FUEL ALCOHOL

FUEL ALCOHOL: CONTINUOUS FERMENTATION

Before discussing continuous fermentation techniques, we should first examine the relative advantages and disadvantages of continuous versus batch fermentation.

Continuous Fermentation

Advantages

1. Rapid fermentation due to a high concentration of yeast cells.
2. Less expensive—less labor intensive; requires less capital cost for fermentation tanks.
3. Increases productivity (when operating correctly).
4. Adaptable to an automatic control system.

Disadvantages

1. Not a commercially "proven" process.
2. Requires a continuous sugar feed.
3. Buildup of contaminants in the fermenter requires periodic cleaning.
4. Not easily controlled or monitored.
5. Feedstock wastage due to "problems."

Batch Fermentation

Advantages

1. Commercially "proven" and used technology.
2. Results are reproducible—batch to batch.
3. Easy to control (normally only pH and temperature).
4. Preventative cleaning minimizes "bad batches."
5. Only one batch goes bad at a time.

Disadvantages

1. Requires a larger capital investment in tanks.
2. Requires more labor.
3. Production schedules must be arranged around a 48- to 72-hour fermentation time.

Continuous fermentation has often been referred to as both a "blessing" and a "plague" for the fermentation industry. Numerous different approaches and techniques have been studied and analyzed. Yet there is still no rational basis for fermentation design, which awaits a fundamental understanding of the problems posed. What follows is a brief description of several of these approaches.

Semi-Continuous Fermenter

This is a halfway point between batch and continuous fermentation which employs the use of six to ten tanks. The first tank is inoculated with twice the usual amount of yeast, then areated. In an oxygen-rich atmosphere the yeast cells multiply vigorously. After the initial charge of air is used up, active fermentation is allowed to continue for 18-48 hours. Then half the contents of the first tank is pumped into the second tank and each tank is topped off with more mash. Fermentation is allowed to come to completion in the first tank. After 24 hours half the second tank is pumped into the third tank and again each tank is topped off. The process continues until half the material from the last tank is pumped into the first tank, in which fermentation has been completed in the meantime, and the tank emptied and cleaned. The

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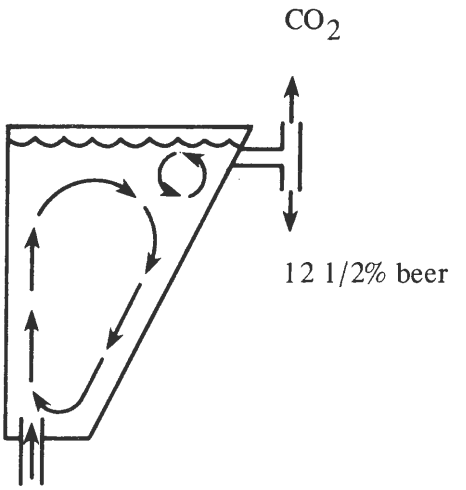
obvious advantages to a semi-continuous mode are the ability to stop quickly if problems occur, and the opportunity to clean and sterilize the receiving tanks. Disadvantages are the need for multiple tanks and pumping equipment.

Continuous Fermenter

The simplest form of a continuous fermenter is a single tank with the ability to remove excess ethanol and yeast cells. Several different techniques have been employed to accomplish this. The most popular is the Wick fermenter which will be described in detail later. Another technique is to create a vacuum in the fermenter which reduces the boiling point of the ethanol to where both distillation and fermentation can take place simultaneously. Using a yeast strain that tolerates relatively high temperatures (95°-110°F) and a modest vacuum, the ethanol concentration of the wort can be kept to a minimum, resulting in vigorous fermentation. The difficulties encountered are in waste product buildup and in controlling the yeast cell population.

The Wick continuous fermenter was designed by Emil Wick of USDA's Western Regional Research Center at Berkeley, California. The fermenter is shaped like a wedge, standing on its point. Raw material containing 20% sugar is pumped in at the bottom and circulates gently in the fermenter because of the carbon dioxide bubbles and the pumping action. The yeast cells tend to circulate with the large mass of rotating liquid, going to the top with the bubbles, then flowing down the slanted side back to the bottom where fresh high-sugar liquid is pumped in. The products come off the shallow side of the top through a "T": the carbon dioxide comes out of the top of the "T" and the ethanol comes out of the side of the "T." The pumping rate of the mash should not exceed one-fourth the container capacity per hour. Wick reports that his fermenter will produce its own volume of 12 1/2% beer every four hours.



The Wick Continuous Fermenter

Modified Tank Fermenter

A simple modification of the single tank fermenter is using two tanks. The first tank is where aerobic propagation of the yeast takes place and the second tank is where anaerobic fermentation occurs. The sugar solution is pumped continuously into the first tank which overflows to the second tank, which overflows to a yeast separator, and sends the liquid to a product stream. The advantage of this system is a high yeast concentration which results in a rapid fermentation. Disadvantages are the need for multiple tanks and the loss of product to yeast propagation.

Tower Fermenter

A tower fermenter is a cylindrical tower in which a high yeast concentration is kept in suspension by the upward flow of gas bubbles and liquid. The sugar solution is pumped in at the base, and is fermented as it flows upward and out the top.

A modification of this is to immobilize the yeast cells in some way and flow the sugar solution

past them. This could be done in a tower format or in a thin film.

In conclusion, it is difficult, given the state of continuous fermentation technology and experience, to state which if any technique is applicable to ethanol production. It is necessary to consider and evaluate all the advantages and disadvantages and their economic impact on production.

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