JURNAL KESEHATAN LINGKUNGAN
JURNAL DAN APLIKASI TEKNIK KESEHATAN LINGKUNGAN

ISSN 1829-9407 (Print)
ISSN 2581-0898 (Online)

Volume 22, No. 1, January 2025 ; Page: 101-108; *DOI: https://doi.org/10.31964/jkl.v22i1.949*

THE EFFECT OF FERMENTATION DURATION OF LIQUID ORGANIC FERTILIZER FROM DIAPERS ON NITROGEN (N) AND POTASSIUM (K) CONTENT

Dhiya Dania Oktafia, Irwan Sulistio, Hadi Suryono, Marlik, Margono
Poltekkes Kemenkes Surabaya, Department of Environmental Health
No. 56 Pucang Jajar Tengah Street, Kertajaya, Gubeng District, Surabaya, East Java 60282, Indonesia
E-mail: dhiyadaniaoktafiakl21@gmail.com

Article Info

Article history:

Received July 24, 2024
Revised January 01, 2025
Accepted January 27, 2025

Keywords:

Diapers
Hydrogel
Liquid Fertilizer
Nitrogen
Potassium

ABSTRACT

Effect Of Fermentation Duration Of Diaper-Based Liquid Organic Fertilizer On Nitrogen (N) And Potassium (K) Content. *The increasing birth rate and number of toddlers each year have led to a rise in diaper usage, resulting in significant diaper waste. Improper management of this waste can cause environmental problems. One potential solution is utilizing diapers as raw material for liquid organic fertilizer production. This study aimed to determine the differences in bacterial starter addition and fermentation duration of liquid organic fertilizer from diapers in terms of nitrogen and potassium content. A quasi-experimental design with a post-test only control group was applied. The study focused on the hydrogel in the diaper's inner layer. The independent variable was fermentation duration (12, 15, 18, and 21 days), while the dependent variables were nitrogen and potassium content, each with six replications. Data were analyzed using One Way ANOVA. Results showed average nitrogen content for fermentation durations of 12 days (0.34%), 15 days (0.43%), 18 days (0.53%), and 21 days (0.64%). The lowest nitrogen content was found at 12 days (0.32%), and the highest at 21 days (0.66%). Average potassium content for fermentation durations was 12 days (0.27%), 15 days (0.36%), 18 days (0.43%), and 21 days (0.54%). The lowest potassium content occurred at 12 days (0.25%), and the highest at 21 days (0.56%). In conclusion, there were significant differences in nitrogen and potassium content across fermentation durations. Further studies are recommended to optimize bacterial starter acclimatization, monitor temperature and pH, and apply sampling techniques according to national standards (SNI).*

INTRODUCTION

Waste is one of the most pressing environmental issues faced by both developed and developing countries [1]. This problem is particularly evident in Indonesia, where population growth—especially among infants and toddlers—has led to a surge in disposable diaper waste. According to the East Java Provincial Office of Population and Civil Registration, the number of infants and toddlers increased from 187,658 in 2018 to 193,150 in 2020. Assuming each child uses 2–3 diapers daily, diaper waste generation may exceed 200 million pieces annually.

Population census data indicate a consistent increase in the number of newborns and toddlers from 2018 to 2020. This growth correlates with higher diaper usage and potential waste generation. With an estimated 2–3 diapers used per child per day, the annual volume of diaper waste could reach approximately 208,491,285 pieces. Diapers, which are designed from plastic-based materials for infant care, have been mass-produced since the early 20th century. The first diapers were reusable cloth-based products that required washing after use [2]. However, the emergence of disposable diapers has led to increased waste accumulation due to their convenience and single-use nature. Without proper management and utilization, the high usage of disposable diapers poses a serious environmental threat [3].

The environmental impact of diaper waste is largely due to its plastic and chemical content. Diapers consist of super absorbent polymer (SAP) resin capable of absorbing more than 30 times its weight in liquid [4]. Other chemical components include polyacrylate granules and fiber. These materials are non-biodegradable, requiring 450 years to decompose in marine environments and 500 years in landfills [5].

Human urine contains three macronutrients—nitrogen, phosphorus, and potassium—which can be utilized to produce Liquid Organic Fertilizer (LOF) [6]. Fermented hydrogel has been found to contain macronutrient levels of 0.63% potassium, 0.61% nitrogen, and 0.54% phosphorus [7]. The increasing problem of diaper waste has prompted researchers to explore environmentally beneficial applications for used diapers [4].

According to Yunus (2019), communities have begun processing diaper waste into LOF to reduce environmental pollution. Fertilizer plays an essential role in enhancing soil fertility and plant growth. Inorganic fertilizers are made from materials containing specific nutrients or minerals [9]. They are produced by combining chemicals with high nutrient concentrations. Although inorganic fertilizers are widely available, they tend to be more expensive than organic fertilizers. Long-term use of inorganic fertilizers may lead to environmental problems [10].

Efforts to reduce environmental pollution from inorganic fertilizers have shifted toward environmentally friendly organic alternatives. Typically, organic fertilizers contain macronutrients such as nitrogen, phosphorus, and potassium [6]. The production of LOF may utilize hydrogel based on research by Rasyidah [11], who stated that "diapers can be used as a base material for organic fertilizer."

Organic fertilizers generally contain NPK macronutrients. The NPK content in diapers can be utilized as the primary material for organic fertilizer production through fermentation. Fermentation is a key step in producing liquid organic fertilizers [12].

Fermentation in organic fertilizer production follows an anaerobic method [13], aiming to optimize nutrient content in the final product. The purpose of this experiment was to analyze the effect of fermentation duration on the levels of nitrogen and potassium in liquid organic fertilizer derived from diapers. The nutrient content standards for nitrogen and potassium refer to Minister of Agriculture Decree No. 261/KPTS/SR.310/M/4/2019.

MATERIALS AND RESEARCH METHODS

This research employed a quasi-experimental design using a post-test only control group approach. The research object was the hydrogel found in the inner layer of diapers. The independent variable was the fermentation duration (12, 15, 18, and 21 days), and the dependent variables were nitrogen and potassium contents. Data collection techniques included six replications, laboratory testing of nutrient content, and literature studies. Primary data were obtained from laboratory analyses of nitrogen and potassium in the diaper-based LOF, while secondary data were collected from relevant journals and books. The data were analyzed using One Way ANOVA to determine the effect of fermentation duration on nitrogen and potassium enhancement.

The tools used in this study included stirrers and fermentation containers. The materials included water, EM4 (Effective Microorganisms), gloves, labels, hydrogel, and molasses.

Research Procedure:

Preparation Phase:
A total of 21 used diapers were collected, measured according to the treatment group. The control group required 3 diapers, while all treatment groups combined (with 6 replications) required 18 diapers.

Hydrogel Separation:
In this phase, the hydrogel layer was separated by cutting open the diapers. Only hydrogel containing urine was used as the primary raw material for fermentation. Once separated, the hydrogel was placed into the fermentation containers.

Solution Preparation:
Based on EM4 packaging instructions, liquid organic fertilizer can be prepared using the ratio of 1 liter EM4 + 1 liter molasses + 50 liters of water. In this study, a scaled-down version was used with a 1-liter water volume, calculated as follows:

$$EM4/Molase = \frac{\text{50.000 Ml Air}}{\text{1.000 Ml EM4/Molase}} = 50\ Ml$$

The control group required 3 diapers + 150 mL of EM4 + 150 mL of molasses + 3 L of water, while all treatment groups combined required 18 diapers + 900 mL of EM4 + 900 mL of molasses + 18 L of water.

Mixing Phase
In this phase, all ingredients—diapers, EM4, molasses, and water—were mixed together and homogenized by stirring. Once the mixture became uniform, the fermentation containers were sealed tightly and moved to the fermentation stage.

Fermentation Phase
The fermentation of liquid organic fertilizer from diapers was carried out under anaerobic conditions. Anaerobic fermentation does not require oxygen to accelerate the decomposition process. To optimize the fermentation process, the containers were shaken daily to ensure consistent mixing, similar to the agitation process in aerobic fermentation.

Following fermentation periods of 12, 15, 18, and 21 days, samples of the diaper-based liquid organic fertilizer were subjected to laboratory analysis to determine the increase in nitrogen and potassium content.

RESEARCH RESULTS AND DISCUSSION

Nitrogen (N) Content in Diaper-Based Organic Fertilizer

Table 1. Nitrogen (N) Content in Diaper-Based Organic Fertilizer

No.	Fermentation Time	Nitrogen Content Percentage (%)							
	(DAY)	K	P1	P2	P3	P4	P5	P6	AVERANGE
1.	12	0,09	0,33	0,37	0,32	0,34	0,33	0,36	0,34
2.	15	0,10	0,42	0,44	0,41	0,43	0,42	0,44	0,43
3.	18	0,11	0,52	0,53	0,52	0,54	0,56	0,53	0,53
4.	21	0,12	0,66	0,62	0,63	0,65	0,64	0,62	0,64

Source: Primary Data, 2024

The nitrogen content of the diaper-based organic fertilizer is presented in Table 1. The highest average nitrogen content was observed in the 21-day treatment at 0.64%, while the lowest average was recorded in the 12-day treatment at 0.34%. It can be concluded that the average nitrogen content has not met the established standard.

Kandungan Kalium (K) Pada Pupuk Organik Diapers

Table 2. Potassium (K) Content in Diaper-Based Organic Fertilizer

No.	Fermentation Duration (DAY)	Nitrogen Content (%)							
		K	P1	P2	P3	P4	P5	P6	AVERANGE
1.	12	0,05	0,27	0,30	0,25	0,26	0,27	0,29	0,27
2.	15	0,07	0,36	0,39	0,34	0,37	0,35	0,37	0,36
3.	18	0,09	0,42	0,44	0,41	0,43	0,46	0,44	0,43
4.	21	0,10	0,53	0,56	0,52	0,54	0,52	0,55	0,54

Source: Primary Data, 2024

The potassium content of the diaper-based organic fertilizer is presented in Table 2. The highest average potassium content was found in the 21-day treatment at **0.54%**, while the lowest average was observed in the 12-day treatment at **0.27%**. It can be concluded that the average potassium content has not met the established standard.

Analysis of the Effect of Fermentation Duration of Diaper-Based Organic Fertilizer on Nitrogen (N) and Potassium (K) Content

Table 3. Analysis of the Effect of Fermentation Duration of Diapers on Nitrogen (N) and Potassium (K) Content

No.	VARIABLE	P Value	nOTE
1.	Nitrogen (N) Content	0,000	H0 ditolak
2.	Potassium (K) Content	0,000	H0 ditolak

Source: Primary Data, 2024

The analysis of the effect of bacterial starter addition and fermentation duration on the nitrogen and potassium content of the organic fertilizer was conducted using ANOVA, yielding p-values of 0.000 for both parameters. The results indicate that p-value (0.000) < α (0.05), thus H_0 is rejected and H_1 is accepted. The interpretation of the ANOVA results confirms that there are significant differences among the treatment groups (12, 15, 18, and 21 days of fermentation) in terms of nitrogen and potassium content.

Nitrogen (N) Analysis in Diaper-Based Liquid Organic Fertilizer

The percentage of nitrogen content during the fermentation periods of 12, 15, 18, and 21 days was still below the required standard. Several factors contributed to the low nitrogen content in the diaper-based liquid organic fertilizer. One major factor was the insufficient number of microorganisms or bacterial starter used to decompose the organic material. This aligns with the findings of Viantini [14], who stated that the significant addition of EM4 influences nitrogen increase due to the elevated number of microorganisms responsible for breaking down organic matter. This results in increased levels of nitrogen in the form of NH_4^+ and NO_3^- produced during decomposition. Microorganisms play a vital role in accelerating the breakdown and decomposition of organic matter. In this study, EM4 and molasses were each added at 150 mL per treatment as microbial starters. A lack of bioactivator in the liquid fertilizer may affect the fermentation process and overall NPK content quality [15].
Another factor may be the potential ineffectiveness of EM4 or the inability of the added molasses to fully penetrate the hydrogel, resulting in suboptimal fermentation. Fadilah [16] also noted that several factors influence the protein degradation process, including material properties, types of microorganisms used in fermentation, environmental conditions, and fermentation duration.

Additionally, the reduction in nitrogen content may have occurred during sample collection for laboratory analysis, as nitrogen may have escaped in gaseous form when the fermentation vessel was opened. This is supported by Bachtiar and Ahmad [17], who explained that fermentation and nutrient analysis often involve nitrogen loss due to molecular reduction, causing a decline in nitrogen content. The volatilization of nitrogen or ammonia gas during composting is a major factor contributing to low nitrogen levels. Meriatna [18] emphasized that the amount of nitrogen that volatilizes as ammonia gas depends on whether the container is tightly sealed, which directly impacts nitrogen retention. Low concentrations of ammonia and nitrogen in the air result in gas loss. Further studies are needed to optimize sample preservation methods, follow relevant Indonesian National Standards (SNI), and conduct bacterial starter acclimatization to enhance outcomes [19].

Potassium (K) Analysis in Diaper-Based Liquid Organic Fertilizer

The potassium content percentages during the fermentation periods of 12, 15, 18, and 21 days were also found to be below the standard threshold. Several factors may have contributed to the low potassium levels, such as an inadequate number of microorganisms responsible for decomposing organic material during fermentation. Aqidah [20] stated that higher microorganism populations lead to greater macronutrient content.

Another contributing factor was bacterial growth and aeration during anaerobic fermentation. Fadilah [16] observed that bacteria might not function optimally when exposed to air but thrive in anaerobic environments. Potassium increase rates are highly sensitive to the presence and activity of bacteria, as microorganisms use potassium as a catalyst during decomposition. Bacteria and fungi can bind and store potassium in their cell walls. Continued decomposition results in the release of potassium.

The reduction in substrate pH can also affect potassium availability, as potassium is readily absorbed by organic acids produced by microbes. Furthermore, the absence of a particle-size reduction step contributes to lower potassium concentration, as microorganisms struggle to break down complex organic compounds with large surface areas. The production of materials with high potassium content is significantly influenced by the reduction in particle size [21].

Analysis of Fermentation Duration on Nitrogen (N) and Potassium (K) Content

Variation in fermentation duration led to fluctuations in the nitrogen concentration of the diaper-based organic fertilizer. Both nitrogen and potassium contents were shown to vary based on fermentation length. Table 2 indicates that the 21-day treatment yielded the highest average nitrogen and potassium contents, at **0.64%** and **0.54%**, respectively. In contrast, the 12-day treatment resulted in the lowest averages, at **0.34%** and **0.27%**. The results suggest that nitrogen content increased with longer fermentation durations. Wardah [22] reported that the duration of fermentation in Trichocompost fertilizer significantly affected the NPK content.

The nitrogen content in the 12-day treatment was lower than that in the 21-day treatment, which may have been influenced by the microbial growth phase during fermentation. Initially, microbial growth enters a lag phase, during which microorganisms adapt to the new environment. The length of this phase varies depending on environmental conditions and microbial species [14]. The increase in nitrogen content at 21 days could be attributed to the log phase, where rapid microbial cell division occurs until reaching a maximum population. During this phase, microorganisms absorb nutrients from the substrate to build cells and support metabolic activity, resulting in significant organic matter decomposition [23].

Kusumadewi [24] also reported that nitrogen content in organic fertilizers is generally lower than the standard due to microbial growth and activity during fermentation. In the lag phase, microorganisms adapt before growing and dividing, resulting in slower decomposition activity.

The low potassium content may have been influenced by incomplete fermentation and inadequate availability of organic substrate. Kusumadewi [24] stated that potassium levels are often low when microbes decompose organic matter slowly under suboptimal aerobic or anaerobic conditions. Well-conducted fermentation processes tend to yield higher potassium concentrations. Saputri [25] supported this finding by stating that potassium acts as a catalyst that accelerates fermentation. High potassium concentrations in liquid fertilizers are associated with greater degradation of materials and faster fermentation. The failure of microorganisms to thrive in the medium may explain the low potassium levels in both aerobic and anaerobic fermentation. During early adaptation and growth stages, microbes produce less potassium, and the organic material in the liquid organic fertilizer remains insufficiently decomposed, resulting in low potassium availability.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study on the production of liquid organic fertilizer from diapers, the following conclusions can be drawn. The average percentage of nitrogen content at fermentation durations of 12, 15, 18, and 21 days was (0.34%), (0.43%), (0.53%), and (0.64%), respectively. The average percentage of potassium content at fermentation durations of 12, 15, 18, and 21 days was (0.27%), (0.36%), (0.43%), and (0.54%), respectively. It can be concluded that there was a significant difference, with a p-value of (0.000), in the fermentation duration of liquid organic fertilizer made from diapers on the nitrogen and potassium content. Suggestions for future researchers include conducting bacterial acclimatization, paying attention to the sampling technique particularly in terms of preservation for laboratory testing in accordance with the Indonesian National Standard (SNI) for water sample collection methods, adding bacterial starters to increase the quantity of microorganisms, and conditioning the fermentation environment.

REFERENCES

1. Sari IK. Analisis Berbagai Metode Pengolahan Sampah Sebagai Solusi Permasalahan Sampah di Kabupaten Lumajang. J EnviScience (Environment Sci. 2022;6(2):82–95.
2. Susanti P. Analisis Keputusan Konsumen Muslim Dalam Memilih Diapers. Skripsi Progr Stud Ekon Islam Fak Ekon dan Bisnis Islam Univ Islam Negeri Fatmawati Sukarno Bengkulu. 2022;
3. Alfiah R, Ratnawati SR. Pemanfaatan Popok Bayi Bekas Sebagai Media Tanam Guna Mereduksi Pencemaran Lingkungan Di Desa Sambirejo. In: PISCES: Proceeding of Integrative Science Education Seminar. 2021. p. 149–59.
4. Ramdani N, Mustam M, Harun AP, Azis H, Setiawan IMA. PERAN POLIMER SUPER ABSORBEN PADA POPOK BAYI DALAM MENGONTROL KELEMBABAN TANAH. EduMatSains J Pendidikan, Mat dan Sains. 2021;6(1):91–100.
5. Utami KB, Syamsuddin A. Pengaruh Lama Fermentasi Terhadap Kualitas Nitrogen, Fospor dan Kalium pada Pupuk Trichokompos. AGRIEKSTENSIA J Penelit Terap Bid Pertan. 2021;20(2):160–8.
6. Pamurti AA, Prabowo D. Edukasi dan Pelatihan Pengolahan Limbah Diapers menjadi Pupuk Tanaman pada Warga Kelurahan Sendangguwo Semarang. J Pengabdi KOLABORATIF. 2023;1(1):64–9.
7. Prasetyo FD, Triasti RD, Ayuningtyas E. Pemanfaatan Limbah Popok Bayi (Diapers) Sebagai Media Tanam. J Rekayasa Lingkung. 2021;21(1):41–9.
8. Yunus NM. Pengaruh Pemberian Kompos Berbahan Dasar Limbah Diapers (Popok Sekali Pakai) terhadap Pertumbuhan Tanaman Pacar Air (Impatiens balsamina L.). J Biog. 2019;4(2):24–8.
9. Kamsurya MY, Botanri S. Peran bahan organik dalam mempertahankan dan perbaikan kesuburan tanah pertanian; review. J Agrohut. 2022;13(1):25–34.
10. Septiani M, Nurohmah A, Khumaira F, Rohmah A, Dewi NS, Ma'rifah DN, et al. Pemberdayaan Masyarakat dengan Pemanfaatan Limbah Daun Sebagai Pupuk Bokashi. Indones J Community Serv. 2021;1(1):201–8.
11. Rasyidah R, Selvia IN, Siruwahni D. Identifikasi Kandungan Pupuk Organik Cair dari Hidrogel Limbah Diapers Terhadap Penambahan Spirulina platensis. BEST J (Biology Educ Sains Technol. 2022;5(2):405–10.
12. Eralita N, Setiawan YA. Pelatihan Pengelolaan Sampah Rumah Tangga Menjadi Pupuk

Organik Cair Di Desa Karang Bawang, Banyumas. Karunia J Has Pengabdi Masy Indones. 2023;2(4):24–9.
13. Darnah, Haroh I, Kiswanto. Edukasi Pembuatan Pupuk Organik Cair (POC) Dengan Metode Fermentasi Anaerob di Desa Gas Alam. J Repos UNMUL. 2021;2(5):1–7.
14. Viantini AM, Erlita D, Puspitasari A, Nugraheni IA. PENGEMBANGAN PRODUK BARU PUPUK ORGANIK CAIR DARI LIMBAH CAIR INDUSTRI VIRGIN COCONUT OIL DENGAN METODE FERMENTASI. J Rekayasa Lingkung. 2022;22(2).
15. Setyawati H, Anjarsari S, Sulistiyono LT, Wisnurusnadia JV. Pengaruh Variasi Konsentrasi Em4 Dan Jenis Limbah Kulit Buah Pada Pembuatan Pupuk Organik Cair (Poc). J Atmos. 2022;3(1):14–20.
16. Fadilah HF, Kusuma MN, Afrianisa RD. Pemanfaatan bioslurry dari digester biogas menjadi pupuk organik cair. Semin Nas Sains dan Teknol Terap VII 2019. 2019;(70):513–8.
17. Bachtiar B, Ahmad AH. Analisis kandungan hara kompos johar cassia siamea dengan penambahan aktivator promi. Bioma J Biol Makassar. 2019;4(1):68–76.
18. Meriatna M, Suryati S, Fahri A. Pengaruh waktu fermentasi dan volume bio aktivator EM4 (effective microorganisme) pada pembuatan pupuk organik cair (POC) dari limbah buah-buahan. J Teknol Kim Unimal. 2019;7(1):13–29.
19. Alfarisi CD, Zahrina I, Yenie E, Yenti SR. Pengolahan Limbah Padat Industri Tahu Menjadi Pupuk Kompos. J Ilm Biosaintropis. 2023;9(1):81–8.
20. Aqidah N, Ibrahim B, Nontji M. Analisis Unsur Hara Makro Pupuk Organik Berbahan Dasar Serbuk Gergaji Kayu Dan Limbah Kotoran Ayam Dengan Berbagai Konsentrasi Effective Microorganism-4 (EM-4). AGrotekMAS J Indones J Ilmu Peranian. 2022;3(1):9–20.
21. Purba ESB. Pengaruh Lama Fermentasi Pupuk Organik Cair Limbah Cair Tahu Dan Daun Lamtoro Dengan Penambahan Bioaktivator Em4 Terhadap Kandungan Fosfor Dan Kalium Total. Skripsi Progr Stud Pendidik Biol Jur Mat Dan Ilmu Pengetah Alam Fak Kegur Dan Ilmu Pendidik Univ Sanata Dharma Yogyakarta. 2019;3:1–109.
22. Wardah, Utami KB, Syamsuddin A. Pengaruh Lama Fermentasi Terhadap Kualitas Nitrogen, Fospor dan Kalium pada Pupuk Trichokompos. | J Agriekstensia. 2021;20(2):160–8.
23. Chapelle FH. Ground-water microbiology and geochemistry. John Wiley & Sons; 2000.
24. Kusumadewi MA, Suyanto A, Suwerda B. Kandungan Nitrogen, Phosphor, Kalium, dan pH Pupuk Organik Cair dari Sampah Buah Pasar Berdasarkan Variasi Waktu. Sanitasi J Kesehat Lingkung. 2020;11(2):92–9.
25. Saputri I. Analisis NPK pupuk organik cair dari berbagai jenis air cucian beras dengan metode fermentasi yang berbeda. J Agrotech. 2021;11(1):36–42.