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Effect of Draft Tube, its Height and Air Flow Rate on Growth Kinetics of Baker's yeast in Bubble Column

P.V. Chavda[1,*], P.B. Vanzara[2], R.A. Sengupta[3]
[1]Department of Biotechnology Engineering, V.V.P. Engineering College, Rajkot, Gujarat, India
[2]Department of Chemical Engineering, V.V.P. Engineering College, Rajkot, Gujarat, India
[3]Department of Chemical Engineering, M.S. University, Vadodara, Gujarat, India

Abstract

The significance of baker's yeast to meet the demand of food in a world of low agricultural production and rapidly increasing population makes its production extremely important. Choosing a proper type of bioreactor is a key step in achieving maximum yield. In the present work, batch cultivation of Saccharomyces cerevisiae was carried out in Rectangular Bubble Column (RBC) and Rectangular Draft Tube Bubble Column (RDTBC) with different draft tube height and their relative performances at varying air flow rates were evaluated.

Keywords: *Baker's yeast, Draft tube Bubble Column, Growth kinetics*

****Author for Correspondence*** E-mail: poojachavda2010@gmail.com

INTRODUCTION

A large part of the earth's population is malnourished, due to poverty and inadequate supply of food. Scientists are concerned whether the food supply can keep up with the world population increase, with the increasing demands for energy, the ratio of land area required for global food supply or production of bioenergy, the availability of raw materials, as well as the maintenance of wild biodiversity [1]. Therefore, the production of microbial biomass for food consumption is a major concern for the industry and the scientific community.

Saccharomyces cerevisiae biomass, mainly in the form of baker's yeast, represents the largest bulk production of any single-cell microorganism in the world. Several million tons of fresh baker's yeast cells are produced yearly for human food use [2] and other applications in food industries. The significance of baker's yeast to meet the demand of food in a world of low agricultural production and rapidly increasing population makes its production extremely important [3].

Choosing a proper type of bioreactor is a key step in achieving maximum yield. In the case of microbial cultivation, the fermentation environment and conditions provided by the bioreactor will have to match the specific needs of the microorganisms, in order to get higher productivity and specific growth rate [4]. The critical aspect of fermenter design is to satisfy the need of gas–liquid mass transfer. In this context, the bubble columns usually are the most economical bioreactors for baker's yeast production

Bubble columns and its variant the draft tube bubble columns are commonly used in aerobic fermentation processes because of their simple construction, lack of moving parts, effective mixing without high shear force, greater oxygen transfer efficiencies and ease of maintenance. In addition, in the bubble column reactor cells are not exposed to large variations in shear forces and thus are able to grow in a more stable physical environment. In contrast, in stirred tank reactors, high shear conditions will arise near the impeller, causing cell damage or cell stress and thus lowering productivity. Choosing a proper type of bioreactor is a key step in achieving maximum yield [5, 6].

In the present work, batch cultivation of *S. cerevisiae* was carried out in Rectangular Bubble Column (RBC) and Rectangular Draft Tube Bubble Column (RDTBC) with different draft tube height and their relative performances on growth kinetics of Baker's yeast was evaluated at varying air flow rates.

MATERIALS AND METHODS

Experimental Setup

In this investigation, RDTBC (Figure 1) fabricated with transparent acrylic sheets had geometrical specifications as mentioned in Table 1.

Table 1: *Specifications of RDTBC.*

Parts	Specifications m			
	W	D	H	T
Outer Column	0.107	0.04	1	0.005
Draft Tube – 1	0.08	0.01	0.7	0.004
Draft Tube – 2	0.08	0.01	0.6	0.004

W: Width, D: Depth, T: Thickness, H: Height

Primary Cultivation of Baker's Yeast

The *S. cerevisae* strain obtained from the local sources was revived on YEPD broth (10 kg/m^3 yeast extract, 10 kg/m^3 peptone, 20 kg/m^3 dextrose) in Erlenmeyer flask under shaking condition and was transferred on YEPD agar plates for selection of larger colonies which were then preserved on YEPD slants.

Inoculum Preparation

The strain was inoculated in a sterilized inoculum medium (sucrose from sugar cane juice 70 kg m^{-3}, $(NH_4)_2SO_4$ 10 kg m^{-3}, Yeast extract 5 kg m^{-3}, KH_2PO_4 2 kg m^{-3}, $MgSO_4$ 4 kg m^{-3}) at 100 rpm, 30°C for 24 hrs.

Production of Baker's Yeast

Batch cultivation was carried out in RBC, RDTBC with different heights of draft tubes and with 70 cm draft tube at different air flow rates. Sterilized production medium (composition same as inoculum media) having volume equivalent to 75 cm of static height was transferred aseptically into the sterilized fermenter and inoculated with 10% of inoculum.

Analytical Techniques

Measurement of Optical Density

Optical density of diluted samples was measured at 600 nm using spectrophotometer and was related to biomass concentration (x) using calibration curve of optical density versus biomass concentration. Finally, specific growth rate, μ was calculated by non-linear regression analysis using equation (1) [7].

$$x = x_0\, e^{\mu t} \quad (1)$$

Where, x_o is initial biomass.

Measurement of Sugar Depletion

Total sugar in % w/v was measured in cell free supernatant of the sample using Cole's method.

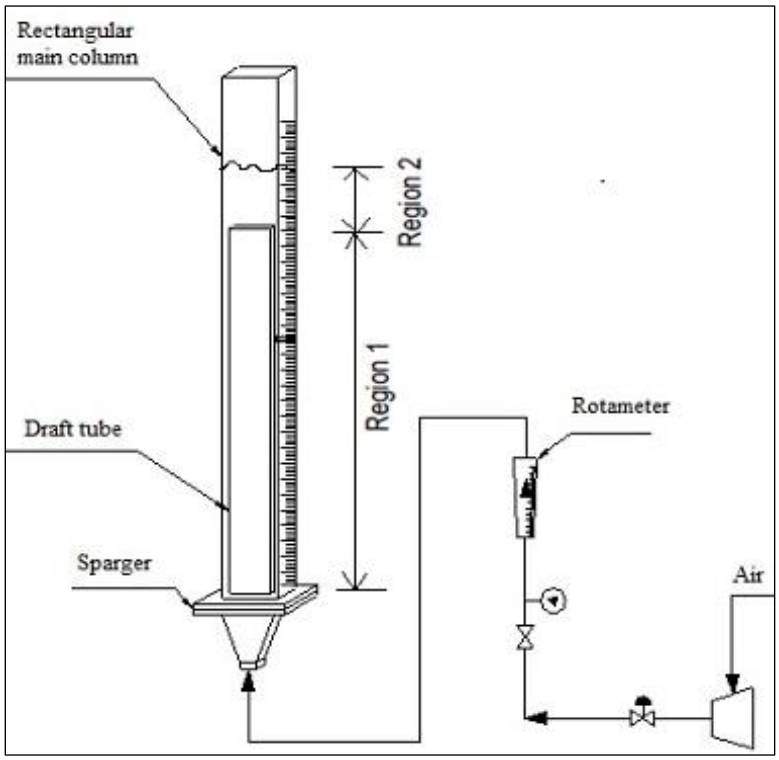

Fig. 1: *Schematic of Experimental Setup of RDTBC.*

RESULTS AND DISCUSSION

Effect of Draft Tube in a Bubble Column on Biomass Yield

RDTBC demonstrated relatively superior performance in terms of biomass production (Figure 2) and sugar depletion (Figure 3) due to the patterned gas flow in the device which induces a plug flow behavior in the gas as well as in the liquid. The values of μ in RDTBC were 0.467 h^{-1} which is higher compared to RBC having 0.401 h^{-1}, under similar conditions.

Effect of Draft Tube Height on Specific Growth Rate

Better performance was observed in RDTBC with 70 cm draft tube where the cell concentration increased by 20% (Figure 4) and sugar depletion curves diverged after 4 hours (Figure 5) which can be attributed to the superior hydrodynamic and mass transfer characteristics. The values of μ with 70 cm and 60 cm draft tube were 0.467 h^{-1} and 0.445 h^{-1} respectively. Consequently, only the 70 cm draft tube was used for further experimentation.

Using biomass concentration (Figure 6) and sugar depletion rate (Figure 7), the values of μ obtained were 0.454 h^{-1}, 0.467 h^{-1} and 0.472 h^{-1} for 2 LPM, 4 LPM and 6 LPM respectively. Increase in μ with air flow rate was obviously due to supply of more oxygen in the fermenter. However the cell production did not improve exceptionally due to oxygen transfer capability of the fermenter system.

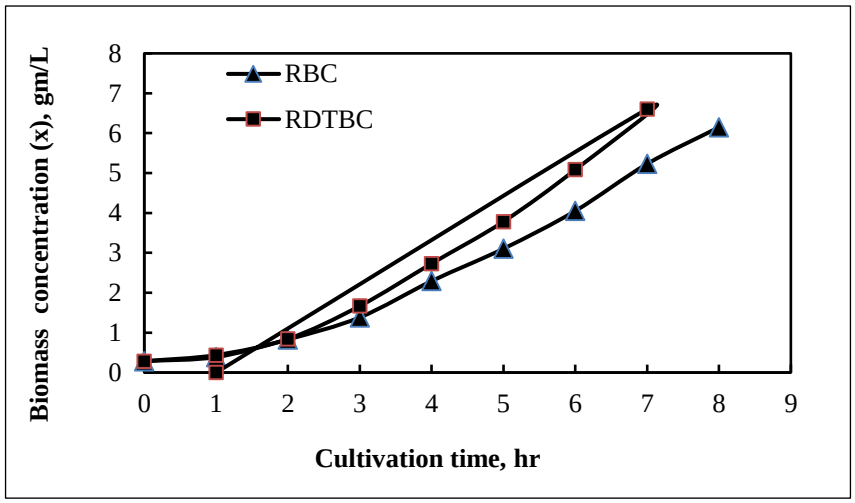

Fig. 2: *Effect of Draft Tube on Biomass Production.*

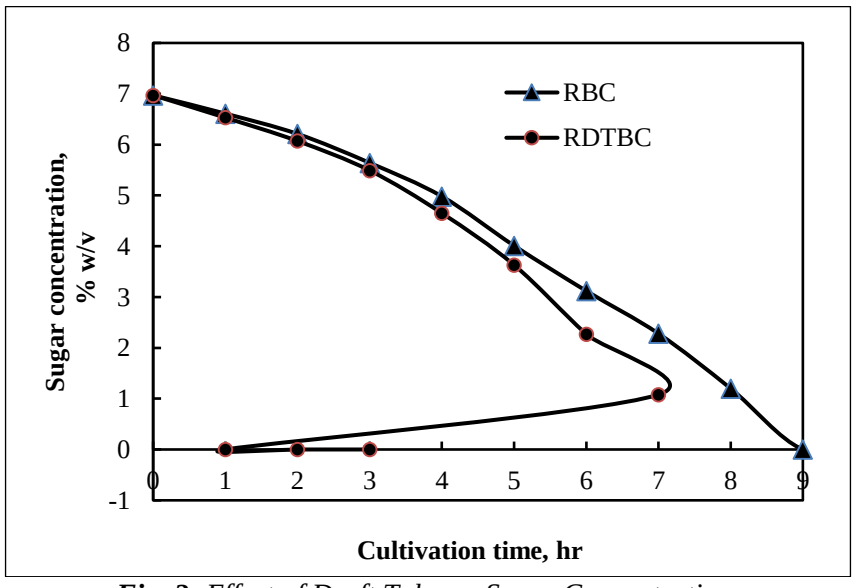

Fig. 3: *Effect of Draft Tube on Sugar Concentration.*

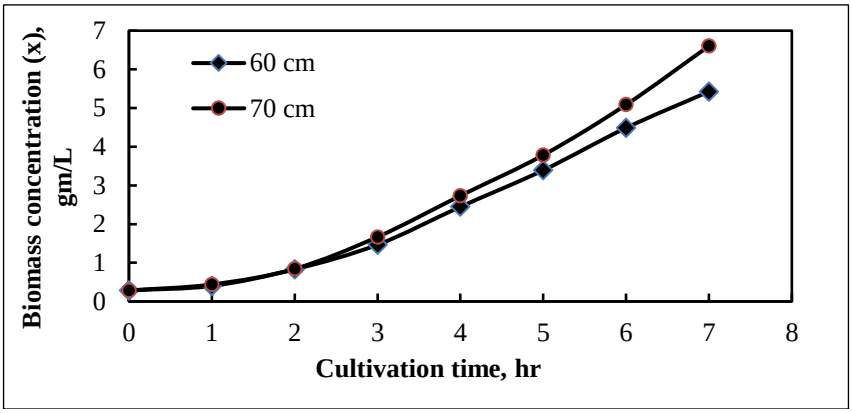

Fig. 4: *Effect of Draft Tube Height on Biomass Production.*

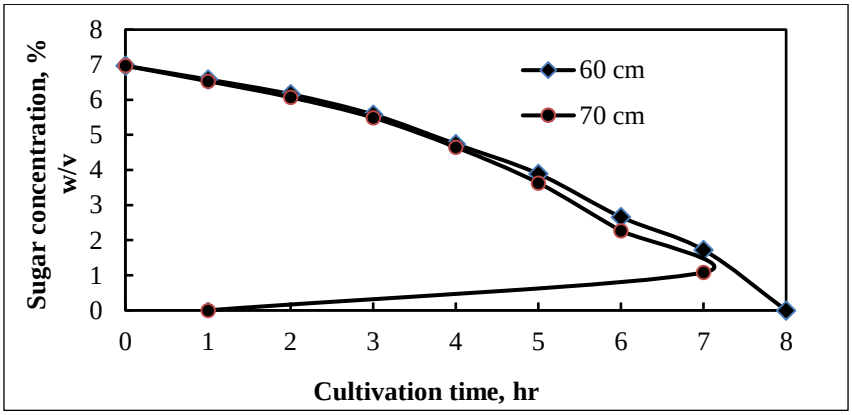

Fig. 5: *Effect of Draft Tube Height on Sugar Depletion.*

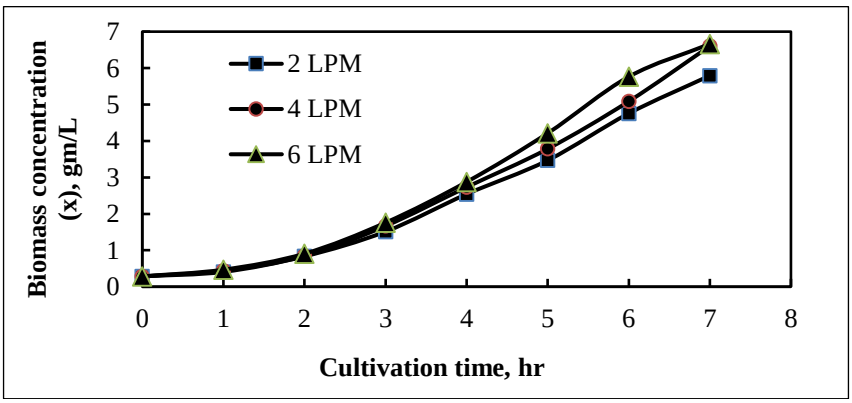

Fig. 6: *Effect of Air Flow Rate on Cell Concentration.*

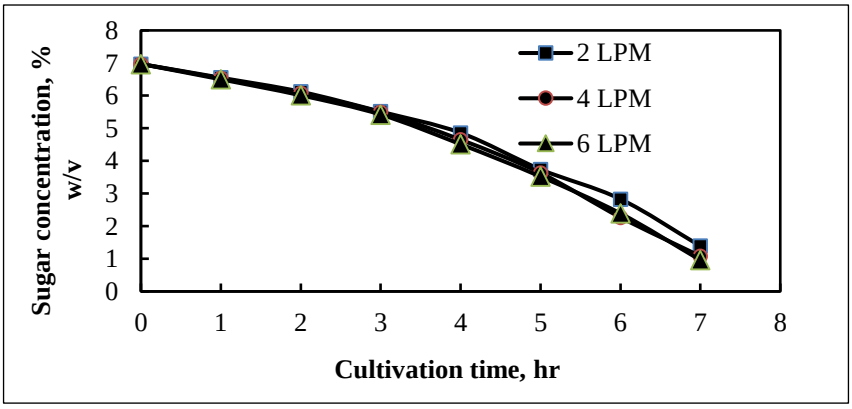

Fig. 7: *Effect of Air Flow Rate on Sugar Depletion.*

CONCLUSIONS

The conclusions drawn from this investigation are summarized as follows:

Draft tube bubble column operated with specified geometrical and operational conditions was found to be an efficient bioreactor for baker's yeast production due to its superior hydrodynamic and mass transfer characteristics. Also the DTBC approached the behaviour of bubble column in shorter draft tube device.

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