REVIEW ARTICLE

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Yeast Cells Secondary Metabolites and their Industrial Applications; A Review

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Abstract: Yeasts are the members of the fungi kingdom, single cell eukaryotic microorganisms. About hundred million years ago first yeast was originated and till now at least 1500 species have been identified. Through fermentation process yeast like Saccharomyces cerevisiae produces Co2 and alcohol from carbohydrates which have vital importance in baking and beverages industries as well as used as biofuels. Yeasts are considered as the most thoroughly researched and experimentally used among eukaryotic microorganisms because this provided valuable information related to the biology of eukaryotic cells as well as humans. However, some species such as Candida albicans are harmful to humans. In recent years, yeasts have been used to generate electricity in microbial fuel cells and producing ethanol used in biofuel industry. There is a biological curiosity from decades that how the microbes can produce the electricity. Now the researchers have predicted that the microbes produced electricity from organic matter which can be used in watches and cameras as a power source as well as for bioreactors. The microbial fuel cells divert the electrons from ETC of the yeast and generates the electricity. The widely used yeast for biotechnology and food engineering are now used for fuel engineering that is the major step towards advancement.

Keywords: Microbial Fuel Cells, Yeasts, Bio-Fuel, Fuel Engineering, Yeast Biotechnology

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INTRODUCTION

Yeasts are unicellular eukaryotes and classified as a member of Fungi kingdom. The size of yeast cell depends upon the species of universe typically measuring 3 to 4μm in diameter, but some yeast species grow in 40μm size (1). With over 1,500 species of yeast can be identifi Yeasts are major unicellular, some may be multicellular due to the formation of pseudohyphae. Yeasts are present in soil, water and fruits surface and in various types of food. These are also present on animal skin or inside an animal symbiotically. Yeast is one of the earliest domesticated organisms. *S. cerevisiae* is the most significant species that has been used to produce bread, beer, and wine. Yeast cells have been used to produce electricity by a microbial fuel cell (MFCs). The yeast has been producing ethanol for the biofuel industries (2).

The cell wall of yeast is present around the cell, outside of space named periplasmic space. The cytoplasm and cell membranes are present inside of cell wall with multiple unique functions which have made the yeast more thoroughly studied organism. The cell wall contains glucans and mannoproteins that are responsible for the physical protection wall for inner structures of cell. Cell wall is connected by glean and chitin chains across space to the cell membrane. Space contains many enzymes, these enzymes are responsible for the regulation of yeast metabolism. The cell membrane plays an essential role in regulation what substance has to go into and out of the cell (3). The cell membranes contain lipids and sterols. These lipids and sterols are the major cause of membrane integrity. Under fermentation conditions, membrane integrity confirms the yeast cell survive, as well as the proper absorption of amino acids and sugars (Fig. 1a and Fig. 1b). The break downs from fructose and glucose to ethanol occur in the cytoplasm. After ethanol is produced, it is secreted into the medium. The yeast cell also produces many by-products in the fermentation process into the medium such as esters, acetic acid and glycerol. The vacuole is most important in the yeast cell because it is used to store many enzymes as well as amino acids for the protein synthesis in the metabolism (4). Synthesis of protein is essential to give enzymes for sugar absorption, sugar breakdown and the formation of biomass of yeast cell.

YEAST HABITAT

Yeast is best grown in a slightly acidic pH

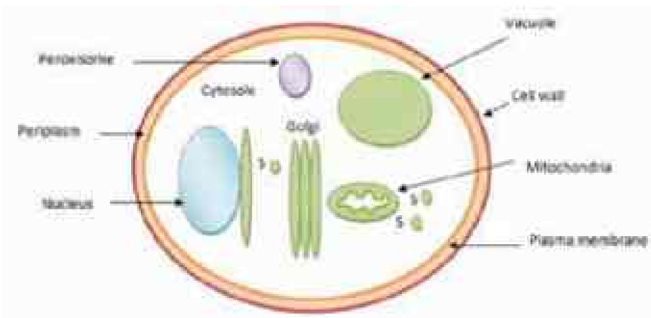

Figure 1a: Schematic diagram of Yeast cell environment. Yeast growth depends upon the specific range of temperatures. For example, growth of *Leucosporidium frigidum* take place at 2°C to 20°C, *Candida* slooffi at 28 to 45°C, Saccharomyces telluris at

5 to 35°C and both Schizosaccharomyces pombe and Saccharomyces cerevisiae can grow at 30°C.

BUDDING

Asexual reproduction is a common means of

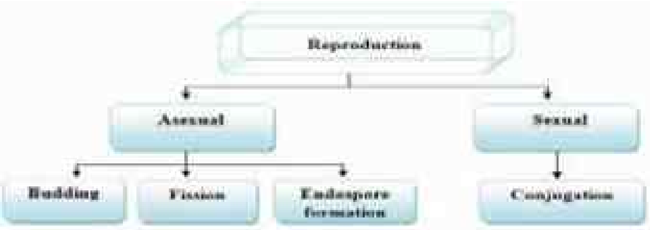

Figure 1b: Schematic representation of Yeast cell life cycle o

vegetative growth via budding in yeast cells. Yeast cell gradually increases in size under favorable condition. The nucleus divides mitotically, one of which migrate into the newly formed outgrowth and form a bud. The bud separates from the parent cell and becomes an independent cell. Sometimes multiple buds one or more chains are appearing due to the repeated budding yeast cell are called as pseudomycelium.

FISSION YEAST CELL CYCLE

This process occurs only in some yeast cells. In

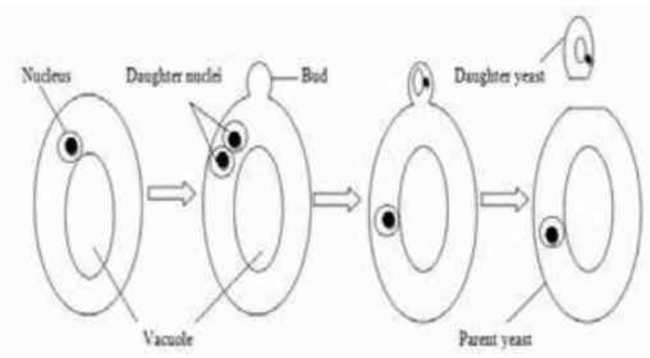

Figure 2: Schematic diagram representing the budding of yeast cells for multiplication this process, the nucleus of the cell is divided into two parts. The two nuclei are separated by the transverse wall. The cell wall is formed in the middle and divides into two cells each having a nucleus (Fig 3).

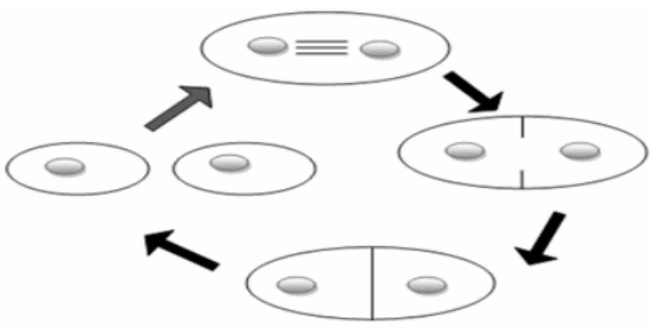

Figure 3: Schematic Diagram representing the fission yeast cell cycle

ENDOSPORE FORMATION

In this process, protoplast divides into four parts under unfavorable condition each become surrounding by a thick wall.

SEXUAL REPRODUCTION

Sexual reproductions occurs at the cell of the growing season under unfavorable condition. Two haploid somatic cell fuses together to form a diploid zygote nucleus. During the sexual union, two cell fuse (plasmogamy) and this is followed by the fusion of the two nuclei (karyogamy).

ETHANOL FERMENTATION

Ethanol fermentation is a biological process during which two molecules of pyruvates generated from glucose metabolism under oxidative phase but due to the limited supply of oxygen yeasts are able to convert sugar such as glucose into pyruvate and carbon dioxide then into ethanol (5). Yeast can act in the presence and absence of oxygen. In both processes, electrons are transferred from the 1 glucose molecule (6 carbons) and 2 molecules of pyruvates (3 carbons) are produced by the glycolysis process (6). In ethanol fermentation, the one glucose molecule breaks down into two pyruvates (7). This reaction is the exothermic reaction the energy is conserved through the transfer of inorganic phosphate groups and ADP, resulting in the production of ATP and converts the NAD+ to NADH. Then under limited supply of oxygen, the two pyruvates molecules break down into two acetaldehydes. Then acetaldehydes are converted into two ethanol molecules with the utilization of NADH produced during glycolysis phase from NAD+ (Fig 4)(8).

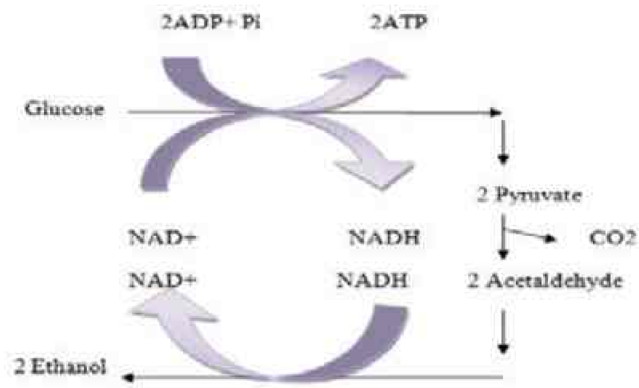

Figure 3: Conversion of a glucose molecule into two molecules of pyruvates and then pyruvate into ethanol with the circulation of energy in the form of ATP and NADH.

DIRECT ETHANOL FUEL CELL

Biologically renewable energy generation technologies have gained huge interest due to increased cost and security risk of energy. Subsequently, glucose a bio-renewable feedstock used to produce direct electricity generation, has regained momentum. Microbes catalyze the chemical reactions which metabolize the change of chemical energy into electrical energy (9, 10). Fuel cells convert chemical energy into the electrical energy. Ethanol used as a fuel in fuel cell is one possible technology because ethanol is more effective for the environment (8). The ethanol produced globally around 90 billion liters per annum. Liquid hydrogen in the form of abundant alcohol which has a more energy density and easier to transport has become attractive replacement to hydrogen for the direct oxidation fuel cell. Many alcohol fuels are used for different purpose like methanol is used in fuel cell because methanol fuel cell is easier to oxidize other than alcohol fuels and it has a simplest molecular structure without carbon bond but the disadvantages of methanol produce a toxin and unsafe for consumers (11). The ethanol is less toxic as compared to methanol. As it has high energy density 8.0 Kw.h/kg than methanol 6.1 2kW.h/kg .Through fermentation biotechnology process, the ethanol could be produced from renewable proportions such as molasses, sugar cane and corn, etc (12). Ethanol is easier to reform due to its simplest molecular structure. Most important CO emitted during this process. Ethanol is a defensible fuel source and direct ethanol fuel cell (DEFC) could be the best choice for energy production in the future. Ethanol is fed into the anode in the dilute state and converted according to the following reaction.

$$C_2H_5OH + 3H_2O \quad 2CO_2 + 12H^+ + 12\,e^-$$

Ethanol is oxidizing in the form of proton and carbon dioxide. The protons are transported through the membrane and electron flow the circuit (13).
At the cathode, oxygen is reduced according to the following reaction.

$$3_2O \quad + \; 12H^+ \qquad 6H_2O$$

The protons react with the oxygen in the air available at the cathode interface and from water

(Fig 5) (8).
The overall reaction of the (DEFC) is thus;

$$C_2H_5OH + 3O_2 \quad 3H_2O + 2CO_2$$

The electrochemical reactions occur in cathode and anode electrolytes.

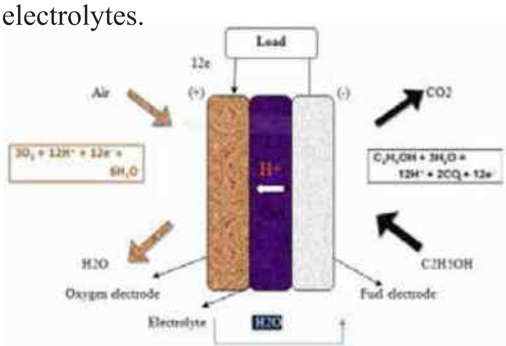

Figure 5: Direct ethanol fuel cell (DEFC) for the production of electricity from chemical energy.

ELECTRICITY IS GENERATED FROM BIO-MASS

Biomass could produce electricity by using waste material such as garbage and agricultural waste. There are many different methods used to convert the biomass into electricity (14). The first one is simply, waste material can be burned to make stream or biomass could be converted into biofuels which are then burned to produce electricity (Fig. 6). The streams turn the turbine which is a machine with blades that spin like a fan. The spinning blades transfer energy to an electrical generator that makes electricity (15).

Further, gasification of biomass could be done. Gasification is a thermo chemical process which the carbonaceous substance (biomass) are converted into gas in the presence of gasifying agent (16). The resulting gas mixture is called syngas or producer gas.

WORKING OF THE GASIFICATION PROCESS

Biomass particle would be prepared for pyrolysis development and then particles are pretreated like cleaning, drying and chopping to make small pieces. These particles will go to the pyrolysis

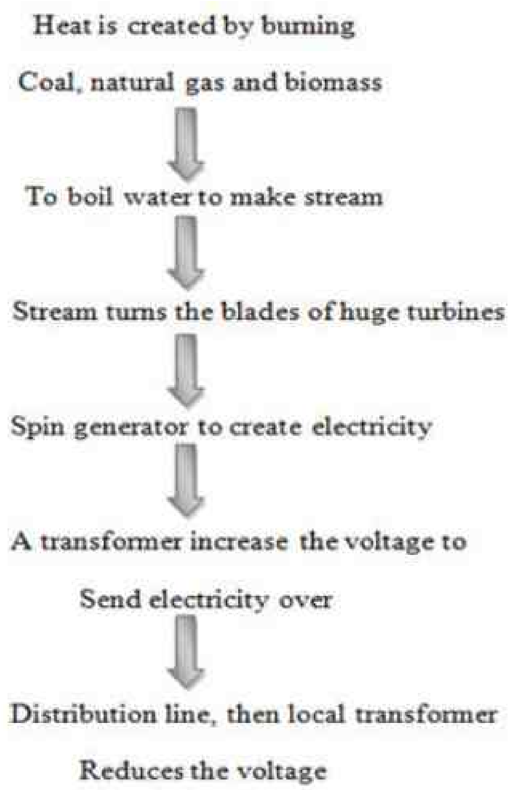

Figure 6: Representing the whole process of electricity production by the utilization of biomass reactor. Pyrolysis reactor,the stream pipe will give stream and combustion chamber will give heat. Pyrolysis

development process takes place in absence of oxygen. During this process, syngas will be produced but it contained many particles, then it will go to the cyclotron to remove the remaining particles. Where burn particles will be extracted in the burn collector from the gas and gas moved to the gas conditioner and char particles and another particle will be separated particle-free gas produced. This syngas is further used in electricity. Ruiz *et al.*, (2013) described that fuel cells could be used to generate electricity from gasified biomass. If we have biogas with high enough purity we can use fuel cells to produce bio-electricity (17).

MICROBIAL FUEL CELL

Microbial fuel cell (MFCs) or biological fuel cells are biochemical devices that convert the chemical energy to electrical energy by using microorganism (18). Yeasts are using in microbial fuel cells as they are nonpathogenic in nature and tolerate various harsh environmental conditions.

The microorganism uses as a catalyst to oxidize organic and inorganic matter to produce electricity. The microbial fuel cell could be grouped into two general categories; mediated and unmediated (19). The first microbial fuel cell used mediated, the chemical transfer electron from the bacteria in the cell to the anode. The second microbial fuel cell used unmediated, in this type microorganism use an outer membrane that can transfer electron to anode part directly (20). Microbial fuel cell contained two chambers anode and cathode these chambers are separated by a proton exchange chamber (PEM). In one chamber of the cell, the yeast cells are feed on glucose solution. The mediator is used to pick the electron and transfer them to an external circuit. Methylene blue is a mediator, enter the yeast cell and take an electron. The electrons pass through the external circuit. In the second chamber of the cell, the electron is accepted by potassium hexacyanoferrate (III) and the resulting produce water. Hydrogen ions cross from a cation exchange membrane that which separates the two chambers (Fig. 7). Further Nicon alloy could be used as electron transfer which safe the energy during waste water treatment and produce electricity. Microbial fuel cells (MFCs) normally generate 0.4 -0.6 V and 3-50mA. This is enough to power a very low current motor. If

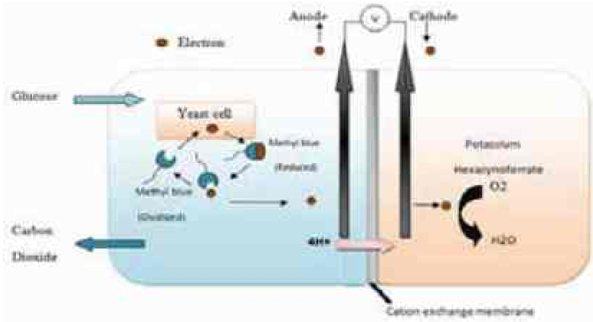

Figure 5: Production of electricity by yeast cells as fuel cells many cells are attached in series, it is possible to light a light-emitting diode (LED) (21).

CONCLUSION

As yeasts are the members of the fungi kingdom, unicellular eukaryotic microorganism. These organisms are able to metabolize glucose both in2the presence and absence of oxygen so they are producing CO and alcohol from carbohydrates which have vital importance in baking and beverages industries as well as used as biofuels. Recently yeasts have been used in microbial fuel cells to generate electricity and producing ethanol for the biofuel industry. There is a biological curiosity from decades that how the microbes produces the electricity. Now the researchers have predicted that the microbes produced electricity from organic matter which is used in watches and cameras as a power source as well as for bioreactors. The microbial fuel cells divert the electrons from the electron transport chain of the yeast and generate the electricity. Although it was reported that yeast cells produced electricity but optimization of different physical and chemical parameters are required to produce electricity at an industrial level from these fuel cells. So further research is required to explore the microbes able to act as fuel cells.

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