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Utilization of Milk Sludge and Dairy Cow Urine in Dairy Farm Liquid Waste for Soil Conditioner Production

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Abstract

Milk sludge is generated from dairy industrial wastewater treatment and contains substantial organic matter, making it a promising resource for organic soil conditioner. Liquid organic soil conditioners can be produced through the combination of milk sludge and cow urine. This study aimed to identify the most effective dosage of milk sludge in dairy wastewater for improving the quality of liquid organic soil conditioners. An experimental approach was applied using a Completely Randomized Design (CRD) with four treatment levels: P1 (0%), P2 (10%), P3 (20%), and P4 (30%), each with four replications. The parameters evaluated included fecal and non-fecal coliform populations determined by the MPN and confirmation tests, organic carbon content, pH, and temperature. The results demonstrated that all treatments significantly influenced organic C levels, pH, and coliform counts. A 30% concentration of milk sludge in dairy wastewater, observed at the third week, yielded liquid organic soil conditioners that satisfied the minimum technical standards stipulated in the Indonesian Ministry of Agriculture Regulation No. 261 of 2019.

Keywords: Coliform; Milk Sludge; Liquid Waste; Organic Soil Improver; Dairy Farming

1. Introduction

Pangalengan District is one of the districts in Bandung Regency with dairy farms and milk processing facilities. Generally, dairy farmers in Pangalengan District utilize solid and liquid waste from dairy farms for biogas and vermicompost. Urine is an underutilized liquid waste from dairy cattle. An adult cow in a livestock business can produce 10-15 liters of urine/day, urine can be utilized because it contains nitrogen compounds, auxin-a (*auxentriollic acid*) and auxin-b (Vebriyanti et al, 2022). Urine in cattle consists of 92% water, 1.00% nitrogen, 0.2% phosphorus, and 0.35% potassium. Urine contains the most minerals nitrogen (N) and potassium (K) (Dhananjay Patra, Nalin Bharti, 2024). The nutrient content of urine includes N, P, K, Ca, Mg which are bound in organic compounds including urea, ammonia, creatinine and keratin, livestock urine can be absorbed by plants and urine from livestock contains growth hormones in plants that can stimulate plant growth and development (Indrawaty, 2016).

Waste can be obtained from intensive livestock farming, in addition to waste can be obtained from the milk processing industry which is still underutilized. Milk contained in liquid waste has a high organic content. The milk processing industry is required to process liquid waste before the waste is discharged into rivers. Organic materials dissolved in liquid waste are filtered through several filtering stages, then channeled into a holding pond. This waste processing will produce *sludge* or milk mud that settles in the holding pond. Every 2000 grams of milk waste (*slurry*) can be obtained 250 grams of milk mud and its nutritional value is quite high as a source of protein, namely a crude protein content of

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34.98%, lactose 4.42%, crude fiber 9.77%, crude fat 11.04%, calcium 2.33%, and phosphorus 1.05%, Mg 0.4% on a dry matter basis (Marlina, 2007).

Milk sludge from the dairy processing industry remains underutilized, but it actually has potential as an organic soil conditioner. Milk sludge can be returned to farmers to be mixed with cow urine, then stirred and aerated to form an organic soil conditioner. The use of milk sludge and dairy cow urine is expected to provide a source of organic carbon and nitrogen in organic soil conditioners. Liquid waste, dairy cow urine, and milk sludge-based fertilizers (PTO) could provide a solution to the problems faced by most dairy farms in the liquid waste management sector.

Organic soil amendments (OAMs) serve to prevent soil erosion and pollution, change the hydrophobic and hydrophilic properties of the soil, thereby changing the soil's capacity to retain water and increasing several nutrients in the soil. The main active ingredient of OAMs is carbon (C). One of the requirements for making OAMs according to the Decree of the Minister of Agriculture of the Republic of Indonesia No. 261/KPTS/SR.310/M/4/2019 is that the minimum organic C content in OAMs is 10%. The nutritional content of milk sludge contains 22.46% protein and 4.96% fat, and 55.61% organic C can be a source of organic C (Ellin et al, 2023).

The obligation to process liquid waste is stated in the Decree of the Minister of Agriculture of the Republic of Indonesia No. 261/KPTS/SR.310/M/4/2019, which can be a solution for the dairy farming industry and the milk processing industry because in the decree the waste from dairy farming and the milk processing industry can be processed into organic fertilizer, biofertilizer, and organic soil improver (PTO). The requirements for making products that are easy to achieve after processing dairy farming liquid waste and urine and milk sludge from the milk processing industry are obtained as organic soil improver. The minimum requirements for PTO according to the Decree of the Minister of Agriculture of the Republic of Indonesia No.261/KPTS/SR.310/M/4/2019 include a minimum C-organic content of 10%, a minimum pH of 4-9, *and E. coli* less than 1 x 102 cfu /g.

Organic soil conditioners are defined as natural, organic or mineral materials, in solid or liquid form that can improve soil structure, can change the capacity of the soil to retain water, and can improve the soil's ability to hold nutrients, so that water and nutrients are not easily lost, but plants are still able to utilize the water and nutrients (Dariah and Nurida, 2015). The main concept of using soil conditioners is the use of soil aggregates to prevent erosion and pollution, change the hydrophobic and hydrophilic properties, so that it can change the capacity of the soil to retain water, and increase the soil's ability to hold nutrients by increasing the cation exchange capacity (CEC) (Arsyad 2000). Furthermore, according to the Decree of the Minister of Agriculture of the Republic of Indonesia No. 261 / KPTS / SR.310 / M / 4/2019, soil conditioners function as carbon enhancers in the soil, organic soil stabilizers, and neutralize soil acidity.

The selection of PTO materials needs to be done properly to get good results. The availability of livestock liquid waste, urine, and milk sludge which are waste from milk processing is abundant and can be used as the main material for PTO. Previous research on the nutrient content in liquid organic fertilizer with spoiled milk as the base material added with *Effective Microorganism* 4 (EM4) and cocopeat in reactor 3 (1: 5: 30) contained nutrients of pH 4.17, total P_2O_5 1.010, total K_2O 1.113 and C-organic 10.486 (Triwuri, et al., 2019).

2. Materials and methods

2.1. Materials

Liquid waste, cow urine, milk sludge from the dairy processing industry, and molasses. The equipment used includes devices for processing, measuring, sterilization, and analysis.

2.2. Method

The study used an experimental method, with four treatments consisting of four levels of milk sludge concentration, namely P1 (0%), P2 (10%), P3 (20%), and P4 (30%) of a mixture of liquid waste and dairy cow urine and four repetitions. The sample preparation stage, namely mixing 8 L of dairy farm liquid waste with 2 liters of dairy cow urine, then adding milk sludge according to the treatment concentration, stirring, aerating in a 10 L jar for 2 weeks to reduce pathogenic bacteria,

The 15-tube MPN test to determine the presence of coliform bacteria was carried out using *lactose broth media* , incubated for ±24 hours, followed by a booster test using EMBA media (*Eosin methyline blue agar*) was carried out to identify fecal and non-fecal coliform colonies on EMBA media based on changes in colony color. The C-organic test was carried out using the Walkley Black method, using $K_2Cr_2O_7$, H_2SO_4, ferroin, and $FeSO_4$ solutions.

2.2.1. Observed Variables

The variables observed in this study include:

- Coliforms using the 15 tube MPN Test. Observation of the sample is positive for containing coliform bacteria if there are air bubbles in the Durham tube
- Booster Test, positive gas tubes are streaked on EMBA media to determine fecal coliforms (*Escherichia coli*) and non-fecal coliforms.
- Organic Carbon Content (C-Organic): using the *Walkley and Black method*
- pH
- Temperature

2.3. Statistical Analysis

This study used a Completely Randomized Design (CRD) with four treatments and three replications, and an observation period of four weeks. Observation data from each variable (organic carbon content, pH, and the presence of *Escherichia coli* bacteria) were analyzed using analysis of variance (ANOVA) to test for significant differences between treatments. If the analysis results showed significant differences, a further Tukey test was performed.

3. Results and Discussion

3.1. The Effect of Treatment on MPN Coliform Bacteria

The results of the MPN coliform test are shown in Table 1.

Table 1 MPN Values of Coliform Bacteria

Observation Time (week)	**Milk Sludge Concentration**				**F**
	0%	**10%**	**20%**	**30%**	
	……………MPN/ml ……………				
1	3.5 ^{a}	8.7 ^{a}	16 ^{a}	12.6 ^{a}	Ns
2	0.87 ^{a}	0.27 ^{a}	0.4 ^{a}	0.4 ^{a}	Ns
3	16 ^{a}	16 ^{a}	16 ^{a}	12.6 ^{a}	Ns
4	10.7 ^{a}	12.6 ^{a}	16 ^{a}	16 ^{a}	Ns
Minister of Agriculture Decree Standards No. 261 of 2019	*Escherichia coli* $< 1 \times 10^2$ MPN/ml				

The presence of coliform bacteria in milk sludge and dairy cow urine in dairy farm wastewater at various observation times showed that the average MPN value indicated that the wastewater was safe to use according to the technical requirements of the Ministry of Agriculture Decree No. 261 of 2019, namely the *Escherichia coli bacteria content* $<1 \times 10^2$ MPN/ml. In addition, differences in milk sludge concentrations had the same effect on the number of coliform bacteria.

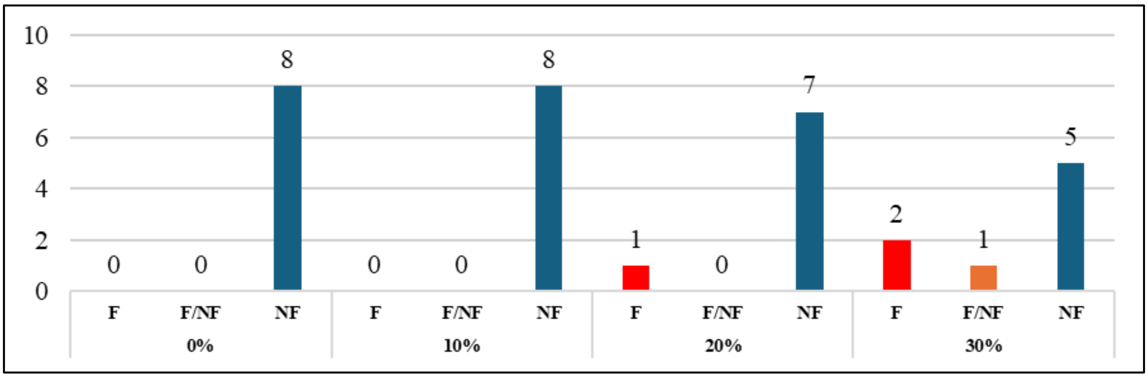

Figure 1 Observation Results of the Strengthening Test for Fecal and Non-Fecal Bacteria

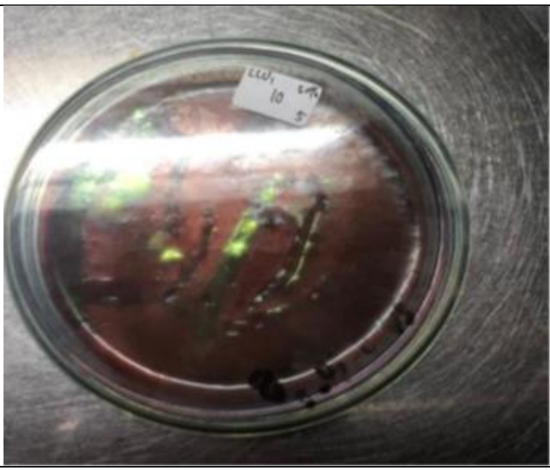

Figure 2 Fecal Coliform Colonies (metallic green)

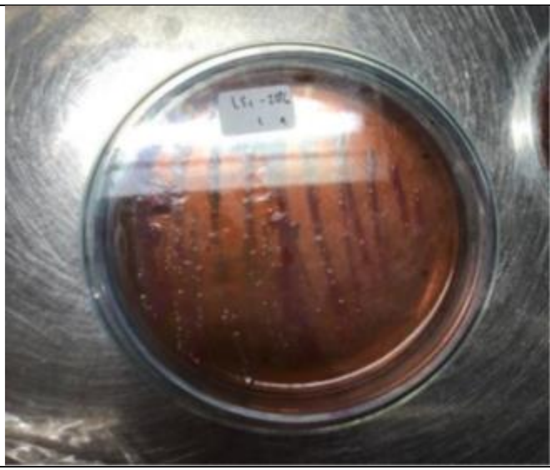

Figure 3 Non-fecal Coliform Colonies (pink)

Figure 1 Observations on the presence of coliform bacteria in samples with different milk sludge (P2, P3, P4) for four weeks showed that in the first week, samples with milk sludge concentrations of 0% and 10% in both replication 1 and 2 did not show the presence of fecal bacteria. However, at treatment of P3 and P4, especially P4, fecal bacteria were detected in both replications, indicating the potential for contamination at high milk sludge levels.

The second week showed that all treatment (P1-P4) were generally free of fecal bacteria in replicates 1 and 2, although a small amount of fecal bacteria was found at the P4 replicate 2. This suggests that contamination remains possible at higher concentrations, albeit at low levels.

In the third and fourth weeks, all samples at all concentrations and replicates were free of fecal bacteria, indicating that the liquid waste conditions no longer supported the growth of coliform bacteria. Observations using EMBA media showed a color change from metallic green (Figure 2) to pink or a combination of both, indicating the metabolic activity of coliform bacteria, especially *Escherichia coli* . According to WHO (2015), bacterial growth is influenced by temperature, water activity, pH, and oxygen availability. The optimal temperature *for E. coli* is around 37°C (Kurniati et al., 2020), while in this study the average temperature of milk sludge ranged from 23–27°C, still within the range that supports its growth.

High water activity is required for biochemical reactions and substance transport, while the optimum pH for *E. coli growth* is 6.0–8.0. Milk sludge pH measurements during the study were in the range of 7.9–8.5, conditions that remain conducive to the growth of these bacteria. Oxygen availability also plays a crucial role, given that *E. coli* is a facultatively anaerobic Gram-negative bacterium that can grow under both aerobic and anaerobic conditions (Kurniati et al., 2020). Incubation was carried out under aerobic conditions, thus supporting optimal growth.

In the third week, the colony color on the EMBA medium changed to pink (Figure 3), indicating the presence of non-fecal coliform bacteria such as *Citrobacter* . This is in line with the identification bacteria (James G Cappuccino & Natalie Sherman, 2013 ;Nengsih, 2022).), which state that pink color on the EMBA medium indicates non-fecal coliforms. Based on these results, the milk sludge in dairy farm wastewater meets the minimum technical requirements as an organic soil amendment.

3.2. The Effect of Treatment on C-Organic Content

The C-organic content in the mixture of waste, urine and milk sludge is listed in Table 2.

Table 2 Average C-organic Content of Milk Sludge in Liquid Waste Dairy Farming

Observation Time (Sunday)		Milk Sludge Concentration				F
		0%	10%	20%	30%	
		...%...				
1		5.8 a	6.4 a	4.9 a	4.7 a	Ns
2		5.13 a	6.4 a	6.3 a	6.8 a	Ns
3		6.6 a	7.6 ab	9.2 ab	10.4 b	*
4		6.8 a	7.3 ab	9.7 bc	11.4 c	*

The average organic C content in the mixture of milk sludge and dairy cow urine in dairy farm wastewater ranged from 4.9% to 11.4%. Based on the results of the Tukey test, in weeks 1 and 2, differences in milk sludge concentration did not have a significant effect on the organic C content. This result is consistent with the analysis of variance (ANOVA) which showed that variations in milk sludge concentration did not provide a significant difference in weeks 1 and 2. The decrease in organic C content during this period was caused by the decomposition process of organic matter from milk sludge, in which microorganisms utilize organic C as a source of energy and carbon (Hina Khatoon et al., 2017). Milk sludge itself has a high organic C content, namely 55.61%, during the decomposition process, indigenous bacteria found in milk sludge play an active role in breaking down organic compounds into simpler forms (Ellin et al., 2023).

Differences in results began to appear in weeks 3 and 4, where Tukey's test showed significant differences between treatments. In week 3, the treatment with a 0% milk sludge concentration produced an organic C content of 6.6%, while the treatment with a 30% concentration produced 10.4%. In week 4, significant differences were found between the P1 and P3, P1 and P4, and P2 and P4 treatments. Based on the provisions of the Ministry of Agriculture Decree No. 261 of 2019, the minimum requirement for organic Carbon content for organic soil conditioner is 10%. Only the treatment with a 30% milk sludge concentration in weeks 3 and 4 met this standard and was therefore considered the most effective. Meanwhile, the treatments with concentrations of P1, P2, and P3 did not meet the minimum standard.

The increase in organic C content in the 3rd and 4th weeks was caused by the completion of the initial stage of decomposition which released organic acids and essential nutrients, thus stimulating soil microbial activity (Stephanos et al, 2022). This increased microbial activity accelerated the process of decomposition of organic matter, producing compounds that contributed to the increase in organic C. Treatment with a 30% milk sludge concentration was proven to provide optimal results in increasing organic C content during the composting process of dairy farm liquid waste and was ready for application, in line with the opinion of (Bot and Benites, 2005; Stephanos et al, 2022) that the concentration of organic C in the soil describes the content of soil organic matter, which serves as a standard for soil management.

3.3. The Effect of Treatment on pH

The pH in the mixture of waste, urine and milk sludge is listed in Table 3.

Table 3 Effect of treatment on pH of Dairy Farm Liquid Waste

Observation Time (Week)		Milk Sludge Concentration				F
		0%	10%	20%	30%	
		...%...				
1		8 a	8.1 ab	8.1 ab	8.3 b	*
2		8.5 a	8.3 a	8.4 a	8.4 a	Ns
3		8.2 a	8.2 a	8.3 a	8.3 a	Ns
4		8.2 a	8.3 a	8.3 a	8.3 a	Ns

The average pH results in dairy farm wastewater ranged from 8–8.5. Tukey's test results showed that in the first week, treatment with 0% and 30% milk sludge concentrations had a significantly different effect on pH. This increase in pH was caused by the breakdown of organic matter in the sludge, which released ammonia during the biosorption process, thereby increasing the pH in agricultural waste (Sandrawati et al., 2019).

However, in the second to fourth week, the results of the Tukey test showed no significant difference in the average pH between treatments. Overall, the pH during the study met the technical requirements according to the Ministry of Agriculture Decree No. 261 of 2019, so that the waste can be applied as an organic soil conditioner.

Changes in pH in liquid waste are generally influenced by the content of organic matter, alkaline or acidic compounds contained in milk sludge, and the activity of microorganisms. Milk sludge contains organic matter that can decompose, producing acidic compounds such as lactic acid and acetic acid, which have the potential to lower the pH (Dameanti et al., 2022). Soil pH conditions affect the availability of nutrients for plants. Neutral to slightly acidic pH is considered optimal because it can maintain nutrient availability, support the life of beneficial microorganisms, suppress element toxicity, and provide ideal conditions for root and plant growth .

3.4. The Effect of Treatment on Temperature

The Effect of treatment on temperature in dairy farm liquid waste is listed in Table 4

Table 4 The Effect of treatment on temperature

Observation Time (Sunday)		Milk Sludge Concentration				F
		0%	10%	20%	30%	
		... ^{0}C...				
1		23.3 ^{a}	23.4 ^{a}	23.4 ^{a}	23.3 ^{a}	ns
2		22.8 ^{a}	22.7 ^{a}	22.7 ^{a}	22.8 ^{a}	ns
3		24 ^{a}	24 ^{a}	24 ^{a}	24 ^{a}	ns
4		23.3 ^{a}	23.3 ^{a}	23.4 ^{a}	23.3 ^{a}	ns

Table 4 shows the results of temperature measurements in four treatments: milk sludge concentrations of 0%, 10%, 20%, and 30%. The average temperature of milk sludge and dairy cow urine in dairy farm wastewater ranged from 22.7–24°C. Tukey's test results showed that from the first to the fourth week, the average temperature between treatments did not show significant differences.

4. Conclusion

Based on the research results, it can be concluded that the addition of milk sludge to a mixture of liquid waste and dairy cow urine at concentrations of 0%, 10%, 20%, and 30% has different effects on the organic C content and acidity level (pH). However, these concentration variations did not show a significant effect on temperature or the presence of coliform bacteria. In addition, this study shows that the time required for the milk sludge condition to meet the requirements according to the provisions of the Ministry of Agriculture is approximately 3–4 weeks. The recommendation for this study is to use a milk sludge concentration of 30% with a fermentation time of approximately 3 to 4 weeks, so that the resulting waste has an organic C content according to the standard, namely approximately 10%.

Compliance with ethical standards

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Disclosure of conflict of interest

There are no conflicts of interest to disclose.

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