Anaerobic co-digestion of fish waste and primary sludge: Biochemical methane potential and mixing ratio

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Keywords: fish waste, primary sludge, anaerobic digestion, biochemical methane potential test
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Fish processing generates waste such as heads, guts, fins, skin, and bones, which presents a disposal challenge (Rowland et al., 2021). Fish waste is suitable for anaerobic digestion due to its high biogas production potential resulting from its rich protein and fat content (Xu et al., 2016). The high protein and lipid content of fish waste can lead to problems such as ammonia toxicity and fatty acid accumulation. However, these problems can be addressed by co-digestion with organic wastes such as primary sludge (Wu et al., 2021). Therefore, this study aims to derive the optimal mixing ratio of fish waste and primary sludge anaerobic co-digestion.

The biochemical methane potential test was carried out in a batch reactor and the substrates used were fish waste from a local restaurant and primary sludge from the Wonju municipal wastewater treatment plant (MWTP) in South Korea. The inoculum was collected from the anaerobic digester at the Wonju MWTP. To measure biogas production, the digested sludge was starved at 35°C for 27 days, excluding any spontaneously generated biogas in the sludge. The mixing ratio (weight basis) of fish waste : primary sludge was 0:100 (R1), 3:97 (R2), 7:93 (R3), 12:88 (R4), 50:50 (R5), and 100:0 (R6). The substrate and inoculum were mixed in a 1:1 ratio based on volatile solids. Anaerobic digestion was carried out in an incubator at 35°C after purging with nitrogen gas at 15 L/min for 1 minute. A manometer was utilized to confirm that the biogas volume was at least 10 mL. Subsequently, the amount and composition were measured. After 53 days of digestion, pH, alkalinity, solids, and volatile fatty acids were measured. A kinetic analysis was performed using a modified Gompertz model based on the cumulative methane yield data. Next-generation sequencing was used to analyze the archaea genus and family, and bacterial genus and family.

R4 achieved the highest methane yield of 459 mL/g VS_{added}. The methane yield of R6 was higher than R1, confirming that fish waste is a suitable substrate for anaerobic digestion(Figure 1).

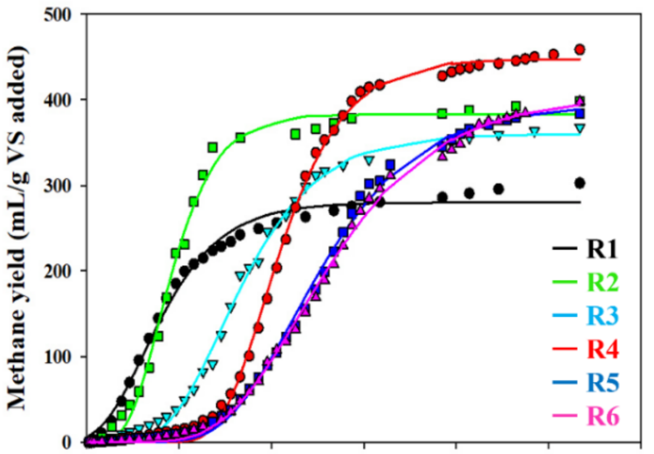

Figure 1. Methane yield from anaerobic co-digestion reactor of fish waste and primary sludge

The pH and alkalinity increased with the increase in fish waste content. The concentration of volatile fatty acids was low in all reactors, regardless of the fish waste content. The period during which the methane content of biogas reaches up to 60% was delayed when the amount of fish waste increased. This delay might be caused by the high protein and fat contents of fish waste.

The modified Gompertz model predicted the highest methane yield in R4 at 448 mL/g VS_{added} and the lowest in R1 without fish waste at 280 mL/g VS_{added}. The lag phase exhibited an increasing trend with increasing fish waste content (Table 1). This is because fish waste has a longer hydrolysis period due to its high protein and lipid content compared to primary sludge. R^2 showed high values (≥ 0.992) in all reactors and the suitability of the model is indicated by the low difference between measured and predicted (1.6 – 7.4%).

Table 1. Modified Gompertz model results using cumulative methane yield from the reactors

Parameter	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
λ (day)	1.56	8.93	8.84	14.52	15.06	14.77
R_m (mL/g VS_{added}/day)	22.39	41.94	23.15	34.94	19.75	18.00
R^2	0.992	0.995	0.997	0.998	0.997	0.998
Measured methane yield (mL/g VS_{added})	302.7	397.8	367.6	458.5	384.2	397.9
Predicted methane yield (mL/g VS_{added})	280.2	383.3	360.1	447.8	394.9	404.3
Difference between measured and predicted (%)	7.4	3.6	2.0	2.3	2.8	1.6

With increasing fish waste content, Methanobacterium, Methanobrevibacter, Methanothrix, Methanolinea, Methanoregulaceae, Methanotrichaceae, and Candidatus Cloacamonas decreased. With higher fish waste content, Methanospirillum, Methanospirillaceae, and Dysgonomonadaceae increased. Methanospirillum, which utilizes carbon dioxide to produce methane (Christensen et al., 2018), showed an increasing trend with higher fish waste content. This is consistent with the finding that methane production increased with increasing fish waste content. As cumulative methane production increased, there was an increase in Fervidobacterium and Fervidobacteriaceae.

In this study, the methane yield of R4 was found to be highest at 459 mL/g VS_{added}, identifying the optimal mixing ratio of 12:88 for anaerobic co-digestion of fish waste and primary sludge. The modified Gompertz model for R4 showed an R^2 of 0.998 and the difference between measured and predicted values was 2.3%, indicating a good fit. As the fish waste content increased, methane production also increased, confirming the methane production potential of fish waste.

Acknowledgements

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(MOE)(2022RIS-005).

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