Co-anaerobic Digestion of Chicken Manure and Selected Additives for Biogas Production

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Abstract. Huge amount of chicken manure from poultry producers in Manjung, Perak has caused endemic flies problems across the region. The present study focused on co-anaerobic digestion of chicken manure (CM) with saw dust (SD) and local herbs such as serai wangi (SW), peppermint (PPM) and orange peel waste (OPW) as additives for potential biogas production. The aim of the study was to evaluate the effect of additives towards the biogas production and methane yield of co-anaerobic digestion of chicken manure with saw dust. The C/N ratio of chicken manure and saw dust is 30 and the ratio between feedstock to inoculum is 70:30. The concentration of additives were 10, 20 and 30 part per hundred of feedstock (pphf). The operating temperature was 35°C and the experiment was conducted for 50 days. The results show that the co-anaerobic digestion of chicken manure and saw dust with the addition of 10pphf SW has the highest methane yield (59.30%) while the control produced the highest biogas yield (9734 mL). The presence of 10pphf SW for the co-anaerobic digestion of chicken manure and saw dust produced a better quality of biogas.

1. Introduction
Manjung which is a district in Perak, Malaysia, is known for its agriculture and tourism sector. The district plays an important role in the contribution of the chicken production which approximately 10% of the total national production comes from the district alone. At a typical steady-state chicken population of 14 million, Manjung’s poultry generate an approximately 1400 tons of chicken droppings daily for disposals [1]. This has led to many problems such as unpleasant odour, health problems and increasing population of flies since the chicken manure act as a food source for the flies [1].

Chicken manure contain organic matter which is biodegradable and therefore anaerobic digestion should be considered as an alternative to minimize the amount of poultry waste and to recover energy from the production of biogas. Biogas composed mainly of methane (CH₄) and CO₂ with a trace of other gases such as nitrogen (N₂), oxygen (O₂), hydrogen sulphide (H₂S) and ammonia (NH₃) [2,3]. Before methane is produced, the substrate that contain carbohydrate or proteins undergoes many steps including...
hydrolysis, acidogenesis and acetogenesis that break down the substrate into simpler elements such as acetic acid and hydrogen [4,5].

Essential oils (EO) are typically produced by plants which are fragrant and contain a variety of volatile molecules such as phenol-derived aromatic components, terpenoids and terpenes where they are also insecticide potential, larvicidal and reproduction inhibitors [6]. In Malaysia, essential oils such as serai wangi, peppermint and orange peel are used for many purposes such as aromatherapy, medicinally and act as a natural insect repellent. Infusing these plants as additives for the co-anaerobic digestion of chicken manure and saw dust could solve the fly problems in Manjung. Past research has shown that the AD of serai wangi, peppermint and orange peel alone were able to produce biogas [7–9] but its purpose as fly deterrent agent towards the digestate is yet to be discovered.

The purpose of this research is as follows: (1) to characterize the additives in terms of total solids, volatile solids and energy content, (2) to evaluate the effect of additives towards the biogas production and methane yield from the co-anaerobic digestion of chicken manure and saw dust.

2. Methodology

2.1. Feedstock and inoculum

Two kg of chicken manure (CM) were provided from Dindings Poultry Sdn. Bhd, Manjung and stored in a refrigerator at 4°C throughout the study. The fresh manure is produced after 40 days of one broiler cycle. Cow dung (CD) was obtained from a cow farm in Kampung Gajah, Perak Malaysia and was used as an inoculum. Saw dust (SD), the C/N adjustment material were provided by Wan Sang Sawmill Enterprise S/B. Oranges were obtain from Tesco Seri Iskandar, Perak while peppermint was obtained from Econsave Seri Iskandar Perak and Serai Wangi were obtained from Green Garden Resources, Ayer Hitam Johor. The orange peel, peppermint and serai wangi were blended into small pieces by using a blender.

2.2. Lab scale digesters

The co-digestion of chicken manure (CM) and saw dust (SD) was carried out in a batch test with the carbon to nitrogen (C/N) ratio of 30. The ratio of feedstock to inoculum was 70:30 and solid to water ratio was 1:3. The amount of serai wangi (SW), peppermint (PPM) and orange peel waste (OPW) will be added are 10, 20 and 30pph of the feedstock (pph f). The mixtures were filled in a 1.5L bottles and were placed in an oven at temperature of 35°C for 50 days.

2.3. Analytical methods

Total solids (TS) and volatile solid (VS) of feedstock and inoculum were measured by using APHA methods 2540g. Elemental compositions (C, H, N, S) of feedstock were recorded by CHNS Analyzer (Perkin Elmer EA Series II CHNS/O 2400). The moisture content of chicken manure and saw dust were measured by HX-240 Moisture Analyzer. The energy content of the feedstock and additives were determined by a bomb calorimeter (ASTM D240-17). The pH value of the mixtures was adjusted to a range of 7.0 to 8.0 by using Sulfuric Acid and was measured in duplicate using Mettler Toledo FG2-Kit FiveGo™ Portable pH meter.

Volume of biogas was measured for every 5 days by using water displacement method and the composition of biogas was determined by using a gas chromatography (GC-8AIT) equipped with thermal conductivity detector (TCD).

3. Results and discussions

3.1. Characterization of feedstock and additives

Table 1 shows the properties and characteristics of feedstock and additives. The carbon to nitrogen (C/N) ratio of CM was 8.21 which is higher compared to the previous work reported in [1] which was 3.83. C/N ratio for SD is higher than chicken manure due to its lower nitrogen content. CM and SD alone is not suitable for AD due to the low C/N ratio which can inhibit methane production and increase ammonia production while high C/N ratio can inhibit microbial metabolism. Srivastava et al. (2020) studied the anaerobic co-digestion on defatted microalgae residues and rice straw and reported that the C/N ratio of 30 is effective for AD process [10]. The energy content was found to be 6905, 12869, 9109, 17181, and 16326 J/g, respectively. This shows their capacity as organic matters for co-anaerobic digestion process.
Table 1. Properties and characteristics of feedstock and additives

| Parameter                | CM     | S     | SW   | PPM   | OPW   |
|--------------------------|--------|-------|------|-------|-------|
| TS (%)                   | 48.54  | 66.46 | 26.4 | 10.63 | 23.82 |
| VS (%)                   | 54.27  | 74.80 | 75.2 | 76.05 | 78.22 |
| C (%)                    | 36.20  | 48.43 | -    | -     | -     |
| H (%)                    | 5.46   | 6.74  | -    | -     | -     |
| N (%)                    | 4.41   | 0.59  | -    | -     | -     |
| S (%)                    | 0.85   | 0.06  | -    | -     | -     |
| C/N ratio                | 8.21   | 82.08 | -    | -     | -     |
| Moisture (%)             | 44.10  | 39.90 | -    | -     | -     |
| Energy Content (J/g)     | 6905   | 12869 | 9109 | 17181 | 1632  |

3.2. Daily production of biogas
The amount of biogas produced from the co-digestion of chicken manure with saw dust as the control with and without additives for every 5 days at a temperature of 35 ± 2°C are presented in Fig. 1. It was observed that on the 5th day, biogas has already produced with additives at 10pphf and 30pphf, however for the control and 20pphf SW, the production of biogas is delayed which was on the 10th day of the production. The biogas production for all samples was found to be fluctuated for 50 days may be ascribed to the change of metabolism in the bacteria during the digestion process [7]. For 10 pphf and 20 pphf PPM as well as control, the production of biogas increased gradually until it reaches its peak on the 35th day 10pphf PPM), 40th day (control and 20pphf PPM) and dropped progressively, while the biogas production of 10pphf SW reaches its peak on the 50th day. The progressive drop could be related with microbial degradation of the substrate to produce biogas most probably caused from the continuous decrease in substrate in the reactors which is usually substrate limited for a batch anaerobic digestion process [11]. For OPW, the biogas production was maintained relatively low after the 10th day may be due to the low pH of the orange peel waste. On the 50th day of the digestion, the pH for 10pphf, 20pphf, 30pphf OPW was 4.98, 4.98 and 5.17 which is not a suitable pH for anaerobic digestion process. This corresponds with the findings in [12–15] which has shown the inhibitory effects of orange peel waste towards anaerobic digestion.

3.3. Cumulative production of biogas
Figure 2 shows the plot of cumulative biogas production against the retention time for the 10 reactors. The result suggest that the control produced the highest amount of biogas yield (9734mL) followed by 10pphf PPM (8176mL) and 20pphf of peppermint (7749mL). The lowest biogas produced was the 20pphf SW which is 1110mL. The higher and faster biogas generation from the control could be ascribed to the higher rate of decomposition of the animal waste since the digestive system of cows and birds has undergone a form of digestion respectively [16]. For additives such as PPM and SW, the slow production of biogas is may be due to the slow degradation of the additives which they contain fibrous tissues such as lignin, suberin, cutin etc. [16].
Figure 1. Biogas yield at 5 days intervals from feedstock and with additives at (a) 10pph, (b) 20pph, (c) 30pph dosage.
Figure 2. Cumulative biogas production for 50 days from feedstock and with additives at (a) 10pph, (b) 20pph, (c) 30pph dosage.
3.4. Methane yield

The quality of biogas can be described in Fig. 3. It is observed that no methane was produced on the 10th day of the digestion. This is maybe due to the high lignin content in the saw dust which it is not easily degraded and slows the process. Methane started to yield on the 20th day for all sample. The control reaches its peak on the 30th day of the digestion which is 54.33%, while for 10pph of SW and PPM reaches its peak on the 50th day which are 59.30% and 44.95%. Based on Figure 3, it can be observed that the methane content for 10pph SW has increased gradually until 50th day, suggesting that the quality of biogas could be higher after the 50th day of digestion. It was also observed that the methane content of biogas from the control increased from 54.33% to 59.30% when 10pph SW is used as additive which indicates an improvement in biogas quality. This result corresponds with the findings.

![Figure 3](image1.png)

**Figure 3.** Percentage of methane yield for 50 days from feedstock and with additives at (a) 10pph (b) 20pph (c) 30pph.
stated in [11] where the co-digestion of chicken manure with SW achieved an average methane content of 66.20%. As for orange peel waste, although the biogas yield is comparable with other additives, but in terms of quality in biogas, they are the lowest. The presence of limonene in the orange peel waste is known for its toxic effect towards anaerobic digestion process as it inhibits both methanogenic and hydrolytic- acidogenic bacteria [15].

4. Conclusion

Though the co-anaerobic digestion of chicken manure and saw dust produced more volume of biogas than adding any additives, however methane content was higher with the addition of 10pph SW. OPW could not be an additive as they possessed a toxic effect towards anaerobic digestion process. A longer retention time period would allow a proper decomposition of additives such as 10pph SW and PPM which would increase the biogas yield with improved biogas quality [11]. Future research work will involve optimization of the biogas production by combining the additives. In addition, fly test will be conducted after composting the digestate in order to observe the effectiveness of the additives in deterring the flies.

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