Research Article

Proximate Composition of Sludge from Different Types of Animal Manure

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Abstract | This study aimed to determine the nutritional value of sludge (a by-product of biogas) based on their proximate composition. The sludge was made from animal manure of ruminants, pseudo-ruminants, and non-ruminants. The study was divided into seven treatments: 100% cow dung (T0), 100% broiler manure (T1), 100% rabbit manure (T2), 50% cow dung + 50% broiler manure (T3), 50% cow dung + 50% rabbit manure (T4), 50% broiler manure + 50% rabbit manure (T5), 33.4% cow dung + 33.3% broiler manure + 33.3% rabbit manure (T6). The parameters measured were dry matter (DM), ash content, crude protein (CP), crude fiber (CFi), and crude fat (CFa). The treatments were statistically tested using a one-way analysis of variance in a completely randomized design. As a result, different types of animal manure sources significantly ($p < 0.05$) affect all parameters (DM, Ash, CP, CFi, and CFa) in sludge. The T4 had the highest DM (93.12%), followed by T6, T0, T5, T1, T2, and T3. The result showed that the ash content of T2 was higher than the other treatments. Interestingly, for both CP and CFa, the highest and lowest values were achieved by T1 and T5, respectively. In contrast, the T1 (11.57%) and T5 (53.55%) treatments act differently for CFa content. Due to its potential nutrient content within the sludge, it may be possible to use it as a new feed resource for local farm businesses.

Keywords | Proximate composition, sludge, animal manure

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INTRODUCTION

Indonesia's livestock population is increasing from various ruminants, pseudo-ruminants, and non-ruminants, which leads to higher waste or manure production. Millions of tons of animal waste are produced annually worldwide, both in developed and developing countries (Raja and Wazir, 2017). The manure production in Brazil, the Slovak Republic, and France was 1.9 Kt/year, 20 Mt of dry matter per day, and 120 Mt/year, respectively (Chávez-Fuentes et al., 2017; Leip et al., 2019; Loyon, 2018). Globally, specifically chicken manure, it is estimated that the world produces approximately 20.708 million tons per year, Asia produces about 11.514 million tons, and Europe produces about 2.039 million tons (Bhatnagar et al., 2022; Jurgutis et al., 2020). Khalil et al. (2019) reported an estimation of manure production from beef cattle, rabbit, and chicken (broiler) was 12.9, 0.02, and 26.8 million tons/year, respectively.

Animal waste production could increase the potential negative environmental impact, such as water and soil pollution, if not treated properly. Therefore, animal waste is proposed as the main source material for biogas production to decrease this adverse effect. Chaump et al. (2019) stated that one kilogram of cow dung could generate 0.03-0.05

m^3 of biogas, whereas 50,000 cattle could deliver around 20,000 m^3/day. In Vietnam, livestock waste from pigs, water buffalo, and cattle has been used for biogas production (Yerima et al., 2019). In Indonesia and other developing countries, most biogas is produced in small-scale digesters and only used for home-scale utilization (cooking and lighting) (Khalil et al., 2019).

Numerous factors, including the design of the biodigester reactor, the kind of raw material used, the temperature, pH, and the presence of additional nutrients or chemicals, significantly impact the quality and volume of biogas produced from animal waste (Khalil et al., 2019). The raw material source from livestock waste should be selected based on quantity, availability, sustainability, and nutrient content (Abubakar, 2022). Exploring various livestock compositions, which will significantly matter concerning biogas output, is critical. Elalami et al. (2019) stated that chicken manure, a product of the diverse composition of other organic materials, also being one of the most widely used feedstocks for the anaerobic production of biogas. However, the poultry residue is rich in nitrogen and is therefore not recommended for efficient anaerobic digesters.

An anaerobic-type digester (25 liters) made from plastic material is commonly used as it can accommodate different substrates in biogas production. Atelge et al. (2020) added that biogas can be synthesized using other biomass sources, providing an oxygen-free environment in the presence of anaerobic microorganisms. The biogas process produces gas and sludge, which contain organic substances. Sludge, formed in odorless black mud, consists of 64.73% dry matter, 10.84% crude protein, 34.02% crude fiber, 2.00% crude fat, 16.84% ash, 3,305.84 kcal/kg of gross energy, 52.54% ADF, and 74.12% NDF (proximate analysis result from Animal Nutrition and Feed Laboratory, Brawijaya University). Sludge can be used as alternative feed ingredients for animals or fish. The livestock manure from various feedstock produces different outputs of biogas (Bharathiraja et al., 2018), affecting the sludge's quality and composition. Therefore, this study aimed to examine the proximate composition of sludge from different animal manure types: cow dung, chicken manure, rabbit manure, and sludge mixture.

MATERIAL AND METHODS

Study Site

The collection of livestock wastes (cow dung, broiler manure, and rabbit manure) as the primary materials for biogas and biogas processing was conducted at the Sumber Sekar Laboratory's Teaching and Research Farm (Batu, East Java Province, Indonesia). The proximate analysis was done at the Laboratory of Animal Nutrition and Feed, Faculty of Animal Science, Brawijaya University (Malang, Indonesia).

Experimental Procedure

In this study, a lab-scale 25-liter anaerobic-type digester was used. The anaerobic digester was made up of plastic material. A plastic pipeline material (3/8" inch or 9.5 mm in diameter) was used as the inlet and outlet chambers. The sludge was removed from the bottom end of the digester on the 50th day when the fermentation process ended. The temperature was kept at ambient temperature, so the fermentation was operated in mesophilic conditions. The treatments used in this study are provided in Table 1.

Table 1: Types of animal manure treatments

Treatments	Animal Manure
T0	100% cow dung
T1	100% broiler manure
T2	100% rabbit manure
T3	50% cow dung + 50% broiler manure
T4	50% cow dung + 50% rabbit manure
T5	50% broiler manure + 50% rabbit manure
T6	33.4% cow dung + 33.3% broiler manure + 33.3% rabbit manure

The chemicals used in the proximate analysis were tablet Kjeldahl, H_2SO_4, HCl, NaOH, EDTA, aquadest, acetone, and hexane, following the procedure from AOAC (2005). Thermogravimetry evaporated the water content for dry matter through heating at 105 ˚C for 20 minutes. Protein and fat content were analyzed using the Kjeldahl and extractor Soxhlet tools. Ash or inorganic material is obtained through combustion at 400-600 ˚C high temperatures. The weight lost during combustion represents the organic material content. The crude fiber was obtained by adding chemical materials: H_2SO_4 (1,25%) and NaOH (1,25%).

Statistical Analysis

All data from seven treatments were computed in an Excel program. The data were then analyzed by ANOVA with a complete randomized design, following seven treatments with three replication arrangements. Further treatment's mean differences were separated by using the Duncan test.

RESULTS

The proximate composition is essential to analyze sludges from different animal manure types. In this study, the different treatments of varying materials had a significant ($p < 0.05$) effect in all proximate parameters (dry matter, ash, crude protein, crude fiber, and crude fat percentage), as presented in Table 2. The T4 reached the highest dry matter (DM) with 93.12% of DM, whereas the T3 had the lowest DM (76.85%). The ash content varied from 16%

Table 2: Proximate analysis (%) of sludge made from different types of animal manure

Treatments	Dry Matter	Ash	Crude Protein	Crude Fiber	Crude Fat
T0	89.21 ± 0.45[c]	16.00 ± 1.60[a]	8.42 ± 0.85[a]	32.28 ± 0.24[b]	3.96 ± 0.92[b]
T1	84.66 ±1.02[b]	22.10 ± 1.27[c]	19.49 ± 0.56[d]	11.57 ± 1.09[a]	19.32 ± 0.76[d]
T2	83.36 ± 1.52[b]	36.27 ± 1.51[f]	8.04 ± 0.50[a]	36.36 ± 2.00[d]	0.43 ± 0.26[a]
T3	76.85 ± 0.95[a]	17.94 ± 1.06[b]	8.35 ± 0.48[a]	34.44 ± 1.21[c]	5.04 ± 0.67[c]
T4	93.12 ± 0.99[e]	21.35 ± 0.82[c]	10.61 ± 0.43[b]	43.31 ± 0.65[f]	0.82 ± 0.15[a]
T5	88.68 ± 0.47[c]	33.26 ± 1.35[e]	7.99 ± 0.54[a]	53.55 ± 0.77[g]	0.33 ± 0.09[a]
T6	90.90 ± 0.94[d]	25.58 ± 1.48[d]	12.44 ± 1.11[c]	38.35 ± 1.19[e]	0.97 ± 0.10[a]

Note: Different superscript within the same column indicated significant differences ($p < 0.05$).

to 36.27%. The highest ash percentage was achieved by T2 (36.27%), followed by T5 (33.26%), T6 (25.58%), T1 (22.10%), T4 (21.35%), T3 (17.94%), and T0 (16%). The crude protein (CP) content of the sludge was ranging from 7.99% (T5) to 19.49% (T1). The T5 and T1 treatments recorded the highest (53.55%) and lowest (11.57%) crude fiber (CFi) content. The T0, T2, T3, T4, and T6 treatments have more than 30% CFi (32.28% - 43.31%). Mean crude fat (CFa) content varied from 0.33% (T5) to 19.32% (T1). The highest CFa is achieved by sludge made from 100% of cow dung.

DISCUSSION

Sludge is a by-product of anaerobic fermentation, which is thought to have a high nutrient content. It is known that the nutrient content in sludge depends on the type of mixture of ingredients and the fermentation process carried out (Isemin et al., 2019; Nwokolo et al., 2020). The findings of this study prove the theory that different material or animal waste types used as ingredients in the biogas process affect the sludge's nutrient components ($p < 0.05$). The DM of sludge from all treatments in this study was higher than the DM reported by Moningkey et al. (2016), which has 85.5% DM. The DM of sludge is influenced by the DM of primary material used in biogas processing. The sludge analyzed by Moningkey et al. (2016) was made from a mixture of cow dung and rumen content. Usman et al. (2019) found that poultry waste had 90.38±0.03% of DM, whereas the DM of rabbit manure varied from 72.8 – 73.4% (Asiegbu and Oikeh, 1995). The DM of cow dung was 57% (Moussa Baldé et al., 2019). The previous references showed that the DM of chicken manure is higher than that of other animal waste. The methane efficiency in biogas production increases with feedstock dry matter value (Dach et al., 2020) and is inversely proportional to the DM content in the sludge. This research proves this theory, which shows that sludge originating from chicken manure has low DM.

The ash content of sludge ranges from 25.18–46.05% (Folgueras et al., 2015; Namkung et al., 2018). Isemin et al. (2019) and Lee et al. (2021) reported 29.4% and 21.1% of ash content in animal waste sludge made from horse and cow manure, respectively. Therefore, it can be concluded that the ash content in this study is still within the range according to the literature. Zhang et al. (2020) stated that cow manure sludge has a higher volatile and calorific value and a lower ash content (22.07%) than TDS (textile dyeing sludge). The ash content affects the torrefaction after anaerobic digestion. As the initial feedstock ash content increased, the rate of heating value growth reduced as a function of torrefaction temperature (Isemin et al., 2019).

Biomass ash primarily consists of alkali metals (sodium and potassium), alkaline earth metals (calcium and magnesium), silicon, sulfur, chlorine, and phosphorus. Sodium (Na) and potassium (K) elements possess the capability to modify the sequence of pollutant release containing nitrogen (N), sulfur (S), and chlorine (Cl) elements (Tang et al., 2018). Furthermore, the presence of silicon (Si) and aluminum (Al) has been observed to impede the formation of slag by creating compounds with high melting points (Li et al., 2019).

The T1 and T5 acted differently for crude protein and fiber. Treatment T1, which uses 100% broiler manure, has the highest CP and lowest CFi, while T5, which uses a mixture of 50% broiler and 50% rabbit manure, has the opposite value. Moningkey et al. (2016) reported 26-30% of CFi content and 11.69-12.18% of CP content in the rumen and sludge mixture. The study of Fajarudin et al. (2013) reported that the crude protein content of dried animal waste sludge ranged from 6.86 to 9.47%—the CP in sludge increases along with the increasing anaerobic digestion time. Another study by Pulunggono et al. (2013) reported the range for CP content in sludge added with urea is around 7.67% – 10.46%. Therefore, it can be concluded that the CP in this study is still within the range according to the literature, except for the T1 treatment (100% cow dung), which has the highest CP content.

A report by Pertiwiningrum et al. (2017) found that the CFi of biogas sludge made from cow dung with chicken manure addition was 14.39%. In sludge added with urea treatment, the CFi ranged from 26.31% - 31.39% (Pulunggono et al., 2013). These previous findings were lower than the CFi in this study except for the T1. Crude fiber content indicated the amount of cell wall composed of cellulose, hemicellulose, and lignin. Hülsemann et al. (2023) and Patinvoh et al. (2017) stated that the fiber substrate is highly resistant to microbes during anaerobic digestion, especially the lignocellulose. Therefore, a high crude fiber content left in biogas slurry could indicate low efficient biogas production.

The results implied that CFa value is affected by the different types of animal manure in sludge. Li et al. (2001) reported 1.5-4% CFa content in sewage sludge mixed with pig manure. The study of Møller et al. (2014) reported that the CFa correlated with methane potential in biogas production. Organic matter from manure with a high CFa content has a greater CH_4 yield after 30 days due to a higher fat content in their corresponding diets, so feces from a diet with fat supplementation will have a better value and increase the economic performance of the biogas plant. This effect could be explained by lipids producing more theoretical CH_4 than carbs and proteins (Long et al., 2012).

Sludge can still be used as fertilizer or an alternative feed source. The bio-slurry produced from this research has a good nutrient composition for use as fertilizer. High crude protein indicates a high N content as well. It also contains other minerals, such as phosphorus and potassium, which plants need. Wagaw (2016) also found that slurry's micro and macro minerals are higher than manure and compost. Indonesia's national standard of fish food is dry matter 88%, ash < 12%, protein 25-30%, fat 2-10%, and crude fiber 6-8% (SNI 01-7242-2006). Based on this requirement, some parameters of the studied sludge were out of range. Sludges' ash and crude fiber content were too high, whereas the fat and protein content were lower than required. Sun et al. (2019) reported that increased fiber in fish food is not beneficial to the fish's growth since it may reduce the digestibility of dry matter and the efficiency ratio of other nutrients. The ash content in fish food affects fish's digestibility and growth (Zaenuri et al., 2014). Hence, further sludge treatment should be done to increase its nutrient quality for further utilization as fish feed. Zaenuri et al. (2014) added that the sludge thickening process could reduce the ash content in sludge to 50%, dewatering to 5%, drying to 1.44%, and then burning to 0.3%.

CONCLUSION

The various types of animal manure sludge have a significant impact (statistically significant at P<0.05 level) on multiple parameters, including DM, Ash, CP, CFi, and CFa. Among the treatments, T4 exhibited the highest DM value. T3 displayed a comparatively elevated ash content compared to the other treatments. The highest CP content was observed in T1, while T5 had the lowest CFa content. T5 recorded the highest CFi value, whereas T1 had the lowest CFi value. The promising nutrient composition in the sludge suggests the potential for its utilization as a novel feed resource for local farming enterprises.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

NOVELTY STATEMENT

Inadequate animal waste management during production can potentially exacerbate environmental deleterious pollution effects. Consequently, animal waste has been suggested as a primary feedstock for biogas production to mitigate these undesirable consequences. Biogas production engenders the generation of gaseous and sludge components, the latter of which encompasses organic constituents. Notably, the diversity in livestock manure sourced from varying feedstocks yields distinct biogas outputs, influencing the resultant sludge's compositional attributes and quality.

AUTHOR'S CONTRIBUTION

MJ, OS, SM, and AM designed and coordinated the study. MJ, OS, and SM supervised the experiment. AM experimented, analyzed the data, and drafted the manuscript. MJ, OS, and SM took part in critically checking this manuscript. All authors read and approved the final manuscript.

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