Development of Baker's Yeast Production on a Commercial Scale

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Development of baker's yeast production on a commercial scale has been conducted through fundamental studies in 2 l and 150 l fermenters. Composition of production media and fermentation protocol that yield good quality and high concentration of yeast above 60 g/l, and also the growth pattern in each stage of fed-batch fermentation were obtained from the experimental data of the 2 l fermenter. Based upon these results, yeasts were cultured in the 150 l fermenter to investigate the scale-up effect. Furthermore, energy consumption in agitation and air supply for the sufficiently large value of k_La required in the 150 l fermenter were computed. This data will be crucial in the design of a 1500 l fermenter that is planned for the next phase of this study. In the 150 l fermenter, pH, temperature, dissolved oxygen, the content of exit gases such as O_2 and CO_2 were monitored in situ. Feed rate of molasses was controlled by RQ around the value of 1. Since RQ correlated with the production of ethanol, this measure suppressed the catabolite repression effectively.

Introduction

Almost all of baker's yeast utilized in Thailand is presently imported. Due to the rapid growth of the bakery and related industries, its demands are increasing sharply toward a breakeven point for economic investment of the yeast production plant in the country. This project has thus been initiated to carry on research and development work for the baker's yeast production process that could be disseminated to local entrepreneurs in a near future.

Although, the baker's yeast production process is already existed and quite well-known, the practical technique and know-how are not readily available freely, and thus should be developed locally to avoid buying expensive technology from abroad. Furthermore experience and capability developed can then be applied to other similar R&D works. The entire work comprises three major steps: a survey/analysis of available data and experimental studies using small-scale laboratory fermenters; a scale-up study in a 150-liter fermenter; and finally a study and trial run on a pilot plant with the baker's yeast production capacity of approximately 1 ton per month. This will thus provide the technology and know-how for scaling up to a full-size industrial process.

Materials and Methods

Microorganisms

Baker's yeast, *Saccharomyces cerevisiae* were selected from palmyra palm by identifying pure yeast strain present in this plant. The selection was based on the ability of the yeast to produce CO_2 gas in Durham tube.

Media and Reagents

Molasses was obtained from Rajburi Sugar Factory. Commercial grade urea and mineral salts were used in pilot scale experiments. Batch culture medium was composed of diluted molasses which had total sugar concentration (T.S.) of 80 g/l and 1 g/l $(NH_4)_2SO_4$. In fed-batch culture, feed stock was composed of diluted molasses (300-500 g/l T.S.), urea (0.05 g/g T.S.), KH_2PO_4 (0.03 g/g T.S.), MgSO4.7H2O (0.025 g/g T.S). Initial broth has the same component but is smaller in concentration : diluted molasses (reducing sugar concentration of 5 g/l); 1.5 g/l urea; 0.5 g/l KH_2PO_4; 0.5 g/l $MgSO_4.7H_2O$.

Culture Condition and Methods

Yeast were transferred from slant to culture medium in shake flask to provide growth in batch culture. After 18 hours the medium was transferred to fermenter in which the fed batch fermentation was started. For fermentation in 150 l fermenter a second batch culture in a 30 l fermenter was required to obtained a proper amount of inoculum.

Temperature of fermentation was maintain at 30°C. pH was controlled at 4.5 by addition of H_2SO_4 solution.

Analytical Methods and Data Acquisition System

Reducing sugar was determined by Somogyi and Nelson method. Total sugar was determined by using phenol method. Ethanol was analyzed by gas

chromatograph. Cell dry weight was obtained by incubating yeast in hot air oven at 80°C for 24 hours.

The 2 l fermenter was a standard laboratory unit of Tokyo Rikakikai Model M-100 (Mini Jarfermenter). The pilot scale fermentation system consisting of 150 l fermenter completed with auxiliaries, piping and aseptic system and computerized monitoring/analyzing instruments and control system was designed and developed at our laboratory at KMITT. Continuous discharge type Westfalia separator (Model NA-07-076) was used to concentrate yeast from the fermentation broth.

Results and Discussion

Molasses is used as a raw material for our baker's yeast production process, for it is presently the cheapest source of sugar although its color would cause some difficulty in treating the wastewater.

Two-stage fed batch fermentation was used to produce baker's yeast at high cell density. In the first stage, yeast were grown to the concentration of about 20 g/l, then were washed and concentrated by the continuous centrifugal separator. These refreshed yeast were used to inoculate the second fermentation step so that high cell concentration above 60 g/l was obtained. This procedure was first developed and tested in a 2 l laboratory fermenter in which manually controlled step wise molasses feed rate was used to maintain reducing sugar and ethanol concentrations at minimum levels. An example of the results for the two stage fermentation were given in Fig. 1 and 2. The reducing sugar and ethanol concentrations were controlled to be at a low level of about 10 and 15 g/l respectively. The average yield and productivity obtained were in the range of 0.4 and 3.5 g/l/hr respectively, pH and temperature were maintained at 4.5 and 30°C respectively and dissolved oxygen was above 20% sat. The yeast activity for making dough and bread was tested and the results were satisfactory and comparable with those of commercial yeast.

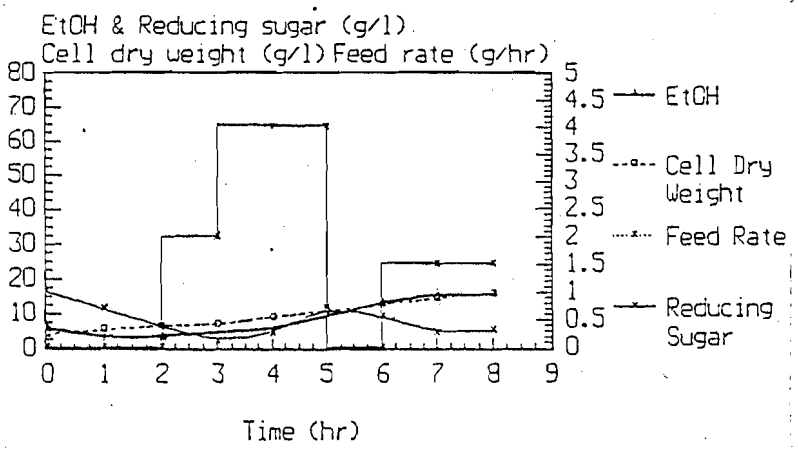

Fig.1 Growth and feed pattern of yeast culture in 2 l fermenter (stage 1)

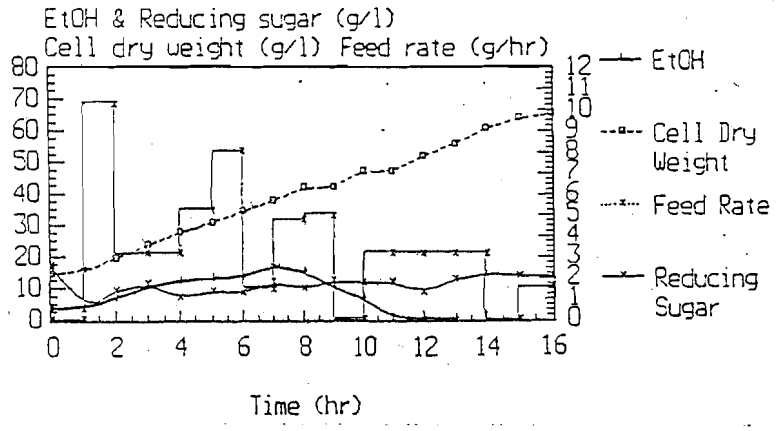

Fig.2 Growth and feed pattern of yeast culture in 2 l fermenter (stage 2)

The fermentation system was then scaled up to a 150 l pilot scale in order to confirm the results and to obtain other necessary practical design and operating data. This system is completely installed with auxiliary system required for sterilization and aseptic operations as well as monitoring/analyzing instrument interfaced to a microcomputer system capable of recording data, calculating parameters and results, and controlling the fermentation process (Fig. 3 and 4). The result of manually controlled yeast culture in this fermenter is shown in Fig. 5 which indicates that high yeast concentration can be produced by the fed batch process. The reducing sugar level could be controlled to be at low level in the first period of fermentation then it was gradually increased to 14 g/l at the end. pH could be maintained at around 4.5 but dissolved oxygen was always lower than 20% of saturation value. the yield and productivity were in the range of 0.4 and 3.9 g/l/hr.

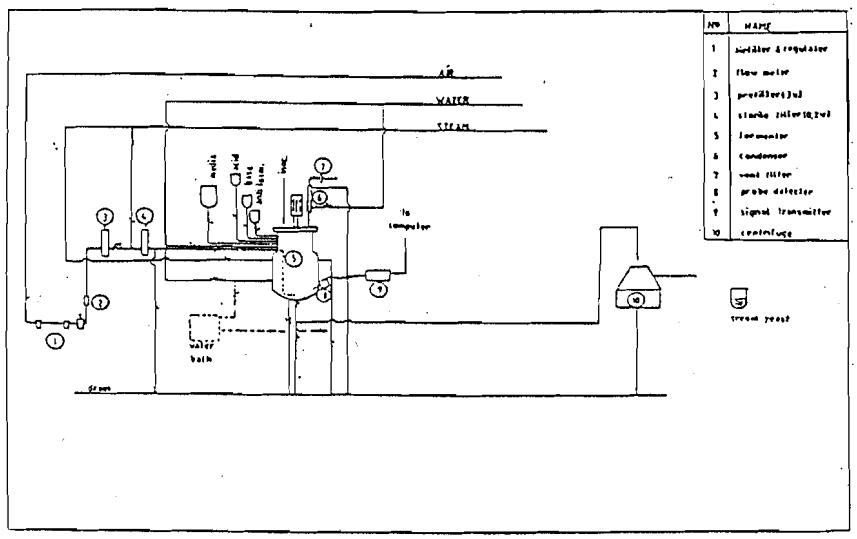

Fig.3 Diagram of 150 l fermenter system

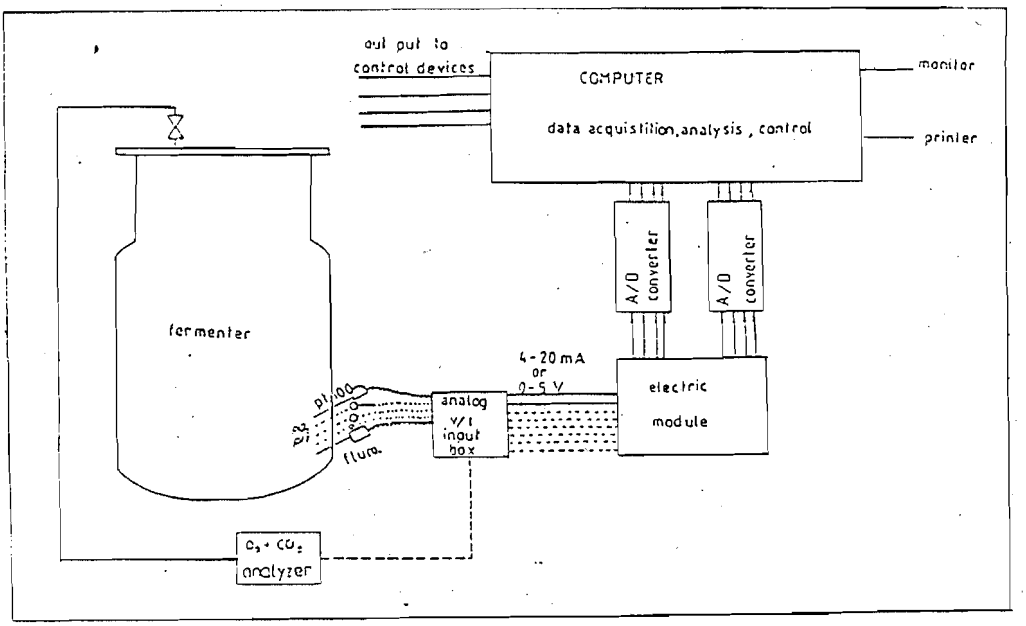

Fig.4 Data acquisition, analysis and control system of 150 l fermenter

Other design data were also collected for scaling up purpose. From the torque, agitation speed, and air supply rate measured during the fermentation period, the maximum power consumption (6 hp/m^3) and the maximum k_La (about 900 hr^{-1}) were calculated corresponding to the maximum oxygen uptake rate required at the maximum growth rate. These data are required for designing and scaling up of actual scale production plant.

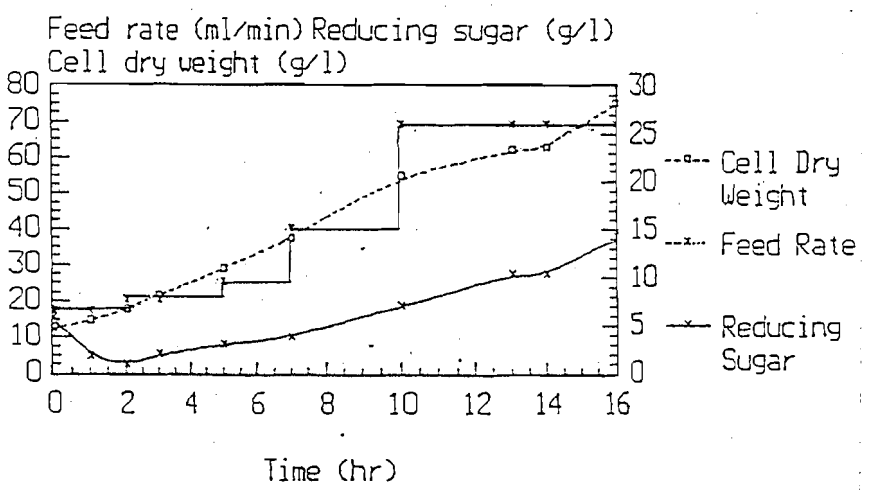

Fig.5 Growth and feed pattern of yeast culture in 150 l fermenter (stage 2)

Furthermore the 150 l fermentation system was used to develop and study a computer control feed program in order to maximize yeast production. To prevent sugar accumulation which lead to ethanol formation, a feed back proportional control was used to maintain the respiratory quotient at about 1. The predetermined specific growth rate was used to predict the molasses feed rate required throughout the fermentation period. The results are given in Fig. 6 and 7.

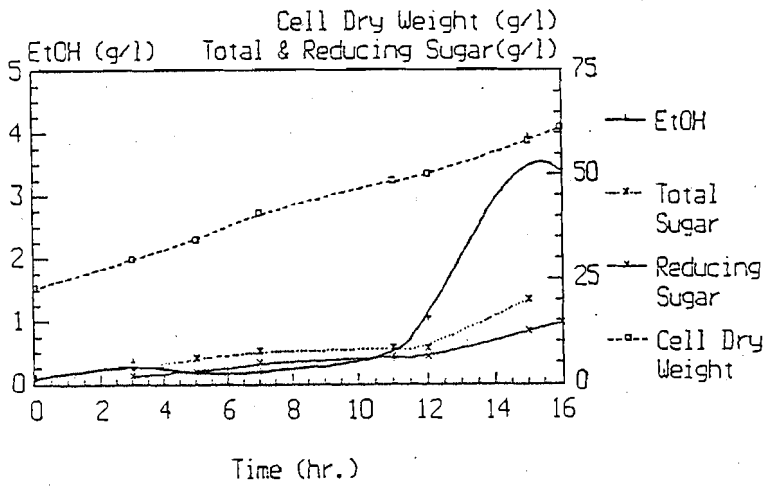

Fig.6 Growth pattern of yeast culture in 150 l fermenter using RQ control (stage 2)

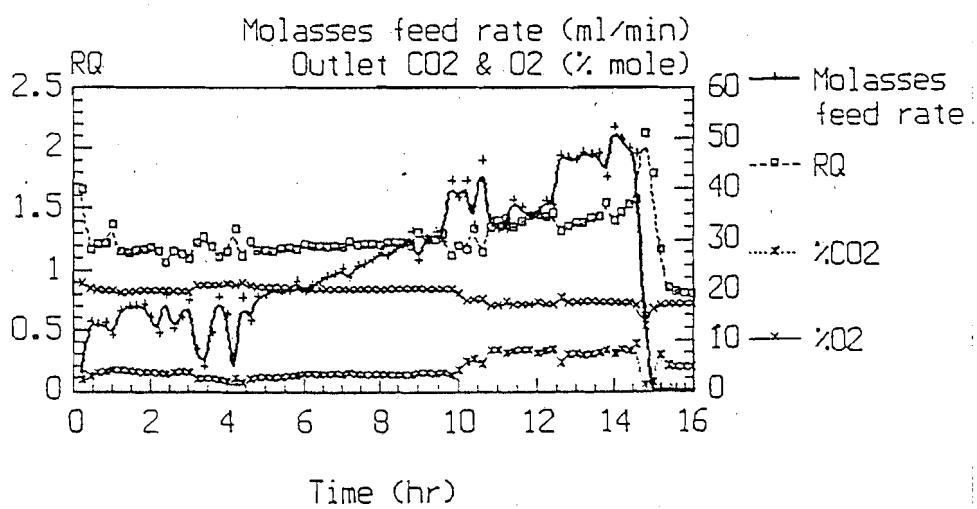

Fig.7 Feed rate and RQ during fermentation in 150 l fermenter using RQ control (stage 2)

The computer control of feed rate was able to prevent ethanol formation for almost of the entire fermentation period but was not effective in the last period in which the preset specific growth rate may not be applicable. To solve this problem, the value of specific growth rate for the last period should be gradually reduced so that the real'sugar requirement of yeast can be accurately predicted. pH was maintained around 4.5 but dissolved oxygen was lower than 20% sat. The productivity was 3 g/l/hr and yield was about 0.4.

The 150 l system is presently run to improve and gather further design and control data as well as to produce baker's yeast for actual market trial in selected bakeries.

The final stage of the process development for the baker's yeast production is to design, build, and operate a prototype plant with about 1 ton per month capacity. This will confirm scaling up procedure and data and provide actual information concerning operating conditions, data, problems, etc that make it possible to design and scale up to a commercial scale with confidence. Presently, the plant has already been designed, fabricated, and being installed. It is expected to be completed and commissioned in a near future. The production scheme was developed as shown in Fig. 8. The plant components, equipment, and the specifications are listed in Table 1 and 2. Fig. 9 shows the piping and instrument diagram of the process. After commissioning, the prototype plant will be used to study in a large scale production to improve equipment efficiency and finalize production methods. Finally, the yeast produced from the plant will be used for market trial, and the economic feasibility will be confirmed before the dissemination of the technology.

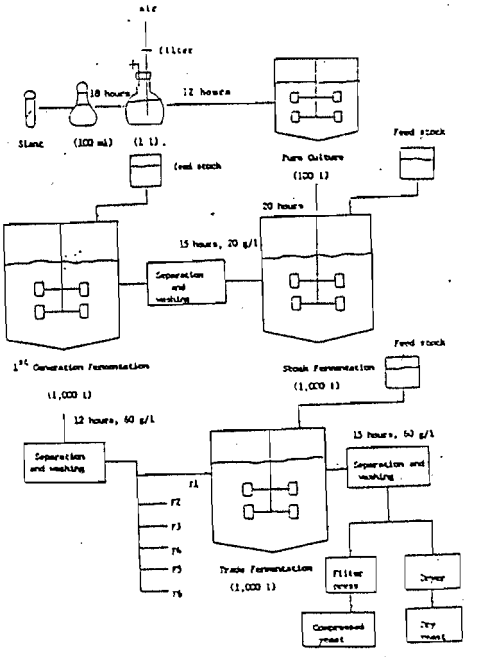

Fig.8 Flow diagram of baker's yeast prodduction in pilot plant

Table 1 Capacity of various tanks used for baker's yeast production in pilot plant

Tank	Working vol (l)	Total vol (l)
1. Fermenter	1000	1500
2. Molasses store tank	3	5
3. Dilution tank	600	1000
4. Molasses feed tank	600	1000
5. Hot water tank	300	500
6. Yeast cream tank	300	500
7. Acid tank	40	60
8. Alkali tank	40	60
9. Antifoam tank	15	30
10. Urea tank	30	50
11. Cooling water tank	1200	1600

Table 2 Capacity of equipments in pilot plant

Equipment	Capacity
Centrifuge	1000 l/hr
Filter press	100 l/hr
Chiller	148300 Btu/hr
Cooling tower	40 GPM (37°C-32°C)
Air Compressor	4000 l/min
Molasses pump	3 m^3/hr
Hot water pump	6 m^3/hr
Tap water pump	6 m^3/hr
Molasses feed pump	50 l/hr
Urea feed pump	10 l/hr
Acid pump	3 l/hr
Alkali pump	3 l/hr
Antifoam pump	3 l/hr
Yeast cream pump	2 m^3/hr
Chiller pump	15 m^3/hr
Cooling water pump	15 m^3/hr
Cooling tower pump	15 m^3/hr

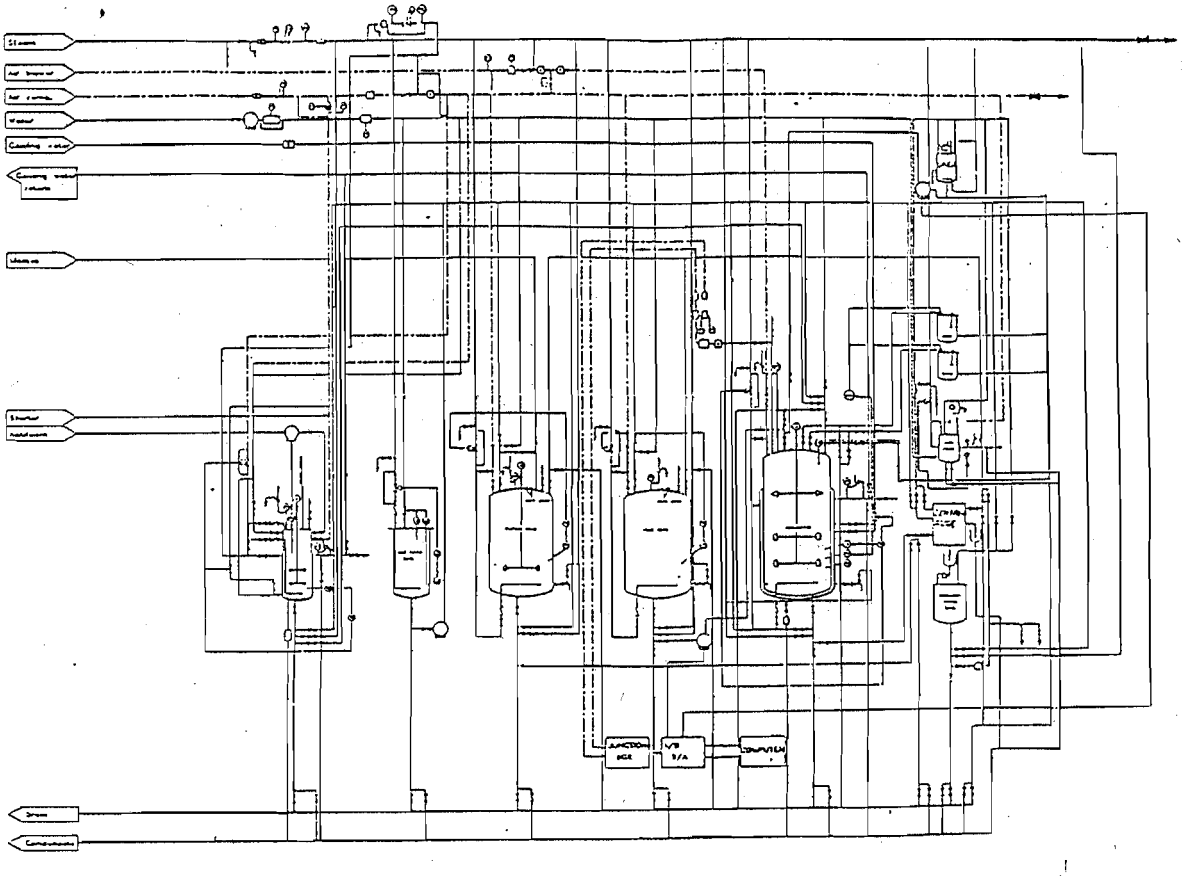

Fig.9 Piping and Instrument diagram of baker's yeast pilot plant

Acknowledgements

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