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The Effect of Dosage and Application Interval of Tofu Waste Liquid Organic Fertilizer on the Growth and Yield of Tomato (*Lycopersicum esculentum*)

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ABSTRACT

Tofu liquid waste contains organic materials that can be utilized as liquid organic fertilizer (LOF). This study aims to determine the effect of dose and interval of LOF from tofu liquid waste on tomato plants (Lycopersicum esculentum. L). This study, conducted from April to July 2024 in Gajah Bendo Village, Pasuruan, examined the impact of tofu liquid waste-based Liquid Organic Fertilizer (LOF) on tomato plants (Lycopersicum esculentum. L). Utilizing a Completely Randomized Design (CRD) with two factors in triplicates, the researchers tested four dosage levels (0, 100, 200, and 300 ml/plant) and three application intervals (6, 10, and 14 days). The results of the study found that the combination of LOF tofu liquid waste dosage at a dose of 300 mL/plant with an application interval of 14 days resulted in the fastest flowering age compared to other treatment combinations. However, the combination of dosage and application interval treatments did not significantly affect the parameters of plant height, number of fruits, and fruit sets. The LOF application even tended to reduce the harvest weight of tomato fruit compared to the control treatment. Future research can focus on the optimal fermentation time of liquid waste to prepare LOF and apply the LOF on tomato plants under more controlled conditions such as in a greenhouse.

1. INTRODUCTION

Tomatoes (*Lycopersicum esculentum* L.) are a vegetable widely cultivated in various regions, both in the highlands and lowlands. Tomatoes have high economic value because they can be consumed directly or processed into various products such as juice, fruit extract, and concentrate. According to data from the Directorate General of Horticulture (2025), tomato production in Indonesia experienced a significant increase from 976,772 tons in 2018 to 1,168,744 tons in 2022. Despite a slight decline to 1,143,788 tons in 2023, production again showed a positive trend, reaching 1,152,791 tons in 2024. Overall, these achievements demonstrate serious efforts to develop tomato cultivation, including the implementation of more efficient agricultural technologies and practices.

In all plant cultivation processes, fertilizer is an indispensable element of production. However, the excessive use of chemical fertilizers has had a negative impact on the environment and soil fertility. Therefore, more environmentally friendly fertilizer alternatives are needed. One promising alternative is the use of liquid tofu waste as a liquid organic fertilizer (LOF) because of availability and high organic content (Cahyani *et al*., 2021; Kurniawan *et al*., 2024). The tofu industry is a process that produces a large amount of wastewater that remains underutilized. Pambudi *et al*. (2021) reported that the tofu industry produces 18.8 m^3 of wastewater per ton of soybeans, slightly below the standard of 20 m^3/ton. Based on five household tofu industries, Marchelina & Jabbar (2025) reported that liquid tofu waste is characterized by high COD (Chemical Oxygen Demand) of 42.35-55.50 g/L and low pH of 3.04-4.35. According to Karuwung *et al*. (2017), liquid tofu waste also contains protein (40-60%), carbohydrates (25-50%),

and fats (10%). The protein in tofu waste can be broken down by soil microorganisms into nitrogen compounds that are easily absorbed by plants. Other previous studies (Rasmito *et al*., 2019; Simanjuntak *et al*., 2021) showed that LOF liquid tofu waste contains important nutrients, namely N-total (0.28-0.38%), P_2O_5 (0.20-0.25%), and K_2O (0.3%).

Fertilization effectiveness using LOF is determined by the application dose. As previously reported by Jevi (2023), it was shown that applying 300 ml of tofu waste liquid fertilizer (POC) significantly increased the growth and productivity of tomato plants. In addition to the dose, the frequency or interval of application also determines the success of LOF fertilization. Research by Pratiwi *et al*. (2021) found that applying 100% tofu waste liquid fertilizer (POC) and watering three times per week significantly increased the growth, production, and fruit weight of red chili plants. Marlina *et al*. (2023) concluded that non-fermented tofu liquid waste at a concentration of 75% resulted in the best and maximum growth and production of red chili plants in peat media. The potential of tofu wastewater as a liquid organic fertilizer has been studied for several types of plants, such as corn (Mardhiana *et al*., 2021), tomatoes (Ramadhon & Hadid, 2024), red chilies (Pratiwi *et al*., 2021; Marlina *et al*., 2023; Marcelina & Jabar, 2023), mustard greens (Marian *et al*., 2019; Fatiha *et al*., 2022). However, combinations of LOF dosage and application intervals from tofu liquid waste for tomato plants have not been widely studied. Therefore, this study aims to examine the effect of the dose and application interval of LOF from tofu liquid waste on the growth and yield of tomato. It is expected that an optimal combination can be found that can meet the nutritional needs of tomato plants during the vegetative and generative phases. The results of this study are expected to provide practical recommendations for farmers in increasing tomato productivity sustainably by utilizing tofu waste as an organic fertilizer.

2. METHOD

2.1. Place, Materials, and Tools

This research was conducted from April 2024 – July 2024 in Gajah Bendo Village, Beji Sub-district, Pasuruan Regency, East Java. Materials used in this study included soil, charcoal from rice husks, manure, insecticide, Servo F1 tomato seeds, liquid tofu waste, EM4, and NPK 16:16:16. Important tools included seed trays, hand sprayers, buckets, measuring cups, analytical scales, hoes, and 40 x 40 cm polybags. According to a brochure provided by PT. East West Seed Indonesia Servo F1 variety is characterized by plant height 92–146 cm, first flower emergence at 30-33 DAT, harvest age 62-65 DAT, and fruit harvest 31-53 fruit/plant, and harvest yield 45.34–73.58 ton/ha at plant density of 25,000 plant/ha.

2.2. Experimental Design

This research was conducted by applying a Completely Randomized Design (CRD) consisting of 2 factors. The first factor was the application dose of tofu liquid waste LOF (P) with four levels: P0 (Control, 0 LOF), P1 (LOF 100 ml/plant), P2 (LOF 200 ml/plant), and P3 (LOF 300 ml/plant). Each treatment was given 2.8619 g of NPK base fertilizer per plant. The second factor, the fertilization interval (V), consisted of three levels: V1 (6 days), V2 (10 days), and V3 (14 days). All treatment combinations were replicated three times, resulting in 36 experimental units. Each experimental unit consisted of three sample plants. Each sample was planted in 40x40 cm polybags with a spacing of 70 cm × 50 cm between polybags.

2.3. LOF Preparation

The preparation of liquid organic fertilizer (LOF) begins with the collection of tofu liquid waste from the tofu processing plant. A total of 10 liters of tofu liquid waste was mixed with 5 liters of water, 150 ml of EM4 solution and 250 g of melted brown sugar, then stirred until homogeneous. The mixture was fermented for 10 days in a closed container. Once fermentation was complete, LOF was ready for application.

2.4. LOF Application

Servo F1 tomato seeds were sown in a 1:1 mixture of soil and compost in seedling trays. Twenty-day-old seedlings were transferred to 40x40 cm polybags containing a 2:1:1 mixture of soil, manure, and rice husk charcoal. LOF fertilization with tofu liquid waste was carried out starting 14 days after planting (DAT) at varying doses and intervals

according to the design. Plant maintenance included watering, replanting, weeding, staking, pruning, and pest and disease control using fungicides, if necessary. Harvesting was carried out when the plants were 62-65 days after planting. This is characterized by a change in the color of the fruit to reddish yellow. Harvesting is carried out twice a week for five harvest periods, for a total of 10 harvests.

2.5. Observation and Measurement

Observed plant growth and yield parameters included plant height, number of leaves, age at first flowering, total number of fruits per plant, total fruit weight per plant, and fruit set. Plant height and leaf number were observed weekly starting from 7 days after planting until harvest at 65 days after planting. Fruit set is the percentage of flowers that successfully develop into fruit, and was calculated using Equation (1).

$$Fruit\ Set = \frac{\sum flowers\ that\ successfully\ become\ fruit}{\sum total\ flowers} \times 100\% \quad (1)$$

2.6. Data Analysis

Experimental data was statistically analyzed using ANOVA. If the random sample test results showed significant effect, further Honestly Significant Difference (HSD) test was conducted at a significance level of 5%.

3. RESULTS AND DISCUSSION

3.1. LOF Characteristic

Table 1 shows the characteristics of the tofu industrial wastewater-based LOF used in this experiment. The tofu industrial wastewater-based LOF showed an organic matter content of 1.32% (organic carbon) with NPK nutrients of 0.2% (nitrogen), 0.31% (PO5), and 0.41% (KO). This LOF was acidic with a pH of 4.36 and a C/N ratio of 6.6 (low). These results are slightly better than the LOF from lamtoro leaves reported by Septirosya *et al*. (2019) with 0.1196 (N), 0.0896 (PO5), and 0.0023 (KO).

Table 1. Characteristic of LOF made of tofu liquid waste

Parameter	Value	Marian & Sumiyati (2019)
Nitrogen	0.20%	--
Phosphor (P2O5)	0.31%	0.24%
Potassium (K2O)	0.41%	0.54%
Organic Carbon (C-organic)	1.32%	2.80
CN ratio	6.6	--
pH	4.36	--

Table 2. Effect of treatment factors on the average height (cm) of tomato plants at age of 7-56 DAT

Treatment	Plant Age (DAT)							
	7	14	21	28	35	42	49	56
P0 (Control, 0 mL)	11.44	16.67	32.89	48.67	64.22	70.78	82.22	82.00
P1 (100 mL/plant)	11.11	16.78	27.56	44.56	69.00	76.89	91.67	90.33
P2 (200 mL/plant)	11.44	18.33	33.56	47.33	66.33	76.22	86.56	85.78
P3 (300 mL/plant)	11.44	16.44	31.22	54.56	73.67	76.78	81.78	80.11
Sig. HSD 5%	ns (*F*: 1.0, *p*: 0.41)	ns (*F*: 0.21, *p*: 0.89)	ns (*F*: 0.29, *p*: 0.83)	ns (*F*: 1.23, *p*: 0.32)	ns (*F*: 2.66, *p*: 0.07)	ns (*F*: 2.74, *p*: 0.07)	ns (*F*: 2.99, *p*: 0.05)	ns (*F*: 1.05, *p*: 0.39)
V1 (6 days)	11.44	18.33	32.89	45.89	66.00	76.22	86.56	85.78
V2 (10 days)	11.44	16.44	30.33	44.56	69.00	76.22	86.56	85.67
V3 (14 days)	11.22	16.78	33.56	54.56	73.67	76.89	91.67	90.33
Sig. HSD 5%	ns (*F*: 0.19, *p*: 0.83)	ns (*F*: 0.50, *p*: 0.61)	ns (*F*: 0.41, *p*: 0.67)	ns (*F*: 2.60, *p*: 0.10)	ns (*F*: 1.18, *p*: 0.32)	ns (*F*: 1.32, *p*: 0.29)	ns (*F*: 0.54, *p*: 0.59)	ns (*F*: 1.39, *p*: 0.37)

Note: DAT = day after transplanting; ns = not significant; *F* = F-calculated value; *p* = significance value, that is P(F-cal > F-table).

3.2. Plant Height (cm)

Table 2 shows the effect of the dose and application interval of liquid tofu waste LOF on the development of tomato plant height up to 56 days after planting. Tomato plants grew almost uniformly from about 11 cm at 7 DAT to between about 80 cm and 90 cm at 56 DAT. The height of the plants at 56 DAT from our research results (82-90.33 cm) was slightly higher than the height of the tomato plants reported by Septirosya *et al*. (2019) with an average height of 77.9 to 87.8 cm. Analysis of variance (ANOVA) results showed no significant interaction between the dose and application interval of liquid tofu waste LOF on plant height ($p > 0.05$). The single factors of LOF dose as well as application interval of LOF, separately, also had no significant effect on all weekly observations. Reason for the insignificant effect of LOF may be the suboptimal fermentation time (10 days). In comparison, several other studies have fermented tofu liquid waste into LOF for longer periods, up to 14 days (Suhairin *et al*., 2020), 15 days (Arifan *et al*., 2022), or 20 days (Lussy *et al*., 2022). Although statistically insignificant, the highest plant high (90.33 cm) at 56 DAT was resulted at LOF dose of 100 mL/plant, or interval application 14 days.

3.3. Number of Leaves

Number of leaves is one important vegetative parameters for plants because it directly affects photosynthesis activity. Growing more and better leaves is one of the benefits expected from using organic fertilizer, which, when applied correctly, can increase the availability of nutrients needed for plant growth. Table 3 and 4 provide the effect of combination treatments on the number of leaves of tomato plants at 21 and 35 DAT. ANOVA results showed that the treatment interaction significantly affected leaf number in both observation periods. At 21 DAT, the P2V3 treatment (300 mL/plant, 10-day interval) produced the statistically lowest number of leaves, at 5.33, lower than the number of leaves produced by the other 11 treatment combinations. At 21 DAT, the control treatment produced a nominally higher number of leaves, with a trend toward decreasing leaf number as the LOF application dose increased.

At 35 DAT, the number of leaves changed compared to the 21 DAT observation. Three treatment combinations producing the highest number of leaves were P1V2 (200 mL/plant, 6-day interval) with 19.44 leaves, followed by P3V3 (300 mL/plant, 14-day interval) with 17.56 leaves, and P1V1 (100 L/plant, 6-day interval) with 16.67 leaves. The number of leaves produced by these three treatment combinations was not statistically different, but was greater than the number of leaves produced by treatments V0P1, V0P2, V1P2, and V3P2. These four treatments produced the lowest number of leaves. This result is consistent with Raharjo & Prihatiningrum (2022) and Septirosya *et al*. (2019) who reported that the frequency of LOF application significantly affected the number of leaves of tomato plants.

Table 3. Effect of treatment on the average number of leaves of tomato plants at age of 21 DAT

Time	Number of leaves				
	Interval	Control	100 mL/plant	200 mL/plant	300 mL/plant
21 DAT	Once every 6 days	9.22 b	8.56 b	8.78 b	7.44 b
	Once every 10 days	8.22 b	7.78 b	6.78 ab	5.33a
	Once every 14 days	8.89 b	8.22 b	8.89 b	8.56 b
	Significance	$F = 3.23$; $p = 0.02$			

Note: Numbers followed by the same letter indicate no significant difference in the 5% HSD test; DAT = days after transplanting; F = F-calculated value; p = significance value, that is P(F-cal > F-table)

Table 4. Effect of treatment on the average number of leaves of tomato plants at age of 35 DAT

Time	Number of leaves				
	Interval	Control	100 mL/plant	200 mL/plant	300 mL/plant
35 DAT	Once every 6 days	15.56 ab	16.67 b	19.44 b	15.44 ab
	Once every 10 days	14.78 a	14.22 a	15.33 ab	14.11 a
	Once every 14 days	14.11 a	16.56 b	15.11ab	17.56 b
	Significance	$F = 2.92$; $p = 0.03$			

Note: Numbers followed by the same letter indicate no significant difference in the 5% HSD test; DATT = days after transplanting; F = F-calculated value; p = significance value, that is P(F-cal > F-table)

3.4. Flowering Age

Table 5 shows the effect of interaction of LOF dose and application interval on the first flower emergence. The results of ANOVA revealed that there was a significant interaction between the dosage and application interval of LOF on the first flower emergence. Treatment combination of dosage 300 mL/plant applied with 14-day interval resulted in fastest emergence of flower (26.89 DAT), which is about 5.76% faster than that of control. This finding is better than those of other studies reported that LOF from tofu waste did not statistically significant on the first flower emergence of red chili (Marlina *et al*., 2023), or tomato (Ramadhon & Hadid, 2024). It is believed that the main component responsible for accelerating the flowering period is the phosphorus (P) concentration of LOF. According to Hidayat *et al*. (2018), phosphorus regulates the distribution of photosynthates between the plant's source organs and reproductive organs, which is crucial for photosynthesis and carbohydrate metabolism, as reported by.

Table 5. Effect of treatment on the first flower emergence (day) of tomato plants

Interval	First flower emergence			
	Control	100 mL/plant	200 mL/plant	300 mL/plant
Once every 6 days	28.78 a	28.22 a	27.22 ab	29.22 a
Once every 10 days	30.56 a	27.33 ab	29.00 a	27.56 ab
Once every 14 days	28.44 a	27.44 ab	28.78a	26.89 b
Significance	$F = 13.34$; $p = 0.00$			

Note: Numbers followed by the same letter in the same column indicate no significant difference in the 5% HSD test.

Table 6. Effect of LOF tofu waste dose and application interval on the mean of total fruit harvest

Experiment Factors	Number of Fruits (fruit/plant)	Fruit Set (%)
LOF Dosage		
P0 (Control, 0 ml)	19.00	53.86
P1 (100 ml/plant)	12.22	48.40
P2 (200 ml/plant)	13.11	56.04
P3 (300 ml/plant)	13.44	41.19
Significance	$F = 0.49$; $p = 0.69$	$F = 0.82$; $p = 0.50$
LOF fertilization interval		
V1 (6 days)	19.00	51.53
V2 (10 days)	13.78	48.40
V3 (14 days)	12.56	56.04
Significance	$F = 2.28$; $p = 0.12$	$F = 0.60$; $p = 0.56$

Note: DAT = days after transplanting; tn = not significant; F = F-calculated value; p = significance value, that is P(F-cal > F-table)

3.5. Fruit Set and Total Number of Fruits

Table 6 presents the effect of LOF dosage and application interval on the number of fruits per plant and fruit sets of the tomatoes. Statistical analysis reveals that no interaction between the two factors was observed on the tomato fruitsets. Similarly, according to the results of ANOVA, there was no significant effect of the single factor LOF dosage as well as LOF application interval on the total number of fruits and frit sets.

Figure 1 shows feature of tomatoes resulted from treatment combination of LOF dosage and application interval ready for harvest. Open field cultivation cannot control other factors with more dominant effect than the treatment being tested. For example, severe weather conditions (heavy rain and strong winds) and pest infestations cannot be controlled. It is worthy to note that during the experiment, some adverse weather condition (heavy rain and strong wind) occurred. Such as strong winds and heavy rain, might disrupt the vegetative development of plants in the field. Direct physical damage, including broken branches and leaf fall, was a direct result of this situation and greatly inhibited development. This is consistent with what Gardiner *et al*. (2016) found, that plants may have a major impact on their vegetative development when physically damaged. This highlights the importance of conducting experiments in a more controlled environment, such as a greenhouse or plastic house.

Figure 1. Tomato plants resulted from treatment combination of LOF dosage and application interval ready to harvest: (a) Control (0 mL/plant); (b) LOF dose 100 mL/plant; (b) LOF dose 200 mL/plant; and (b) LOF dose 300 mL/plant.

3.6. Total Fruit Weight per Plant (g)

Results of ANOVA reveal that the total fruit weight of plants is significantly influenced by the interaction between treatment dosage and the interval of liquid tofu waste LOF fertilization (Table 7). The results show that the fertilization interval and dosage of liquid tofu waste LOF significantly affect the fruit weight per plant, but the combined effect of both is not significant. The control group achieved a maximum average total fruit weight of 577.78 grams after 6 days of treatment. Among the groups given LOF, the group with the largest total fruit weight (478.42 grams) was the group that processed 200 cc of liquid tofu waste per plant at 10-day intervals.

This is can be resulted from potassium (K) content in the LOF that is already available. Potassium (K) is the main ingredient in cell and meristem tissue division,. In addition to increasing assimilation translocation into the phloem and strengthening plant organ tissues, K has other beneficial effects (Agussimar, 2016). Furthermore, according to Marian & Sumiyati (2019), tofu waste contains important minerals, including nitrogen (0.24%), phosphorus (0.54%), potassium (0.34%), and carbon (2.803%). Saptorini *et al.* (2021) found that the use of liquid organic fertilizer made from tofu waste can increase fruit weight, number of leaves, and overall plant growth; therefore, our findings are consistent with theirs.

Table 7. Fruit yield as a result of fertilization and dosage intervals on LOF from tofu liquid waste

Interval	Fruit weight (g/plant)			
	Control (0)	100 ml/plant	200 ml/plant	300 ml/plant
Once every 6 days	577.78 b	341.56 ab	461.87 b	432.78 b
Once every 10 days	438.19 b	337.67 a	200.89 a	333.97 a
Once every 14 days	475.77 b	281.56 a	478.42 b	250.34 a
Significance	$F = 2.63$; $p = 0.04$			

Note: Numbers followed by the same letter in the same column indicate significant differences in the 5% HSD test; F = F-calculated value; p = significance value, that is P(F-cal > F-table)

4. CONCLUSION

Tofu industrial liquid waste has the potential to be a liquid organic fertilizer (LOF) that can be applied to tomato plants. The effectiveness of LOF application of tofu liquid waste on tomato plants is influenced by the dosage and interval or frequency of application. The results of the study found that the combination of LOF tofu liquid waste dosage at a dose of 300 mL/plant with an application interval of 14 days resulted in the fastest flowering age compared to other treatment combinations. However, the combination of dosage and application interval treatments did not significantly affect the parameters of plant height, number of fruits, and fruit sets. The application of LOF tofu liquid waste fertilizer even tended to reduce the harvest weight of tomato fruit compared to the control treatment. Future research can focus on the optimal fermentation time of liquid waste to prepare LOF and apply the LOF on tomato plants under more controlled conditions such as in a greenhouse or plastic house.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
PAP	✓	✓			✓	✓		✓	✓	✓				
Dja	✓	✓		✓						✓		✓		
FDD	✓	✓		✓						✓		✓		

C: Conceptualization
M: Methodology
So: Software
Va: Validation
Fo: Formal Analysis
I: Investigation
D: Data Curation
R: Resources
O: Writing - Original Draft
E: Writing - Review & Editing
Vi: Visualization
Su: Supervision
Fu: Funding Acquisition
P: Project Administration

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