used to catalyze biochemical reactions that modify the structure, texture, flavour, and nutritional properties of various food products. Here are some ways in which enzymes are utilized in food processing:
- **Baking:** Enzymes like amylase, protease, and lipase are used in baking to improve dough handling, texture, and crumb structure. Amylase breaks down starch into simpler sugars, which aids in fermentation and browning. Protease can strengthen the dough, while lipase contributes to the flavor and texture of the final product.
- **Brewing:** In brewing beer, enzymes such as amylase and protease are used to convert starches in malted barley into fermentable sugars and proteins into amino acids, respectively. This process is crucial for fermentation and the development of flavor and foam stability.
- **Cheese Making:** Enzymes like rennet are essential in cheese making to coagulate milk proteins (casein) and separate curds from whey. Other enzymes may also be used to modify texture and flavor during cheese ripening.
- **Fruit Juice Production:** Enzymes such as pectinase are used in fruit juice production to break down pectin, a polysaccharide found in cell walls, thus aiding in juice extraction and clarification.
- **Dairy Processing:** Enzymes like lactase are used to hydrolyze lactose into its constituent sugars, glucose, and galactose, making dairy products like lactose-free milk accessible to lactoseintolerant individuals.

Enzymes in Detergent Formulation

Enzymes are essential components in many detergent formulations due to their ability to break down and remove various stains and soils effectively. Here are some common types of enzymes used in detergent formulations and their functions

- **Proteases:** Proteases are enzymes that break down proteins into smaller peptides and amino acids. They are effective in removing protein-based stains such as blood, grass, egg, and sweat stains from fabrics.
- **Amylases:** Amylases hydrolyze starch molecules into simpler sugars such as glucose. They are useful for removing starchy stains like pasta sauce, gravy, and chocolate from clothing.
- **Lipases:** Lipases break down fats and oils into fatty acids and glycerol. They are effective in removing oily stains such as grease, oil-based food stains, and lipstick marks.
- **Cellulases:** Cellulases break down cellulose, a complex carbohydrate found in plant fibers. They are used to enhance the removal of stains like grass, mud, and food residues from cotton and other cellulose-based fabrics. Cellulases also help prevent pilling and restore fabric smoothness.
- **Pectinases:** Pectinases break down pectin, a polysaccharide found in fruits and vegetables. They are effective in removing fruit and vegetable stains from fabrics. These enzymes work synergistically with surfactants and other detergent ingredients to break down stains and soils, improving the overall cleaning performance of the detergent.

Enzymes in Textile Processing

Enzymes play a significant role in textile processing, offering various benefits such as improved fabric quality, reduced environmental impact, and increased efficiency. Here are some common applications of enzymes in textile processing.

- **De-sizing:** Enzymes such as alpha-amylase are used to remove sizing agents applied to yarns during the weaving process. Sizing agents, typically starch-based, provide stiffness and improve the weaving process. An enzymatic desizing offer more eco-friendly alternative to traditional chemical desizing methods, as it requires lower temperatures and reduces water and energy

consumption.

- **Bio-polishing:** Cellulase enzymes are used in bio-polishing to remove protruding fibers (fuzz) and 16 surface impurities from fabric surfaces. This process improves fabric softness, enhances luster, and reduces pilling, resulting in a smoother and more uniform appearance. Bio-polishing is commonly applied to cotton, linen, and viscose fabrics.
- **Denim Finishing:** Enzymes are utilized in denim finishing to create various effects such as stone washing, enzyme washing, and acid washing. Cellulase enzymes are particularly effective in stone washing by selectively removing indigo dye from denim fabrics, resulting in a faded or worn-out appearance. Enzyme washing achieves similar effects but with less harshness on the fabric.
- **Biobleaching:** Enzymes like peroxidases are used in biobleaching to remove residual lignin and other impurities from natural fibers such as cotton and linen. Biobleaching enhances fabric whiteness and brightness while reducing the need for chlorine-based bleaching agents, which can be harmful to the environment.
- **Degumming:** Enzymes are employed in degumming processes to remove sericin and other natural gumming agents from silk fibers. This step improves silk softness, dyeability, and overall quality.
- **Color Fading:** Enzymes can be used to selectively fade or modify the color of dyed fabrics, providing unique design possibilities for textile manufacturers. Enzymes in textile processing offer several advantages, including reduced water and energy consumption, shorter processing times, improved fabric quality, and lower environmental impact compared to conventional chemical treatments. However, it's essential to optimize enzyme formulations, processing conditions, and safety measures to ensure effective and sustainable textile processing operations.