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# Pre-Treatment and Co Digestion of Withered Flower Waste to Enhance Production of Biogas

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**Abstract**

This comprehensive study is dedicated to optimizing biogas production from withered flower waste, employing diverse pre-treatment techniques (physical, chemical, hydrothermal, and biological) and innovative co-digestion strategies. The implementation of physical treatments, such as milling, microwave, and ultrasonic methods, effectively enhanced the accessibility and digestibility of the flower waste, resulting in a notable increase in biogas yield. Chemical treatments demonstrated significant improvements in feedstock digestibility and delignification levels, contributing to enhanced biogas production efficiency. Notably, the hydrothermal treatment process, conducted within the optimal temperature range, exhibited a substantial boost in anaerobic digestion performance. Additionally, the biological pre-treatment utilizing Aspergillus fumigatus SL1 showcased remarkable enzymatic activity, facilitating the breakdown of complex organic compounds within the waste material. Co-digestion experiments involving a blend of cow dung, chicken manure, pig manure, and sewage waste underscored the significant impact of varying substrate compositions on methane production efficiency, emphasizing the potential for synergistic effects in biogas production. Collectively, the findings highlight the promising potential of these combined techniques in advancing sustainable waste management and promoting renewable energy generation.

**Keywords:** Co-Digestion, Flower waste, Biogas

## Introduction

The pressing need for sustainable energy sources and the responsible management of organic waste materials have become paramount in our modern world. As populations continue to grow and environmental concerns intensify, innovative solutions that address both energy demands and waste management have gained prominence. Biogas production, a promising avenue in this regard, offers a sustainable energy source while simultaneously tackling the issue of organic waste disposal. Withered flower waste, represents a unique and underutilized organic resource that can be harnessed for biogas production. In this context, this study investigates into the scope of pre-treatment and co-digestion strategies for withered flower waste, with the primary objective of enhancing biogas production. By exploring the potential of this renewable resource and the various methods to optimize its biogas yield, this research contributes to the ongoing efforts to address energy sustainability and waste management challenges. The investigation into pre-treatment and co-digestion of withered flower waste holds the promise of not only reducing the environmental impact of waste disposal but also providing a greener and more sustainable energy source for our ever-growing energy needs.

## Objectives

- To estimate the effect of different pre-treatment strategies (physical, chemical, hydrothermal and biological) on methane production
- To evaluate the influence of the co-digestion of various animal manure on methane production in a novel three stage anaerobic digester.

## Methodology

### Physical pre-treatment of the flower waste

Physical pre-treatment of the flower waste, three distinct techniques were employed to modify its structural characteristics, ensuring optimal conditions for the subsequent anaerobic digestion process. The first method, milling, involved the utilization of a milling apparatus to disrupt the cellular organization of the substrate, resulting in a reduction in particle size. Through mechanical forces, the flower waste underwent a thorough breakdown, facilitating improved accessibility during the digestion phase.

In the case of microwave treatment, the flower waste was exposed to microwave irradiation at 560 W until the fluid phase exhibited bubbling, signifying the effective application of heat. To guarantee the uniform distribution of heat, the samples were maintained under microwave treatment for 30 seconds, ensuring the thorough penetration of heat within the waste material while preventing any undesired thermal degradation.

Furthermore, the ultrasonic pre-treatment method necessitated subjecting the flower waste to ultrasonic waves with a working frequency of 20 kHz and a power output of 130W. Careful attention was paid to ensuring uniform exposure of the waste material to the ultrasonic waves, promoting effective disruption of the cellular matrix and facilitating improved digestibility during the subsequent anaerobic digestion process. These meticulous physical pre-treatment methods were implemented to enhance the accessibility and biodegradability of the flower waste, thereby contributing to the overall efficiency of biogas production during the anaerobic digestion process

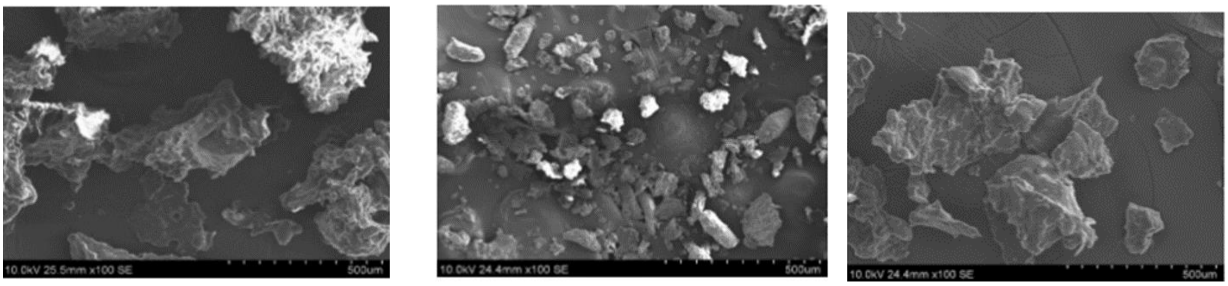
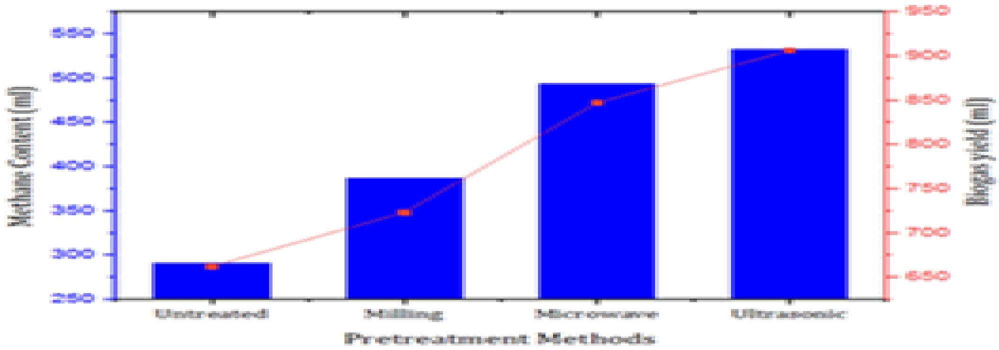


**Figure1,2,3: SEM image of non-treated substrate,ultrasonicated substrate microwave treated substrate**

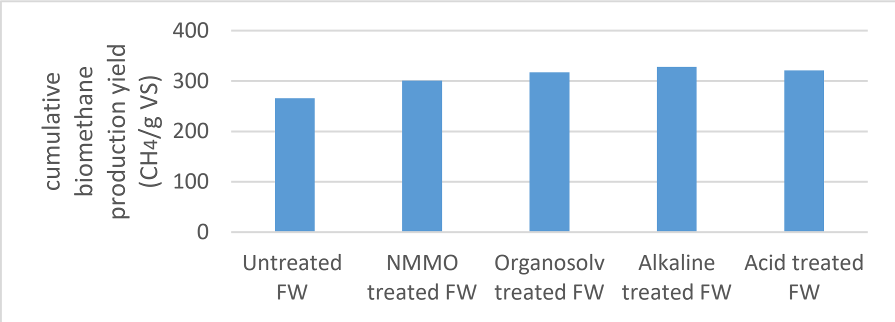



**Graph 1: Different treatment methods producing quantity of methane to amount of biogas generated**

**Chemical pre-treatment**

Chemical pre-treatment was undertaken to improve the digestibility of the feedstock, aiming to augment the production of biogas during the anaerobic digestion process. Various chemical treatments were employed to modify the composition and structure of the flower waste, thereby enhancing its susceptibility to enzymatic breakdown and subsequent biogas generation. The primary objective of the chemical pretreatment was to promote an increase in the production of biogas through improved delignification levels within the waste material. The specific chemical pretreatment methods employed in this study were carefully chosen to facilitate the breakdown of complex organic compounds, thus rendering the flower waste more amenable to efficient biogas production. The detailed procedures and results of each chemical pretreatment approach were meticulously analyzed to determine their effectiveness in enhancing the overall efficiency of the anaerobic digestion process.

**Graph 2: Representing amount of methane produced with various chemical treatment done on flower waste**




**Hydrothermal pre-treatment**

Hydrothermal pre-treatment was implemented in this study, drawing upon existing research that underscores the efficacy of thermal pre-treatment in augmenting both the extent and rate of anaerobic digestion. Extensive investigations have indicated the favourable outcomes of employing thermal pre-treatment techniques to enhance the biodegradability of organic substrates, including flower waste. A key consideration in this process was the identification of the optimal treatment temperature range, which has been established through consensus among various research studies. The recommended temperature range for the hydrothermal pre-treatment was determined to be between 80°C and 180°C, ensuring the effective breakdown of complex organic compounds and the promotion of favourable conditions for subsequent anaerobic digestion. This methodology aimed to leverage the benefits of hydrothermal pre-treatment to facilitate the efficient conversion of flower waste into biogas, ultimately contributing to a more sustainable and effective waste-to-energy conversion process.

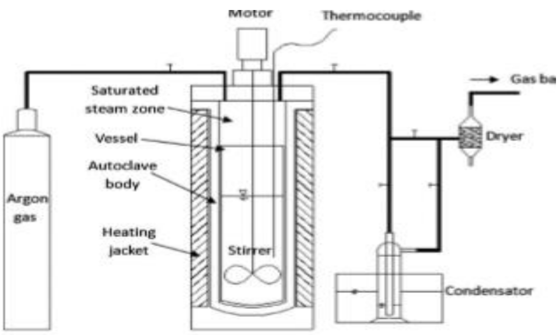



**Figure 4: Hydrothermal and digestion tests**

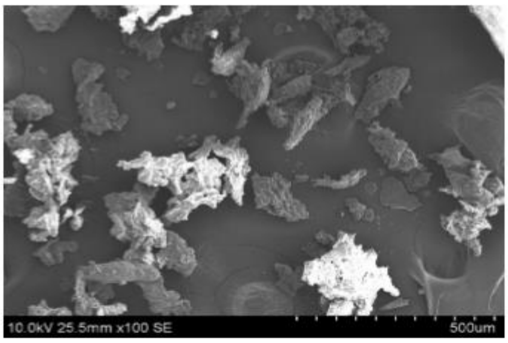
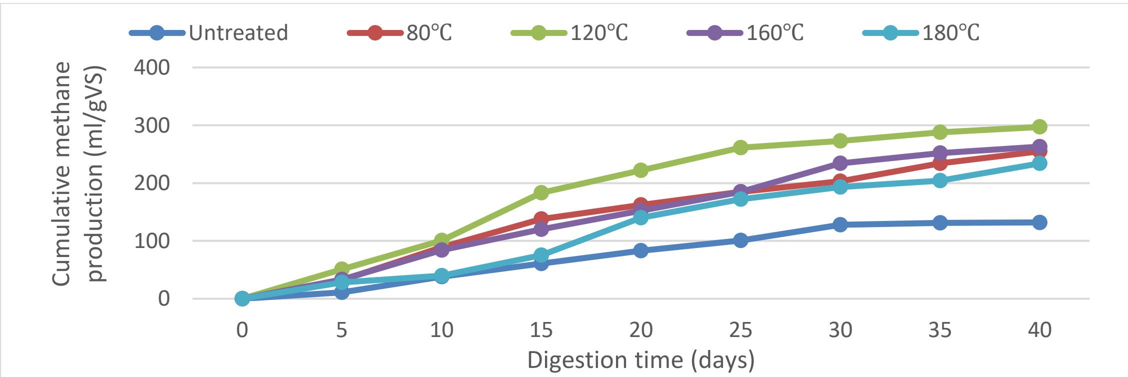



**Figure 5: SEM image of hydrothermally treated substrate**

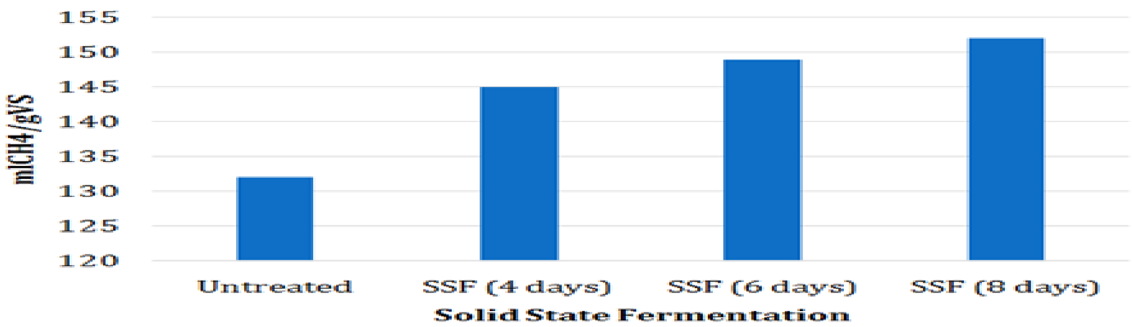



**Graph 3: Representing quantity of Methane generated by varying temperature in digestion unite with respect to time**

**Biological pretreatment**

Biological pretreatment was conducted using a solid-state fermentation (SSF) approach, employing the isolated fungus Aspergillus fumigatus SL1. The methodology involved the cultivation of Aspergillus fumigatus SL1 on potato dextrose agar (PDA) under controlled conditions to promote optimal growth and metabolic activity. The SSF process aimed to facilitate the enzymatic degradation of complex organic compounds within the flower waste, enhancing its digestibility during the subsequent anaerobic digestion phase.

To initiate the biological pretreatment, the cultivation of Aspergillus fumigatus SL1 was carried out at a temperature of 40°C on potato dextrose agar (PDA) medium. The process was repeated four times to ensure the robust growth and development of conidia, a crucial component for enzymatic activity. The selected temperature and medium were chosen to provide the ideal conditions for the proliferation and metabolic activity of Aspergillus fumigatus SL1, thereby promoting the effective breakdown of lignocellulosic components present in the flower waste. This biological pretreatment method was meticulously executed to harness the enzymatic potential of the isolated fungus, contributing to the enhanced biodegradability and subsequent biogas production of the flower waste material.




**Graph 4: Influence of Solid state fermentation wrt to time**

**Co-Digestion of Substrate**

The co-digestion process involved the utilization of various organic substrates, namely cow dung (CD), chicken manure (CM), pig manure (PM), and sewage waste (SW), collected from poultry farms in Bangalore. The biological methane production potentials (BMPs) of the CD, CM, PM, and SW mixtures were examined using different ratios in 1-liter digesters to evaluate their respective contributions to biogas production.

Three distinct treatment ratios were considered for the co-digestion experiments:

- Treatment A involved the utilization of the substrate mixture at a ratio of 1:1:1:1 (CD: CM: PM: SW).
- Treatment B utilized a ratio of 2:1:1:1 (CD :CM :PM :SW) and
- Treatment C employed a ratio of 3:1:1:1 (CD: CM: PM :SW)

The co-digestion experiments were conducted under controlled conditions to assess the methane production potential of the various substrate mixtures. Through the examination of different ratios and their respective contributions to biogas production, this methodology aimed to identify the most effective substrate combination for maximizing methane production during the anaerobic digestion process. The comprehensive analysis of the co-digestion process provided valuable insights into the synergistic effects of different organic substrates, paving the way for the optimization of biogas production from a diverse range of organic waste materials.

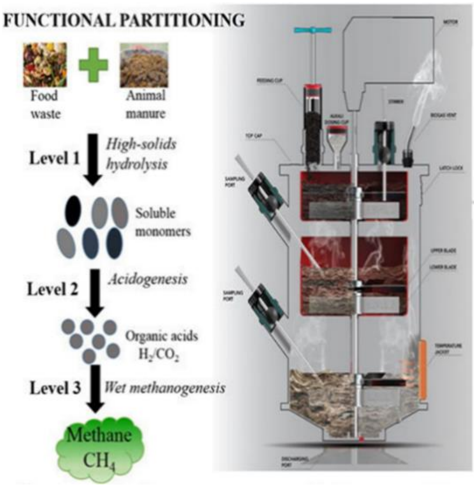
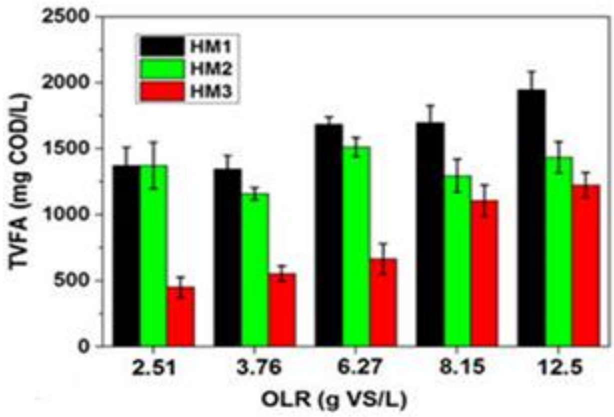
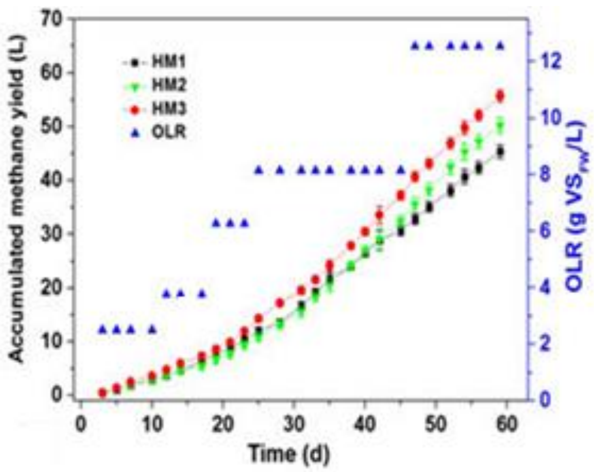



**Figure 6: Representing functional partitioning for Co-digestion process**




**Graph 5: Representing accumulated methane yield**

**Graph 6: Representing TVFA concentration**




**Results**

Based on the comprehensive analysis presented in this study, it is evident that various pretreatment techniques, including physical and chemical approaches, play a pivotal role in enhancing the anaerobic digestion (AD) of flower waste and mixed organic substrates. The findings underscore that these pretreatment methods significantly improve biogas production and degradation efficiencies, as demonstrated by higher biogas yield and enhanced removal of total solids (TS), volatile solids (VS), and chemical oxygen demand (COD).

Notably, the application of chemical pretreatments such as NMMO, organosolv, and alkaline methods was found to be particularly effective in augmenting the cumulative biomethane potential, as well as the kinetics of biomethane production. Specifically, the alkaline pretreatment emerged as a robust technique, resulting in notable enhancements in specific rate constant (k0) and maximum biogas production rate (Rm). These outcomes were further supported by analyses of water retention value (WRV) and volatile fatty acid (VFA) content, which indicated an increase in accessible surface area and VFA production post-pretreatment.

Furthermore, the investigation into hydrothermal pretreatment revealed that an optimal temperature of 120°C led to the highest biogas and methane yields, surpassing those obtained from direct digestion of the raw substrate. Nevertheless, it was observed that exceeding this temperature threshold adversely affected biogas/methane yields, emphasizing the critical role of hydrolysis in influencing anaerobic digestion performance.

Moreover, the study highlighted the advantages of anaerobic co-digestion, demonstrating that the combined treatment of various waste types, such as animal manure and other organic wastes, led to a more efficient methane production process compared to treating these wastes separately. The implementation of a three-stage anaerobic digester further enhanced the hydrolytic and acidogenic efficiencies, ultimately accelerating the methanogenesis process for improved methane generation.

Overall, these findings underscore the potential of employing diverse pretreatment techniques and co-digestion strategies in optimizing biogas production and organic waste management, thus providing valuable insights for the advancement of sustainable and efficient bioenergy production systems.

**Conclusion**

The study successfully demonstrated the effectiveness of various physical, chemical, hydrothermal, and biological pre-treatment methods in enhancing the production of biogas from withered flower waste. Physical pre-treatment techniques such as milling, microwave treatment, and ultrasonic treatment significantly improved the accessibility and digestibility of the flower waste, contributing to increased biogas yields during anaerobic digestion. Chemical pre-treatment methods proved to be instrumental in enhancing the digestibility of the feedstock, leading to a notable increase in biogas production, along with improved delignification levels. Hydrothermal pre-treatment within the recommended temperature range of 80°C to 180°C exhibited promising results, effectively enhancing both the extent and rate of anaerobic digestion, thereby improving the overall biodegradability of the flower waste. The solid-state fermentation (SSF) process utilizing the isolated fungus Aspergillus fumigatus SL1 demonstrated significant enzymatic activity, contributing to the breakdown of complex organic compounds within the flower waste and enhancing its digestibility during the anaerobic digestion phase. The successful implementation of these pre-treatment methods underscores their potential in advancing sustainable waste management practices and promoting the efficient conversion of organic waste into a valuable energy resource.

Furthermore, the co-digestion experiments involving a combination of cow dung, chicken manure, pig manure, and sewage waste highlighted the significant impact of varying substrate compositions on the overall methane production efficiency. The distinct treatment ratios demonstrated the synergistic effects of different organic substrates, emphasizing the potential for maximizing biogas production through the optimized utilization of diverse organic waste materials. Collectively, the findings from the pretreatment and co-digestion studies contribute to the advancement of sustainable waste management practices and renewable energy production strategies. These results provide valuable insights into the development of effective biogas production systems, promoting the utilization of organic waste as a valuable resource for sustainable energy generation while mitigating environmental pollution and promoting circular economy principles.

**References**

[1] Carrere, H., Rafrafi, Y., Battimelli, A., Torrijos, M., Delgenes, J.P. and Motte, C. (2012). 'Improving methane production during the co-digestion of waste-activated sludge and fatty wastewater: Impact of thermo-alkaline pretreatment on batch and semi-continuous processes', *Chemical Eng*ineering Journal

[2] Bustamante, M.A., Alburquerque, J.A, Restrepo, A.P., De la Fuente, C., Paredes, C., Moral, R. and Bernal, M.P. (2012), 'Co-composting of the solid fraction of anaerobic digestates to obtain added-value materials for use in agriculture', *Biomass Bioenergy* 43.

[3] Bhattacharya, J.K., Kumar, S. and Devotta, S. (2008), 'Studies on acidification in two- phase biomethanation process of municipal solid waste', *Waste Management* 28.

[4] Chengliu Gou., Zhaohui Yang., Jing Huang., Huiling Wang., Haiyin Xu., Like Wang. (2014), 'Effects of temperature and organic loading rate on the performance and microbial community of anaerobic co-digestion of waste activated sludge and food waste' *Chemosphere* 105

[5] Gharpuray, M.M., Gharpuray, YLee,. H., Fan, L.T. (1983), 'Structural Modification of to lignocellulosics by pretreatmentsenhance enzymatic hydrolysis'. *Biotechnology and Bioengineering* 25, 157-172

[6] Hosseini, S. M., Aziz, H. A. and Syafalni, A. M. (2015), 'Enhancement of rice straw biodegradability by alkaline and acid thermochemical pretreatment process: optimization by response surface methodology (RSM)', *Journal of Applied Sciences Research* 1, 1-12.

[7] Jackowiak, D., Bassard, D., Pauss, A. and Ribeiro, T. (2011), 'Optimisation of a microwave pretreatment of wheat straw for methane production', *Bioresource Technology* 102,

[8] Jimenez, J., Guardia-Puebla, Y., Romero-Romero, O., Cisneros-Ortiz, M. E. Guerra, G., Morgan Sagastume, J. M. and Noyola, A. (2014). 'Methanogenic activity optimization 58(3), *323-325.* using the response surface methodology during the anaerobic co-digestion of agriculture and industrial wastes', *Biomass Bioenergy*, 71, 84-97.

*[9]* Jung, K.Y., Yeole, T. Y. Gokhale, S., Hajarnis, S.R. and Ranade, D.R. (1996), 'Effect of brackish water on biogas production from cattle dung and methanogens', *Bioresource Technology*