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Production of Liquid Organic Fertilizer Made From Kirinyuh Leaves with Added Chicken Bone Meal Using the EM4 Bioactivator

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Abstract
Continuous use of chemical fertilizers leads to decreased soil fertility, nutrient imbalance, and environmental pollution. One alternative fertilizer is liquid organic fertilizer (POC), which can improve the physical, chemical, and biological properties of the soil while providing nutrients. Kirinyuh leaves (Chromolaena odorata) have great potential as a raw material for POC due to their high macro and micro nutrient content and bioactive compounds that support plant growth. This study aims to produce liquid organic fertilizer from kirinyuh leaves with the addition of chicken bone meal that meets the standards of the Regulation of the Minister of Agriculture of the Republic of Indonesia Number 261/KPTS/SR.310/M/4/2019, and to evaluate the effect of fermentation time and dosage of chicken bone meal on fertilizer quality. Fertilizer is made through a fermentation process using EM4 as a bioactivator with variations in fermentation time and dosage of chicken bone meal. The results showed that fermentation time and dosage of chicken bone meal significantly affected the quality of POC. The concentrations of N, P, and K increased until the 21st day of fermentation due to increased microbial activity in decomposing organic matter, then decreased slightly or did not increase significantly on the 28th day as it entered the fermentation maturation phase. The addition of chicken bone meal increased the concentration of nutrients, especially phosphorus and potassium, while the C/N ratio increased until the 21st day and decreased on the 28th day, indicating that the decomposition process was effective.
Keywords: *liquid organic fertilizer, chromolaena odorata, chicken bone meal, fermentation, EM4*

Abstrak
Penggunaan pupuk kimia terus-menerus menyebabkan penurunan kesuburan tanah, ketidakseimbangan unsur hara, dan pencemaran lingkungan. Salah satu pupuk alternatif adalah pupuk organik cair (POC), yang dapat memperbaiki sifat fisik, kimia, dan biologi tanah sekaligus menyediakan unsur hara. Daun kirinyuh (*Chromolaena odorata*) memiliki potensi besar sebagai bahan baku POC karena kandungan unsur hara makro dan mikro yang tinggi serta senyawa bioaktif yang mendukung pertumbuhan tanaman. Penelitian ini bertujuan menghasilkan pupuk organik cair berbahan dasar daun kirinyuh dengan penambahan tepung tulang ayam yang memenuhi standar Peraturan Menteri Pertanian Republik Indonesia Nomor 261/KPTS/SR.310/M/4/2019, serta mengevaluasi pengaruh waktu fermentasi dan dosis tepung tulang ayam terhadap kualitas pupuk. Pupuk dibuat melalui proses fermentasi menggunakan EM4 sebagai bioaktivator dengan variasi waktu fermentasi dan dosis tepung tulang ayam. Hasil penelitian menunjukkan bahwa waktu fermentasi maupun dosis tepung tulang ayam berpengaruh signifikan terhadap kualitas POC. Konsentrasi N, P, dan K meningkat hingga hari ke-21 fermentasi akibat meningkatnya aktivitas mikroba dalam mendekomposisi bahan organik, kemudian sedikit menurun atau tidak meningkat secara signifikan pada hari ke-28 seiring memasuki fase pematangan fermentasi. Penambahan tepung tulang ayam meningkatkan konsentrasi unsur hara, terutama fosfor dan kalium, sementara rasio C/N meningkat hingga hari ke-21 dan menurun pada hari ke-28, yang menunjukkan bahwa proses dekomposisi berlangsung efektif.
Kata Kunci: *pupuk organik cair, Chromolaena odorata, tepung tulang ayam, fermentasi, EM4*

1. Introduction

Agricultural productivity plays a crucial role in ensuring global food security. However, the intensive and continuous application of chemical fertilizers has contributed to declining soil fertility, nutrient imbalance, and environmental pollution. Excessive use of inorganic fertilizers may also reduce soil organic matter, decrease microbial activity, and impair soil structure, ultimately affecting long-term agricultural sustainability [1]. Therefore, the development of environmentally friendly fertilizers has become an important strategy for improving soil quality while maintaining crop productivity. Liquid organic fertilizer (LOF) has emerged as a promising alternative because it supplies nutrients in a readily available form that can be rapidly absorbed through plant roots and leaves. In addition to providing essential nutrients, LOF contributes to improving the physical, chemical, and biological properties of soil by increasing organic matter content and stimulating beneficial microbial activity. Furthermore, the production of LOF from agricultural biomass and organic wastes supports circular agricultural practices by reducing waste generation and decreasing dependence on synthetic fertilizers [1] [2].

One of the potential raw materials for LOF production is *Chromolaena odorata* (kirinyuh), an invasive weed that is widely distributed in tropical regions. Despite being considered an undesirable plant, *C. odorata* contains considerable amounts of macro- and micronutrients, including nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, and zinc. These nutrients play important roles in chlorophyll synthesis, root development, photosynthesis, water regulation, and plant resistance to environmental stress. In addition, *C. odorata* contains various bioactive compounds such as flavonoids, alkaloids, saponins, tannins, and phenolic compounds, which exhibit antimicrobial properties and may enhance plant resistance against pathogens [3] [4] [5]. The utilization of this invasive weed as a fertilizer raw material also provides environmental benefits by reducing biomass waste and minimizing weed infestation. To improve the mineral composition of liquid organic fertilizer, chicken bone meal can be incorporated as an additional nutrient source. Chicken bone waste is abundantly generated by the poultry industry and contains high concentrations of calcium and phosphorus, two essential elements required for root development, cell wall formation, and plant metabolism. Previous studies have reported that chicken bone meal contains approximately 28–36% calcium, 12–18% phosphorus, and 1–3% magnesium, making it a valuable mineral supplement for organic fertilizers [6]. Compared with other animal bones, chicken bones are more readily available, easier to process, and possess a favorable mineral composition, making them suitable for sustainable fertilizer production [7] [8].

The effectiveness of liquid organic fertilizer is also strongly influenced by the fermentation process. Effective Microorganisms 4 (EM4) is widely used as a bioactivator because it contains beneficial microorganisms capable of accelerating the decomposition of organic matter and converting nutrients into forms that are more readily available for plant uptake. The metabolic activities of these microorganisms enhance the mineralization of nitrogen, phosphorus, and potassium, thereby improving fertilizer quality. Previous studies have demonstrated that the application of EM4 increases nutrient availability and enhances the effectiveness of the fermentation process in producing high-quality liquid organic fertilizer [9]. Several studies have investigated the utilization of *Chromolaena odorata* or chicken bone waste separately for fertilizer production. However, studies evaluating the combined use of *C. odorata* leaves and chicken bone meal, particularly by investigating the effects of fermentation period and chicken bone meal dosage on nutrient composition and fertilizer quality, remain limited. In addition, information regarding the optimum fermentation conditions required to produce liquid organic fertilizer that complies with the Indonesian National Standard specified in the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 261/KPTS/SR.310/M/4/2019 is still insufficient.

Therefore, this study aimed to produce liquid organic fertilizer from *Chromolaena odorata* leaves supplemented with chicken bone meal and fermented using EM4 as a bioactivator. The effects of fermentation period and chicken bone meal dosage on the characteristics of the resulting fertilizer were evaluated based on organic carbon, nitrogen, phosphorus, potassium, pH, and C/N ratio. It was hypothesized that the addition of chicken bone meal combined with variation in fermentation period would increase the content of macronutrients (nitrogen, phosphorus, and potassium) and improve the C/N ratio, thereby producing liquid organic fertilizer of better quality that complies with the established standard. This study is expected to provide several benefits: (1) enhancing soil and plant fertility to support more productive agriculture; (2) supporting the utilization of *C. odorata* leaves as raw material for liquid organic fertilizer as well as chicken bone waste as a valuable source of calcium and phosphorus; and (3) providing an environmentally friendly, locally-based alternative liquid organic fertilizer as an effort to reduce dependence on chemical fertilizers.

2. Material and Methods

Materials

The main materials used in this study included kirinyuh leaves obtained from Dukuh Puthuk, Sawahan Village, Sawahan Subdistrict, Nganjuk Regency, and broiler chicken bones obtained from Medokan Ayu Market, Rungkut Subdistrict, Surabaya City. The bioactivator used was EM4 Pertanian (PT Songgolangit Persada), a brownish-yellow solution with a pH of 4 - 9 containing a consortium of effective microorganisms such as Lactobacillus sp., Rhodopseudomonas sp., Bacillus sp., Streptomyces sp., and Saccharomyces sp. to accelerate the fermentation and decomposition of organic matter. The fermentation process was carried out in a 15-liter gallon-sized fermenter equipped with a gas delivery hose to maintain stable pressure, as well as a 1-liter bottle filled with water that served as both a gas reservoir and a one-way valve to maintain anaerobic conditions throughout the fermentation process.

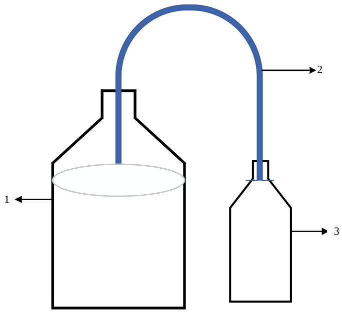

Figure 1. Research Tool Series
Description of the tool series : (1) Fermentor 15 L, (2) Tube, (3) Bottle 1 L.

Methods

This study aimed to produce liquid organic fertilizer (LOF) from *Chromolaena odorata* leaves supplemented with chicken bone meal as an additional nutrient source. The study began with the preparation of the equipment and materials, including twenty-five 15-L plastic containers, 15 m of transparent plastic tubing, *C. odorata* leaves, 20 bottles of EM4 solution, and 5 kg of palm sugar. Chicken bone meal was then prepared by washing 2 kg of chicken bones with clean water, followed by boiling at 100°C for 60 min. The boiled bones were cut into approximately 5 cm pieces and dried in an oven at 70°C until the moisture content was reduced. The dried bones were subsequently ground using a blender and sieved through a 60-mesh sieve to obtain chicken bone meal with a uniform particle size. *C. odorata* leaves were chopped into approximately 2 cm pieces, and 2 kg of the chopped leaves were placed into each container. Subsequently, 500 mL of EM4 solution and 600 mL of dissolved palm sugar solution were added as nutrient sources for microorganisms during the fermentation process. Chicken bone meal was then added according to the predetermined dosages of 0, 10, 20, 30, and 40 g, and the mixture was thoroughly stirred to ensure homogeneity. Fermentation was carried out at room temperature (approximately 30°C) for 0, 7, 14, 21, and 28 days. Finally, the resulting liquid organic fertilizer was characterized by determining its organic carbon (C-organic), nitrogen (N), phosphorus (P), potassium (K), and pH.

3. Results and Discussion

The research results showed that all treatments exhibited a similar pattern where C-organic content continuously increased from day 0 to its peak on day 21, then decreased on day 28 [10]. This pattern was influenced by two factors: the mass of chicken bone meal (TTA) and fermentation time. During the first 21 days, both factors drove the increase in C-organic content, with higher TTA mass and longer fermentation time producing higher C-organic levels. At day 0, C-organic content ranged from 10.745% (without TTA) to 11.763% (40 g TTA), indicating that fermentation had not yet begun as microorganisms in EM4 were still in the initial adaptation phase and had not actively decomposed organic matter [10]. The 9.5% increase in initial C-organic content with TTA addition occurred because chicken bone meal contributed not only calcium and phosphorus minerals but also organic components such as collagen protein with small amounts of carbon and nitrogen [11].

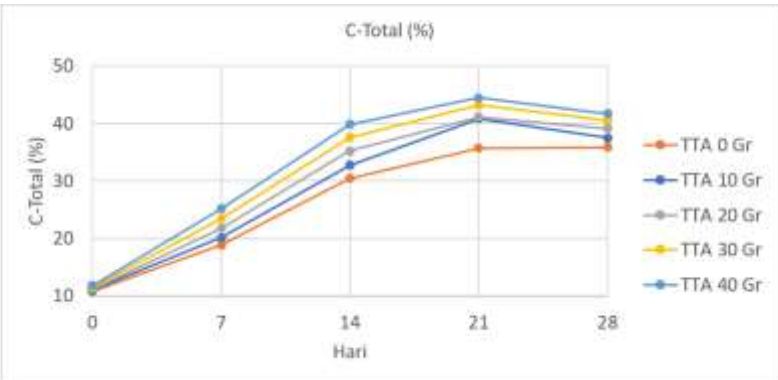

Fig. 1. The Relationship Between Organic Carbon Content and TTA Mass and Fermentation Time

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Table 1. Results of the Organic Carbon (C-Organic) Analysis of Liquid Organic Fertilizer

Sample	**C Total (% weight)**				
	Day:				
	0	**7**	**14**	**21**	**28**
TTA 0 Gr	10,745	18,864	30,482	35,742	35,864
TTA 10 Gr	10,982	20,146	32,764	40,864	37,482
TTA 20 Gr	11,246	21,735	35,248	41,135	39,164
TTA 30 Gr	11,487	23,482	37,586	43,186	40,586
TTA 40 Gr	11,763	25,164	39,864	44,468	41,724

Source : Environmental Laboratory, Mechanical Laboratory & Calibration Mutiara, Sidoarjo, Indonesia, 2026

The increase on day 7 indicated that microorganisms in EM4 (photosynthetic bacteria, lactic acid bacteria, yeast, actinomycetes, and fermentative fungi) had started decomposing organic matter [12]. Kirinyuh leaves provided cellulose, hemicellulose, and lignin as cell wall components, while TTA added collagen protein as an additional carbon source. Research by Lie et al. (2024) stated that Chromolaena odorata fermentation produced approximately 20.40% cellulose and 9.23% lignin, confirming the potential of this plant as an organic material source. Furthermore, [13] explained that cellulolytic bacteria produce cellulase enzymes that convert cellulose into glucose, while fungi such as Trichoderma produce ligninase enzymes that break down lignin into simpler phenolic compounds. Through this hydrolysis process, carbon previously locked in complex structures of cellulose, hemicellulose, lignin, and collagen was converted into simpler soluble forms, increasing measurable C-organic content.

Entering day 14, C-organic content increased by 58.4-63.3% compared to day 7 across all treatments, indicating that microorganisms had entered the exponential growth phase, making organic matter decomposition more intensive [10]. Peak C-organic content occurred on day 21, with an increase of 11.6-24.7% compared to day 14. The highest value was achieved by the 40 g TTA treatment at 44.468%, showing that the combination of 40 g TTA and 21 days fermentation was the most optimal condition, characterized by interaction between variables where TTA addition increased available organic substrate while fermentation time provided sufficient time for EM4 microorganisms to hydrolyze and decompose organic matter maximally [14]. Upon entering day 28, C-organic content decreased by 5.8-8.3% in TTA 10 g, 20 g, 30 g, and 40 g treatments, indicating that most easily degradable organic matter had been utilized. Remaining organic carbon was used by microorganisms as energy sources to maintain metabolic activity, while some was released as carbon dioxide (CO_2) as a result of microbial respiration [15]. Based on the Indonesian Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019, liquid organic fertilizer must have minimum C-organic content of 10%. All treatments in this study met this standard, with C-organic content ranging from 10.745-44.468%, and even at the end of fermentation (day 28), all treatments still had C-organic content above 35%.

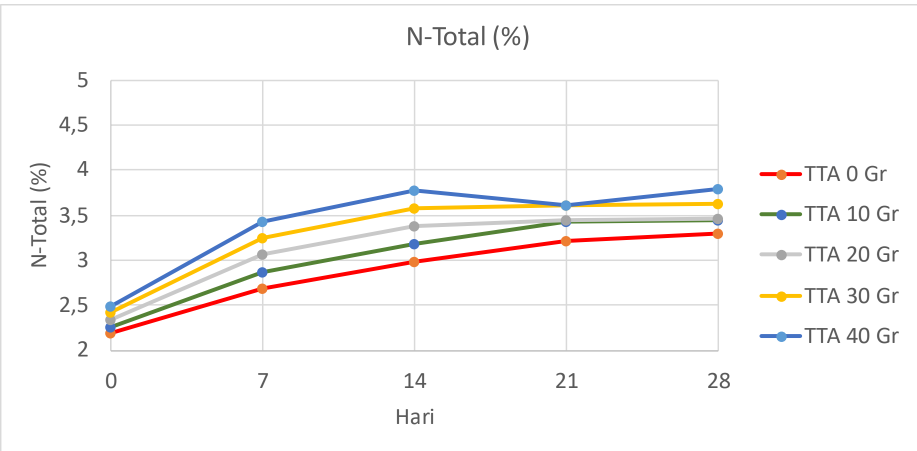

Fig. 2. The Relationship Between Organic Nitrogen Content and TTA Mass and Fermentation Time

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Table 2. Results of the Organic Nitrogen (N-Organic) Analysis of Liquid Organic Fertilizer

Sample	N Total (% weight) Day: 0	7	14	21	28
TTA 0 Gr	2,184	2,685	2,985	3,216	3,305
TTA 10 Gr	2,263	2,874	3,186	3,429	3,446
TTA 20 Gr	2,341	3,063	3,387	3,442	3,468
TTA 30 Gr	2,418	3,249	3,584	3,606	3,625
TTA 40 Gr	2,496	3,433	3,782	3,611	3,787

Source : Environmental Laboratory, Mechanical Laboratory & Calibration Mutiara, Sidoarjo, Indonesia, 2026

Total nitrogen content in all treatments increased from day 0 to day 28, with an increase rate of 51.3% (TTA 0 g), 52.3% (TTA 10 g), 48.2% (TTA 20 g), 49.9% (TTA 30 g), and 51.7% (TTA 40 g), indicating that fermentation time was the relatively dominant factor for this parameter because the magnitude of increase between TTA doses tended to be uniform. This nitrogen increase occurred due to two factors. First, decomposition of proteins and amino acids in kirinyuh leaves and chicken bone meal by proteolytic bacteria in EM4 (Bacillus sp. and Lactobacillus sp.) into ammonium [16]. Chicken bone protein contains considerable organic nitrogen, approximately 2.9% of chicken bone chemical composition, equivalent to ±15.6% protein, so the TTA mass variable also contributed additional nitrogen from the start of fermentation. N content at initial conditions (day 0) was recorded about 31% higher in 40 g TTA compared to 0 g TTA. This was supported by [17], who stated that organic matter addition can increase microbial activity and accelerate nitrogen mineralization, making more nitrogen available in forms usable by plants. Second, nitrogen mineralization by EM4 microorganisms during fermentation, as explained by [10], where nitrogen content actually increased with longer fermentation time.

Within this time range, microorganisms in EM4 entered the exponential growth phase characterized by very rapid cell division, so organic matter decomposition into dissolved nitrogen occurred more intensively; the increase then flattened or decreased after microbial growth slowed upon entering the stationary phase, when live and dead cell counts reached equilibrium. The correlation between independent variables was evident from the difference in increase rates between TTA treatments that increased with more days, indicating that the effect of TTA mass on N content was strengthened by decomposition time, not merely additive. At 40 g TTA, a temporary decrease of about 4.5% occurred between days 14-21, because some nitrogen was released as ammonia gas (volatilization) or used by microorganisms for biomass synthesis, consistent with [18], who explained that temporary nitrogen decrease marks microorganism entry into stationary phase. Additionally, all samples showed above the minimum macro-nutrient content ($N+P_2O_5+K_2O$) of 2-6% as required by Indonesian Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019.

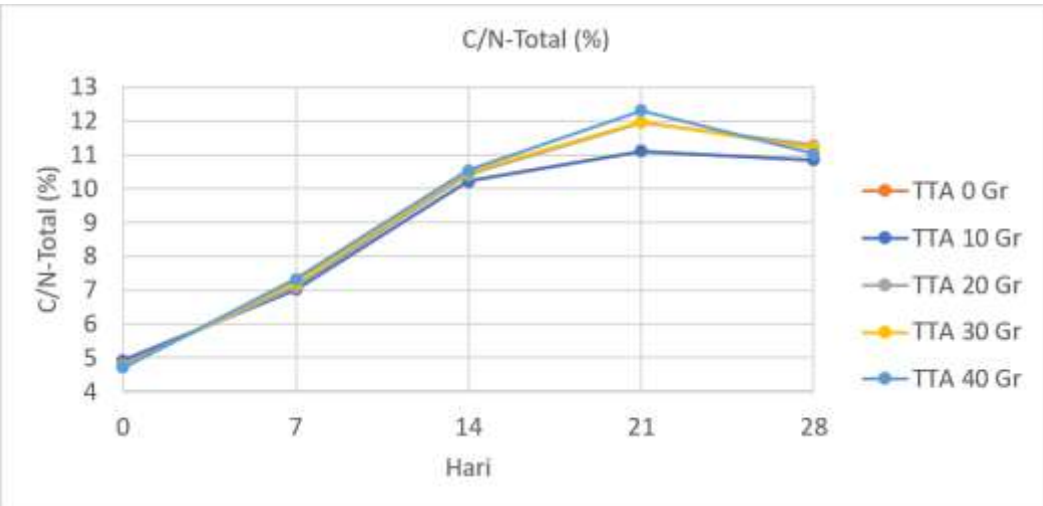

Fig. 3. The Relationship Between Organic C/N Content and TTA Mass and Fermentation Time

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Table 3. Results of the Organic (C/N) Analysis of Liquid Organic Fertilizer

Sample	C/N Total (% weight)				
	Day:				
	0	**7**	**14**	**21**	**28**
TTA 0 Gr	4,920	7,025	10,213	11,115	10,853
TTA 10 Gr	4,853	7,009	10,283	11,918	10,876
TTA 20 Gr	4,804	7,096	10,406	11,951	11,292
TTA 30 Gr	4,751	7,228	10,487	11,975	11,198
TTA 40 Gr	4,713	7,331	10,540	12,313	11,024

Source : Environmental Laboratory, Mechanical Laboratory & Calibration Mutiara, Sidoarjo, Indonesia, 2026

The research results showed that the C/N ratio increased in all treatments from day 0 to its peak on day 21, with increases of 125.9% (TTA 0 g), 145.6% (TTA 10 g), 148.8% (TTA 20 g), 152.1% (TTA 30 g), and highest at 161.3% (TTA 40 g), before decreasing on day 28. This pattern resulted from two anaerobic decomposition stages occurring at different rates: dissolved carbon release occurred faster in the early stages, primarily from hemicellulose component hydrolysis. This is because hemicellulose has a structure that is more easily degraded and decomposes at lower temperatures compared to cellulose and lignin. Meanwhile, cellulose hydrolysis occurred at a relatively slower rate. The composition of Chromolaena odorata consisting of 11.37% hemicellulose and 5.15% cellulose supported this differential hydrolysis rate, where components with higher percentages (hemicellulose) would be more dominant in early degradation stages [19]. Nitrogen release from protein ammonification occurred more slowly with some loss through ammonia volatilization in oxygen-free conditions, so the C/N ratio tended to increase first before finally decreasing when nitrogen mineralization rate caught up with carbon decomposition rate.

This aligns with research by [20], explaining that the increase in C/N ratio in liquid organic fertilizer can occur because the proportion of carbon that dissolves and extracts into the fermentation medium is greater than the proportion of available nitrogen. In initial conditions before decomposition begins, nitrogen is still in stable organic form and has not undergone volatilization, so N content is relatively high, causing the C/N ratio to be at low values. In the final fermentation phase, there is an increase in nitrogen-fixing bacteria populations that contribute to increased nitrogen content in liquid organic fertilizer. Additionally, research by [21] stated that the type and substrate of the bioactivator used significantly affect nutrient content and microbial activity during fermentation, where richer substrates tend to encourage more active microbial metabolism in early fermentation stages.

The correlation between independent variables was clearly visible: greater TTA mass resulted in higher C/N ratio percentage increases, because TTA added both carbon reserves (collagen and fat) and organic nitrogen reserves (bone protein), but the rate of carbon release during anaerobic decomposition remained faster than nitrogen release rate. The highest C/N ratio value was obtained in the 40 g TTA treatment on day 21 at 12.313%, while the lowest was in the 40 g TTA treatment on day 0 at 4.713%. All C/N ratio values obtained remained below the maximum limit set in Indonesian Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019, which is ≤25, so all treatments produced in this study met the applicable liquid organic fertilizer quality standards in Indonesia.

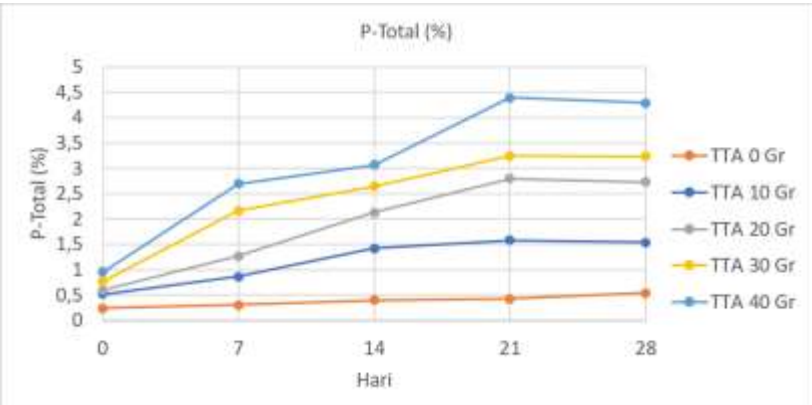

Fig. 4. The Relationship Between Organic Phosphor Content and TTA Mass and Fermentation Time

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Table 4. Results of the Organic Phosphor (P-Organic) Analysis of Liquid Organic Fertilizer

Sample	P Total (% weight)				
	Day				
	0	7	14	21	28
TTA 0 Gr	0,242	0,312	0,399	0,425	0,542
TTA 10 Gr	0,518	0,868	1,422	1,583	1,539
TTA 20 Gr	0,593	1,273	2,135	2,798	2,733
TTA 30 Gr	0,771	2,163	2,649	3,243	3,235
TTA 40 Gr	0,958	2,695	3,064	4,393	4,285

Source : Environmental Laboratory, Mechanical Laboratory & Calibration Mutiara, Sidoarjo, Indonesia, 2026

Based on research results, total phosphorus content increased sharply with higher TTA mass and longer fermentation time, with increases from day 0 to day 21 of 75.6% (TTA 0 g), 205.6% (TTA 10 g), 371.9% (TTA 20 g), 320.6% (TTA 30 g), and 358.6% (TTA 40 g), showing that TTA mass had a far more dominant effect on this parameter compared to C-organic and N-total parameters. Phosphorus in kirinyuh leaves was relatively low, at P:0.26% [22], so the main source of P-total in this POC came from minerals in TTA containing 12-18% phosphorus [11]. Phosphorus in mineral form was not immediately available and had to be solubilized by phosphate-solubilizing bacteria (PSB) contained in EM4, including Pseudomonas sp., Rhizobium sp., and Bacillus sp. [23].

The phosphate solubilization mechanism by PSB in EM4 occurs through two main pathways. First, PSB releases simple organic acids such as gluconic acid, citric acid, and oxalic acid. These acids work in two ways: lowering pH (acidity) around bacteria so phosphate minerals become more soluble, and chelating calcium (Ca^{2+}), iron (Fe^{3+}), and aluminum (Al^{3+}) ions that typically bind phosphate, thus releasing previously bound phosphate into dissolved form [24]. Second, PSB also produces phosphatase and phytase enzymes that function to break phosphate bonds in organic compounds, releasing inorganic phosphate that plants can easily absorb [24]. The combination of these two mechanisms explains why P-total content was highly dependent on the presence of TTA as a phosphate mineral source and fermentation time as the determinant of PSB activity duration.

Research by [10] explained that phosphorus content is strongly influenced by fermentation duration and bioactivator volume used, where longer fermentation time results in higher phosphorus content because the varied composition of organic matter causes nutrient fermentation to also increase with fermentation duration. This was further reinforced by [23], who stated that phosphorus content continues to increase with longer fermentation time because microorganisms in EM-4, particularly phosphate-solubilizing bacteria of strains Pseudomonas sp. and Lactobacillus sp., continuously work to break bonds of phosphate-binding compounds, so phosphorus increasingly dissolves and becomes available in POC solution. The peak total P content on day 21 was achieved by 40 g TTA at 4.393%, indicating that higher TTA addition provides greater potential phosphorus sources available for microbial decomposition, because materials with higher phosphorus content provide more phosphate substrate that can be solubilized by enzymatic activity during fermentation. This shows that the liquid organic fertilizer results have exceeded the minimum phosphorus content requirement of 2-6% as set in Indonesian Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019.

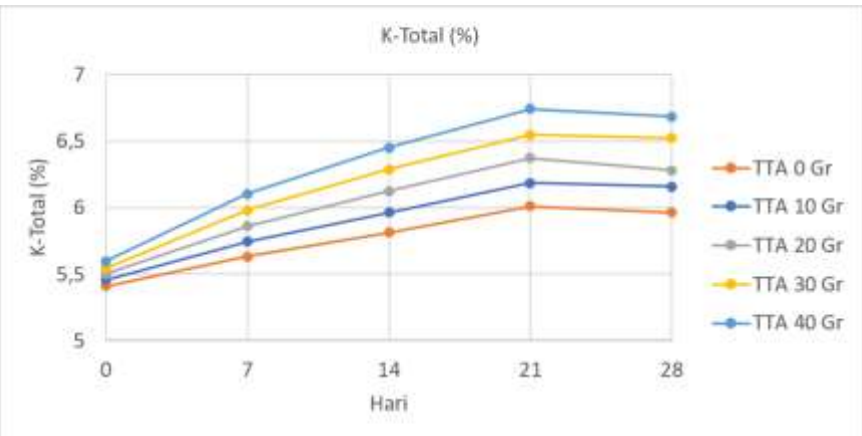

Fig.5. The Relationship Between Organic K Content and TTA Mass and Fermentation Time

Table 5. Results of the Kalium Organic (K-Organic) Analysis of Liquid Organic Fertilizer

Sample	K Total (% weight)				
	Day				
	0	7	14	21	28
TTA 0 Gr	5,413	5,632	5,812	6,012	5,963
TTA 10 Gr	5,458	5,745	5,964	6,186	6,158
TTA 20 Gr	5,503	5,861	6,125	6,373	6,283
TTA 30 Gr	5,549	5,982	6,287	6,548	6,525
TTA 40 Gr	5,598	6,104	6,453	6,743	6,683

Source : Environmental Laboratory, Mechanical Laboratory & Calibration Mutiara, Sidoarjo, Indonesia, 2026

Based on research results, total potassium content increased in all treatments from day 0 to the peak on day 21, with increases ranging from 11.1% (TTA 0 g) to 20.5% (TTA 40 g). Chicken bone meal contained no significant potassium (0.01-0.03%), so the main source of K-total in this POC came from kirinyuh leaves, which have K content of 5.40% [22], with TTA mass contributing only through its indirect effect on microbial activity and fermentation intensity. The correlation between independent variables was evident from the increasing magnitude of difference in K content between TTA treatments as fermentation progressed, confirming interaction between both variables for this parameter. The increase aligned with anaerobic decomposition of organic matter, which gradually released potassium from its complex bonds into soluble form [25] [18]. Additionally, organic acids produced as byproducts of fermentation metabolism helped dissolve potassium previously bound to organic matter, thus increasing its availability in POC solution with longer fermentation time [26].

Peak K-total content was achieved on day 21 for all treatments, with highest increase (20.5%) at 40 g TTA. Achieving the peak between days 14-21 was consistent with [26], who stated that potassium reaches optimum conditions in this period, reinforced by [10] that the best potassium results are obtained when fermentation has run optimally, because EM4 accelerates the fermentation reaction while enriching fertilizer nutrient content. On day 28, K-total content in all treatments decreased around 0.35-1.41% compared to day 21, but remained above day 0 values. This decrease occurred because substrate available for decomposition began to decrease, so some potassium that had been released into solution was reutilized in remaining substrate decomposition, consistent with [10] and [18]. Referring to research objectives, the treatment combination with the highest K-total increase (20.5%) was 40 g TTA with 21 days fermentation, and all treatments across all fermentation time ranges met the potassium content threshold required by Indonesian Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019 (2-6%).

4. Conclusion

Based on the results of this study, the liquid organic fertilizer made from Chromolaena odorata leaves with the addition of chicken bone meal successfully met the Liquid Organic Fertilizer Quality Standard set out in the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 261/KPTS/SR.310/M/4/2019, in terms of C-organic, nitrogen, phosphorus, and potassium content. The fermentation period and the dosage of chicken bone meal influenced the levels of C-organic, nitrogen, phosphorus, and potassium, with each parameter tending to increase up to the 21st day. The optimum treatment was obtained with the addition of 40 grams of chicken bone meal and a fermentation period of 21 days, as it produced the best liquid organic fertilizer characteristics compared to the other treatments.

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