BIOLOGICAL HYDROGEN PRODUCTION USING AN ANAEROBIC FLUIDISED BED BIOREACTOR

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DECALARATION

I declare that this is my own, unaided work. It is being submitted for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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LIAM JED THOMPSON

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PREFACE

Some aspects of the work conducted for this dissertation have or will be presented as papers or posters elsewhere.

CHAPTER 1A

Thompson, L. J., Gray, V. M., Lindsay, D., von Holy, A. (submitted). Anaerobic Fluidised Bed Reactors – A Review in the South African Context. South African Journal of Science.

CHAPTER 2B

Thompson, L. J., Gray, V. M., Lindsay, D., von Holy, A. (2004). Scanning Electron Microscopy Study of Biofilm Formation Using Different C:N:P Ratios. Microscopy Society of Southern Africa

ABSTRACT

The production of H_2 was monitored using an automated, semi-continuously fed anaerobic fluidised bed bioreactor containing 2 facultatively anaerobic bacteria, *Enterobacter cloacae* (*E. cloacae* Ecl) and *Citrobacter freundii* (*C. freundii* Cf1). Shake flask tests using Endo formulation with modified C:N:P ratios, showed that a 334:28:5.6 ratio gave the highest attached counts of *E. cloacae* Ecl and *C. freundii* Cf1 in both single and binary species biofilms grown on granular activated carbon. Once the reactor had achieved steady state after 30 days using the modified C:N:P ratio, pH, redox potential, temperature, volatile fatty acids and the H_2 production rate were monitored. The H_2 production rate of 95 mmol H_2 / (l x h) compared favourably with previous studies. Bacterial biofilms counts for both *E. cloacae* Ecl and *C. freundii* Cf1 remained high around 9.0 log cfu/g granular activated carbon, although biomass overgrowth could not be controlled in the reactor. The efficiency of converting sucrose into H_2 was calculated at 20.5%. Therefore use of this technology to power a 5.0kW proton exchange fuel cell for a single rural household is currently not feasible due to the high organic load required. Pooling of wastewater generation capacity, improvement of bacterial strain selection and feed formulation, pH control, gas removal and purification are factors that need to be considered for future improvement of conversion efficiencies. Use of this technology would be most suited for industrial processes generating large volumes of wastewater high in carbohydrates. Alternatively, municipal wastewater treatment facilities could be converted into electricity generating facilities through the combination of this technology and proton exchange membrane fuel cells.

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LIST OF ABBREVIATIONS

AFBR	–	Anaerobic Fluidised Bed Reactor
CSTR	–	Continuously Stirred Tank Fermentor
HRT	–	Hydraulic Retention Time
UASB	–	Upflow Anaerobic Sludge Blanket Reactor
CASBER	–	Carrier Assisted Sludge Bed Reactor
RBC	–	Rotating Biological Contactor
AEBR	–	Anaerobic Expanded Bed Reactor
GAC	–	Granular Activated Carbon
EPS	–	Exopolysaccharides
COD	–	Chemical Oxygen Demand
SRT	–	Solids Retention Time
L_{bf} / δ	–	Biofilm Thickness
r_{bp}	–	Biofilm Coated Particle Radius
r_c	–	Radius of the Biofilm Solid Support Particle
B_p	–	Dry Mass in the Biofilm Covered Particle
ρ_b	–	Biofilm Dry Mass Per Unit Wet Biofilm Particle Volume
B_c	–	Biofilm Mass Density
N_s	–	Quantity of Supporting Material
V	–	Bioreactor Volume
F_s	–	Effective Particle Weight
V_p	–	Particle Volume
ρ_s	–	Particle Density
ρ_L	–	Liquid Density
g	–	Gravitational Acceleration
F_D	–	Drag Force
C_D	–	Drag Coefficient
A_p	–	Projected Area
U_s	–	Superficial Fluid Velocity
U_t	–	Terminal Velocity
ε_{BR}	–	Bed Porosity
n	–	Bioreactor Expansion Index
B_s	–	Biofilm Shearing
ε	–	Specific Power Input
σ_{bf}	–	Mechanical Strength of Biofilm
τ_{bf}	–	Shear Stress on Biofilm

F	–	Flow Rate
L_{BR}	–	Bioreactor Height
U_s	–	Fluidisation Velocity
A_{BR}	–	Cross Sectional Area of Bioreactor
P_{rf}	–	Reactor Fluid Density
D_{bf}	–	Mass Transfer Coefficient
A_{bf}	–	Surface area of particle
K_{bf}	–	First Order Reaction Rate Coefficient
K_{bf}^{L}	–	Overall First Order Reaction Rate Coefficient
Sc	–	Bulk Phase Concentration of Substrate
S_{bf}	–	Substrate Concentration at Biofilm-Liquid Interface
U_{mf}	–	Carrier Fluidisation Velocity
S_i	–	Feed Concentration
Q_i	–	Feed Flowrate
L	–	Diffusion Layer
d_p	–	Carrier Particle Diameter

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