# OPTIMIZATION OF INFLUENCING PARAMETERS FOR DRY ANAEROBIC CO-DIGESTION OF LIGNOCELLULOSIC BIOMASS

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Degree of Master of Philosophy

Department of Chemical and Process Engineering

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## Declaration of the Candidate and Supervisor

"I, W.A.A Lakshitha declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where, the acknowledgement is made in the text.

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Name of the Supervisor: Prof: P.G Rathnasiri

…… ……

Signature of the supervisor Date

## Abstract

Anaerobic digestion offers an attractive solution for recovering energy from rice straw (RS) which is a lignocellulosic agricultural residue produced in huge quantities in Asia and Africa. Given the high solids content of this feedstock, high solids anaerobic co-digestion in batch mode is a process that can be applied. In this study, optimal operating conditions for the co-digestion of RS with cow dung (CD) in pure batch reactors and batch reactors with leachate recirculation are assessed. The preliminary experiments carried out in pure batch conditions showed that the initial concentration of RS in the mixture of substrates, i.e., $S_0$, (g VS rice straw /kg of mixture) is an important parameter. Only the batch reactors with the lowest $S_0$ values (29g $VS_{RS}$/kg) produced biogas after a long lag phase of 14 days. The use of digestate from a previous batch as an inoculum was investigated with $S_0$ values of 29 and 55 g $VS_{RS}$/kg. Re-use of the digestate as an inoculum source drastically improved both the initial degradation kinetics and the methane yield measured after 60 days for the $S_0$ of 29 g $VS_{RS}$/kg, as lag phase time period almost reached to zero and final methane yield of this reactor was 222 ml/g VS. This indicates a 104 % increase of specific methane yield increase compared to the reactor that only has the same $S_0$ concentration but the substrate mixture comprises only RS and CD. However, for 55 g $VS_{RS}$/kg, the degradation kinetics were affected: after two months, 32% of the biodegradable organic matter was not eliminated.

Leachate recirculation experiments were conducted in leach-bed reactors (LBRs) with $S_0$ between 30 and 65 g $VS_{RS}$ /kg, the highest methane yield was recorded at the lowest $S_0$ value, confirming that in batch mode during high solids anaerobic co-digestion (HS-AcoD) conditions, an initial RS concentration around 30 g $VS_{RS}$/kg is recommended for industrial applications.

Then mathematical modeling was applied to estimate kinetic parameters related to HS-AcoD process using the modified Gompertz model. Results obtained from Batch experiment no.3 (i.e., the three consecutive batches) were considered for the mathematical modelling. Modified Gompertz model very closely predicted the ultimate methane yield ($M_{max}$) with $R^2$ almost 0.99 in each scenario. Degradation kinetics improved drastically with the strategy of re-using digestate, as for the Batch-2 the lag phase period ($\lambda$) reduced from 14 days to almost zero. Ultimate methane yield increased by 104% through this approach. Degradation kinetics were negatively affected with the increase of TS% within the substrate mixture even though digestate was reused as an inoculum. In Batch-3 ultimate methane yield was 138 ml/g VS which was a 38% reduction compared to Batch-2, even though digestate was used as the main inoculum source for the both batches. But it was a 27% increase compared to Batch-1 which CD was used as the only inoculum.



**Key words:** High solids anaerobic co-digestion, lignocellulosic biomass, leachate recirculation, mesophilic, mathematical modelling, kinetic parameters

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# LIST OF ABBREVIATION

AcoD- Anaerobic Co-Digestion

AD- Anaerobic Digestion

ADM1- Anaerobic Digestion Model no.1

BMP- Biochemical Methane Potential

CD- Cow Dung

CSTR- Continuous Stirred Tank Reactor

FW- Food waste

GC- Gas Chromatography

HAc- Acetic Acid

HS-AD- High Solids Anaerobic Digestion

LBR- Leach Bed Batch Reactor

LS-AD- Liquid State Anaerobic Digestion

MSW- Municipal Solid Waste

RS- Rice Straw

TS- Total Solids

UASB- Up flow Anaerobic Sludge Blanket

VFAs -Volatile Fatty Acids

VS- Volatile Solids