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TECHNOLOGY JAMMU

विद्याधनं सर्वधन प्रधानम्

Biohydrogen Production

Outline

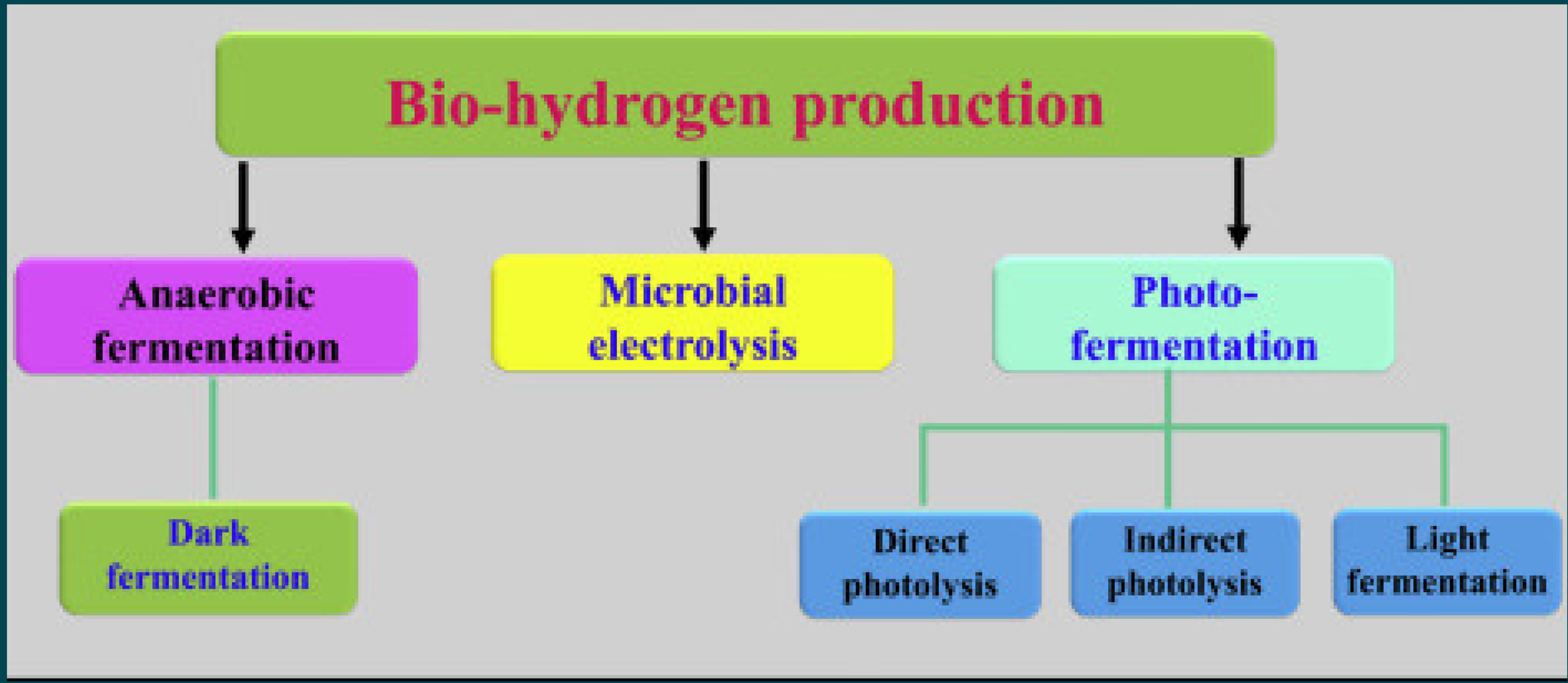
1) Introduction
2) Basic methods of biohydrogen production
3)Direct biophotolysis
4)Indirect biophotolysis
5) Photo Fermentation
6) Dark Fermentation

Introduction

- Currently the CO2 concentration exceed 350 ppm by vol. which increase the green house effect hence increasing global temperatures.
- Biohydrogen is H2 that is produced biologically. Interest is high in this technology because H2 is a clean fuel and can be readily produced from certain kinds of biomass.
- Biohydrogen is a fuel produced by microbialmetabolism, similar to bioethanol orbiogas (CH : CO mixture)

Basic methods of biohydrogen production

1. Production of biohydrogen by algea.
2. Microbial Electrolysis Cell
3. Fermentation
4. Stream reforming


Bio-hydrogen production
Anaerobic fermentation
Microbial electrolysis
Photo-fermentation
Dark fermentation
Direct photolysis
Indirect photolysis
Light fermentation

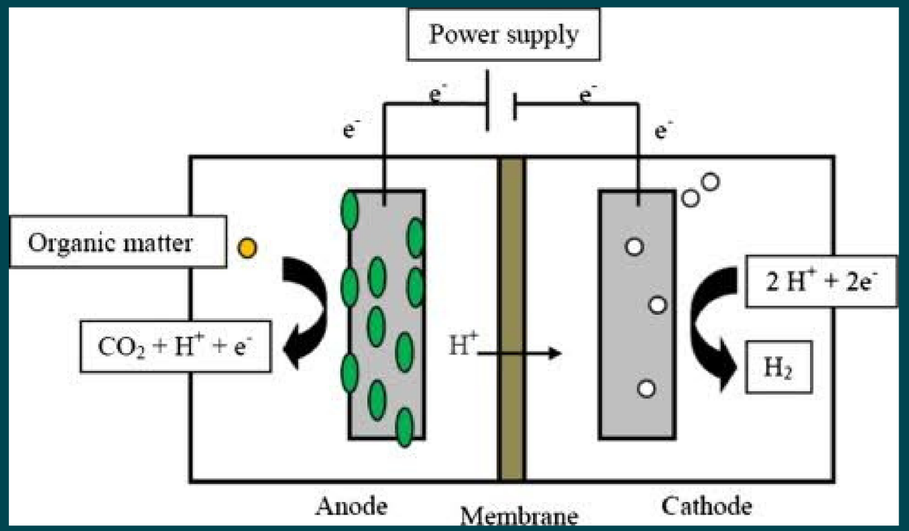
Microbial Electrolysis cell

- In a microbial electrolysiscell (MEC), catalyzed oxidation of organic compounds in the anode chamber is typically combined with the chemical evolution of hydrogen in the cathode chamber.
- So, the current production is directly proportional to H2 production in anaerobic conditions. Reaction occurring are as follows:

Anode : CH3COO-+4H2O-->2HCO3+9H+8e
Cathode : 8H+8e-->4H2

(Here taking acetate as organic substrate)

([CH3COO-]=[HCO3]=10 mM, pH 7, 298.15 K, hydrogen pressure=1 bar; ΔG=93.14 kJ/mol; emf =-0.12 V)



science direct image resource

- As we can see ΔG is +ve ,so rxn in not spontaneous .So an additional valtage is needed for making it spontaneous which can be derived from nerst equation.

- However,the applied voltage needs to be larger than equilibrium voltage (Eeq) of the elechemical cell given as Eeq =Ecat -Ean

(Ecat & Ean are half cell potential of cathode and anode respectively)

$$Ean=Ean°-(RT/8F)\ln([CH3COO-]/[HCO3]^2[H+]^9)$$

Ean°=0.187V. Under standard biological conditions, the anode potential is 0.279 V

$$Ecat =E0cat°\ -(RT/2F)\ln\ [pH2]/[H]^2$$

- where Ecat°=0 V . Under standard biological conditions, the cathode potential is 0.414 V. Thus Eeq=0.14,but in actual scenerio it is in the range of 0.2-1 V.

- The efficiency of hydrogen production depends on which organic substances are used. Lactic and acetic acid achieve 82% efficiency, while the values for unpretreated cellulose or glucose are close to 63%.

Biophotolysis

Refrence
file:///C:/Users/rajra/Downloads/7933-Article%20Text-17449-1-10-20210822.pdf

- **Biophotolysis or photofermentation are driven by photonic energy to produce hydrogen by using water as the material resource.**
- **In biophotolysis, microalgae are used because they can produce hydrogen in closed systems. .**
- **Biophotlysis is done in moderate temperatures and pressures (e.g., standard temperature and pressure).**

Direct Biophotolysis

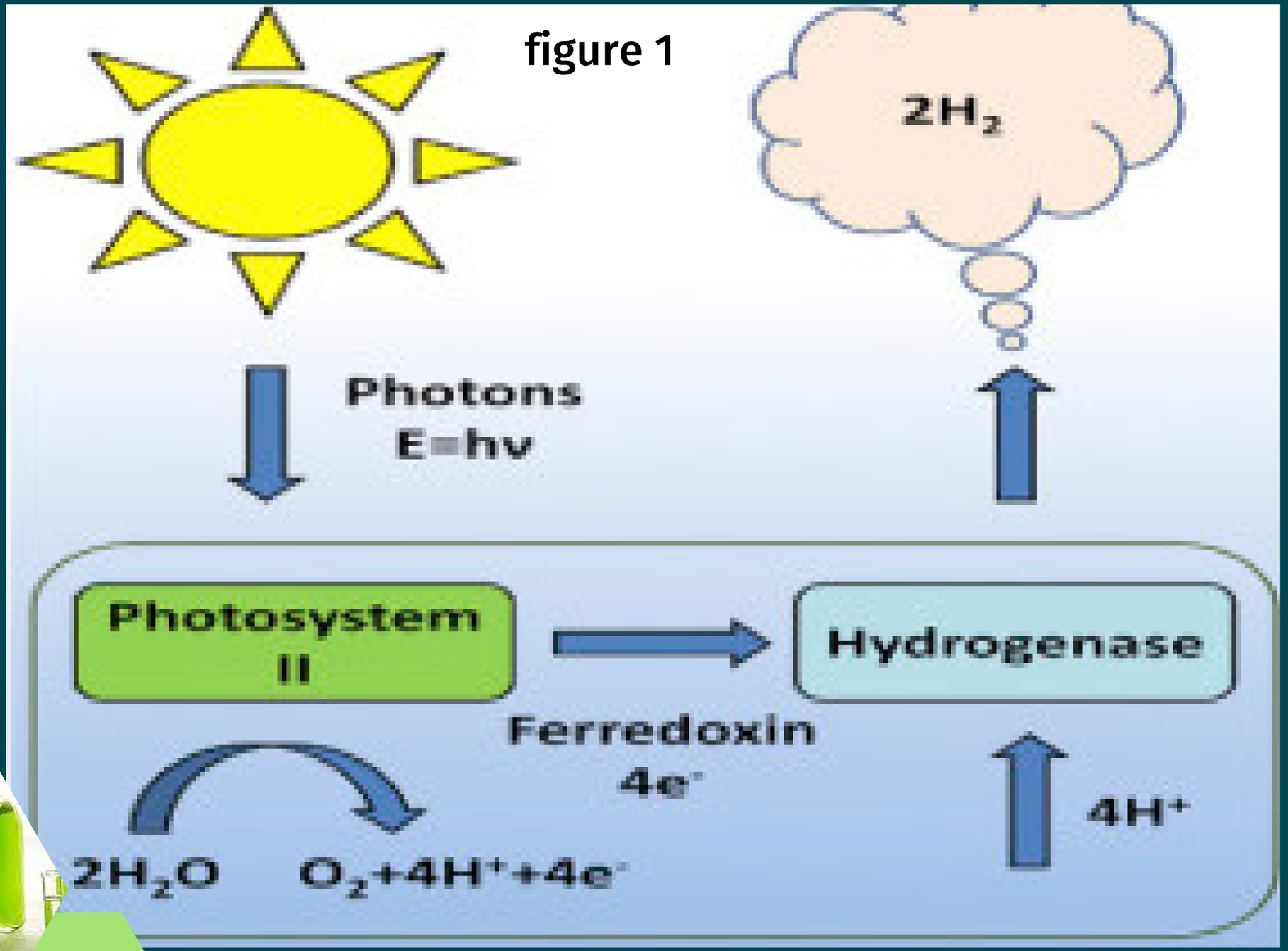
- **Direct biophotolysis is a biological process that can produce hydrogen *directly from water* using *microalgae photosynthesis* system to convert solar energy into chemical energy in the form of hydrogen, the reaction is generally as follows:**

(Photosynthesis)

$$2H_2O + \text{Solar energy} \xrightarrow{\text{photosynthesis}} 2H + O_2$$

- The microorganisms green algae and cynobacteria are used here.
- The overall reaction is mediated by the concerted action of the two photosystems (PSI and PSII) of cyanobacteria, which are utilized in plant-type photosynthesis.
- Hydrogen production by green microlgae take place in ***anaerobic conditions*** in the dark to induce activation of enzymes involved in hydrogen metabolism.
- Green microalgae have the genetic machinery,enzymatic,metabolic and electron-transport to photoproduce hydrogen.

figure 1


$2H_2$
Photons
E=hv
Photosystem
II
Hydrogenase
Ferredoxin
$4e^-$
$4H^+$
$2H_2O$
$O_2+4H^++4e^-$

INDIRECT BIOPHOTOLYSIS

- Indrect biophotolysis is the production of hydrogen from water via microlalgae and cyanobacteria photosynthetic system to convert solar energy into chemical energy.

It is carried out by two steps:-

a) The first step is the biomass production through photosynthetic system

b) Second step which utilise the biomass rich-carbohydrate for hydrogen production fermentation

Steam Reforming

Steam-Methane Reforming :

Most hydrogen produced today in the United States is made via steam-methane reforming, a mature production process in which high-temperature steam (700°C–1,000°C) is used to produce hydrogen from a methane source, such as natural gas

Steam methane reforming reaction:

$$CH_4 + H_2O (+HEAT) \rightarrow CO_2 + H_2O$$

water-gas shift reaction," the carbon monoxide and steam are reacted using a catalyst to produce carbon dioxide and more hydrogen.

Water-gas shift reaction

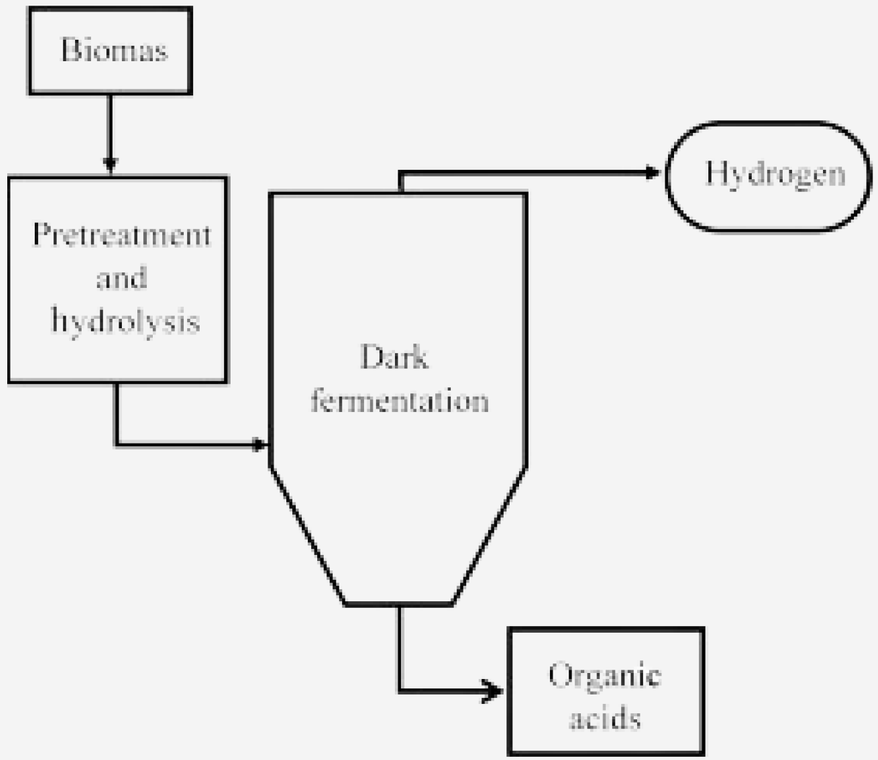
$CO + H_2O \rightarrow CO_2 + H_2$ (+ small amount of heat)

carbon dioxide and other impurities are removed from the gas stream, leaving essentially pure hydrogen

Dark fermentation

- It is a type of biological production of hydrogen.
- Carried out by obligate anaerobes & facultative anaerobes in the absence of light & oxygen
- Bacteria act on the substrate and generate hydrogen.
- Substrate is lignocellulosic biomass, carbohydrate materials like wastewater from industry, sugar-containing crop residues, and municipal solid waste.
- Pretreatment of the biomass greatly affects the efficiency of the dark fermentation.
- Efficiency affecting parameters are the microorganism involved and the sugar content of the substrate

Dark fermentation block diagram



Hydrogen yield in dark fermentation

Theoritically

1 mol of glucose can produce 12 mol of hydrogen

$$C_6H_{12}O_6 + 2H_2O \rightarrow 12H_2 + 6CO_2$$

But dark fermentation produce only 4 mol of hydrogen

$$C_6H_{12}O_6 + 12H_2O \rightarrow CH_3COOH + 4H_2$$

The maximum efficiency is only 33%

further studies express hydrogen yield as 0.47lit/gm of COD when sucrose is used and 0.27lit/gm of COD when glucose is used as substrate

Reference

Tip: Use links to go to the various resources

How: Highlight text, click on the link symbol on the toolbar, and paste the link of the document or websites that you want to reach.

- https://www.canva.com/design/DAFMOZLQUnI/-rImBzYibZIZNvmD-qC8rA/edit?utm_content=DAFMOZLQUnI&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton

- https://www.frontiersin.org/articles/10.3389/fenrg.2021.753878/full
- https://www.youtube.com/watch?v=qaMDiT6iEBQ
  Biohydrogen: For Future Engine Fuel Demands
- Source: Springer-eBooks
- Author: Demirbas, Ayhan

Thank You

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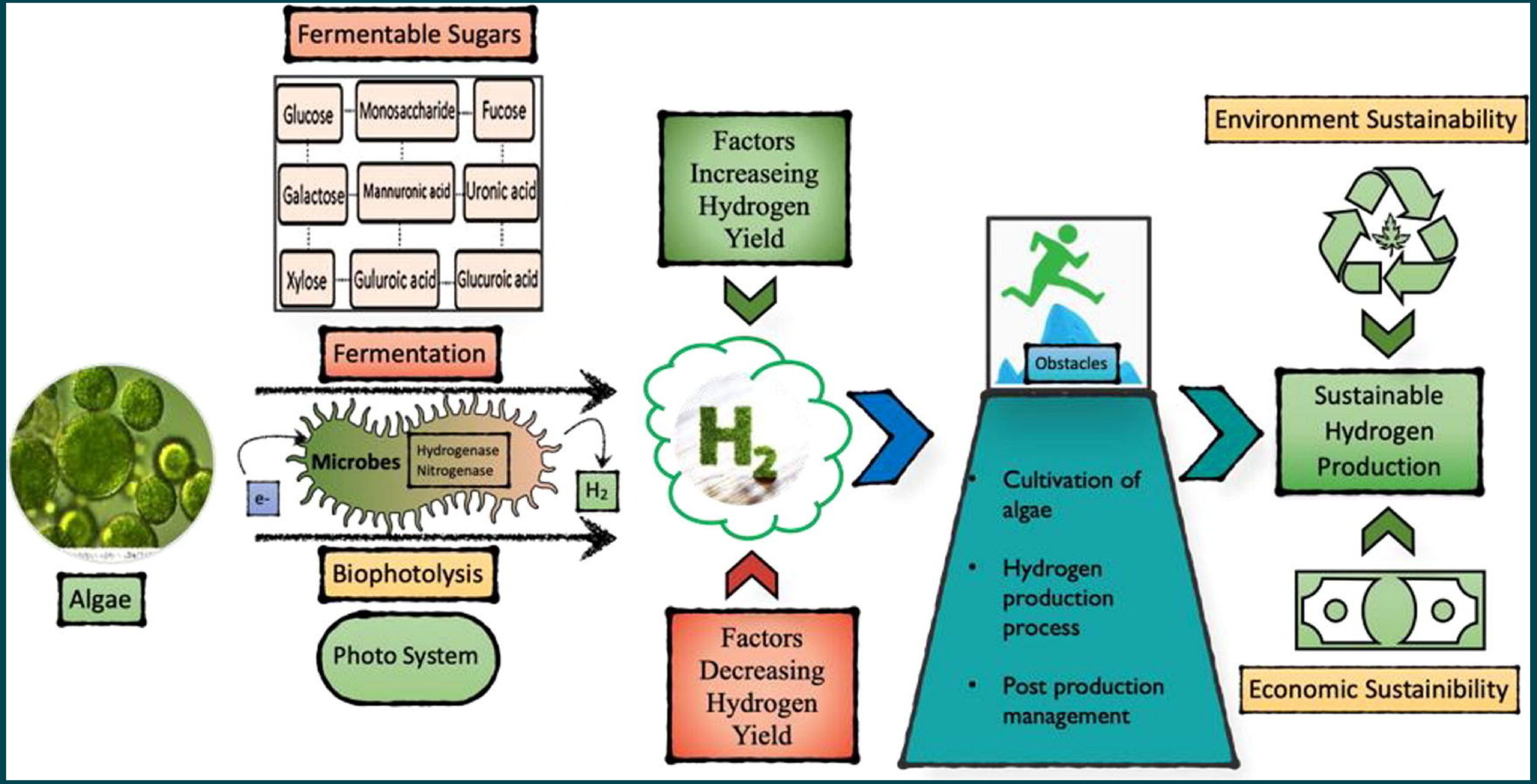
Fermentable Sugars
Glucose
Monosaccharide
Fucose
Galactose
Mannuronic acid
Uronic acid
Xylose
Guluroic acid
Glucuroic acid
Fermentation
Algae
Microbes
Hydrogenase
Nitrogenase
e-
H2
Biophotolysis
Photo System
Factors Increaseing Hydrogen Yield
H2
Factors Decreasing Hydrogen Yield
Obstacles
Cultivation of algae
Hydrogen production process
Post production management
Environment Sustainability
Sustainable Hydrogen Production
Economic Sustainibility