



Mineral Content, Vitamin Profile, and Dietary Fiber Fractions of Aqueous Leaf Extracts from Four Sundanese Traditional Vegetables in Indonesia

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Abstract

Lalapan, the traditional Sundanese raw vegetable salad of Indonesia, is a significant component of the daily diet for millions of Indonesians; however, the nutritional composition, particularly the mineral, vitamin, and dietary fiber fractions of its constituent leafy vegetables, remains insufficiently characterized in the scientific literature. Objective This study aimed to determine the mineral content (calcium, potassium, iron, and magnesium), β -carotene, vitamin C, and dietary fiber fractions (soluble, insoluble, and total) in aqueous leaf extracts of four lalapan vegetables: gandaria (*Bouea macrophylla*), kemangi (*Ocimum americanum*), pohpohan (*Pilea melastomoides*), and selada (*Lactuca sativa*). Methods: Fresh leaves were subjected to aqueous maceration extraction as described. Mineral analysis was performed by atomic absorption spectrophotometry (AOAC 975.03), β -carotene by HPLC (AOAC 45.1.34), vitamin C by titration (AOAC 967.21), and dietary fiber by the enzymatic-gravimetric method. Data are presented as mean $\pm$ SD from triplicate analyses. Results: Pohpohan exhibited the highest calcium (1697.05 ± 11.70 mg/100 g) and magnesium (1990.11 ± 6.01 mg/100 g) content, while selada contained the highest potassium (8709.03 ± 34.36 mg/100 g). Kemangi demonstrated the greatest β -carotene concentration (7.69 ± 0.13 mg/100 g), and Gandaria the highest vitamin C (59.66 ± 3.53 mg/100 g). Pohpohan also recorded the highest total dietary fiber ($22.11 \pm 1.40\%$) with a predominance of soluble fiber (12.24%). Conclusion: All four lalapan species are nutritionally valuable, with pohpohan and kemangi demonstrating exceptional mineral and vitamin profiles. These findings support promoting lalapan as a functional food component in Indonesian dietary guidelines.

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Introduction

Dietary diversification through the regular consumption of leafy vegetables is a globally recognized strategy for addressing micronutrient deficiencies and diet-related chronic diseases (WHO, 2020). In Indonesia, traditional raw vegetable practices collectively known as lalapan represent an ancestral dietary habit rooted in Sundanese culture (West Java) that has persisted across generations and spread throughout the Indonesian archipelago. Lalapan typically consists of fresh or lightly blanched leaves consumed alongside rice and protein-rich dishes, serving as an inexpensive, accessible source of micronutrients for the Indonesian population (Hakim et al., 2021). Despite its widespread consumption, the scientific characterization of lalapan vegetables remains fragmentary. Existing nutritional databases and published studies have tended to focus on more commercially prominent leafy vegetables such as spinach (*Spinacia oleracea*), kale (*Brassica oleracea*), and kangkung (*Ipomoea aquatica*), while species endemic to or preferentially consumed within Indonesian traditional food systems, particularly pohpohan (*Pilea melastomoides*) and gandaria leaves (*Bouea macrophylla*) are substantially understudied (Mahmud et al., 2018; Ruel et al., 2021). This constitutes a critical research gap, as the absence of validated nutritional data hinders the integration of these vegetables into evidence-based national dietary recommendations and food composition databases.

Furthermore, prior studies on lalapan and related Indonesian traditional vegetables have rarely analyzed the full spectrum of nutritionally relevant parameters in a single investigation, particularly the fractionation of dietary fiber into its soluble (SDF) and insoluble (IDF) components. This distinction is nutritionally critical: SDF is associated with glycemic modulation, cholesterol reduction, and prebiotic effects, while IDF promotes intestinal transit and fecal bulk formation (Dahl et al., 2020; Makki et al., 2022). The simultaneous characterization of minerals, liposoluble vitamins (β -carotene), water-soluble vitamins (vitamin C), and both fiber fractions in a single comparative study of lalapan vegetables is novel. It has not been reported in the peer-reviewed literature. Research Gap: Previous studies have examined individual components (e.g., antioxidant activity or total phenolics) of some lalapan species in isolation, but no peer-reviewed publication has simultaneously characterized the mineral profile (Ca, K, Fe, Mg), β -carotene, vitamin C, and fractionated dietary fiber of gandaria, kemangi, pohpohan, and selada leaves in aqueous extracts reflecting realistic household preparation methods.

Novelty: This study introduces a comparative multi-nutrient analysis of four lalapan leaf species using aqueous maceration, the predominant preparation mode practiced by Indonesian households, thereby generating nutritional data that is ecologically valid and directly applicable to public health nutrition recommendations in Indonesia. The dietary fiber fractionation data for *Pilea melastomoides* (pohpohan) are, to the authors' knowledge, the first to be reported in the peer-reviewed literature. Therefore, this study aimed to determine and compare the mineral content (Ca, K, Fe, Mg), β -carotene, vitamin C, and dietary fiber fractions (soluble, insoluble, and total) in aqueous leaf extracts of four lalapan vegetables: gandaria (*Bouea macrophylla*), kemangi (*Ocimum americanum*), pohpohan (*Pilea melastomoides*), and selada (*Lactuca sativa*), and to discuss their implications for Indonesian public health nutrition.

Materials and Methods

Study Design and Sampling

This study employed a descriptive-laboratory design, with triplicate analyses of each parameter for each vegetable species. Fresh leaf samples of gandaria (*Bouea macrophylla* Griffith), kemangi (*Ocimum americanum* L.), pohpohan (*Pilea melastomoides* [Poir.] Wedd.), and selada (*Lactuca sativa* L.) were procured from local traditional markets in Samarinda, East Kalimantan, Indonesia. Leaves

were selected based on freshness criteria: uniform color, absence of visible disease symptoms or mechanical damage, and structural integrity. All four species are routinely consumed as lalapan in Indonesian households.

Sample Preparation and Aqueous Extraction

Prior to extraction, leaves were sorted (sortasi), washed under running water, drained, and chopped to reduce particle size and increase surface area, facilitating compound extraction. Aqueous maceration was performed according to the method of Verawati et al. (2016), with modifications. Water was selected as the extraction solvent to simulate typical household preparation practices, given its universal availability, low cost, and food-grade suitability. Fresh samples were macerated in distilled water at room temperature for a standardized duration, filtered, and used for subsequent analyses.

Mineral Analysis

Mineral content (calcium/Ca, potassium/K, iron/Fe, and magnesium/Mg) was determined following AOAC Official Method 975.03 (AOAC International, 2012). Samples (1 g) were subjected to wet ashing using HNO_3 and H_2SO_4 (98%), and the digest was analyzed by Atomic Absorption Spectrophotometry (AAS). Standard curves for each mineral were prepared using certified reference standards dissolved in HNO_3 (3 N) and diluted with deionized water to 500 mL. Absorbance readings were converted to mineral concentrations using regression equations derived from the standard curves. Results are expressed as mg per 100 g of fresh weight extract.

β -Carotene Determination

β -Carotene was quantified using High-Performance Liquid Chromatography (HPLC) following AOAC Method 45.1.34. Samples (1.25 g) were extracted with ethanol and saponified with KOH (50%) by reflux at 80°C for 2 hours. After acidification with glacial acetic acid, the extract was made up to 25 mL with ethanol:THF (1:1) and allowed to stand for 12 hours before filtration. Chromatographic separation was performed on a C18 column with a mobile phase of methanol:ethyl acetate:acetonitrile (23:9:68 v/v/v) at a detection wavelength of 450 nm, injection volume of 1 mL, and flow rate of 0.1 mL/min. Results are expressed as mg/100 g of fresh weight.

Vitamin C Determination

Vitamin C was determined by the titrimetric method using 2,6-dichlorophenolindophenol (DCPIP) as the indicator following AOAC Method 967.21. A standard curve was established using ascorbic acid solutions at concentrations of 0, 2, 4, 8, and 10 mg/mL. Samples (1 mg) were dissolved in 0.5 mg oxalic acid in aqueous solution (1 mg/mL) and titrated against DCPIP until a persistent pink color was observed for 15 seconds. Vitamin C content was calculated from the standard curve and expressed as mg/100 g of fresh weight.

Dietary Fiber Analysis

Total, soluble (SDF), and insoluble (IDF) dietary fiber were determined by the enzymatic-gravimetric method of Asp et al. (1983), which remains an established reference for food fiber fractionation. Samples (10 g) were suspended in sodium phosphate buffer (pH 6.0) with termamyl (100 μL) and incubated at 100°C for 15 minutes to gelatinize starch. pH was adjusted to 1.5 with 0.1 N HCl, and pepsin (100 mg) was added, followed by incubation at 40°C for 60 minutes with agitation. After adjustment to pH 6.8 with 0.1 N NaOH, pancreatin (100 mg) was added and incubated under the same conditions. The digest was filtered; the residue (IDF) was washed with 95% ethanol and acetone, then dried and ashed. The filtrate was precipitated with 95% ethanol, filtered, and dried for SDF determination. Total dietary fiber was calculated as the sum of SDF and IDF. Results are expressed as percentages of fresh weight.

Statistical Analysis

All analyses were performed in triplicate ($n = 3$). Results are expressed as mean $\pm$ standard deviation (SD). Descriptive statistics were used to compare nutritional parameters across the four vegetable species. Data were compiled and processed using Microsoft Excel 2019.

Results and Discussions

Mineral Content of Lalapan Leaf Extracts

The mineral contents (Ca, K, Fe, and Mg) of the four lalapan leaf extracts are presented in Table 1. Marked interspecies variation was observed across all minerals analyzed.

Table 1. Mineral content (mg/100 g fresh weight) of aqueous extracts of four lalapan leaf species (mean $\pm$ SD, $n = 3$)

Mineral	Gandaria (<i>Bouea macrophylla</i>)	Kemangi (<i>Ocimum americanum</i>)	Pohpohan (<i>Pilea melastomoides</i>)	Selada (<i>Lactuca sativa</i>)
Calcium (Ca)	27.80 $\pm$ 0.36	495.60 $\pm$ 0.44	1697.05 $\pm$ 11.70	917.09 $\pm$ 5.10
Potassium (K)	1779.87 $\pm$ 27.23	4595.80 $\pm$ 89.68	3034.41 $\pm$ 31.06	8709.03 $\pm$ 34.36
Iron (Fe)	20.28 $\pm$ 0.17	29.95 $\pm$ 0.04	20.69 $\pm$ 0.08	23.34 $\pm$ 0.22
Magnesium (Mg)	449.95 $\pm$ 1.91	1568.40 $\pm$ 4.49	1990.11 $\pm$ 6.01	797.54 $\pm$ 0.47

Note: Values represent mean $\pm$ standard deviation of triplicate analyses. AAS = Atomic Absorption Spectrophotometry; AOAC 975.03.

Pohpohan (*Pilea melastomoides*) exhibited the highest calcium content (1697.05 $\pm$ 11.70 mg/100 g), followed by selada (917.09 $\pm$ 5.10 mg/100 g) and kemangi (495.60 $\pm$ 0.44 mg/100 g), while gandaria demonstrated markedly lower calcium (27.80 $\pm$ 0.36 mg/100 g). Potassium was highest in selada (8709.03 $\pm$ 34.36 mg/100 g) and lowest in gandaria (1779.87 $\pm$ 27.23 mg/100 g). For iron, kemangi exhibited the greatest concentration (29.95 $\pm$ 0.04 mg/100 g), with relatively narrow variation among the four species (range: 20.28–29.95 mg/100 g). Magnesium followed a pattern similar to calcium, with pohpohan and kemangi recording the highest values (1990.11 $\pm$ 6.01 and 1568.40 $\pm$ 4.49 mg/100 g, respectively).

β -Carotene and Vitamin C Content

The β -carotene and vitamin C concentrations are shown in Table 2. Kemangi demonstrated the highest β -carotene content (7.69 $\pm$ 0.13 mg/100 g), markedly exceeding selada (3.15 $\pm$ 0.01 mg/100 g) and pohpohan (1.06 $\pm$ 0.04 mg/100 g). Gandaria leaves yielded no detectable β -carotene under the analytical conditions applied (<0.02 mg/100 g). In contrast, gandaria exhibited the highest vitamin C content (59.66 $\pm$ 3.53 mg/100 g), followed by kemangi (44.41 $\pm$ 3.90 mg/100 g), with pohpohan and selada recording substantially lower values (5.12 $\pm$ 0.25 and 7.20 $\pm$ 0.82 mg/100 g, respectively).

Table 2. β -Carotene and vitamin C content (mg/100 g fresh weight) of aqueous extracts of four lalapan leaf species (mean $\pm$ SD, n = 3)

Leaf Species	Scientific Name	β -Carotene Content (mg/100 g)	Vitamin C Content (mg/100 g)
Gandaria	Bouea macrophylla	<0.02 (nd)	59.66 $\pm$ 3.53
Kemangi	Ocimum americanum	7.69 $\pm$ 0.13	44.41 $\pm$ 3.90
Pohpohan	Pilea melastomoides	1.06 $\pm$ 0.04	5.12 $\pm$ 0.25
Selada	Lactuca sativa	3.15 $\pm$ 0.01	7.20 $\pm$ 0.82

Note: nd = not detected (<0.02 mg/100 g). β -Carotene determined by HPLC (AOAC 45.1.34); Vitamin C by DCPIP titration (AOAC 967.21).

Dietary Fiber Fractions

Dietary fiber fractionation results are presented in Table 3. Pohpohan exhibited the highest total dietary fiber (22.11 $\pm$ 1.40%), with a notable predominance of soluble dietary fiber (SDF: 12.24 $\pm$ 0.90%) over insoluble dietary fiber (IDF: 9.88 $\pm$ 0.50%), yielding an SDF:IDF ratio of approximately 1:0.8. Gandaria demonstrated the highest IDF (15.95 $\pm$ 1.10%) with comparatively low SDF (3.11 $\pm$ 1.40%), resulting in a ratio of 1:5.1—the highest IDF predominance among all species. Selada recorded the lowest total dietary fiber (12.41 $\pm$ 1.80%).

Table 3. Dietary fiber fractions (% fresh weight) of aqueous extracts of four lalapan leaf species (mean $\pm$ SD, n = 3)

Leaf Species	Soluble Dietary Fiber (%)	Insoluble Dietary Fiber (%)	Total Dietary Fiber (%)	SDF:IDF Ratio
Gandaria (B. macrophylla)	3.11 $\pm$ 1.40	15.95 $\pm$ 1.10	19.06 $\pm$ 0.30	1:5.1
Kemangi (O. americanum)	7.48 $\pm$ 2.30	8.91 $\pm$ 0.80	16.39 $\pm$ 1.50	1:1.2
Pohpohan (P. melastomoides)	12.24 $\pm$ 0.90	9.88 $\pm$ 0.50	22.11 $\pm$ 1.40	1:0.8
Selada (L. sativa)	5.97 $\pm$ 1.20	6.44 $\pm$ 0.70	12.41 $\pm$ 1.80	1:1.1

Note: SDF = soluble dietary fiber; IDF = insoluble dietary fiber; TDF = total dietary fiber; SDF:IDF = ratio of soluble to insoluble fiber. Analyzed by the enzymatic-gravimetric method (Asp et al., 1983).

Discussion

Mineral Profile: Interspecies Variation and Nutritional Significance

The mineral data presented in this study reveal substantial interspecies variation among lalapan vegetables, with implications for their relative contributions to Indonesian dietary mineral intakes. Pohpohan's exceptionally high calcium content (1697.05 mg/100 g extract) is noteworthy in a national context where dairy consumption remains low, and calcium deficiency is prevalent among Indonesian women of reproductive age (Sekiyama et al., 2021). Although calcium bioavailability from plant sources is modulated by oxalate and phytate content, anti-nutritional factors not measured in

the present study, the sheer magnitude of Pohpohan's calcium concentration suggests significant nutritional relevance even after accounting for reduced absorption efficiency (Guéguen & Pointillart, 2020). Comparative data from Petropoulos et al. (2021) on *Lactuca sativa* cultivars reported calcium values of 25–67 mg/100 g fresh weight in whole leaves, substantially lower than the selada extract values in the present study (917.09 mg/100 g), a discrepancy attributable to the concentration effect of aqueous maceration extraction, which increases nutrient density per unit weight relative to whole-leaf fresh weight analysis.

The high potassium concentration in selada (8709.03 mg/100 g) warrants attention in the context of hypertension management. Dietary potassium is inversely associated with blood pressure through renal natriuresis and vasodilation mechanisms, and WHO (2020) recommends increasing potassium intake as a primary dietary intervention for hypertension prevention. Gonçalves et al. (2021) reported that leafy vegetables are among the most potassium-dense food groups globally, and the present data indicate that selada-type lalapan may deliver disproportionately high potassium relative to its caloric contribution. Iron content was relatively uniform across species (20.28–29.95 mg/100 g), with kemangi recording the highest value. Rahman et al. (2023) demonstrated that *Ocimum* species have iron concentrations ranging from 15.4 to 31.2 mg/100 g in dried extracts, consistent with our findings after accounting for moisture differences. Magnesium concentrations in pohpohan (1990.11 mg/100 g) and kemangi (1568.40 mg/100 g) substantially exceed values reported for conventional leafy vegetables in global food composition databases, underscoring the potential of underutilized indigenous Indonesian species as dietary magnesium sources, a mineral critical for over 300 enzymatic reactions and increasingly recognized for its role in insulin sensitivity and glycemic regulation (Veronese et al., 2021).

Provitamin A and Vitamin C: Functional Significance and Comparative Analysis

Kemangi's β -carotene concentration (7.69 ± 0.13 mg/100 g) positions it among the most provitamin A-rich lalapan vegetables and compares favorably with published data on culinary basil species. Marrelli et al. (2021) reported β -carotene contents of 3.5–8.2 mg/100 g in *Ocimum basilicum* cultivars, aligning closely with the present findings for *O. americanum*. The WHO (2022) has identified vitamin A deficiency as a persistent public health concern in Indonesia, particularly among children under five years of age, and has promoted kemangi as a locally available, low-cost provitamin A source, making it a highly actionable dietary recommendation. The near-total absence of β -carotene in gandaria leaves (<0.02 mg/100 g) is consistent with the pale green-yellow leaf morphology of *Bouea macrophylla* and likely reflects minimal chloroplast-associated carotenoid biosynthesis in this species, as carotenoid concentration is strongly correlated with chlorophyll content and photosynthetic tissue density (Saini et al., 2020). This finding also highlights species-specific variation within lalapan, precluding nutritional generalization across the category.

Gandaria's high vitamin C content (59.66 ± 3.53 mg/100 g) is particularly valuable given its dual role as an antioxidant and an iron absorption enhancer. Ascorbic acid converts dietary non-heme iron (Fe^{3+}) to the more bioavailable ferrous form (Fe^{2+}) in the intestinal lumen, and the simultaneous presence of iron (20.28 mg/100 g) and vitamin C in gandaria extract suggests a synergistic nutritional effect when consumed together (Abbaspour et al., 2020). Kemangi, which had the highest iron concentration among the four species, also provided substantial vitamin C (44.41 mg/100 g), further supporting its iron bioavailability. In contrast, pohpohan's low vitamin C (5.12 mg/100 g) despite high mineral content suggests that its iron may be less bioavailable in the absence of ascorbic acid. This finding has practical dietary implications: lalapan combinations that pair pohpohan with vitamin C-rich plants (e.g., gandaria or fresh citrus) could optimize iron absorption, aligning with food synergy principles articulated by Jacobs & Tapsell (2021).

Dietary Fiber Fractions: Mechanisms and Public Health Implications

The dietary fiber data reveal distinctly different SDF:IDF profiles across the four lalapan species, each with unique functional implications. Pohpohan's high SDF (12.24%) and relatively balanced SDF:IDF ratio (1:0.8) suggest substantial prebiotic potential. Soluble fibers, including pectins and beta-glucans, are fermented by colonic microbiota to produce short-chain fatty acids (SCFAs) such as butyrate, propionate, and acetate, which exert anti-inflammatory effects on intestinal epithelial cells, modulate immune function, and contribute to satiety signaling via free fatty acid receptor activation (Makki et al., 2022; Zhao et al., 2021). A high SDF content also reduces postprandial blood glucose excursions by viscosity-dependent inhibition of gastric emptying and intestinal glucose absorption, a mechanism particularly relevant in Indonesia, where the prevalence of type 2 diabetes mellitus has reached epidemic proportions, affecting approximately 19.5 million adults in 2021 (IDF, 2021). Dahl et al. (2020) demonstrated in a systematic review that SDF intakes of 5–10 g/day are associated with significant reductions in fasting blood glucose and HbA1c, underscoring the clinical relevance of Pohpohan's SDF content.

Gandaria's predominantly IDF profile (IDF: 15.95%, SDF:IDF = 1:5.1) complements the SDF-dominant pohpohan. Insoluble fiber accelerates intestinal transit time, increases fecal bulk, and reduces colonic intraluminal pressure, thereby contributing to colorectal cancer prevention and the management of constipation (Gul et al., 2022). The WHO recommends a total dietary fiber intake of at least 25 g/day for adults, a threshold rarely achieved in Indonesian populations whose diets are characterized by high refined carbohydrate consumption and low vegetable intake (Fahmida et al., 2020). The total dietary fiber content of all four lalapan species (12.41–22.11%) is nutritionally significant, particularly when expressed on a dry-weight basis or in the context of regular daily consumption. Nirmala et al. (2022) reported total dietary fiber values of 8.3–18.7% across a range of Southeast Asian traditional leafy vegetables, values consistent with the lower end of our findings for selada and the upper end for pohpohan, respectively. The notably high total fiber in pohpohan compared to selada (22.11 vs. 12.41%) may reflect the higher cellulose and pectin content characteristic of the Urticaceae family (to which *Pilea* belongs) relative to Asteraceae species (*Lactuca*), as cell wall composition diverges markedly between plant families and correlates with fiber fraction distribution (Condezo-Hoyos et al., 2021). Collectively, these findings reinforce the nutritional value of lalapan as a multi-functional dietary component that simultaneously provides minerals, antioxidant vitamins, and fiber types with complementary physiological effects—a profile highly relevant to the prevention of the double burden of malnutrition (micronutrient deficiency combined with diet-related chronic disease) that characterizes the current Indonesian nutrition transition (Ruel et al. 2021; Fahmida et al. 2020).

Conclusion

This study provides the first simultaneous comparative characterization of mineral content (Ca, K, Fe, Mg), β -carotene, vitamin C, and fractionated dietary fiber (soluble, insoluble, total) in aqueous leaf extracts of four Sundanese lalapan vegetables—gandaria (*Bouea macrophylla*), kemangi (*Ocimum americanum*), pohpohan (*Pilea melastomoides*), and selada (*Lactuca sativa*). Pohpohan demonstrated superior calcium, magnesium, total dietary fiber, and soluble fiber content, while selada exhibited the highest potassium, and kemangi the highest β -carotene concentration. Gandaria contributed the highest vitamin C. These species-specific nutritional profiles indicate that lalapan diversity, rather than reliance on a single species, is essential for maximizing its public health nutritional impact. The findings support the scientific validation and promotion of lalapan as a culturally embedded functional food within Indonesian dietary guidelines, with specific relevance to addressing micronutrient deficiencies, improving glycemic health, and supporting gastrointestinal

well-being. Future studies should investigate anti-nutritional factors, mineral bioavailability, and the effects of culinary preparation methods on the nutritional integrity of lalapan vegetables.

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