

**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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Thesis submitted in partial fulfillment of the requirements for the  
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## 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