Membrane bioreactor concept with potential use in food biotechnology

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Received: 31 May 2011; Accepted: 25 August 2011

Abstract
Proposed membrane bioreactor is in line with the recent biotechnological developments through a series of specific characteristics: continuous flow operation, allows high pressure variations due to component geometry is modular, it can be adapted for large productions. Conditions of energy use is much lower due to pressure generated by the accumulation of gases produced by microorganisms. DFs from barley, triticale, oat and wheat. The obtained value of the regression coefficient was $r = 0.917$.

Keywords: self pressurized membrane bioreactor, yeast, modular membrane bioreactor

1. Introduction
Obtaining useful compounds using the living as a production system has experienced an unprecedented trend in recent years, biotechnology became key industries prove their worth by high returns characteristic of living matter. Nature provides an enormous variety of microorganisms if they are putting their productive potential technological benefits can provide an important and viable alternative to existing synthesis processes. This study proposes the use of metabolic activity of microorganisms for getting a high pressure generator. This is possible through the accumulation of gas resulting from metabolism in a closed environment. As a result, the pressure created can be used both as a driving force in membrane separation of the product of metabolism and as a potential energy gained for other processes that use pressure.

The yeasts have been extensively studied over time, being involved in important branches of food industry based on fermentation and wine-making technology, beer and bakery technology.

2. Materials and Method
Fluids are considered incompressible. However, P.M.B. Fernandes have found in conditions which apply hydraulic pressure above 50 MPa yeast cell morphology is affected, Some wild yeast survived at 220 MPa [1]. In conclusion, closed environment, can be easily obtained as the limit pressure, metabolic activity is not affected by the condition to eliminate the constant-products of metabolism and nutrient medium composition remains constant. Certainly one factor is the strength of the membranes involved in limiting the accumulation of pressure separation to the nominal level required by the manufacturer.

Given that the technically can design and build a bioreactor to mechanically to any pressure remain two variables to consider:

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1. Mechanical pressure resistance of the membrane ($P_M$)
2. The maximum pressure that the yeast cell has its own metabolic activity ($P_{\text{max yeast}}$).

Maximum final pressure generated by fermentation in bioreactor, $P_f$ is:

$$P_f = P_M \text{ if } P_M < P_{\text{max yeast}}$$  \hspace{1cm} (1)

If $P_f = P_{\text{max yeast}}$ and $P_{\text{max yeast}} < P_M$ membrane applied pressure is insufficient to allow separation.

Observing the condition of equation (1) we can say there is the possibility of using gas pressure generated during alcoholic fermentation for the purpose of getting high hydraulic pressure.

**Process description.** As stated above, we aim to obtain practically useful for both separation pressure product of metabolism found in the biomass - ethanol - and in order to build upon mechanical or hydraulic excess gas accumulated at the top of the bioreactor. Constant supply of nutrient media and culture, the culture of constant discharge and the separation constant dead maintain constant ethanol production of carbon dioxide and thus obtain the entire system working pressure. Also, always maintaining the optimal level of nutrient concentrations, metabolic activity during which a culture of microorganisms is used will be constant at the value obtained previously in the literature or by testing and allows adjustment of the exhaust flow yeast culture. Therefore, defining the tasks assigned it by adjusting the mass flow to achieve a balance in supply and exhaust.

Mass balance equation between supply and exhaust have the form:

$$M_{\text{nm}} + M_{\text{sc}} = M_{\text{dc}} + M_{\text{et}} + M_{\text{CO2}} + M_{\text{rpm}}$$ \hspace{1cm} (2)

where:
- $M_{\text{nm}}$ - nutrient medium mass [g];
- $M_{\text{sc}}$ - starter culture mass [g];
- $M_{\text{dc}}$ - mass of death culture [g];
- $M_{\text{et}}$ - separate ethanol mass [g];
- $M_{\text{CO2}}$ - mass of carbon dioxide released [g];
- $M_{\text{rpm}}$ - nutrient-poor medium mass [g].

Therefore, we can define the interdependence of mass flows in the system as follows:

$$\Phi_{\text{nm}} + \Phi_{\text{sc}} = \Phi_{\text{dc}} + \Phi_{\text{et}} + \Phi_{\text{CO2}} + \Phi_{\text{rpm}}$$ \hspace{1cm} (3)

where:
- $\Phi_{\text{nm}}$ - the nutrient medium supply flow [kg·m$^{-2}$·s$^{-1}$];
- $\Phi_{\text{sc}}$ - feeding the starter culture flow [kg·m$^{-2}$·s$^{-1}$];
- $\Phi_{\text{et}}$ - the exhaust death culture flow [kg·m$^{-2}$·s$^{-1}$];
- $\Phi_{\text{et}}$ - flow through separated ethanol membrane [kg·m$^{-2}$·s$^{-1}$];
- $\Phi_{\text{CO2}}$ - the exhaust stream of carbon dioxide released [kg·m$^{-2}$·s$^{-1}$];
- $\Phi_{\text{rpm}}$ - exhaust flow of nutrient-depleted medium [kg·m$^{-2}$·s$^{-1}$].

**Plant operation.** The installation is composed of membrane bioreactor directly connected to it, culture medium supply tank (T1), starter culture supply tank (T2), hydraulic drive system and a high pressure storage container of carbon dioxide or other gases [2] depending on hydraulic drive system design.

The main segment of the system is the membrane bioreactor. Operation in a closed system is ensured by valves located on the supply and drain paths thereof with which to regulate flows. It consists of the bioreactor itself directly coupled to the membrane separation module.

Starter culture membrane bioreactor supply is provided by the T1 buffer tank and the nutrient medium through the buffer tank T2. They are kept at working pressure of the membrane bioreactor with open positions that the valves V2 and V4, respectively closed position of valves V1 and V3. The circulation of culture, the medium and recycle of it into the system is provided by pumps P1 and P2 corresponding to T1 and T2 tanks.

In turn, buffer tanks, for maintain the constant pressure in bioreactor, are supplied with material up to maximum level at atmospheric pressure by closing valves V2 and V4 and opening valves V1 and V3. As a result, we have two circuits which supply a buffer tank at atmospheric pressure and the other, constantly feeding the bioreactor on its working pressure.

Feeding the bioreactor with starter culture is achieved by a uniform distribution in the vicinity of the sediment layer at the base of the machine. In this way at the top of the layer will be always deposited yeast with maximum metabolic activity that will cover the full yeast whose activity decreases as they move towards the drain at the bottom.
Figure 1. Block diagram for obtaining hydraulic pressure using biotechnological methods

Figure 2. Coupling in series of membrane bioreactors
Recycling the nutrient medium must be made over the dispenser order not to disrupt the yeast sedimentation. It will make successive passes in front of the membrane separation module that removes constant the dissolved ethanol using pervaporation membrane process [3] from nutritive medium using just the driving force the pressure of carbon dioxide resulted from fermentation.

Due to the limitation of useful work pressure of the membrane, obtaining a useful high and very high pressures can be done by a hydraulic pressure transformer. Consequently, the use of lower pressures to obtain a high pressure leads to a slowing of the overall process of obtaining energy. The solution to the problem mentioned above is the modular design of the bioreactor so that it will present a mass and thus high energy efficiency. In the figure below is illustrated the possibility of coupling in series of several membrane bioreactors, described above.

4. Conclusion

Obtain energy by the method presented in this work may have wide applicability in various fields such as energy and mechanical. Driving force by using pressure provided by bacterial metabolism resulting gases can also be used to separate and obtain useful compounds in food and pharmaceutical industries.

Modular configuration offers unlimited possibilities in terms of productivity.

Using energy from the two coupled, gas pressure and metabolism of ethanol by burning it produces a maximum energy efficiency.

It should be noted given the environmental aspect of CO₂ storage in the form of ice. If you are working at high pressure, 70 atm of carbon dioxide used can be saved by decompression in the form of dry ice and then use this form.

Acknowledgements

This research is supported by the European Social Fund, through the Human Resources Development Operational Programme 2007-2013, the project POSDRU/89/1.5/S/63258 Postdoc School for Zootechnical Biodiversity and Food Biotechnology based on Ecoeconomy and Bioeconomy Required by Ecosanogenesis.

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