Casein whey as booster for anaerobic co-digestion of primary sludge

A thesis presented in partial fulfilment
of the requirements for the degree of

Master of Engineering
in
Environmental Engineering

by

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2012

We need to leave oil before oil leaves us.

Fatih Birol, Chief Economist

International Energy Agency

Abstract

Spare capacity found in many municipal primary sludge digesters could be used to improve the biogas production through the addition of other organic waste. This work investigates the potential of casein whey as an additional substrate. The amount of whey required for maximum biogas production and stable reactor performance was tested, along with the use of cow manure as an additional substrate to enhance reactor stability.

Bench-scale continuously stirred tank reactors were operated at 38 °C with an initial hydraulic retention time of 20 days. Biogas production was recorded daily and compared to a control reactor. To assess reactor stability, pH, alkalinity, chemical oxygen demand (COD) and volatile fatty acid concentration were measured.

To manage seasonal production, whey (W) was stored at ambient temperature prior to utilisation. This caused 74 % of the lactose to ferment to mainly L-lactate, accompanied by a pH drop from initially 4.5 to 3.6 and decreased COD. While fresh whey co-digested with primary sludge (PS) did not improve the biogas production, stored whey utilised at the ratio 10:3 (PS:W) improved the biogas production to 150 % of the control.

Cow manure (CM) co-digested with primary sludge and fresh whey at the ratio 10:7:1 (PS:W:CM) improved the biogas production by up to 200 % after slow acclimatisation to the whey. The addition of cow manure to primary sludge and stored whey did not improve the biogas production beyond the 150 % achieved without cow manure.

Investigation into why cow manure improved biogas production in primary sludge and whey co-digestion established that fungi found in cow manure could play an important role in the hydrolysis of complex material and therefore the biogas production.

Improved biogas production from fresh whey was only achieved when cow manure was provided. It appeared that additional lactic acid bacteria supplied by cow manure was required to ferment the high lactose concentration in fresh whey.

This work has shown how the seasonal availability of whey can be effectively used to improve the biogas production from municipal sludge digestion. During peak milk production fresh whey could be co-digested with primary sludge and cow manure at the ratio 10:5:1 (PS:W:CM) achieving 178 % biogas production. If cow manure is difficult to obtain, the ratio 10:3:0.1 is recommended, achieving 138 % biogas production. When the availability of fresh whey decreases, stored whey at the ratio 10:3 (PS:W) is recommended without cow manure, producing 150 % biogas compared to primary sludge alone.

Utilising whey as a viable substrate would improve productivity of municipal sludge digesters as well as alleviating environmental issues associated with whey disposal.

Acknowledgements

First and most thanks deserves my supervisor Dr. Nicola Powell for all the help, support and patience. Her presence during the process of completing this thesis has saved me more than once from despair.
I would like to thank my supervisor Prof. Andy Shilton mostly for giving me the chance to do this master but also for all his help, guidance and critical input into this work.

For the financial support of my work and my thesis I owe thanks to Palmerston North City Council and the Pre-Seed Accelerator Fund. Greatly appreciated is also the help of all staff members at the Palmerston North Wastewater Treatment Plant.

I would like to acknowledge the technical and administrative staff at the School of Engineering and Advanced Technology, Massey University, that were involved. Special thanks to John Sykes and Ann-Marie Jackson for their assistance in the laboratory work for this thesis. Many thanks to John for the hours we have spent on one of the problems that I encountered and for all the assistance with chemistry.
Further, I would like to thank Kathy Hamilton, College of Science, for her help.

A special mention goes to the "boys" in the back of the PTC, namely John Ralphs and Quentin Bechet, who were always there to answer my questions, to fill gaps or momentary blanks, and helped to keep me sane.

My gratitude to Hannahbess Thomson-Laing, who read, corrected and re-viewed countless pages of drafts, proposals, etc. and supported me despite all difficulties. Finally I would like to thank all my friends for their support during my Master, in particular Peri Chapelle.

Last but not least, I am indebted to my wonderful family; without you I would not be who I am and where I am now. Thank you for believing in me and supporting me even when my desires take me to the other side of the world.

Abbreviations

%	-	Percent
°C	-	degree Celsius
atm	-	Standard atmosphere
ATP	-	Adenosine triphosphate
BOD_5	-	Biochemical oxygen demand
$C_{12}H_{22}O_{11}$	-	Lactose
$C_2H_3O_2^-$	-	Acetate
C_2H_6O	-	Ethanol
$C_3H_3O_3^-$	-	Pyruvate
$C_3H_5O_3$	-	Lactic acid
$C_3H_5O_3^-$	-	Lactate
$C_5H_7O_2N$	-	Bacterial tissue
$C_6H_{12}O_6$	-	Galactose
$C_6H_{12}O_6$	-	Glucose
$CaCO_3$	-	Calcium carbonate
CH_3COOH	-	Acetic acid
CH_4	-	Methane gas
CHO_2^-	-	Formate
CL	-	Compost leachate
CM	-	Cow manure
CO_2	-	Carbon dioxide
$CoCl_2$	-	Cobalt(II) chloride
COD	-	Chemical oxygen demand
COD:N:P	-	Chemical oxygen demand to nitrogen to phosphorus ratio

CSTR	-	Continuously stirred tank reactor
d	-	Days
DNA	-	Deoxyribonucleic acid
EMP pathway	-	Embden-Meyerhof-Parnas pathway
FW	-	Fresh whey
$FeCl_2$	-	Iron(II) chloride
g	-	Gramm
GC	-	Gas chromatograph
H^+	-	Hydron
H_2	-	Hydrogen gas
H_2O	-	Water
H_2S	-	Hydrogen sulphide
H_2SO_4	-	Sulphuric acid
HRT	-	Hydraulic retention time
HS^-	-	Hydrosulphide ion
IC	-	Ion chromatograph
K	-	Potassium
$K_2Cr_2O_7$	-	Potassium dichromate
K_2O	-	Potassium oxide
kg	-	Kilogram
kWh	-	Kilowatt hour
l	-	Litre
LAB	-	Lactic acid bacteria
LDH	-	Lactate dehydrogenase
L_N	-	Norm litre
m	-	Metre

m^3	-	Cubic metre
mg	-	Milligram
MJ	-	Megajoule
ml	-	Millilitre
mm	-	Millimetre
mmol	-	Millimole
mol	-	Mole
N	-	Normality of a solution
N	-	Nitrogen
NAD^+	-	Nicotinamide adenine dinucleotide
NADH	-	Reduced form of nicotinamide adenine dinucleotide
NH_3	-	Ammonia
NH_4^+	-	Ammonium
NH_4^+-N	-	Dissolved ammonium as nitrogen
$NiCl_2$	-	Nickel(II) chloride
NIWA	-	National Institute of Water and Atmospheric Research
nm	-	Nanometre
ODM	-	Organic dry matter
OLR	-	Organic loading rate
P	-	Phosphorus
pH	-	Minus the decimal logarithm of the hydrogen ion activity in a solution
PS	-	Primary sludge
Q	-	Volumetric flow rate (m^3/s)
RNA	-	Ribonucleic acid
RO	-	Reverse osmosis
rpm	-	Revolutions per minute

sCOD	-	Soluble chemical oxygen demand
SiO_2	-	Silicon dioxide
SRT	-	Solid retention time
StW	-	Stored whey
t	-	Tonne
tCOD	-	Total chemical oxygen demand
TKN	-	Total Kjeldahl nitrogen
TS	-	Total solids
UASB	-	Upflow anaerobic sludge blanket
V	-	Volume
VFA	-	Volatile fatty acids
vol	-	Volume
VS	-	Volatile solids
W	-	Whey
ww	-	Wet weight
WWTP	-	Wastewater treatment plant
$ZnCl_2$	-	Zinc chloride

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[1] Appendix C can be folded out and contains a table displaying all reactors, the feedstock combination and the feed ratio applied to each reactor.

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