OPTIMISATION OF INDUSTRIAL WHEY ETHANOL FERMENTATION PROCESS

by

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ABSTRACT

Ethanol is produced from whey at four distilleries in New Zealand. The Anchor Ethanol Co. distillery at Tirau was established in the 1981 and employs a continuous fermentation process. The aim of this work was to characterise the production yeast employed at this plant and to evaluate possible methods by which this commercial fermentation could be optimised.

Fermentation and assimilation tests confirmed the production yeast (strain Fi) as a strain of *K. marxianus*. The kinetics of ethanol fermentation of lactic acid casein whey serum were examined in continuous culture. The data were best fitted with a Langmuir plot and gave μ_{max} of 0.21 h^{-1} and K_s of 4.94 g/l. A maximum ethanol productivity of 1.27 g/l.h was achieved at a dilution rate of 0.10 h^{-1}. Experiments were conducted in shake flask cultures using semi-synthetic media and sulphuric acid casein whey permeate to investigate the effect of lactate on the fermentation performance of the yeast. Lactic acid is present naturally in lactic acid casein whey at a concentration of about 7 g/l and may be present at concentrations up to 30 g/l, if there is gross bacterial contamination or if the whey were concentrated. Lactate added up to 30 g/l in the presence of 50 or 100 g/l lactose had no effect on the ethanol production rate or yield, although the biomass yield was slightly reduced.

The yeast strain Fi was grown aerobically on the slops, the liquid remaining after ethanol distillation, which contains 7 g/l lactic acid as the major component. The biomass produced was used as an inoculum for the whey ethanolic fermentation and performed as well in this role as an inoculum pre-grown on lactic whey. Continuous culture of the yeast grown aerobically on slops was again best fitted with Langmuir plot to give μ_{max} of 0.30 h^{-1} and K_s of 0.32 g/l.

The yeast by-product from whey ethanolic fermentation was autolysed in a batch or continuous systems. On the basis of α-aminonitrogen release, yeast grown aerobically autolysed more readily than yeast grown anaerobically. The optimum autolysis condition of 55°C and pH 5.5 for anaerobically grown yeast was established on the basis of the α-aminonitrogen released after 6 h and the stimulatory effect of the lysate on the ethanol fermentation. Continuous autolysis was conducted successfully and the autolysate produced at dilution rate of 0.10 h^{-1} gave the highest stimulatory effect on the ethanol fermentation. Improvements in the ethanol productivity and production rate of 10-20 % were observed following the addition of autolysate. A direct relationship between the α-AN utilized and the ethanol volumetric productivity was established.

Overall this work has identified three potential areas for process intensification:

1. An increase in the operating dilution rate from the current value of 0.07 h^{-1} to the optimum of 0.10 h^{-1} will lead to an approximately 30% increase in throughput.
2. The use of distillation slops containing lactic acid as a growth medium for inoculum production. This will enable an extra of 62,000 kg of ethanol per year to be produced from the lactose currently used for growth of the inoculum.
3. The addition of a continuously produced autolysate to the ethanolic fermentation will improve the fermentation rate and allow the whey throughput to be increased further.

Each of these options could be implemented at the commercial plant with a payback period of one year or less.

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ABBREVIATIONS

α-AN	α-aminonitrogen
°C	Degree Celcius
D	Dilution rate
EtOH	Ethanol
g	Gram(s)
h	Hour(s)
K_s	Saturation constant
l	Litre(s)
LACWP	Lactic acid casein whey permeate
LACWS	Lactic acid casein whey permeate
M	Molar
ml	Millitre(s)
nm	Nanometre
q_s	Specific substrate uptake rate
rpm	Revolutions per minute
SACWP	Sulphuric acid casein whey permeate
S	Residual substrate
µl	Microlitre(s)
µm	Micrometre(s)
μ_{max}	Maximum specific growth rate
% (w/v)	Percentage weight by volume
% (v/v)	Percentage volume by volume
% (w/w)	Percentage weight by weight
YEP	Yeast Extract Peptone
YEPL	Yeast Extract Peptone Lactose
YEPLL	Yeast Extract Peptone Lactose Lactate