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# Electro Fermentation: A Novel Approach In Fermentation Technology - A Review

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**ABSTRACT**:- *Electro fermentation is a novel approach for increasing the production of microbial products. The article is a summary of the generally used fermenters and the moderations that can be done to improve. The technique of electro fermentation is well known, but not used to its fullest potentials. Thus the study shows what are the advantages of using electro fermentation.*

## INTRODUCTION

A bioreactor provides a controllable environment enabling the biological, biochemical and biomechanical requirements to manufacture engineered product. As the bioreactor aims to create a desired biological product, it is important to closely monitor the reaction parameters like internal and external mass transfer, heat transfer, Fluid velocity, shear stress etc.

Electro fermentation is a technique that optimizes production of microbial products by maintaining cellular redox balance using electrodes. There are major knowledge gaps, which makes the evaluation of the biotechnological potential very hard. The article is an approach to identify beneficial production processes for electro fermentation by elementary mode analysis. Since the fundamentals of electron transport between electrodes and microbes have not been fully uncovered yet, we propose different options and discuss their impact on biomass and product yields.

## BIOREACTOR DESIGN AND OPERATIONS

A good bioreactor design should address improved productivity, validation of desired parameters towards obtaining consistent and higherquality products in a cost effective manner. The design and mode of operation of a bioreactor depends on the production of organism, optimum conditions required for desired product formation, product value and its scale of production. The effective bioreactor is to control and positively influence the biological reaction and must prevent foreign contamination. The capital investment and operating cost are also important factors to be considered in bioreactor design. During the fermentation, monoseptic conditions, optimal mixing with low, uniform shear rates should be maintained throughout the process. A culture can be aerated by one, or a combination, of the following methods: surface aeration, direct sparging, indirect and/or membrane aeration, medium perfusion, increasing the partial pressure of oxygen and increasing the atmospheric pressure (Eibl R et.al, 2008).

## MASS TRANSFER

Adequate mass transfer (oxygen), heat transfer, clearly defined low condition and appropriate feeding of substrate avoiding under or overdosing would need to be maintained in a bioreactor. Proper supply of suspension of solids, sufficient substrate, salts for nutrition, vitamins etc. should be ensured with water availability and oxygen (for aerobic processes). Gas evolution product and by-product removal need to be taken care of. The attributes of a bioreactor should comply with design requirements such as sterilization, simple construction and measuring, process control devices, regulating techniques, scale-up, flexibility in operations, compatibility with upstream and downstream processes, antifoaming measures etc. are essential factors (Sharma K.R, 2012)

The basic features of a bioreactor include headspace volume, agitator system, oxygen delivery system, foam control, temperature & pH control system, sampling ports, cleaning and sterilization system and lines for charging & emptying the reactor (Alaghlavi, 2013). These are briefly described as follows:

## HEADSPACE VOLUME

The working volume of a bioreactor is the fraction of its total volume taken up by the medium, microbes, and gas bubbles and remaining volume is called the headspace. Generally, the working volume will be ~70-80% of the total reactor volume. This, however, depends on the rate of foam formation during the reactor (Van't R, 1991).

 

## AGITATION AND AERATION SYSTEM

Agitator system consists of an external power drive, impeller and the baffles for intense mixing and increased mass transfer rates through the bulk liquid and bubble boundary layers. It provides enough shear conditions required for breaking up of bubbles (srmuni.ac.in). Most microbial fermentations use a Rushton turbine type impeller.

Air delivery system consists of a compressor, inlet air, sterilization system, air sparger and exit air sterilization system to avoid contamination.

Foam control system is an essential element of bioreactor as excessive foam formation leads to blocked air exit filters and builds up pressure in the reactor.

## TEMPERATURE CONTROL

Temperature control system involves temperature probes, heat transfer system (jacket, coil). Heating is provided by electric heaters and steam generated in boilers and cooling is provided by cooling water produced by cooling towers or refrigerants such as ammonia.

## pH CONTROL

pH control system uses neutralizing agents to control pH; these should be non- corrosive, non-toxic to cells when diluted in the medium.Sodium carbonate is commonly used in small scale bioreactor.Sampling ports are used to inject nutrients, water, salts etc. in bioreactors and also for collecting samples. Cleaning and sterilization system is important to avoid contamination. Thermal sterilization by steam is preferred option for economical and large-scale sterilizations of equipment. Sterilization by chemical substances is generally preferred for heat-sensitive equipment. Sterilization is carried out by radiation by UV for surfaces and x-rays for liquids and also by membrane filters having uniform microspores and depth filters with glass wool (Van't R, 1991). Charging & emptying lines are used for input of reactants and withdrawal of products in the bioreactor.

## FROM MICROBIAL FUEL CELLS TO ELECTROFERMENTATION

A bioelectrochemical system (BES) is a type of bioreactor in which both biological and electrochemical processes can take place to generate electricity, hydrogen, or other products of interest. To differentiate the various types of BESs, different names have been given according to the product or service provided Initially, BES research mainly focused on the production of electricity in microbial fuel cells (MFCs). Over the years BESs have been used in many other applications including hydrogen production in microbial electrolysis cells (MECs), chemical production from CO2 reduction in microbial electro synthesis (MES) processes, and water desalination in microbial desalination cells (MDCs). The main bottleneck of all these processes is the requirement of high current densities because electrons are either the desired product (in MFCs) or are the main driving force in MECs including MDCs and MES

## OXIDATION-REDUCTIO POTENTIAL

The oxidation–reduction potential (ORP) of the fermentation medium, also known as the extracellular ORP, is a relevant parameter controlling the microbial metabolism . Indeed, a fermentation process corresponds to a cascade of oxidation and reduction reactions that must be kept in balance. Although these reactions are mostly thermodynamically favorable and spontaneous, they are also constrained by biological regulations within microorganisms and interspecies interactions in microbial communities. In the same way as pH is a measure of proton activity, the extracellular ORP corresponds to the activity of the electrons present in the medium. It is mainly affected by the temperature, the chemical composition of the medium, and the degree of reduction of the metabolites produced by fermentation. It can be easily measured with an ORP sensor located in the medium. The extracellular ORP is particularly important because it can subsequently affect the intracellular ORP through the reduced/ oxidized NAD (NADH/NAD+) balance. Intracellular ORP, representing the redox state inside a cell, can be estimated from the NADH/NAD+ ratio because of intracellular redox homeostasis. It is known to control gene expression and enzyme synthesis, thereby impacting on the whole metabolic process and can modify the metabolic pathways. Chemical control of the extracellular ORP has already been successfully implemented to improve the production of metabolites such as succinate or 1,3-propanediol (1,3-PDO). In this context, BESs might be used to modify the extracellular ORP by supplying or collecting energy in the form of an electric current through the use of electrodes, in a process known as electro-fermentation (EF).

 

## TRADITIONAL INDUSTRIAL FERMENTATIONS

Pure Microbial Cultures versus Enriched Microbiota

Because microorganisms are rarely present as single cultures in nature, it does not come as a surprise that traditional microbial processes, for example in food and beverage production, are based on microbiota, enriched by adequate procedures. However, with industrialization, the practice of microbiota-driven fermentations was gradually replaced with PMC fermentations which better control the microbial environment, growth, and product formation, and allow betterprocess prediction and control.

PMC processes target maximal product formation from a single substrate, usually a sugar. In rare cases, redox balance can be achieved via perfectly balanced fermentations in which all electron equivalents are recovered in a single product, facilitating downstream product separation and purification. More often than not, PMC fermentations generate arrays of metabolites because, even in a single microbial species, several pathways leading to different end-products exist, whereby the cell typically achieves homeostasis. Such processes would benefit from a further increase in selectivity for the target product and in redirecting carbon and electron flow away from biomass synthesis to product formation. This approach typically results in increased product titers, and near-maximal yields and productivities, thus leading to reduced separation costs and improved economics. In other cases (e.g., probiotics production), maximizing biomass yields could be the target, and induced oxidative conditions (at an anode) would improve ATP availability.

## CONCLUSION

Thermodynamics is not the sole limitation in fermentation production yields because most of the overall reactions that take place during fermentation are spontaneous. These limitations are mostly due to cellular regulation that maintains metabolism in redox balance. An electrode within the fermentation medium can externally induce a shift from balanced to unbalanced fermentation, theoretically leading to stoichiometric conversion of a substrate into a product of interest. Thus, EF presents the possibility of exceeding the theoretical maximum yields calculated for balanced fermentations, as shown in silicoby Kracke and Krömer (2014). According to this simulation, many metabolites of economic interest, such as succinic acid or lysine, could be produced at significantly higher yields in EF compared to classic fermentation, with very promising biotechnological output, and could be good candidates for full-scale application of EF. However, such bioelectrochemical conversions require a relatively high current flow to ensure good productivity, although this is less than the current consumed in MES processes, and therefore share similar limitations with most MFCs and MECs. As stressed by Harnisch et al., further fundamental research is needed and several technological hurdles remain to be overcome.

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