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Optimizing Slaughterhouse Waste as Liquid Organic Fertilizer: An Organic Solution to Enhance Cayenne Pepper Production

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ABSTRACT

Cattle rumen waste from slaughterhouses holds economic, social, and ecological value when processed into liquid organic fertilizer (LOF). The application of this LOF has the potential to improve soil fertility, thereby enhancing plant growth and productivity. A collaborative study between the Agrotechnology Study Program of Universitas Kadiri and the Slaughterhouse Technical Unit (UPTD RPH) of Kediri City was conducted to evaluate the effect of LOF derived from cattle rumen waste on the growth and yield of cayenne pepper (*Capsicum frutescens* L.). The research was carried out from October 2022 to January 2023 in the greenhouse of the Geophysics Station (BMKG) located in Sawahan Village, Sawahan Subdistrict, Nganjuk Regency. The experiment used a completely randomized design (CRD) with a single factor: LOF dosage, consisting of six treatment levels: D0 (control), D1 (100 ml/plant), D2 (200 ml/plant), D3 (300 ml/plant), D4 (400 ml/plant), and D5 (500 ml/plant) with four replications. Each experimental unit comprised two plants. Observed parameters included plant height, stem diameter, number of leaves, number of branches, and fruit number and weight. Data were analyzed using analysis of variance (ANOVA), followed by the Least Significant Difference (LSD) test at a 5% significance level. The results indicated that the 500 ml/plant dosage had a highly significant effect on plant height and stem diameter, and a significant effect on the number of branches, but no effect on leaf number. Notably, increasing LOF dosage significantly improved fruit number and weight by 27% at 90 days after transplanting (DAT).

1. Introduction

Chili peppers are horticultural crops widely cultivated in Indonesia due to their suitability to the tropical climate. These plants can thrive in both highland and lowland areas, resulting in a relatively abundant chili production across the country. *Capsicum frutescens* L., commonly known as cayenne pepper is one of the commercially cultivated horticultural crops that contains vitamin A, vitamin C, and essential oils responsible for its pungent flavour and warming sensation (Raras *et al*., 2021). In addition to its role as a food ingredient, chili is also used as a raw material in the food processing industry, an essential oil source, and as an ingredient in traditional medicine and cosmetic products.

The demand for chili continues to rise in line with population growth and the development of the food processing industry. This condition presents chili cultivation as a promising agribusiness opportunity for both domestic and export markets. The per capita demand for cayenne pepper, whether fresh or processed, is estimated at around 4 kg per year (Syarief *et al*., 2016). According to data from Statistics Indonesia (BPS, 2022), the production of cayenne pepper in Indonesia has fluctuated over the past five years. Production increased from 1,153,155 tons in 2017 to 1,508,404 tons in 2020, but declined to 1,386,447 tons in 2021. This decline was influenced by pest infestations, plant diseases, and farmers' limited knowledge of appropriate cultivation practices, ultimately affecting crop productivity.

Chili pepper productivity is strongly influenced by nutrient availability throughout the plant's growth period (Hasibuan *et al*., 2020). Previous studies have demonstrated that the application of LOF can significantly enhance leaf number, plant height, flower production, and fruit yield in chili plants (Rifaldy *et al*., 2019). The use of LOF is gaining increased attention in sustainable agriculture systems due to its ability to improve the physical, chemical, and biological properties of soil, while also reducing dependency on synthetic fertilizers (Setiawan *et al*., 2018). LOF derived from organic waste contributes to enhanced soil microbial activity, improved soil structure, and increased water and nutrient retention capacity (Yuliani & Wibowo, 2021). Moreover, direct foliar application of LOF can stimulate root development, chlorophyll formation, and accelerate the vegetative growth phase of plants.

Organic waste, particularly cattle rumen fluid, holds considerable potential as a source of liquid organic fertilizer. Rumen waste is a by-product of livestock slaughter, especially from cattle, and still contains organic matter and active microorganisms (Sutrisno *et al*., 2020). This waste consists of partially digested feed residues and rumen microflora, both of which serve as sources of nutrients and bioactive compounds beneficial for plant growth. According to (Saragih & Napitupulu, 2019), the utilization of rumen waste as liquid organic fertilizer can improve soil fertility and support plant development due to its content of macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), along with micronutrients and other bioactive substances.

Rumen fluid is known to contain a diverse array of functional microorganisms, including Bacillus sp., Lactobacillus sp., Pseudomonas sp., Cellulomonas sp., and Acinetobacter sp., most of which are facultative anaerobic bacteria. These microorganisms have considerable potential in composting processes due to their ability to enhance the macro- and micronutrient content of the soil and accelerate the decomposition of organic matter (Hudha *et al*., 2020).

The bacterial population in rumen fluid is estimated to range between 1–10 billion cells/mL (Ratnawati *et al*., 2018), making it a valuable biological resource. The high organic matter content in rumen fluid and livestock waste allows their utilization as microbial organic liquid (MOL) bio activators, which play key roles as decomposer agents, plant growth stimulants, and biological control agents for pests and diseases (Hudha *et al*., 2020).

Rumen fluid also contains microorganisms capable of producing a wide range of essential hydrolytic enzymes, such as cellulase, amylase, protease, and xylanase, which actively contribute to the decomposition of complex organic matter (Basri, 2016). In addition to serving as a source of enzymes, rumen fluid provides high levels of organic matter that act as nutrient substrates for microbial activity during decomposition, thereby increasing nutrient availability in organic fertilizers. The organic matter content in rumen fluid has been reported to reach approximately 85.5%, although this value is dynamic and may vary depending on factors such as livestock feed composition, feed retention time in the rumen, and pre-slaughter

handling methods (Tahun *et al*., 2025).

Cattle rumen fluid has a pH of 8.40, which influences the microbiological environment during the composting process. This pH level plays a critical role in determining the activity and survival of decomposer microorganisms involved in the biodegradation of organic matter. In addition, the carbon-to-nitrogen (C/N) ratio of cattle rumen has been recorded at 9.46, an important indicator used to assess compost maturity and the quality of the resulting organic fertilizer (Ratnawati *et al*., 2018).

The Municipal Slaughterhouse (RPH) of Kediri City, as a regional technical implementation unit for livestock slaughter, particularly cattle, faces challenges related to livestock waste management. Field data indicate that each slaughtered cow produces rumen content equivalent to approximately 10–12% of its live body weight. Although the volume is substantial, cattle rumen waste remains largely underutilized. One promising approach for managing this waste is processing it into LOF.

In response to this issue, RPH Kediri has established a research partnership with the Faculty of Agriculture, Universitas Kadiri, aimed at managing and utilizing livestock slaughter waste. As part of this collaboration, RPH Kediri processes cattle rumen waste into LOF. To determine the chemical composition and agronomic potential of the LOF, the Faculty of Agriculture conducted laboratory analyses of the cattle rumen-based formulation. Subsequent field research was conducted to evaluate the effectiveness of cattle rumen LOF as an environmentally friendly alternative organic input to enhance vegetative growth and fruit production in chili cultivation. The findings from this study are expected to contribute scientific insight into the utilization of livestock waste as organic fertilizer and support the implementation of sustainable agricultural practices.

2. Methodology

The study was conducted in the greenhouse of the BMKG Geophysical Station, located in Sawahan Village, Sawahan Subdistrict, Nganjuk Regency, East Java, from October 2022 to January 2023. The experimental site is situated at an elevation of approximately 675 meters above sea level, with air temperatures ranging from 21.0 to 32.0 °C, which falls within the optimal range for the growth of cayenne pepper.

The experiment was arranged using a Completely Randomized Design (CRD) with a single factor: the dosage of cattle rumen waste-based LOF from the municipal slaughterhouse (RPH). The treatment factor (D) consisted of six levels: D0 (0 mL/plant), D1 (100 mL/plant), D2 (200 mL/plant), D3 (300 mL/plant), D4 (400 mL/plant), and D5 (500 mL/plant). Each treatment was replicated four times, resulting in 24 experimental units, with each unit consisting of two plants.

The research began with seedling preparation using a growing medium composed of a 1:1:1 mixture of topsoil, manure, and rice husk charcoal. The mixture was placed into 5 cm cylindrical plastic seedling bags and watered adequately. Seeds were soaked in a solution of warm water, fungicide, and shallot extract for 3–5 hours, drained, and then sown into the seedling medium. The medium was covered with plastic to accelerate germination. The transplanting medium also consisted of topsoil, manure, and rice husk charcoal in a 1:1:1 ratio. Uniformly weighted and labelled 40 × 40 cm polybags were used for transplanting. Transplanting was carried out in the afternoon when seedlings were 2 to 4 weeks old. Plant maintenance included watering, weeding, and pest control when infestations occurred.

The LOF was applied four times during the growing period by drenching it directly onto the root zone of each plant according to the designated dosage. The first application was carried out in the afternoon at two weeks after transplanting (WAT), followed by additional applications at three, four, and five WAT. The first harvest was conducted at 70 DAT, with subsequent harvests at 80 and 90 DAT.

The parameters observed during the experiment included plant height, stem diameter, number of leaves, number of branches, number of fruits, and fruit weight. After field data were compiled, the results were analyzed using analysis of variance (ANOVA). If significant differences were found, the means were further tested using the Least Significant Difference (LSD) test at a 5% significance level. Based on laboratory analysis, the cattle rumen-based LOF from RPH Kediri City contained 3.43% H_2O, 0.74% C, 0.87% N, a C/N ratio of 0.85, 1.03% P_2O_5, and 1.28% organic matter

3. Results and Discussion

The application of LOF derived from cattle rumen waste from the municipal slaughterhouse (RPH) at different dosages had a significant effect on the height of cayenne pepper plants at 20, 40, and 60 DAT (Table 1). At 20 DAT, treatments D4 (36.50 cm) and D5 (38.17 cm) resulted in significantly taller plants compared to other treatments, with D5 producing the greatest height. Treatments D0 through D3 did not differ significantly from each other. A similar trend was observed at 40 DAT, where D4 (74.13 cm) and D5 (77.75 cm) again showed significantly greater plant heights than the other treatments, while D0 to D3 formed a statistically homogeneous group. At 60 DAT, D5 yielded the tallest plants (120.38 cm), significantly different from all other treatments. D4 (113.63 cm) also showed a significant increase, while treatments D0, D1, and D2 resulted in shorter plants and did not differ significantly from each other.

Table 1. Mean plant height as affected by the application of LOF from cattle rumen waste at 20, 40, and 60 DAT

Treatment	Average plant height (cm)		
	20 DAT	40 DAT	60 DAT
D_0	32,17 a	63,38 a	98,50 ab
D_1	32,33 a	63,13 a	97,63 ab
D_2	31,50 a	62,50 a	97,00 a
D_3	33,00 a	66,63 a	103,50 b
D_4	36,50 b	74,13 b	113,63 c
D_5	38,17 b	77,75 b	120,38 d
LSD 5%	2.34	4.34	6.39

Description: Values followed by the same letter within the same column are not significantly different based on the LSD test at the 5% significance level

The application of LOF derived from cattle rumen waste from the municipal slaughterhouse (RPH) had a positive effect on the plant height of cayenne pepper. Based on the treatments applied, increasing doses of LOF, particularly D4 (400 mL/plant) and D5 (500 mL/plant), resulted in greater plant height at all three observation intervals. This indicates that the nutrient content of the LOF such as nitrogen, phosphorus, potassium, and various micronutrients can enhance soil fertility and stimulate vegetative plant growth. The consistent and significant increase in plant height observed with D5 treatment from 20 to 60 DAT suggests that 500 mL/plant is the optimal dose to support the early growth phase of cayenne

pepper. In contrast, lower doses (D0 to D2) did not produce significant differences, indicating that the available nutrients may have been insufficient to support maximum growth. Abdurrahman *et al*., (2019) demonstrated that the application of various concentrations of liquid organic fertilizer (LOF) derived from cow urine had a significant effect on plant height, number of branch nodes, number of fruits, fresh fruit weight, and biomass of cayenne pepper.

The application of cattle rumen-based LOF also significantly affected the stem diameter of cayenne pepper plants across different observation periods. At 20 DAT, D5 treatment (3.72 mm) produced the largest stem diameter, significantly different from D0, D2, and some other treatments. D4 (3.54 mm) also showed a significant increase compared to the control (D0: 3.16 mm), while D1 and D3 were in a statistically similar group. At 40 DAT, the largest stem diameter was again recorded in D5 (7.44 mm), followed by D4 (7.08 mm), both significantly greater than the control (6.34 mm). Treatments D1 and D3 showed intermediate values and did not differ significantly from other lower treatments. At 60 DAT, D5 continued to produce the greatest stem diameter (11.54 mm), followed by D4 (10.98 mm), both of which were significantly different from D0, D1, and D2. D3 showed a slightly higher diameter (10.15 mm), but this was not significantly different from the lower-dose treatments.

Table 2. Mean stem diameter as affected by the application of cattle rumen-based LOF at 20, 40, and 60 DAT

Treatment	Average stem diameter (mm)		
	20 DAT	40 DAT	60 DAT
D_0	3,16 a	6,34 a	9,82 a
D_1	3,28 ab	6,56 ab	10,04 a
D_2	3,14 a	6,29 a	9,74 a
D_3	3,28 ab	6,55 ab	10,15 ab
D_4	3,54 b	7,08 bc	10,98 bc
D_5	3,72 c	7,44 c	11,54 c
LSD 5%	0,32	0,62	0.93

Description: Values followed by the same letter within the same column are not significantly different based on the LSD test at the 5% significance level

Overall, these findings align with the principle that proper organic fertilization can improve soil structure, enhance microbial activity, and provide nutrients gradually, ultimately resulting in better plant growth. The application of LOF derived from cattle rumen waste from the municipal slaughterhouse (RPH) consistently showed a positive effect on increasing the stem diameter of cayenne pepper plants, particularly at the highest dose (500 mL/plant). The increase in stem diameter observed in the D4 and D5 treatments reflects the effectiveness of the nutrient content in the LOF, especially macronutrients such as nitrogen, phosphorus, and potassium, which play critical roles in plant tissue formation. The nitrogen content in liquid organic fertilizer derived from cattle rumen waste plays a crucial role in the vegetative growth of cayenne pepper, particularly in cell division and cell elongation, thereby accelerating stem enlargement (Rizki *et al*., 2015).

The LOF from cattle rumen waste also contains organic matter that can improve soil structure, increase cation exchange capacity, and support soil microbial activity. The combination of these factors enables the plants to grow sturdier with larger and stronger stems, an important indicator of support capacity for both vegetative and generative growth. This study demonstrated that a dosage of 400–500 mL/plant is effective in increasing stem diameter, with significant results observed from 20 to 60 days after transplanting (DAT).

Conversely, lower doses (D0–D2) did not result in meaningful differences in stem diameter, indicating the plants' need for more optimal nutrient availability. At 20 DAT, the highest number of leaves was recorded in treatment D4 (49.00 leaves), followed by D5 (45.25 leaves) and D2 (44.50 leaves), while D1 (31.38 leaves) produced the lowest leaf count. At 40 DAT, a similar pattern was observed, with D4 producing the most leaves (98.25), followed by D5 (90.75) and D2 (89.00), while D1 and D3 resulted in relatively lower leaf numbers. At 60 DAT, D4 again had the highest number of leaves (152.13), followed by D5 (140.50) and D2 (137.88). Conversely, D1 produced the fewest leaves (97.50).

However, statistical analysis showed that differences in the number of leaves among treatments were not statistically significant (ns) at all observation periods. Despite the lack of significant differences, the increasing trend in leaf numbers in higher LOF doses (D2, D4, and D5) indicates a positive potential of cattle rumen-based liquid organic fertilizer in promoting vegetative growth in cayenne pepper. The presence of macro and micronutrients in the LOF, particularly nitrogen which plays a key role in leaf development is presumed to contribute to the observed increase in leaf numbers.

Table 3. Mean number of leaves as affected by the application of cattle rumen-based LOF at 20, 40, and 60 DAT

Treatment	Mean number of leaves		
	20 DAT	40 DAT	60 DAT
D_0	34,88	69,75	108,13
D_1	31,38	63,00	97,50
D_2	44,50	89,00	137,88
D_3	32,75	65,13	101,00
D_4	49,00	98,25	152,13
D_5	45,25	90,75	140,50
LSD 5%	ns	ns	ns

Description: ns = not significantly

Treatment D4 (400 mL/plant) consistently exhibited the highest number of leaves across all observation periods, indicating that this dosage provided optimal conditions for plant growth. However, as the differences were not statistically significant, these findings warrant further investigation, taking into account environmental variability, plant physiological responses, and the stability of nutrient content in the LOF. In general, although the differences in leaf number were not statistically significant, the results nonetheless suggest that the application of LOF derived from cattle rumen waste has the potential to promote leaf growth, particularly at moderate to high dosages.

The application of LOF from RPH cattle rumen waste showed a statistically significant effect on the number of branches in cayenne pepper plants at different observation periods. At 20 days after transplanting (DAT), treatment D5 produced the highest number of branches (5.13), which was significantly different from treatments D0 and D1 (each 2.63). Treatments D3 and D4 (4.13 and 4.25, respectively) also showed increased branching but were not significantly different from D5. At 40 DAT, treatment D5 continued to show the highest number of branches (12.25), significantly higher than the control (D0: 6.00). Treatments D4 (10.38) and D3 (8.50) showed higher values compared to D1 and D2, although the differences among the intermediate groups were less pronounced. At 60 DAT, D5 consistently yielded the highest number of branches (96.25), significantly different from the control and several other

treatments. Treatments D4 and D3 also showed increased branching (89.50 and 79.25, respectively), while D1 recorded the lowest number of branches (54.00).

Table 4. Mean number of branches as affected by the application of cattle rumen-based LOF at 20, 40, and 60 DAT

Treatment	Mean number of branches		
	20 DAT	40 DAT	60 DAT
D_0	2,63 a	6,00 a	65,25 ab
D_1	2,63 a	7,38 ab	54,00 a
D_2	3,50 ab	7,50 ab	74,50 abc
D_3	4,13 bc	8,50 ab	79,25 bc
D_4	4,25 bc	10,38 bc	89,50 bc
D_5	5,13 c	12,25 c	96,25 c
LSD 5%	1,46	3,48	24,56

Description: Values followed by the same letter within the same column are not significantly different based on the LSD test at the 5% significance level

The application of cattle rumen-based LOF from the slaughterhouse (RPH) had a positive impact on increasing the number of branches in cayenne pepper plants, particularly at the highest dosage (500 mL/plant). The increased number of branches indicates a physiological response to the enhanced availability of nutrients, especially nitrogen, which plays a crucial role in the formation of lateral shoots and branching. The organic matter and nutrient content in the LOF improve soil structure, stimulate microbial activity, and enhance nutrient uptake efficiency. These factors contribute to stronger vegetative growth and greater branching. Treatment D5 consistently exhibited the highest number of branches across all observation periods, suggesting that 500 mL/plant is an optimal dosage for promoting branch development. In contrast, lower doses such as D0 and D1 did not result in significant vegetative responses.

Overall, these findings support the use of cattle rumen waste as an effective liquid organic fertilizer for enhancing vegetative growth components in cayenne pepper plants, particularly the number of branches, which plays a critical role in supporting the plant's generative productivity. In addition to nitrogen, cattle rumen-based LOF is also enriched with magnesium, a key activator involved in the energy transport of various enzymatic processes in plants. Magnesium is predominantly found in the leaves and is vital for chlorophyll availability. Adequate magnesium levels are therefore essential to support optimal photosynthesis (Rizki *et al*., 2015).

Based on the observations presented in Table 5, the application of cattle rumen-based LOF had a significant effect on the average fruit weight of cayenne pepper at various harvest ages (70, 80, and 90 DAT. In general, fruit weight increased with both plant age and the amount of LOF applied. At 70 DAT, the control treatment without LOF (D0) resulted in the lowest fruit weight (117.50 g), while treatment D5 yielded the highest (275.00 g). These values are followed by different letters indicating significant differences based on the LSD test at the 5% level, with a critical difference of 16.79 g. A similar pattern was observed at 80 DAT, where fruit weight increased with higher LOF dosages. Treatment D0 produced only 290.00 g, whereas D5 reached 400.00 g. Treatments D1 and D2 formed a statistically similar group but differed significantly from D0 and the higher-dose treatments, according to the LSD value of 17.51 g at the 5% significance level.

Table 5. Average fruit weight of bird's eye chili under cattle rumen-based LOF application at 70, 80, and 90 DAT

Treatment	Harvest age		
	70 DAT	80 DAT	90 DAT
D0	117,50 a	290,00 a	395,00 a
D1	192,50 b	315,00 b	425,00 b
D2	210,00 c	330,00 b	450,00 c
D3	220,00 c	350,00 c	460, 00 c
D4	250,00 d	380,00 d	480,00 d
D5	275,00 e	400,00 e	500,00 e
LSD 5%	16,79	17,51	18,53

Description: Values followed by the same letter within the same column are not significantly different based on the LSD test at the 5% significance level

At 90 DAT, the same trend persisted. The highest fruit weight was recorded under treatment D5 (500.00 g), while the control treatment (D0) yielded only 395.00 g. The differences in fruit weight among treatments were statistically significant, with a LSD value at the 5% level of 18.53 g. Treatments D3, D4, and D5 formed a statistically distinct group compared to the lower-dose treatments and the control. Overall, increasing the dosage of cattle rumen-based LOF from the slaughterhouse (RPH) resulted in greater fruit weight, indicating that this fertilizer can enhance the productivity of cayenne pepper plants. This effect is likely due to improved soil fertility and nutrient availability provided by the nutrient-rich content of the LOF. The findings of (Azisah, 2017) showed that the application of liquid organic fertilizer derived from cattle rumen had a significant effect on the growth and yield (fruit weight) of eggplant.

According to the data presented in Table 6, the application of cattle rumen-based LOF had a significant effect on the number of fruits produced at all harvest ages (70, 80, and 90 DAT). In general, the number of fruits increased with both LOF dosage and plant age. At 70 DAT, the control treatment (D0) produced the lowest number of fruits (58.75), while the highest was observed in treatment D5 (138.00 fruits). These values showed statistically significant differences based on the LSD test at the 5% level, with a critical value of 8.40. Different letters following the numbers indicate significant differences among treatments. A similar pattern was observed at 80 DAT, where the number of fruits increased with higher LOF dosages. Treatment D0 yielded 145.00 fruits, while D5 produced 200.00 fruits. Treatments D1 and D2 formed a homogeneous group that differed significantly from the control and higher-dose treatments. The LSD value for this harvest age was 8.50.

Table 6. Average number of cayenne pepper fruits under cattle rumen-based LOF application at 70, 80, and 90 DAT

Treatment	Harvest age		
	70 DAT	80 DAT	90 DAT
D0	58,75 a	145,00 a	197,50 a
D1	96,25 b	157,50 b	212,50 b
D2	105,00 c	165,00 b	125,00 c
D3	110,00 c	175,00 c	230,00 c
D4	125,00 d	190,00 d	240,00 d
D5	138,00 e	200,00 e	250,00 e
LSD 5%	8,40	8,50	9,26

Description: Values followed by the same letter within the same column are not significantly different based on the LSD test at the 5% significance level

At 90 DAT, the number of fruits continued to increase, with treatment D0 yielding 197.50 fruits and treatment D5 yielding 250.00 fruits. All treatments exhibited statistically significant differences according to the LSD test at the 5% level, with a critical value of 9.26. The higher the dosage of cattle rumen-based LOF applied, the greater the number of fruits produced. This indicates a positive plant response to the enhanced nutrient availability provided by the LOF. Overall, these findings demonstrate that the application of cattle rumen-based LOF significantly increases the number of cayenne pepper fruits. This effect is likely attributed to the nutrient content of the fertilizer, which supports generative plant growth, particularly the formation of flowers and fruits. The increased dosage of LOF proved effective in enhancing plant productivity up to the final observed harvest stage (90 DAT).

4. Conclusion

The application of slaughterhouse cattle rumen waste LOF at a dosage of 500 ml per plant had a highly significant effect on plant height and stem diameter, and a significant effect on the number of branches in bird’s eye chili plants. However, it had no significant effect on leaf number at 20, 40, and 60 DAT. The production of bird’s eye chili, in terms of both fruit weight and number, was significantly affected by the application of cattle rumen based LOF. Increasing the LOF dosage significantly enhanced fruit yield, with improvements of up to 27% in both fruit number and weight observed at 90 DATs.

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