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LANDFILL LEACHATE AS A SOIL CONDITIONER: EFFECTS ON LATOSOL PROPERTIES AND SPINACH (*Amaranthus* viridis) GROWTH

LINDI TEMPAT PEMROSESAN AKHIR SEBAGAI BAHAN PEMBENAH TANAH: DAMPAK TERHADAP SIFAT KIMIA LATOSOL DAN PERTUMBUHAN BAYAM (*Amaranthus viridis*)

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ABSTRACT

Leachate from the Jetis landfill in Purworejo Regency poses a risk of environmental pollution, but it also contains plant nutrients such as nitrogen, potassium, and organic matter. The purpose of this study is to ascertain how different Jetis landfill leachate concentrations affect the chemical characteristics of Latosol and assess how leachate application affects the spinach growth. A non-factorial totally randomized design was employed in this investigation with 6 treatments and 3 replicates. The treatments consisted of applying leachate at several concentrations, specifically 0% (L0), 20% (L1), 40% (L2), 60% (L3), 80% (L4), and 100% (L5). The soil was incubated with leachate for 30 days and then planted with spinach until the maximum vegetative phase. Data analysis was performed using 5% ANOVA followed by 5% DMRT test. The findings demonstrated that the application of leachate significantly raised the pH, CEC, plant height, number of leaves, wet weight, and dry weight of spinach plants. However, it had no discernible on organic-C, total-N, available-P, and available-K. The application of 20% leachate (L1) produced the highest values for plant height, number of leaves, wet weight, and dry weight of plants, which were significantly different from the control (L0). This Jetis landfill leachate is not yet effective as a fertilizer substitute, but it has the potential to be used as a soil conditioner.

Keywords: *Jetis landfill leachate, Latosol, soil chemical properties, spinach*

ABSTRAK

Lindi tempat pemrosesan akhir (TPA) sampah Jetis Kabupaten Purworejo berisiko terhadap pencemaran lingkungan, namun juga mengandung nutrisi tanaman seperti nitrogen, kalium, dan zat organik. Tujuan penelitian ini adalah untuk memastikan bagaimana konsentrasi lindi TPA jetis yang berbeda memengaruhi karakteristik kimia Latosol dan mengkaji bagaimana aplikasi lindi memengaruhi pertumbuhan bayam. Penelitian ini menggunakan metode rancangan acak lengkap non faktorial dengan 6 perlakuan dan 3 ulangan. Perlakuan tersebut terdiri atas pemberian lindi beberapa konsentrasi yaitu 0% (L0), 20% (L1), 40% (L2), 60% (L3), 80% (L4), dan 100% (L5). Tanah diinkubasi dengan lindi selama 30 hari selanjutnya ditanami bayam hingga fase vegetatif maksimum. Analisis data menggunakan Anova 5% dilanjutkan uji DMRT 5%. Temuan menujukkan bahwa pemberian lindi berpengaruh nyata terhadap peningkatan pH, KPK, tinggi tanaman, jumlah daun, berat basah, dan berat kering tanaman bayam. Namun tidak berpengaruh nyata terhadap C-Organik, N-Total, P-Tersedia, dan K-Tersedia. Aplikasi lindi 20% (L1) menghasilkan nilai tertinggi untuk tinggi tanaman, jumlah daun, berat basah, dan berat kering tanaman yang berbeda secara signifikan dari kontrol (L0). Lindi TPA sampah Jetis ini belum efektif sebagai pengganti pupuk, namun berpotensi sebagai bahan pembenah tanah.

Kata kunci: *lindi TPA Jetis, Latosol, sifat kimia tanah, bayam*

INTRODUCTION

The increase in waste volume at the Jetis final waste processing site in Purworejo Regency has resulted in high waste accumulation and significant leachate production. Leachate is liquid waste produced from the leaching process of waste piles and contains various organic and inorganic chemical compounds, heavy metals, and pathogenic microorganisms. Leachate can pollute the environment, such as soil, groundwater, and surrounding water bodies, if not managed properly. Leachate management at the Jetis landfill uses a biological wastewater treatment system, which consists of three ponds, namely anaerobic, facultative, and maturation ponds (Widiarti & Muryani, 2020). Although potentially polluting, leachate also has benefits, as it contains organic compounds such as humic acid, fulvic acid, and nutrients such as nitrogen, phosphorus, potassium, magnesium, and other microelements (Herlina et al., 2015). Leachate contains several macro nutrients including nitrate (NO^{-}), ammonium (NH), phosphate (PO^{3-}), potassium (K), calcium (Ca), magnesium (Mg) and sulfate (SO^{2-}) as well as micro nutrients such as iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) (Nurhasanah, 2012). Some residents around the landfill use leachate to fertilize seasonal crops such as chili peppers and the results depend on the dosage and type of plant. Research Swadesi (2017) hows that the BOD, COD, and heavy metal content in the leachate from the Jetis landfill is still below the quality standard threshold, making it safe to use as liquid fertilizer or soil conditioner if processed correctly.

The Latosol around the Jetis landfill can be used as a growing medium for plants (Kurniawan et al., 2022). However, Latosol has several physical and chemical constraints. Latosol in Indonesia develops from volcanic material with a clay content of more than 40%, a crumbly structure, loose consistency, and homogeneous color. In terms of soil chemistry, there are several problems with Latosol, such as low pH, low cation exchange capacity (CEC), and low nutrient availability, making it difficult for plants to access nutrients. If these problems in Latosol are not corrected, they will result in low crop productivity. Therefore, efforts to improve soil fertility, such as adding fertilizer, are very important to increase crop productivity in Latosol. One effort that can be made to increase crop productivity is to use leachate as a soil conditioner. Crops that are suitable for cultivation in Latosol and are responsive to fertilizer include spinach. A crop that thrives readily all year round, spinach needs essential nutrients like nitrogen (N), phosphorus (P), and potassium (K). Nitrogen (N) nutrients stimulate plant growth in stems, branches, and leaves. Phosphorus (P) nutrients stimulate root growth. In addition, phosphorus also aids assimilation and respiration, and accelerates seed and fruit ripening. Potassium (K) nutrients help in the formation of proteins and carbohydrates in plants. The addition of potassium also makes plants resistant to drought and disease (Novenda & Nugroho, 2016). The plants need more nitrogen when their vegetative parts, the stems and leaves of spinach plants, are used as vegetables. The use of leachate as organic fertilizer on spinach has the potential to increase its growth and improve the fertility of Latosol soil. Thus, the use of leachate as a soil conditioner on spinach plants in Latosol soil has the potential to be an environmentally friendly and sustainable solution to overcome waste problems and increase agricultural productivity around the Jetis landfill. Therefore, the purpose of this study is to: (1) ascertain how different concentrations of Jetis landfill leachate affect the chemical characteristics of Latosol and (2) assess how leachate application affects spinach growth.

MATERIALS AND METHODS

The research conducted was a pot experiment a non-factorial completely randomized design (CRD) with six leachate concentration treatments. There were six leachate treatments with three replicates, resulting in a total of 18 units of experiments conducted. The treatments included the application of 0% concentration (L0), 20% concentration (L1), 40% concentration (L2), 60% concentration (L3), 80% concentration (L4), and 100% concentration (L5) solutions. The applied leachate concentrations were mixed with distilled water according to field capacity.

This research consisted of two main stages, namely the preparation stage and the implementation stage. Soil samples of Latosol were taken from the Jetis landfill area, Purworejo Regency, at a depth of 0 – 30 cm, and leachate samples were taken from the Jetis landfill wetland, Purworejo Regency. Based on the results of laboratory tests conducted by the Purworejo Regency Environment and Fisheries Agency in May 2025, the heavy metal Cd in the leachate was 0.0103 mg/L, which is below the quality standard of 0.1 mg/L. The soil was then dried, refined, and sieved using a 2 mm sieve. After that, a preliminary analysis was carried out on the soil and leachate samples according to the specified parameters. Then, in the implementation stage, two sets of treatments were made to avoid the loss of nutrient content in the leachate when it was taken for soil analysis and continued for planting. The first set was used for laboratory analysis by mixing 1 kg of Latosol soil with leachate at concentrations of 0%, 20%, 40%, 60%, 80%, and 100%. The second set was used as a planting medium with a composition of 3 kg of Latosol and leachate at the same concentrations. The treatment of leachate concentration in the first set was 0 ml of leachate + 229 ml of distilled water for a concentration of 0% leachate (L0), 45.8 ml of leachate + 183.2 ml of distilled water for a concentration of 20% leachate (L1), 91.6 ml of leachate + 137.4 ml of distilled water for a 40% leachate concentration (L2), 183.2 ml of leachate + 45.8 ml of distilled water for a concentration of 60% leachate (L3), 183.2 ml of leachate + 45.8 ml of distilled water for a concentration of 80% leachate (L4), and 229 ml of leachate + 0 ml of distilled water for a concentration of 100% leachate (L5). In the second set of treatments, the leachate concentrations given were 0 ml leachate + 689 ml distilled water for a 0% leachate concentration (L0), 137.8 ml leachate + 551.2 ml distilled water for a 20% leachate concentration (L1), 275. 6 ml of leachate + 413.4 ml of distilled water for a 40% leachate concentration (L2), 413.4 ml of leachate + 275.6 ml of distilled water for a 60% leachate concentration (L3), 551.2 ml of leachate + 137.8 ml of distilled water for an 80% leachate concentration (L4), and 689 ml of leachate + 0 ml of distilled water for a 100% leachate concentration (L5).

Both treatment sets were added with basic N, P, and K fertilizers according to the dosage before being mixed with leachate, then watered with distilled water until reaching field capacity. The amount of water needed to reach field capacity in the first set was 229 ml, while in the second set it was 689 ml. Basic fertilizers such as urea (N: 46%) were applied at a dose of 300 kg/ha or 1.3 g/1 kg of soil for the first set and 3.91 g/3 kg of soil for the second set, TSP (P: 46%) at a dose of 200 kg/ha or 0.8 g/1 kg of soil for the first set and 2.6 g/3 kg of soil for the second set, and KCl (K: 60%) at a dose of 100 kg/ha or 0.45 g/1 kg of soil for the first set and 1.30 g/3 kg of soil for the second set. Incubation was carried out for 30 days by maintaining field capacity through daily weighing. After the incubation period, the soil in the first set was analyzed, while the second set was used for planting spinach by planting three seeds each pot and leaving the best plant after seven days. To maintain field capacity, pots were weighed daily and watered with distilled water. Plant height and number of leaves were observed weekly until maximum vegetative phase. Spinach plants were harvested at the onset of flowering, which occurred approximately 40 days after planting, to measure wet and dry weight.

The soil parameters analyzed were pH H_2O measured by potentiometry, soil cation exchange capacity using the NH_4OAc saturation method, soil organic carbon using the Walkley and Black method, total soil nitrogen using the Kjeldahl method, available soil phosphorus using the Olsen method, and available soil potassium using the NH_4OAc saturation method. The analysis conducted for leachate covers several parameters such as pH using a pH meter, total nitrogen using the Kjeldahl and spectrophotometric methods, total phosphorus using ascorbic acid, total potassium using inductively coupled plasma spectrometry, organic matter using the titrimetric method, BOD using a glucose-glutamic acid solution, COD using closed reflux, and DHL using a conductometer. Spinach growth parameters observed included plant height, number of leaves, wet plant weight, and dry plant weight. The data obtained from the analysis and observation results were tested using 5% Analysis of Variance. If the treatment given has a significant effect, then a Duncan Multiple Range Test (DMRT) at the 5% level is performed.

RESULTS AND DISCUSSION

A. Results of Analysis Before Treatment

1. Latosol

Initial analysis of several Latosol parameters was conducted to determine the initial characteristics of the soil before treatment. The results of the analysis are presented in Table 1.

Table 1. Initial analysis results of Latosol

Parameters	Result	Parameter Units	Harkat (BPT, 2009)
pH H_2O	5.91	-	Slightly Acidic
Organic-C	1.91	%	Low
CEC	19.00	me/100g	Moderate
Total-N	0.28	%	Moderate
Available-P	77.85	ppm	Very High
Available-K	0.39	me/100g	Moderate

Based on preliminary analysis, Latosol around the Jetis landfill has a pH of 5.91 (slightly acidic) due to intensive weathering, which causes leaching of base cations and organic matter, leaving behind Fe_2O_3 and Al_2O_3. The organic carbon content is relatively low (1.91%) because Latosol is a soil that has undergone advanced weathering and leaching processes, resulting in low organic carbon content (Prihatiningtyas, 2023). The CEC value of 19.00 me/100g falls into the moderate category, influenced by the kaolinitic clay type and the small surface area of soil particles (Patricia et al., 2023). Total N (0.28%) and available K (0.39 me/100g) are moderate, indicating nutrient leaching due to weathering. Available P is very high (77.85 ppm), likely due to the slightly acidic pH reducing the solubility of Al and Fe ions, thereby increasing phosphorus availability (Sari et al., 2017), as well as the influence of organic matter from household waste in the landfill area (Panjaitan et al., 2025).

2. Leachate

An initial analysis of the leachate was conducted to determine its initial condition or characteristics. The results of the initial leachate characteristic analysis are presented in Table 2.

Table 2. Results of initial analysis of leachate

Parameters	Result	Parameter Units	Quality Standard
N-Total	108.4*1	mg/L	60*2
P-Total	5.600	mg/L	-
K-Total	190.6595	mg/L	-
pH	8.4	-	6-9*2
BOD	117.2	mg/L	150*2
COD	600.0*1	mg/L	300*2
DHL	2.59	mS/cm	-
Organic compound	28.44	mg/L	10*3

*1) Exceeds quality standards

*2) Source: Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.59/Menlhk/Setjen/Kum.1/7/2016 concerning Quality Standars for Landfill Waste Management Businesses and/or Activities

*3) Source: SNI 06-6989.22-2004

The leachate from the Jetis landfill contains a total nitrogen (N-total) concentration of 108.4 mg/L, exceeding the quality standard (60 mg/L) as per Ministry of Environment and Forestry Regulation No. P.59/Menlhk/Setjen/Kum.1/7/2016. The high nitrogen content in leachate is a result of the decomposition process of organic materials, including food waste, plant waste, and paper (Aji, 2024). The pH of leachate is 8.4, which is within the quality standard limit and is classified as slightly alkaline. This pH is influenced by the methane fermentation phase in old waste (Angrianto et al., 2021). The BOD of 117.2 mg/L is still below the quality standard (150 mg/L), so that easily decomposable organic matter is low (Angrianto et al., 2021). The COD reached 600 mg/L, exceeding the quality standard (300 mg/L) due to the influence of low dissolved oxygen. DHL of 2.59 mS/cm indicates high levels of dissolved ions such as Na^+, Mg^{2+}, and Cl^-. The organic content of 28.44 mg/L exceeds the quality standard limit (10 mg/L). This is due to the high TSS, which inhibits the degradation process of organic matter (Apriyani & Lesmana, 2020).

B. The Effect of Leachate Application on the Chemical Properties of Latosol

The effect of leachate application on the chemical properties Latosol can be seen from the parameters of pH H_2O, Organic-C, CEC, Total-N, Available-P, and Available-K in the soil presented in Table 3.

Table 3. The Effect of Leachate Application on the Chemical Properties of Latosol

Treatment	pH H_2O	Organic-C (%)	CEC (me/100g)	Total-N (%)	Available-P (ppm)	Available-K (me/100g)
L0	5.98a	2.63a	19.38a	0.44a	81.01a	0.37a
L1	6.12b	2.74a	19.60ab	0.37a	82.72a	0.40a
L2	6.14bc	2.44a	24.80bc	0.38a	84.25a	0.45a
L3	6.20cd	2.83a	20.00ab	0.41a	88.47a	0.44a
L4	6.21de	2.69a	27.20c	0.32a	79.21a	0.40a
L5	6.27e	2.71a	23.73abc	0.39a	76.40a	0.37a
SD	0.02	0.14	1.57	0.04	3.26	0.04
SE	0.02	0.06	0.90	0.17	1.46	0.02
CV	0.36	5.33	6.10	10.60	3.98	11.06

Note: columns and rows of numbers followed by the same letter indicate no significant difference according to the DMRT 5% test

L0: 0% leachate concentration
L1: 20% leachate concentration
L2: 40% leachate concentration
L3: 60% leachate concentration
L4: 80% leachate concentration
L5: 100% leachate concentration

Table 3 shows that the application of leachate had a significant effect on increasing the pH of Latosol. The application of leachate at all concentrations showed a significant difference compared to without leachate (L0). The application of 20% leachate concentration was significantly different from the application of 60%, 80%, and 100% leachate concentrations, but was not significantly different from the 40% leachate concentration. A 20% leachate concentration (L1) is the optimal result because leachate application at higher concentrations gives almost the same results and no significant difference in soil pH values. The higher the leachate concentration applied, the higher the soil pH value, from 5.98 (without leachate) to 6.27 (100% leachate). This is due to the alkaline nature of leachate and the release of hydrogen ions (OH^-) that can neutralize hydroxide ions (H^+) in the soil, as well as the presence of organic acids from waste decomposition (Tambun, 2024; Prihatiningtyas, 2023). The application of leachate has no significant effect on the soil organic-C, but tends to increase its value compared to before treatment. The higher the leachate concentration applied, the greater the tendency for organic C content to increase, except at a leachate concentration of 40%. Excessively high leachate concentrations tend to be less effective because high BOD and COD levels inhibit the decomposition of organic matter due to limited oxygen. The decrease in organic C in the 40% leachate treatment (L2) is thought to be due to the priming effect, namely competition among microorganisms in decomposing fresh organic matter, which actually reduces the organic content of the soil (Triadiawarman, 2017).

The application of leachate had a significant effect on the CEC value of Latosol. Table 3 shows that the application of leachate starting from a concentration of 40% showed a significant difference compared to the treatment without leachate. However, the treatment with a leachate concentration of 20% did not differ significantly from the concentration of 40%. Leachate application at concentrations above 40% did not produce results that were significantly different from those at a concentration of 40%. Therefore, leachate application at a concentration of 20% is the optimal treatment because it produces results that are almost the same as those at higher concentrations in terms of soil CEC values. The increase in CEC value was in line with the increase in pH and soil organic matter, which provided negatively charged groups such as humic and fulvic acids to adsorb cations (Prakosa et al., 2020).The highest CEC value was obtained at a leaching concentration of 80% (27.20 me/100g), but its effectiveness was not much different from L1. High DHL levels due to dissolved ions in leachate (Na^{+}, Ca^{2+}, SO_4^{2-}) also contribute to variations in CEC values, but excess Na^{+} can actually reduce CEC by increasing clay dispersion (Yuliatun & Akbar, 2022).

Leachate treatment had no discernible impact in raising the Latosol overall nitrogen concentration. The outcomes of any leachate treatment were not appreciably different from the treatment without leachate (L0), and even tended to be lower. This may be due to the dominance of nitrogen in organic form that has not been fully decomposed, as well as the activity of microorganisms that affect the mineralization and nitrification processes (Saputra et al., 2018). Leachate contains elements needed by plants, such as organic nitrogen, ammonium nitrogen, and nitrate (Lesmana & Apriyani, 2019). The ability of soil to provide nitrogen is influenced by the amount of soil organic matter (Ramadhan et al., 2024).

The application of leachate did not have a significant effect on increasing P-Available in the soil, although there was a tendency for an increase at concentrations of 20–60% and a decrease at concentrations of 80% and 100%. The high P-Available is due to the influence of pH; at a pH between 5.5 and 6.5, P will be available in the form of $H_2PO_4^{-}$ (Tambun, 2024). The application of leachate as an organic material affects P availability directly through mineralization or indirectly by helping to release fixed P (Yuliawati, 2019). High organic C content affects the population of phosphate-solubilizing microorganisms, thereby increasing phosphate solubility and availability for plant uptake (Putriani et al., 2022). However, the decrease in available P at high leachate concentrations (L4 and L5) presumed to be due to organic acids from the decomposition of organic matter, which can inhibit P release by coating the clay surface (Ginting, 2024).

Leachate application had no discernible impact on increasing K-Available, although there was a tendency for an increase at concentrations of 20–60%. The increase in available-K is thought to be due to the K content in the leachate. The increase in K availability may be due to an increase in soil pH and CEC, which are directly proportional to nutrient availability in Latosol (Rahmawati, 2023). Meanwhile, the decrease in available potassium compared to the initial value before treatment may be due to acidic soil pH conditions, which promote potassium fixation and reduce its availability to plants (Gunawan et al., 2019).

C. The Effect of Leachate Application on Spinach Plant Growth

The effect of leachate application on spinach plant growth can be seen from the parameters of plant height, number of leaves, wet plant weight, and dry plant weight presented in Table 4.

Table 4. The Effect of Leachate Application on Spinach Plant Growth

Treatment	Height Plants (cm)	Number Leaves (pieces)	Wet Weight of Plants (gram)	Dry Weight of Plants (gram)
L0	23.50a	16.67a	24.50a	1.53a
L1	35.67b	34.33b	54.17b	4.93b
L2	32.00b	31.33b	52.67b	4.50b
L3	31.00b	30.33b	51.03b	4.43b
L4	30.67b	30.00b	46.07b	4.27b
L5	32.33b	31.67b	53.37b	4.87b
SD	2.58	2.27	4.30	0.36
SE	1.23	1.59	2.92	0.31
CV	8.51	7.81	9.26	8.92

Note: columns and rows of numbers followed by the same letter indicate no significant difference according to the DMRT 5% test

L0: 0% leachate concentration

L1: 20% leachate concentration

L2: 40% leachate concentration

L3: 60% leachate concentration

L4: 80% leachate concentration

L5: 100% leachate concentration

The height of spinach plants observed at maximum vegetative phase shows a significant effect of the leachate treatment. Based on Table 4, the application of leachate at a concentration of 20% (L1) resulted in better plant height compared to the treatment without leachate (L0) and the treatment with a higher concentration of leachate. Higher concentrations produced almost the same results and did not significantly affect spinach plant height. The increase in soil pH due to the addition of leachate also helped the availability of essential nutrients for the plants. The amount of fertilizer applied was in accordance with the pH of the water in the plant growth medium, so that the speed at which plants grow will increase (Karoba et al., 2015).

The application of 20% concentration leachate (L1) had a notable impact on the quantity of spinach leaves. Based on Table 4, the application of 20% concentration leachate showed a greater number of leaves and a significant difference compared to the treatment without leachate application (L0) and showed no significant difference with other higher concentrations. Indirectly, increased plant height has an effect on the increase in the number of leaves. The taller the plant, the greater the number of leaves, because the addition of nodes and the emergence of new shoots always produce new leaves (Siregar et al., 2015). Nutrients applied through fertilization are temporarily bound by the soil colloid surface so that they are not easily washed away by water (Sitohang & Utomo, 2018). Optimal pH causes the availability of nutrients that affect plant growth.

The application of 20% concentration leachate (L1) had a notable impact on the wet weight of spinach plants. At this concentration, there was a significant difference compared to the treatment without leachate. Based on Table 4, the application of 20% concentration leachate (L1) showed the highest wet weight and was essentially the same as the treatment with higher concentrations. This is because the height of the plant and the area or number of leaves affect the wet weight of the plant. The taller and larger or more extensive the number of leaves on a plant, the higher the wet weight of the plant (Prasetya et al., 2009).

The application of 20% concentration leachate (L1) had a notable impact on the dry weight of spinach plants. At this concentration, there was a significant difference compared to the treatment without leachate. Based on Table 4, the 20% concentration leachate treatment the highest dry weight compared to other treatments, which showed no significant difference. This was due to the growth and development of plant tissues, which increased the number and area of leaves, stems, and roots, thereby increasing the wet and dry weight of the plants (Anshar et al., 2015). Appropriate pH will affect plant weight if sufficient nutrients are available in the growing medium (Karoba et al., 2015).

CONCLUSION

The application of leachate from the Jetis final waste processing site in Purworejo Regency has a substantial impact on raising the pH, CEC Latosol, plant height, number of leaves, wet weight, and dry weight of spinach plants, according to the research that was done. However, it has no discernible impact on raising Latosol organic carbon, total nitrogen, available phosphorus, and available potassium of Latosol. The application of leachate with a concentration of 20% (L1) gives the best results in increasing plant height, number of leaves, wet weight, and dry weight of spinach plants. The leachate from the Jetis Final Waste Processing Site in Purworejo Regency is not yet effective for use as a fertilizer substitute, but it has potential as a soil conditioner. Although leachate has the potential to improve soil conditions, its application to food crops such as spinach is recommended to undergo comprehensive testing for heavy metal levels such as Pb, Cd, and Hg to ensure food safety aspects.

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