International Journal on Advanced Science Engineering Information Technology

Vol.10 (2020) No. 4
ISSN: 2088-5334

Quality of Enriched Liquid Organic Fertilizer from Dairy Cattle Wastes on Closed Agriculture System

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Abstract*—Liquid organic fertilizer (LOF) supplementation for solid organic fertilizer can accelerate the availability of plant nutrients. However, the nutrient content of LOF is highly dependent on its sources. The objective of the experiment was to examine the nutrient content of enriched liquid organic fertilizer from dairy cattle wastes. The experiment was conducted at Closed Agriculture Production System Research Station located in Air Duku Village, Bengkulu, Indonesia, at 1054 m above sea level. The experiment was laid out in a Completely Randomized Design with ten treatments and three replications. The treatments consisted of LOF from dairy cattle wastes enriched with *Tithonia diversifolia*, *Ageratum conyzoides*, *Leucaena leucocephala*, and *Gliricidia sepium*, their combination with phosphate rock, the combination of *Tithonia diversifolia*, and *Ageratum conyzoides*, and control. The LOF solution was anaerobically incubated for six weeks. The experiment indicated that during the incubation, solution pH declined for the first two weeks, gradually increased up to week 6. At the end of incubation, control exhibited the highest pH as compared to those with enrichment, indicating that decomposition of green biomass released a considerable amount of hydrogen. Enrichment of LOF considerably increased the contents of C, N, P, K, Ca, and Mg. The addition of phosphate rock to biomasses did not contribute a prominent increase in phosphorus content, possibly due to its low solubility at high pH. LOF enrichment with *Tithonia diversifolia* and *Ageratum conyzoides* had the highest N, P, and Mg contents. Therefore, the enrichment is the most potential for LOF production in closed agriculture system.

Keywords: liquid organic fertilizer; enrichment; closed agriculture system; *Tithonia diversifolia; Ageratum conyzoides.*

I. Introduction

The development of organic farming practices has been associated with the prevention of further soil deterioration due to a massive application of synthetic agrochemicals. Degradation of soil fertility in conventional farming practices has been reported by some researchers [1]–[4]. Solid organic fertilizer is commonly used as the only nutrient plant resources in organic farming practices. The fertilizer can improve soil fertility [5]–[7] and substitute synthetic nitrous fertilizer [8], [9]. However, supplementation of liquid organic fertilizer (LOF) is necessary since plant nutrient release from solid organic fertilizer is slow and often not available when required. Vermicompost fertilization supplemented with LOF has an increase in total soil nitrogen, nitrate-N, exchangeable K, and soil pH, even though it does not affect total soil organic C, exchangeable Al, and available P in soil [10].

The application of solid organic fertilizer with the addition of LOF provides more rapid availability of nutrients during the plant life cycle. The previous study indicated that the use of LOF as a supplement increased N, P, and K uptakes, as well as the yield of sweet corn [11]–[13] and shoot fresh weight of mustard [14], Another result, however, indicates that fertilization using LOF has no significant effect on P and K uptakes and yield of sweet corn [15], [16] as well as on the growth and yield of organic carrot [17]. This inconsistent result might reflect LOF sources and its preparation process, leading to its different nutrient content.

Aerobic fermentation of dairy cattle effluent contains a low concentration of total carbon (318 mg l^{-1}), total nitrogen (60 mg l^{-1}), phosphorus (4 mg l^{-1}), potassium (700 mg l^{-1}) and pH of 6.2 [18]. Cattle urine had 3000 mg l^{-1} nitrogen, 1.6 mg l^{-1} phosphorus, 613300 mg l^{-1} potassium, 20 l^{-1} calcium, 280 mg l^{-1} magnesium, and 490 mg l^{-1} sulfur [19]. Therefore, enrichment of animal effluent based liquid organic fertilizer is essential to increase the nutrient content required for plant growth and development. Plant biomasses and natural minerals are among the sources for this purpose.

Among three green biomasses identified, *Tithonia* is superior in N (1.76%), K (3.92%), and Ca (3.07%) content to *Panicum* and *Chromolaena*. *Panicum* has highest content in P (1.62%), Mg (0.2%) and C (33.40%) [20]. Another study indicates that *Ageratum* contains the highest N, P, K, Ca, and Mg as compared to *Tithonia, Gliricidia, Leucaena, and Eichornia* [21], being the most encouraging source of enrichment. The nutrient content and the availability of each green biomass should be put into consideration of LOF production. The addition of green biomass to LOF from animal effluent is rarely evaluated. Therefore, the study was carried out to examine the nutrient content of enriched liquid organic fertilizer from dairy cattle wastes.

II. Materials and Method

A. Green Biomass Selection

The study started with the identification of green biomasses around the site of the experiment in Selupu Rejang Subdistrict, Rejang Lebong, Bengkulu, Indonesia. A lot of potential plant biomasses were discovered in the area such as *Ageratum, Tithonia, Gliricidia, Leucaena, Eichornia, Panicum* and *Chromolaena*, and nutsedge. Four green biomasses were selected for enrichment based on their abundance around the study area and their nutrient content [21], which was *Ageratum, Tithonia, Leucaena, and Gliricidia*. A combination of rock phosphate with each selected biomass was assigned in a treatment to acquire the best LOF nutrient content.

B. Experimental site and Treatment

The experiment was carried out at Closed Agricultural Production System Research Station in Air Duku Village, Selupu Rejang Sub-District, Rejang Lebong District, Bengkulu, Indonesia. It is located at 1054 m above sea level assigning Completely Randomized Design with ten treatments with three replications. The treatments were an enrichment of liquid organic fertilizer with green biomasses and their combination with phosphate rock, as indicated in Table 1.

TABLE I
TREATMENTS OF LIQUID ORGANIC FERTILIZER ENRICHED WITH GREEN BIOMASSES AND PHOSPHATE ROCK.

Treatment	Enrichment
TD+RP	5 kg *Tithonia diversifolia* (Hemsl.) A. Gray and 2.5 kg phosphate rock
AC+RP	5 kg *Ageratum conyzoides* L and 2.5 kg phosphate rock
LL+RP	5 kg *Leucaena leucocephala* (Lamk.) de Wit and 2.5 kg phosphate rock
GS+RP	*Gliricidia sepium (*Jacq.) Kunth ex Walp and 2.5 kg phosphate rock
TD	10 kg *Tithonia diversifolia* (Hemsl.) A. Gray
AC	10 kg *Ageratum conyzoides* L
LL	10 kg *Leucaena leucocephala* (Lamk.) de Wit
GS	10 kg *Gliricidia sepium* (Jacq.) Kunth ex Walp
TD+AC	5 kg *Tithonia diversifolia* (Hemsl.) A. Gray and 5 kg *Ageratum conyzoides* L
Control	Without enrichment

C. Liquid Organic Fertilizer Preparation

Green biomasses for enrichment were prepared by cutting into 5-6 cm pieces. Liquid organic fertilizer was produced by mixing dairy cattle faces, urine, soil containing local microorganisms, EM-4 [12]. However, the volume was set to 100 liters with fresh water. Before the addition of water, the enrichment was incorporated and altogether was transferred to 130-liter blue container. The container was, then, tightly covered with a cap. The mixture was anaerobically incubated for six weeks. Anaerobic installation was accomplished by connecting a PVC pipe through the hole in the middle of the lid to LOF solution at one end and body of water at the other end. Solution LOF temperature and pH were measured every week. After six weeks, one liter of the solution was sampled for the determination of carbon, nitrogen, phosphorus, potassium, calcium, and magnesium.

D. Statistical Analysis

Analysis of variance was calculated using Proc GLM using SAS version 9.1.3 portable at the confidence level of 95%. Treatment means were separated using Duncan Multiple Range Test at $p<0.05$.

III. Results and Discussion

A. Effect of Enriched LOF on Solution Temperature and pH

Enrichment of LOF does not influence solution temperature as indicated in Table 2. During the incubation, solution temperature ranged from 20.7-24.3 ^{o}C which was always lower than room temperature (23.0-29.0 ^{o}C). Organic matter decomposition normally increases temperature due to heat release during the process [22]. An increase in CO_2 release with increasing temperature was an indication of the organic matter decomposition process [23]. It was also noted by [24] that temperature increased gradually to 80 ^{o}C after 20 days of organic matter decomposition. Another earlier study found out different results where temperature increased drastically to nearly 60 ^{o}C after 50-60 hours of organic matter decomposition [25]. Our finding showed that organic matter decomposition under saturated water did not affect the temperature of the LOF solution; in fact, it was lower than the room temperature.

TABLE II
SOLUTION TEMPERATURE DURING THE INCUBATION

Treatment	Temperature (^{o}C)					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
TD+RP	21.7	21.3	22.0	21.3	22.3	22.3
AC+RP	22.3	21.0	20.7	22.3	22.3	22.3
LL+RP	23.0	21.3	21.3	21.3	23.0	22.0
GS+RP	22.0	22.3	22.3	21.7	22.7	22.3
TD	22.7	21.7	21.3	21.0	23.0	22.0
AC	23.3	21.0	22.0	22.3	23.3	22.3
LL	22.0	21.3	22.3	22.3	22.3	22.7
GS	24.3	22.0	22.7	22.3	24.3	23.0
TD+AC	22.0	21.3	21.7	21.7	22.0	23.3
Control	22.7	21.3	20.7	21.3	21.7	22.7

Throughout the incubation process, solution pH tended to fluctuate and was influenced by the enrichment of the LOF.

It is indicated in Table 3 that solution pH decreased in the first two weeks and increased afterward, finally acquired steady at week 6. The decline in solution pH at the beginning of incubation might have been associated with the production of organic acids during the organic matter decomposition [26]. However, solution pH was still in a range of neutral, which is acceptable for the national standard of LOF. pH decline was observed in the first five days and significantly increased until nearly 15 days after incubation [24].

TABLE III
SOLUTION PH OF ENRICHED LOF DURING THE INCUBATION

Treatment	Solution pH					
	Week 1	Week 2	Week3	Week 4	Week 5	Week 6
TD+ RP	7.84 abc	7.31 ab	7.39 abc	7.77 b	7.81 b	7.76 ab
AC+ RP	6.78 d	6.61 c	7.02 bc	7.23 cd	7,65 bc	7.69 ab
LL+ RP	7.70 abcd	7.22 ab	7.30 abc	7.50 bc	7.81 b	7.76 ab
GS+ RP	7.30 bcd	7.05 abc	7.22 abc	7.49 bc	7.75 bc	7.79 ab
TD	7.96 ab	7.37 ab	7.47 ab	7.48 bc	7.59 bc	7,54 bc
AC	6.89 cd	5.98 d	6.75 c	6.74 e	7.01 d	7.36 bc
LL	7.48 abcd	6.84 bc	7.27 abc	7.12 cd	7.05 d	7.11 c
GS	7.21 bcd	7.16 abc	6.81 c	7.08 ed	7.11 d	7.15 c
TD+ AC	7.50 abcd	7.12 abc	7.05 bc	7.35 cd	7.35 cd	7.41 bc
Cont rol	8.41 a	7.54 a	7.72 a	8.30 a	8.28 a	8.15 a

Means followed by the same letter within a column are not significantly different

Table 3 also shows that the enrichment of LOF has lower pH than control, suggesting that the addition of green biomasses leads to the accumulation of proton released by the decomposition process to the system. A laboratory study noted that the accumulation of biological hydrogen production from sucrose and starch mineralization drastically increased during the first 20 hours, leading to lower the pH [27]. Another study noted that the loss of soil organic matter contributed to an increase in hydrogen production to the soil [28]. Also, the combination of biomass with phosphate rock had slightly higher solution pH than that of sole biomass, indicating that the addition of phosphate rock can neutralize the accumulation of proton production by the green biomass decomposition process. Solubility of rock phosphate increased at high proton availability [29].

B. Nutrient Content of Enriched Liquid Organic Fertilizer

Its nutrient content profoundly determines the quality of LOF. Enrichment of LOF with green biomasses and their combination with phosphate rock significantly increased its nutrient content such as C, N, P, K, Ca, and Mg. In this study, C concentration of LOF was lower than that recommended by the national standard. The lesser C concentration was partly due to different preparation in which the LOF sample was sieved to obtain the strength of the pure solution, deprived of the solid phase. The carbon concentration of the LOF ranged from 10.6 to 37.9 g l^{-1}.

Enrichment of LOF with biomasses and their combination with phosphate rock considerably increases the content of C of the solution, as indicated in Figure 1. Enrichment with sole biomass had greater C concentration than that when combined with phosphate rock. Additionally, C concentration was not significantly different among enrichment with sole biomasses. Enriched LOF with the combination of *Tithonia* and *Ageratum* had lower C concentration than that of the only biomass, indicating a faster decomposition process of the combination. The different C concentrations of enriched LOF might have been related to the lignin content of each biomass. Lignin was an integral part of cell walls resistant to biological degradation [26]. The Low C/N ratio of LOF enriched with the combination of *Tithonia* and *Ageratum* presented in Figure 2 is an indication of the low lignin content of the combination. It is revealed by another study that LOF from green biomasses of water hyacinth, peanut, and *Leucaena* using three bio-activators had C content ranging from 67-86 g l^{-1} [30]. The difference of the C content was due to different lignin content of the green biomasses.

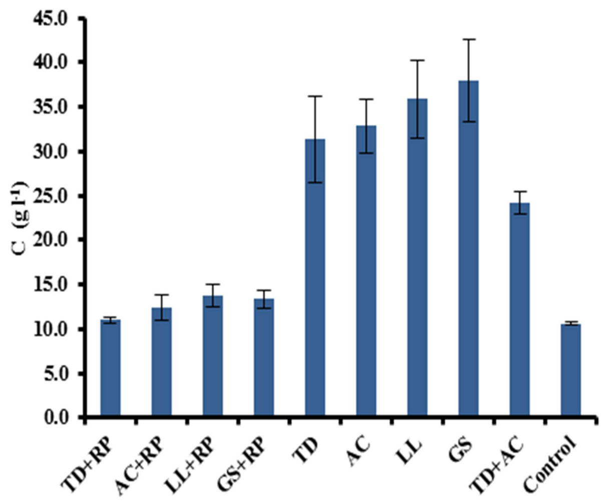

Fig. 1. The carbon content of enriched LOF with green biomass and its combination with phosphate rock

The enrichment with biomass and its combination with phosphate rock also markedly raises N concentration of the LOF, as shown in Figure 2. Sole biomass addition increased N concentration higher than that when combined with phosphate rock. Among green biomasses, *Tithonia* biomass had the highest N concentration, followed by *Ageratum*, *Leucaena*, and *Gliricidia*. A similar trend was observed when the biomasses were in combination with phosphate rock. The enrichment with the combination of *Tithonia* and *Ageratum* biomasses exhibited the highest N concentration, even though it was not significantly different from sole *Tithonia* or *Ageratum*, demonstrating that *Tithonia* and *Ageratum* have higher N content than the other two biomasses. The previous study resulted that *Tithonia* and *Ageratum* had similar content of N but higher than *Leucaena*, water hyacinth, and *Gliricidia* [21]. In terms of N concentration, the combination of the biomasses (*Tithonia* and *Ageratum*) or sole biomass addition is the most potential biomass for the enrichment of LOF. The high N content of LOF is very advantageous for plant growth [13], [31], [32].

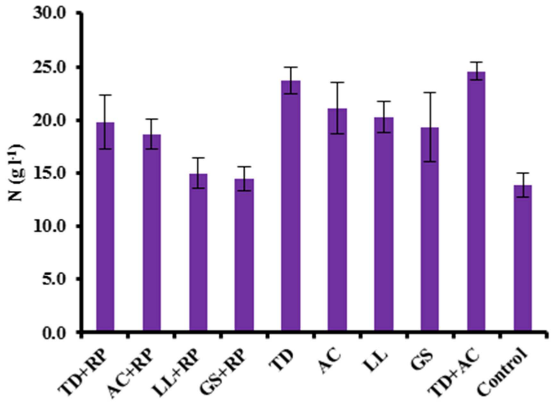

Fig. 2. The nitrogen content of enriched LOF with green biomass and its combination with phosphate rock

A low concentration of C in LOF brought about a low C/N ratio. Highest C/N ratio was attained by the addition of sole *Gliricidia*, followed by *Leucaena* (Figure 3), indicating that *Gliricidia* and *Leucaena* biomasses were more resistant to decomposition than *Ageratum* and *Tithonia*. Even though a *Tithonia*, *Ageratum*, *Leucaena*, and *Gliricidia* had similar content of lignin, the types of the lignin might have been different, causing the difference in C/N ratio [21]. Lignin structure and composition is very complex so that it is resistant to biodegradation [33], [34].

Figure 3 also illustrates that the addition of phosphate rock to green biomasses is likely to lower the C/N ratio than those of sole biomasses. This might have been associated with the increase in solution pH (Table 3), causing an intensification of microbial activities for the composting process. Earlier experiments noted that an increase in pH tended to speed up biological degradation [35], [36]. Bacteria is strained under acid condition leading to that the cell growth is hampered, even deceased [37].

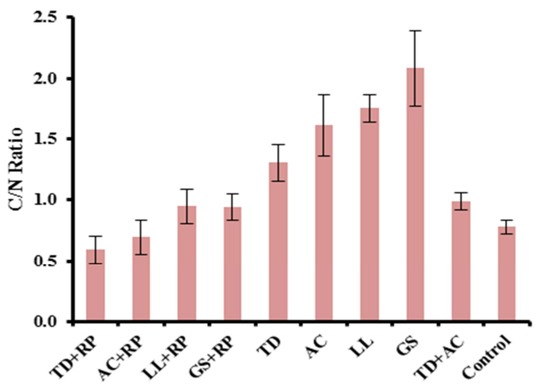

Fig. 3. C/N ratio of enriched LOF with green biomass and its combination with phosphate rock

Enrichment of LOF with green biomass and its combination with phosphate rock prominently increases P concentration (Figure 4). Similar to N content, the combination of *Tithonia* and *Ageratum* had the highest concentration of P in comparison to the other enrichments. This is related to the content of P of the biomasses where *Tithonia* and *Ageratum* had P concentration reaching 0.9% and 1.7%, respectively [21]. Nevertheless, the addition of phosphate rock to biomass did not affect P concentration. This might have been due to the low solubility of phosphate rock at high solution pH (Table 3). The previous study confirmed that soluble P attained 40% in a citric acid solvent and none in distilled water [38]. Moreover, the solubility of phosphate rock sharply declines as pH increases and practically is not soluble at pH of 7.0 [39]. Therefore, the contribution of P on the enriched LOF is more likely from green biomass rather than from phosphate rock. Addition in the form of phosphate rock solution might be the key to avoid the problem.

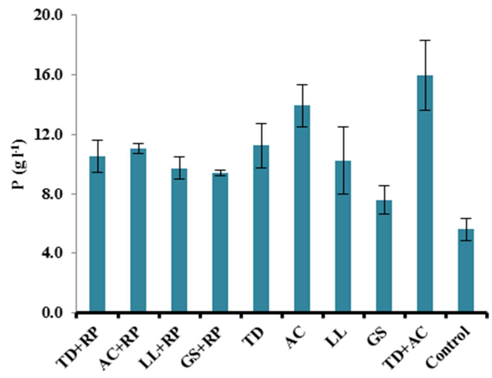

Fig. 4. The phosphorus content of enriched LOF with green biomass and its combination with phosphate rock

Potassium concentration in the LOF shows a different fashion. Although the addition of biomass and its combination with phosphate rock provided a substantial increase in K concentration in LOF as compared to that of control, K concentration was similar among the enrichments (Figure 5). *Ageratum* had higher K content than *Tithonia*, *Leucaena*, and *Gliricidia*, but the contribution to LOF was not significant [21]. A similar result was found out that K concentration in LOF was approximately 6.1 g l^{-1} after 40 days of incubation [30]. The finding of the experiment revealed that K concentration of enriched LOF with biomass and its combination with phosphate rock ranged from 6.5 to 7.9 g l^{-1}.

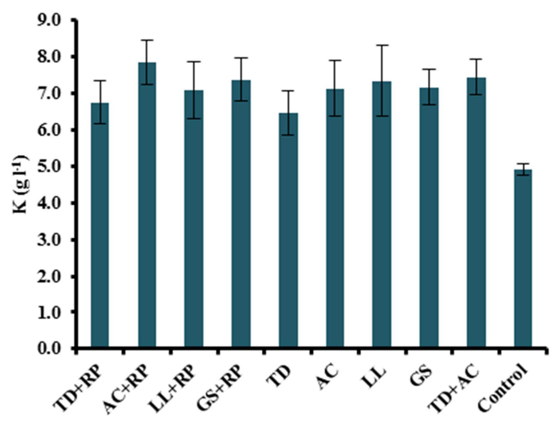

Fig. 5. The potassium content of enriched LOF with green biomass and its combination with phosphate rock

Calcium concentration of enriched LOF with biomass and its combination with phosphate rock was also superior to control (Figure 6). Sole biomass addition had a higher Ca concentration of LOF than that of its combination with phosphate rock, indicating that contribution of biomass on Ca content was more substantial than phosphate rock. The low solubility of phosphate rock ($Ca_5(PO_4)_3F$) at high pH (Table 3) might be the reason for small Ca contribution to LOF. Moreover, sole *Gliricidia* biomass contributed the most top Ca to the LOF followed by *Ageratum* and combination of *Tithonia* and *Ageratum*. Higher content of Ca in the enrichment of *Gliricidia* was associated with its Ca content in which Ca content of *Gliricidia* was 1.42% [40]. This amount was higher than *Leucaena* (1.32%).

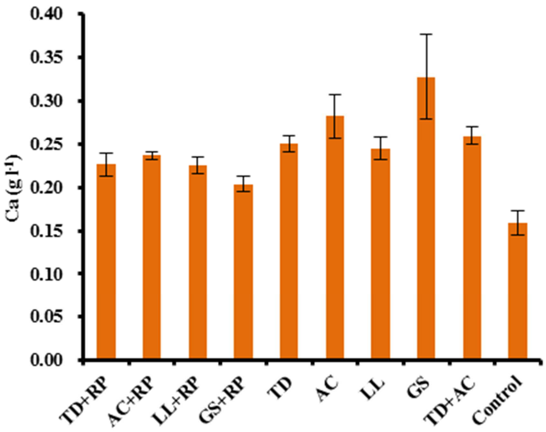

Fig. 6. Calcium content of enriched LOF with green biomass and its combination with phosphate rock

As in the case of other nutrient content of enriched LOF, Figure 7 shows that LOF without enrichment has the lowest concentration of Mg. The highest concentration of Mg has observed in LOF with enrichment of *Tithonia* and *Ageratum combination*, although it was not different from that of sole *Ageratum*. *Ageratum* biomass was superior in Mg concentration to other green biomasses [19]. The concentration of Mg in LOF enriched with the combination of *Tithonia* and *Ageratum* was more than 3.5 times that of control.

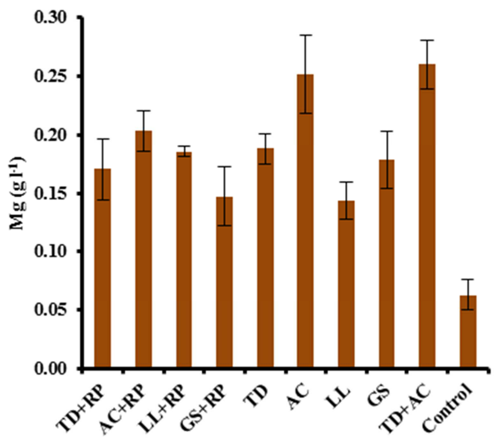

Fig. 7. The magnesium content of enriched LOF with green biomass and its combination with phosphate rock

IV. Conclusion

In general, enrichment of LOF by green biomass and its combination with phosphate rock considerably increased the *concentration* of C, N, P, K, C, and Mg in comparison to those of control. LOF enrichment with the combination of *Tithonia* and *Ageratum* exhibited the highest concentration of N, P, and Mg. At the same time, that of *Gliricidia* had the highest C and Ca concentration as well as C/N ratio. Likewise, the pH of LOF complied with the national standard, which is approximately neutral. Therefore, the enrichment with the combination of *Tithonia* and *Ageratum* was the most potential for LOF production in a closed agriculture system. The two green biomasses are easily found in the tropical highland as fast-growing weeds. In case of limited availability of the two biomasses, sole enrichment of *Tithonia* or *Ageratum* is an alternative for LOF production.

Acknowledgment

Sincerely thank is handed to Directorate General of Research and Extension, the Ministry of Research, Technology, and Higher Education for financial support of the project through 2019 Applied Research Scheme. *Appreciation* also goes to CAPS Research Station, Faculty of Agriculture, the University of Bengkulu, for providing experimental site and other necessary resources.

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