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DETERMINATION OF LEAD (Pb) CONTAMINATION IN LETTUCE (*Lactuca sativa* L.) FROM VARIOUS COLLECTION SOURCES IN BANDA ACEH, INDONESIA

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Abstract

Lettuce (*Lactuca sativa* L.) is widely consumed as a fresh vegetable; the safety of its contents needs attention, especially regarding contamination with the heavy metal lead (Pb). This research was carried out to analyze Pb levels in lettuce obtained from the supermarket, traditional market, and local garden in Banda Aceh City using the Atomic Absorption Spectrophotometry method (AAS) and to evaluate differences in Pb content based on the source of acquisition. The analytical method was validated through linearity, sensitivity, and precision. The Pb calibration curve shows a good linear relationship with a coefficient of determination (R^2) value of 0.9931. The limit of detection (LOD) and limit of quantification (LOQ) values were 0.162 mg/L and 0.492 mg/L, respectively. The precision test at low concentrations yielded a %RSD value of 4.91%, which met the method validation criteria. The results of the analysis showed that the Pb content in lettuce from the supermarket, traditional market, and local garden was 2.54 ± 0.12 mg/kg, 2.60 ± 0.07 mg/kg, and 2.38 ± 0.08 mg/kg, respectively, all of which exceeded the maximum Pb contamination limit according to BPOM (0.2 mg/kg). The one-way ANOVA test showed no statistically significant difference ($p > 0.05$) in Pb levels across the different sources.

Keywords: Food safety, Heavy metals, Lead (Pb), Lettuce (*Lactuca sativa* L.)

Abstrak

Selada (*Lactuca sativa* L.) merupakan sayuran yang sering dikonsumsi dalam kondisi segar sehingga keamanan kandungannya perlu mendapat perhatian, terutama terhadap cemaran logam berat timbal (Pb). Penelitian ini dilakukan untuk menganalisis kadar Pb pada selada yang diperoleh dari supermarket, pasar tradisional, dan kebun lokal di Kota Banda Aceh menggunakan metode Spektrofotometri Serapan Atom (AAS) serta mengevaluasi perbedaan kadar Pb berdasarkan sumber perolehan. Metode analisis divalidasi melalui pengujian linearitas, sensitivitas, dan presisi. Kurva kalibrasi Pb menunjukkan hubungan linier yang baik dengan nilai koefisien determinasi (R^2) sebesar 0,9931. Nilai batas deteksi (LOD) dan batas kuantifikasi (LOQ) masing-masing sebesar 0,162 mg/L dan 0,492 mg/L, sedangkan uji presisi pada konsentrasi rendah menghasilkan nilai %RSD sebesar 4,91% yang memenuhi kriteria validasi metode. Hasil analisis menunjukkan bahwa kadar Pb pada selada dari supermarket, pasar tradisional, dan kebun lokal berturut-turut sebesar 2,54 ± 0,12 mg/kg, 2,60 ± 0,07 mg/kg, dan 2,38 ± 0,08 mg/kg, yang seluruhnya melebihi batas maksimal cemaran Pb menurut BPOM (0,2 mg/kg). Uji one-way ANOVA menunjukkan tidak terdapat perbedaan yang signifikan secara statistik ($p > 0,05$) antara kadar Pb dari berbagai sumber perolehan.

Keywords: Keamanan pangan; Logam berat; Selada (*Lactuca sativa* L.); Timbal (Pb)

1. Introduction

Vegetables are a food commodity widely consumed by the public. Lettuce (*Lactuca sativa* L.) is a type of vegetable often consumed fresh or raw, such as in salads and raw vegetables (Oladimeji and Kumar, 2023). Therefore, ensuring the safety of lettuce consumption is crucial and should be monitored routinely to prevent potential health issues in the community.

Heavy metals are toxic contaminants. One of the heavy metals potentially found in lettuce is lead (Pb) (Meskelu *et al.*, 2024). Pb cannot be degraded naturally and thus accumulates from the soil, irrigation water, and is exposed to vehicle pollution during the distribution process. Ultimately, the lead will be consumed by humans along with the lettuce (Bouida *et al.*, 2022). Once Pb enters the biological system, it can cause damage to body functions, namely damage to the nervous system, digestive system, and even bone damage (Collin *et al.*, 2022). Therefore, monitoring Pb content in lettuce is indeed necessary.

Urban areas such as Banda Aceh have a greater potential to be impacted by Pb contamination in vegetables compared to regions farther from the city (Izquierdo-Díaz *et al.*, 2023). Based on the Regulation of the Indonesian Food and Drug Monitoring Authority (BPOM) number 9 of 2022, the maximum limit for Pb content in vegetable products is 0.2 mg/kg (Badan Pengawas Obat dan Makanan Republik Indonesia (BPOM), 2022). Several studies have reported that Pb content exceeds the maximum limit permitted by BPOM in vegetable products. A summary of Pb contamination levels reported in previous studies is presented in Table 1.

Table 1. Pb contamination levels reported in vegetables from several studies

Location	Vegetable	Pb Concentration (mg/kg)	Reference
Gorontalo City	Lettuce	2.2759	Merlin Darise et al., 2024
North Bekasi	Water spinach	81.983	Situmorang and Simatupang, 2021
Aceh Jaya	Cassava leaves	2.44	Kurniaty et al., 2020

In this study, lettuce consumed by the people of Banda Aceh city was obtained from various sources, such as a supermarket, a traditional market, and a local garden. These sources of supply vary, potentially affecting the Pb levels in lettuce. However, information on Pb levels in lettuce based on the source of supply is limited. Therefore, this research was conducted to evaluate the Pb levels in lettuce from various sources in Banda Aceh City using an Atomic Absorption Spectrophotometer (AAS) as a basis for monitoring the safety of lettuce consumption.

2. Methodology

2.1. Instruments and Materials

The instruments used in this study were an Atomic Absorption Spectroscopy (AAS) (Thermo Scientific iCE 3000), a BUCHI Mixer B-400, an analytical balance, and a microwave digestion system (Anton Paar Multiwave PRO).

The materials used in this study included lettuce from a supermarket, a traditional market, and a local garden originating from Banda Aceh City. The chemicals included concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCl), concentrated hydrogen peroxide (H_2O_2), and lead nitrate ($PbNO_3$), all of which were from Merck.

2.2. Measurement of the Standard Pb Solution

A standard stock solution of Pb 50 mg/L was prepared first by weighing 8 mg of $PbNO_3$ dissolved in 100 mL of distilled water. Preparation of a variation of standard solutions can be seen in Table 2. The absorbance of each standard Pb solution at the respective concentrations was measured using AAS, resulting in the absorbance data. The obtained data were used to generate a calibration curve illustrating the linear relationship between solution concentration and absorbance, which was subsequently used to determine the Pb content in the samples (Kurniaty *et al.*, 2020; Deti Ratih *et al.*, 2025; Putri and Daulae, 2025).

Table 2. Preparation of Standard Pb Solutions

No	Volume of 50 mg/L Pb Stock Solution (mL)	Final Volume (mL)	Concentration (mg/L)
1	0.1	50	0,10
2	0.5	50	0,50
3	1.0	50	1,00
4	1.5	50	1,50
5	2.0	50	2,00
6	2.5	50	2,50

2.3. Precision Test using AAS

This test was carried out using a standard Pb solution with a concentration of 0.1 mg/L, which was measured repeatedly five times under the same AAS conditions. The absorbance values from each repetition were then analyzed to assess the level of data uniformity.

2.4. Lettuce Sampling

Lettuce samples of 500 grams were taken randomly from each source of procurement in Banda Aceh, including a supermarket (Suzuya Mall; 5°32'15.8"N 95°18'24.5"E), a traditional market (Pasar Rukoh; 5°34'31.2"N 95°21'37.6"E), and a local garden (5°34'17.0"N 95°21'40.9"E). The sampling location are shown in Figure 1. Each sample is placed in a clean plastic bag and labeled according to the location of collection, then taken to the laboratory for preparation and analysis of Pb levels.

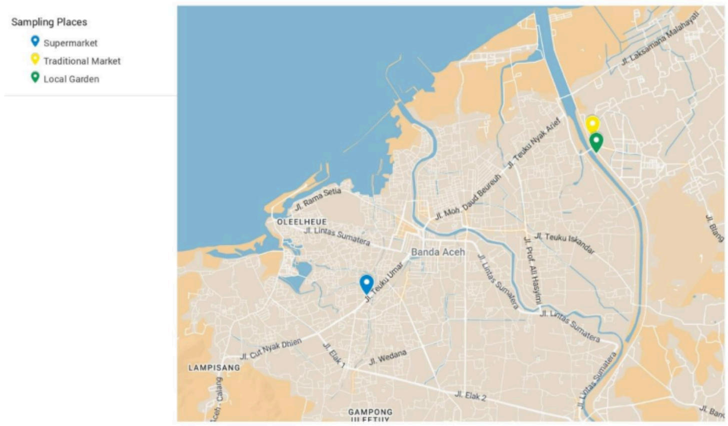

Figure 1. Locations of Lettuce Sampling from Various Sources

2.5. Lettuce Sample Preparation

The samples were cut into small pieces and placed into a grinding tube until filled solid, then homogenized using a BUCHI Mixer B-400. As much as 1 gram of each sample was added to the vessel tube, and 5 mL of HNO_3 (conc.), 1 mL of HCl (conc.), and 1 mL of H_2O_2 (conc.) were added. The sample was digested using microwave digestion for 1 hour. The digested sample was diluted to the volume limit of a 25 mL volumetric flask using distilled water (AOAC International, 2015). The Flowchart of sample preparation can be seen in Figure 2.

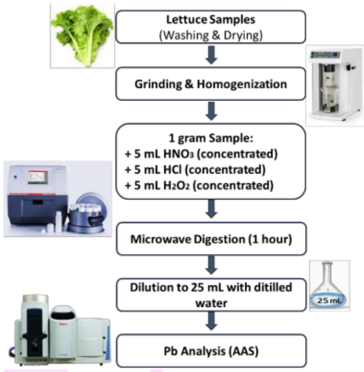

Figure 2. Flowchart of Lettuce Sample Preparation

2.6. Measurement of Pb content in samples

Analysis of prepared lettuce samples using AAS. Each sample was measured to obtain absorbance data. The absorbance data were applied to the linear regression equation of the standard curve to determine the Pb concentration in mg/L, which was then converted to mg/kg in the lettuce samples. Measurement of Pb content in each sample was carried out with three repetitions (Rizaldi *et al.*, 2025).

3. Results and Discussion

3.1. Validation of Pb Analysis Method Using AAS

A standard solution is a solution with a concentration that is known with certainty and functions as a reference in chemical analysis and laboratory tests to determine the concentration of another substance (Trier *et al.*, 2025). In this study, a series of standard solutions with concentration variations of 0.1, 0.5, 1.0, 1.5, 2.0, and 2.5 mg/L was used. The results of the Pb standard series measurements can be seen in Table 3, which shows a clear relationship between concentration and absorbance value. As the concentration of the standard solution series increases, the absorbance value also increases.

Table 3. Results of Pb Standard Measurements using AAS

No	Concentration (mg/L)	Absorbance (A)
1	0,10	0,0028
2	0,50	0,0198
3	1,00	0,0364
4	1,50	0,0516
5	2,00	0,0680
6	2,50	0,0790

The measurement results in Table 3, a calibration curve was created for the Pb metal standard series, which is shown in Figure 3. The linear regression obtained from the Pb standard curve is $y = 0.0317x + 0.0027$ and has a coefficient of determination (R2) of 0.9931, which indicates a nearly perfect correlation level because it is close to a value of 1. The R2 value is ≥ 0.99. A high correlation level indicates good linearity and is worth continuing for sample measurement (Hossain *et al.*, 2022).

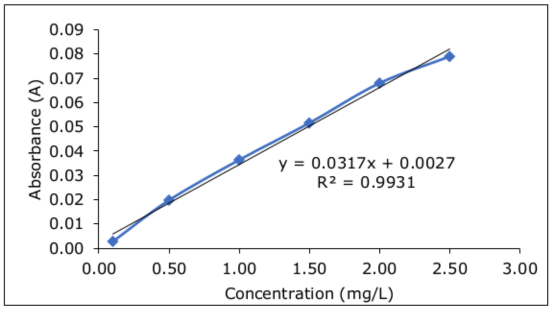

Figure 3. Graph of the standard series of Pb solutions.

The sensitivity of the Pb analysis method using AAS can be shown in the limit of detection (LOD) and limit of quantification (LOQ) values. The LOD and LOQ values can be calculated using the following formula (Habibi, Sulistya and Erikawati, 2024):

$$LOD = \frac{3 \times S_{y/x}}{Slope} \quad (1)$$

$$LOQ = \frac{10 \times S_{y/x}}{Slope} \quad (2)$$

Sy/x : Standard error of regression
Slope : Slope of the calibration curve

Based on the LOD and LOQ calculations, the values obtained were 0.162 mg/L and 0.492 mg/L, respectively, as shown in Table 4. The LOD and LOQ values indicate that the method has good sensitivity because it produces relatively small values and is still within the calibration curve series.

Table 4. Analytical Parameters for Pb Measurement

Analytical Parameter	Result
Standard concentration range (mg/L)	0,10 – 2,50
Regression equation	y = 0,0317x + 0,0027
The R^2 value	0,9931
Regression standard error (Sy/x)	0,002
Limit of detection (LOD, mg/L)	0,162
Limit of quantification (LOQ, mg/L)	0,492
Precision test (%RSD)	4,9102

Precision test is one of the parameters in method validation, which is used to measure the level of uniformity of analysis results when measurements are carried out repeatedly under the same conditions. This test was carried out to assess the consistency of the method and precise data when the procedure is repeated multiple times (Sunartaty and Meutia, 2023). The results of precision testing of heavy metal lead (Pb) at a concentration of 0.1 mg/L can be seen in Table 2. Based on the results of determining the coefficient of variation obtained from a Pb concentration of 0.1 mg/L, the calculation results showed a Relative Standard Deviation (%RSD) of 4.91%. The %RSD value ≤ 5% for analytes at low concentrations indicates that the results of this precision test indicate that the analytical method used has acceptable precision and meets the precision criteria for determining Pb (Zhang *et al.*, 2025). This consistency is a crucial aspect in heavy metal analysis, considering that the accuracy and precision of the measurements directly influence the validity of the results, especially in determining Pb contamination in food samples (Septiani Pratama *et al.*, 2016).

3.2. Determination of Pb Content in Lettuce Samples

Lettuce samples were taken from 3 different places, namely the supermarket, traditional market, and local garden in Banda Aceh City. Figure 4 shows the results of Pb content in lettuce from each source. The Pb content in lettuce from the traditional market was the highest, with an average concentration of 2.60 ± 0.07 mg/kg, and lettuce samples from the supermarket had Pb content with an average of 2.54 ± 0.12 mg/kg. Meanwhile, lettuce obtained from a local garden showed the lowest Pb levels with an average of 2.38 ± 0.08 mg/kg. The results of Pb content in lettuce from the three locations showed that Pb levels were still high, because the maximum limit for Pb contamination in vegetables is 0.2 mg/kg. The high content of Pb in lettuce originating from a local garden may have accumulated from the planting stage, including soil, irrigation water, or environmental exposure (Ikkonen and Kaznina, 2022). Meanwhile, high Pb content in lettuce from a supermarket and a traditional market can be influenced from the initial planting to the distribution process, such as being exposed to air pollution from vehicles (Lange *et al.*, 2024).

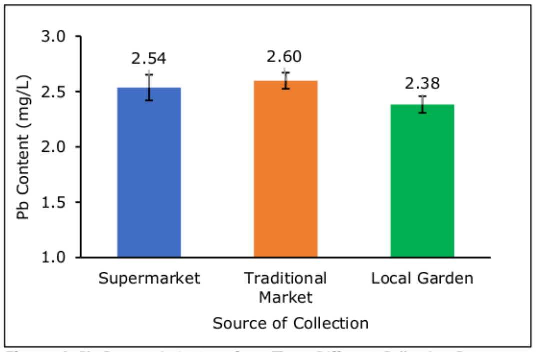

Figure 4. Pb Content in Lettuce from Three Different Collection Sources

The Pb concentration measurements from the three sample sources were further analyzed using one-way ANOVA to determine whether there were statistically significant differences in Pb content among the collection sources, including the supermarket, traditional market, and local garden. The results indicated that there were no significant differences ($p > 0.05$) in Pb levels among the three collection sources. This insignificant difference in Pb levels indicates that Pb contamination is relatively widespread in lettuce. This could be due to similar environmental factors such as air quality, soil conditions, and irrigation water in Banda Aceh City. As a result, even though it comes from three different places, the risk of Pb contamination is still high, and more attention is needed regarding food safety, especially vegetables. To ensure vegetables are not exposed to lead (Pb), cultivation sites should be selected away from pollution sources such as highways and industrial areas. From harvest to distribution, vegetables should be packaged securely to minimize environmental contamination, especially in areas with high traffic activity. Furthermore, vegetables should be washed with running water before consumption to help reduce any Pb residue on their surfaces (Rahardjo and Bella, 2023).

Table 5. One-way ANOVA test of Pb levels in lettuce based on three sources

Parameter	Value
F_{hitung}	2,31
p-*value*	0,17
Result	Not significantly different ($p > 0.05$)

4. Conclusion

In this study, the determination of lead (Pb) content in lettuce obtained from a supermarket, a traditional market, and a local garden in Banda Aceh was successfully carried out using AAS. The analytical method demonstrated good performance, as indicated by high linearity ($R^2 = 0.9931$), good sensitivity with LOD and LOQ values of 0.162 mg/L and 0.492 mg/L, respectively, and acceptable precision (RSD 4.91%). The Pb content in the three lettuce sample acquisition locations ranged from 2.38 to 2.60 mg/kg, all of which exceeded the maximum limit permitted by BPOM (0.2 mg/kg). Statistical analysis using one-way ANOVA test showed no significant difference ($p > 0.05$) in Pb levels in lettuce originating from the three sources.

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