ASPECTS OF FERMENTATION

AND DISTILLATION

IN

ETHANOL PRODUCTION

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by

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Corrections

Page	Line	Replace	With
4	22		insert (Othmer, 1981)
10	10	10 %	10 v/v %
11	11	operation	operating
20	2	insoluble	soluble
24	21	pthalate	phthalate
35	equation 1.19	$\frac{dY_i}{dy}$	$\frac{dY_j}{dy}$
42	16	directionally	directly
64	Figure 2.1	fermenter	fermentor
69	9	calibrated	graduated
70	21	$\pm$ 0.1^{o}C	$\pm$ 0.125^{0}C
80	Figure 3.2	Iron Sand Concentration	Iron Sand Concentration (as received)
81	Table 3.1, for stainless steel	0.26 mm/s 0.19 mm/s	2.6 mm/s 1.9 mm/s
84	Figure 3.4,ln 2	initial	nominal initial
91	Figure 3.8,ln 2	0.2 g/l ..... 0.5 g/l	0.5 g/l ..... 0.2 g/l
184	12	Reynolds Number	length Reynolds Number

ABSTRACT

The fermentation of sugars from biomass to produce liquid fuels is receiving widespread attention as a renewable source of energy. For such processes to become competitive with current alternatives, technology must be improved to increase the efficiency and productivity of the operation. Using ethanol fermentation by *Saccharomyces cerevisiae* yeast as a model system, two aspects of the process were considered in detail.

The first aspect concerned the use of cell recycle in a continuous fermentation. A new technique was developed for the rapid settling of yeast cells in the fermentation medium and involved the addition of dense, inert particles to a yeast suspension at pH 4.5, followed by a rapid change in pH to 8.0 - 9.0. Large flocs formed immediately and settled rapidly, leaving a clear supernatant. Separations of 99.9% were possible, even at yeast concentrations of 50 g/l (dry weight) and increases in settling rate of up to 1600 fold were observed. When the pH was returned to 4.5, the flocs were destroyed.

Seeded settling at constant pH was possible although the flocs were smaller, the settling rates were lower and significantly more seed was required. Flocculation was also found to be influenced to a greater extent by certain components in solution.

Nickel powder was used extensively in these experiments although several other materials were tested, with ground iron sand showing potential for application on a larger scale.

The pH switching technique for seeded settling was used to recycle

yeast cells in a semi-continuous fermentation. Application of the technique to this and similar systems is discussed.

The factors affecting yeast/inert powder flocculation is discussed and a model is proposed to explain the observed experimental behaviour for flocculation, both at constant pH and with rapid pH switching.

The second aspect of ethanol production considered in this thesis was the distillation stage. Equipment and techniques were developed to obtain basic mass transfer information in binary or multi-component systems. A new design of evaporation cell was used to measure the evaporation of ethanol and water mixtures into an air stream in a wind tunnel. This enabled the effect of liquid concentration on evaporation rate to be studied dynamically from batch tests. Radiochemical labelling was used to measure liquid concentrations and proved to be a relatively simple, rapid and precise analytical technique. Coupled with the direct measurement of liquid displacement, precise information on the evaporation loss of both ethanol and water components was obtained.

The pure component evaporation data agreed well with literature correlations and, for the binary liquid mixtures, good agreement was found between the experimentally determined mass transfer flux ratios and those predicted from Gilliland's solution to the multi-component gas diffusion equations.

The velocity dependence of the overall mass transfer coefficients enabled estimates to be made of the distribution of diffusional resistance between the gas and liquid phases.

For the ethanol-water system diffusion was gas film controlled and the overall mass transfer driving forces could best be represented in terms of vapour concentration.

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