# A Study of the Co-digestion of some selected Urban and Agricultural Wastes for Optimum Biogas Production

## 1. Introduction and Background

Anaerobic digestion (AD) is a biological enhancement process where microorganisms break down organic matter in an oxygen-free environment, producing biogas—a mixture of gases primarily consisting of methane ($CH_4$) and carbon dioxide ($CO_2$)—and nutrient-rich digestate. Biogas can be utilized as heat, electricity, or renewable fuel, while digestate is used as fertilizer, contributing to nutrient cycling and sustainable agriculture (Springer Nature, 2024). Within global efforts to mitigate climate change and reduce dependence on fossil fuels, AD is gaining attention as a sustainable waste management and energy production technology.

Organic waste generated from urban activities and agricultural operations continues to increase globally. Urban areas produce large quantities of food waste, market waste, and other biodegradable household waste. Agricultural systems produce livestock manure, crop residues, and other agricultural byproducts (Kriswantoro et al., 2024; PubMed, 2023). Improper treatment and disposal of these wastes pose environmental and public health risks, including greenhouse gas emissions, leachate generation, and soil and water contamination.

Single-substrate digestion processes are often constrained by issues such as nutrient imbalance, accumulation of inhibitory substances, and pH instability, resulting in suboptimal biogas yields. Compared to single digestion, co-digestion—the simultaneous digestion of multiple substrates—can improve nutrient balance (e.g., achieving optimal carbon-to-nitrogen ratios), dilute toxic compounds, enhance microbial diversity and activity, and increase overall biogas production (PubMed, 2017; Agdag et al., 2016). Recent laboratory studies confirm that co-digestion of municipal and agricultural wastes yields higher methane production and greater process stability than treating either substrate alone (PubMed, 2017; Kriswantoro et al., 2024; PubMed, 2023).

Despite compelling evidence of potential, experimental studies on co-digestion strategies for locally relevant combinations of municipal and agricultural waste—particularly under controlled laboratory conditions—remain scarce. Addressing this gap holds promise for unlocking significant energy production potential and advancing sustainable waste management practices.

## 2. Problem definition

The coexistence of high organic waste generation and chronic energy shortages in many developing regions highlights the urgent need for effective strategies for generating energy from waste. Although anaerobic digestion is known for its ecological and economic advantages, current applications are often based on mono-digestion with limited biogas production due to poor substrate properties, nutrient imbalances, and process instability (Li et al., 2018). This limitation is exacerbated in contexts where heterogeneous waste streams prevail and locally optimized substrate combinations have not yet been sufficiently investigated.

While co-fermentation has shown promising results in increasing biogas yield in laboratory and pilot studies, there is a lack of systematic research to identify the best combinations of specific municipal and agricultural wastes, the operating conditions under which they perform optimally, and the mechanistic basis for the observed performance differences in mesophilic anaerobic digestion. Without experimental evidence for such optimized combinations, the potential of organic waste for renewable energy production remains untapped, and opportunities for sustainable waste management are missed.

## 3. Research Objectives and Goals

### 3.1 Objective

The objective of this study is to experimentally investigate the co-digestion of selected municipal solid waste and agricultural waste for optimal biogas production under controlled anaerobic digestion conditions.

3.2 Specific Objectives

1. Characterize the physicochemical properties of the selected municipal solid waste and agricultural waste.

2. Compare biogas yield and process performance between single digestion and co-digestion systems.

3. Identify the substrate mixing ratio that yields optimal biogas production under laboratory conditions.

## 4. Research Questions

1. What are the physicochemical properties of the selected municipal solid waste and agricultural waste?

2. How does co-digestion affect biogas yield compared to single digestion?

3. What substrate mixing ratio yields optimal biogas output under experimental conditions?

## 5. Significance of the Research

This study contributes to the scientific understanding of how substrate diversity and its interactions affect anaerobic fermentation performance. The experimental results provide empirical data on the performance, stability, and yield of co-digestion systems using municipal solid waste and agricultural waste, offering important insights for both research and practice. Practically, it supports engineers and policymakers in designing efficient, low-cost systems for energy recovery from waste, contributing to energy security, improved waste management, and reduced greenhouse gas emissions. This research aligns with Sustainable Development Goals (SDGs) related to affordable clean energy, sustainable cities and communities, and climate action.

## 6. Scope of the Study

This study is limited to laboratory-scale anaerobic digestion experiments using selected organic waste streams from urban and agricultural sources. Experiments will be conducted under mesophilic conditions (approximately 35±2°C). The focus will be on measuring biogas yield, methane content, and process stability over time. This study does not include bioeconomic analysis, large-scale technology implementation, or advanced process modeling.

## 7. Methodology

### 7.1 Research design

This research will use an experimental laboratory design to compare biogas production from mono-fermentation and co-fermentation of selected substrates.

### 7.2 Substrate selection and characterization

Municipal waste (e.g., food waste, market waste) and agricultural residues (e.g., animal manure, crop residues) will be collected at representative locations. The substrates will be characterized in terms of moisture content, total solids (TS), volatile solids (VS), pH, and carbon-nitrogen ratio (C/N) using standard methods for water and wastewater analysis (APHA, 2017) and guidelines from current research on anaerobic digestion.

### 7.3 Anaerobic digestion experiments

Batch anaerobic digesters (with a working volume of between 5 and 10 liters) will be installed and operated under mesophilic conditions. Substrate combinations will be prepared for monodigestion and various co-digestions with different mixing ratios. Gas production will be measured daily using gas meters. The methane content will be evaluated periodically through gas analysis.

### 7.4 Data collection and analysis

Data on biogas volume and methane concentration will be collected daily. Statistical analyses, such as analysis of variance (ANOVA), will be used to evaluate differences in biogas yield between treatments. Process stability parameters (e.g., pH and volatile fatty acids) will be monitored to interpret microbial performance.

## 8. Laboratory experimental setup

The laboratory setup will comprise sealed batch anaerobic digesters equipped with gas collection systems control units to maintain constant mesophilic conditions. A typical setup will include:

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    Collection of Urban & Agricultural Waste

                    |
                    ▼
   Waste Sorting & Removal of plastics a metals
                    |
                    ▼
           Size Reduction / Grinding
                    |
                    ▼
        Substrate Characterization
           (TS, VS, pH, C/N, COD)
                    |
                    ▼
  Mixing at Selected Ratios + Inoculum
                    |
                    ▼
 Loading into Airtight Anaerobic Digester
                    |
                    ▼
       Anaerobic Digestion (Batch)
                    |
                    ▼
       Biogas Production & Collection
(Gas Outlet → Silica Gel → Gas Meter → Collector)
                    |
                    ▼
       Biogas Volume Measurement
                    |
                    ▼
      Methane Composition Analysis (GC)
                    |
                    ▼
        Digestate Analysis (TS, VS)
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**Fig.1 Laboratory low chart**

## 9. Research Timeline

**Activities / Months → 1-3 4-6 7-9 10-12 13-15 16-18 19-21 22-24 25-27 28-30 31-33 34-36**

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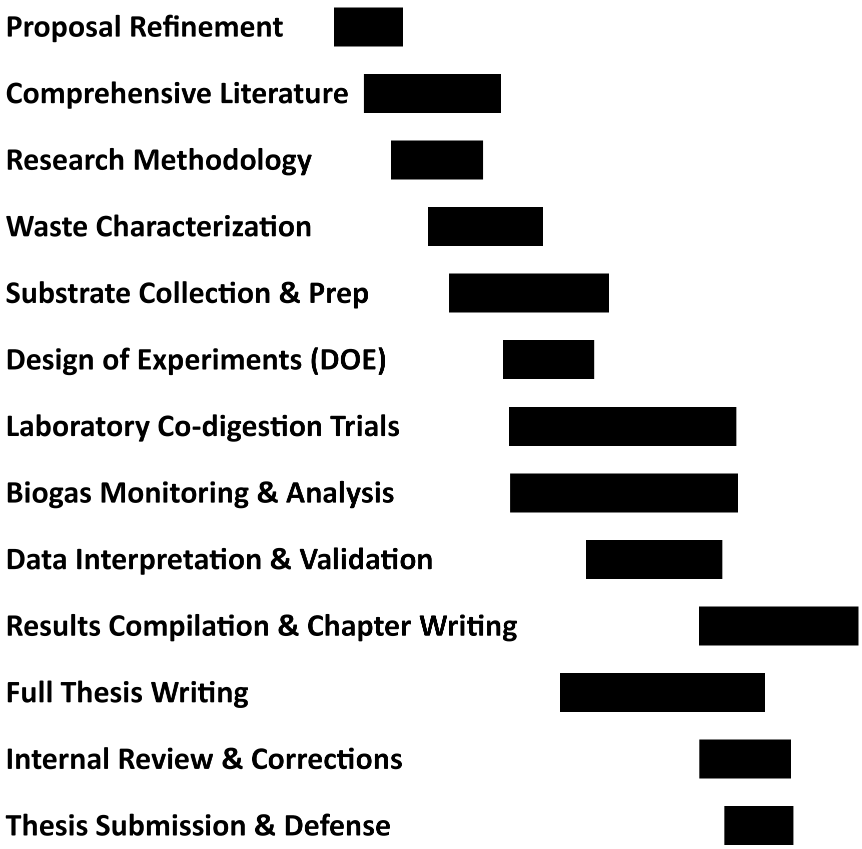


**Fig 2. Gannt Chart**

## 10. Conclusion

This doctoral research proposal aims to achieve optimal biogas yield through experimental studies on the co-digestion of specific urban and agricultural wastes. By systematically comparing single digestion and co-digestion strategies and identifying the optimal substrate blending scheme, this research seeks to provide empirical support for sustainable waste management and renewable energy production. The findings are expected to contribute to both scientific understanding and practical application of waste-to-energy technologies.

## References


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