BIOLOGY, MEDICINE, & NATURAL PRODUCT CHEMISTRY ISSN 2089-6514 (paper)
Volume 15, Number 1, April 2026 | Pages: 1337-1344 | DOI: 10.14421/biomedich.2026.151.1337-1344 ISSN 2540-9328 (online)

Effect of *Moringa oleifera* Leaf Flour Supplementation on Magnesium (Mg) and Potassium (K) Contents of Crackers as a Nutritious Snack

Desi, Abd. Hakim Laenggeng*, Masrianih, Musdalifah Nurdin, Raya Agni, I Nengah Kundera
Departemen of Biology Education, Faculty of Teacher Training and Education, Tadulako University.
Jl. Soekarno Hatta KM 9, 94148. Central Sulawesi, Tel./Fax. (0451) 422611, Indonesia.

Corresponding author*
ah.laenggeng@untad.ac.id

Manuscript received: 27 May 2026. Revision accepted: 23 June 2026, Published: 10 July 2026.

Abstract

Moringa oleifera leaf flour is recognized as a local food ingredient rich in essential minerals, particularly magnesium (Mg) and potassium (K), which play important roles in various physiological functions of the human body. This study was conducted to evaluate the effect of *Moringa oleifera* leaf flour supplementation on the magnesium and potassium contents of crackers. The research employed an experimental approach using a Completely Randomized Design (CRD) consisting of four treatments: 0%, 5%, 10%, and 15% *Moringa oleifera* leaf flour supplementation, with two replications for each treatment. Magnesium and potassium contents were quantitatively determined using the Atomic Absorption Spectrophotometry (AAS) method. The data were analyzed using One-Way Analysis of Variance (ANOVA) at a significance level of 0.05. The results showed that increasing concentrations of *Moringa oleifera* leaf flour tended to increase the magnesium and potassium contents of the crackers, with magnesium levels ranging from 0.06 to 0.09 mg/g and potassium levels ranging from 0.79 to 1.93 mg/g. However, statistical analysis revealed that the addition of *Moringa oleifera* leaf flour did not significantly affect magnesium content ($p = 0.377$), whereas it had a significant effect on potassium content ($p = 0.001$). These findings indicate that magnesium and potassium responded differently to the fortification process. Therefore, *Moringa oleifera* leaf flour demonstrates considerable potential as a fortification ingredient, particularly for enhancing potassium content in crackers as a nutritious snack alternative.

Keywords: *Moringa oleifera*; Potassium; Crackers; Magnesium; Atomic Absorption Spectrophotometry.

INTRODUCTION

Balanced nutrition plays a crucial role in providing the energy, structural nutrients, and regulatory substances required for the body to perform physiological functions optimally. However, changes in dietary habits and modern lifestyles, which increasingly favor convenience and practicality, have led to higher consumption of processed and ready-to-eat foods that are generally low in nutritional value. This trend has the potential to contribute to various health problems, including obesity and chronic diseases (Wahdah et al., 2022; Rizqiya et al., 2023). Crackers are among the most popular snack foods consumed by Indonesian people, both as a standalone snack and as an accompaniment to meals. Generally, crackers are produced from carbohydrate-rich ingredients such as wheat flour and tapioca flour (Husain et al., 2025). Various processing modifications and ingredient additions can be applied during cracker production to improve their nutritional quality. Despite their popularity and appealing taste, crackers typically contain relatively low levels of essential nutrients (Febrianty et al., 2023).

Moringa oleifera leaves represent a local food resource with considerable potential as a source of essential micronutrients. This plant is known to contain various important minerals, including iron (Fe), calcium (Ca), magnesium (Mg), potassium (K), and zinc (Zn), as well as vitamins, particularly vitamin C, which plays a role in supporting immune function and providing antioxidant protection (Sultana, 2020). In addition, moringa leaves are rich in bioactive compounds such as flavonoids and phenolic substances that contribute to antioxidant activity and may help prevent chronic diseases. Due to its exceptional nutritional profile, *Moringa oleifera* is widely referred to as the “miracle tree” because of its extensive nutritional and health benefits (Meireles et al., 2020). The high concentrations of minerals, particularly magnesium and potassium, make moringa leaves a promising fortification ingredient for improving the nutritional quality of food products and supporting the development of functional foods (Saini et al., 2016).

Magnesium (Mg) and potassium (K) are essential minerals that play important roles in muscle and nerve function, maintenance of electrolyte balance, regulation of blood pressure, and cellular metabolic processes. Magnesium is an essential mineral involved in numerous enzymatic reactions within the body. It contributes significantly to vascular homeostasis, metabolic regulation, and electrical activity, making it closely associated with cardiovascular health. Magnesium deficiency has been linked to an increased risk of cardiovascular disorders, including arrhythmias, stroke, hypertension, and heart disease (Siddiqui et al., 2024). Potassium (K^+) is the most abundant intracellular cation in the human body. Approximately 98% of total body potassium is located within cells at a concentration of about 140 mEq/L, while the remaining 2% is found in the extracellular fluid, where concentrations generally range from 3.8 to 5.0 mEq/L. Potassium plays a crucial role in maintaining normal cellular function, regulating membrane potential, supporting nerve impulse transmission, facilitating muscle contraction, and maintaining fluid and electrolyte balance. Disruptions in potassium homeostasis may lead to abnormalities in neuromuscular function, gastrointestinal activity, and cardiac performance. Given the high mineral content of *Moringa oleifera* leaves, particularly magnesium and potassium, their incorporation into food products may enhance nutritional quality and contribute to improved dietary mineral intake (Ferreira et al., 2020). Therefore, this study aimed to evaluate the effect of *Moringa oleifera* leaf flour supplementation on the magnesium (Mg) and potassium (K) contents of crackers as a nutritious snack alternative.

MATERIAL DAN METHODS

Study Area

This study was conducted at the Chemistry Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Tadulako, in April 2026. The research employed an experimental approach using a Completely Randomized Design (CRD) consisting of four treatment levels of *Moringa oleifera* leaf flour supplementation: 0%, 5%, 10%, and 15%, with two replications for each treatment. The use of a Completely Randomized Design was intended to minimize the influence of external factors and ensure that each treatment had an equal opportunity to be represented in the experiment. The magnesium (Mg) and potassium (K) contents of the cracker samples were determined using Atomic Absorption Spectrophotometry (AAS). Prior to statistical analysis, the data were subjected to normality and homogeneity tests to verify compliance with the assumptions required for parametric analysis. Subsequently, the data were analyzed using one-way Analysis of Variance (ANOVA) at a significance level of 0.05 to evaluate the effect of *Moringa oleifera* leaf flour supplementation on the magnesium and potassium contents of the crackers.

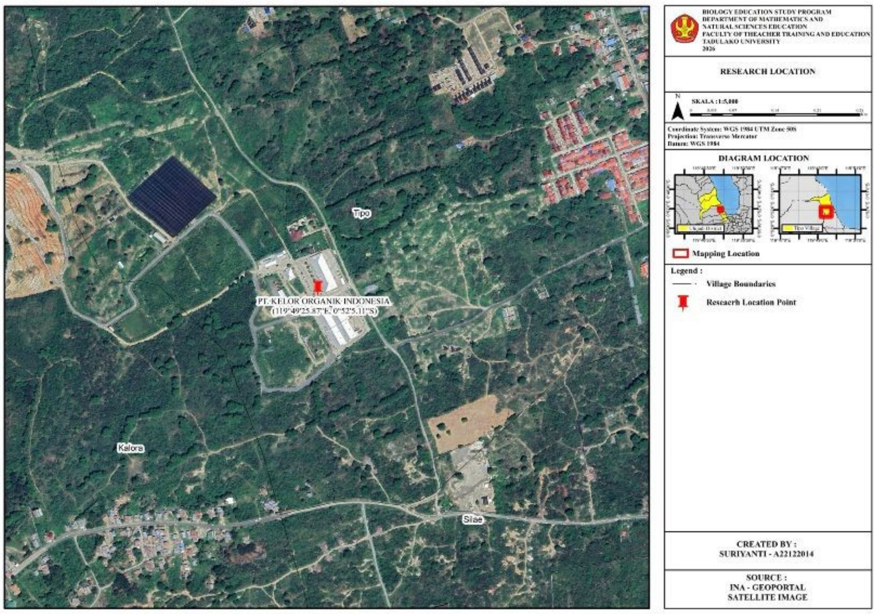

Figure 1. Map of the research location in PT. Kelor Organik Indonesia, Central Sulawesi, Indonesia.

Procedures

Preparation of Samples

The primary ingredients used in this study consisted of tapioca flour and wheat flour supplemented with Moringa oleifera leaf flour at different concentrations. Four treatment groups were prepared: P0 (control, 0% Moringa leaf flour), P1 (5% Moringa leaf flour), P2 (10% Moringa leaf flour), and P3 (15% Moringa leaf flour). The percentages were calculated based on the total flour weight, and the Moringa leaf flour was incorporated by partially substituting the wheat flour in each formulation. The dry ingredients, including tapioca flour, wheat flour, and Moringa leaf flour according to the respective treatment levels, were thoroughly mixed to ensure uniform distribution. Subsequently, seasonings consisting of garlic, salt, and flavor enhancer were added, followed by the gradual addition of water until a homogeneous dough was obtained. The dough was then shaped into elongated cylindrical forms, wrapped in plastic, and steamed for approximately 10 minutes until fully cooked. After steaming, the dough was cooled in a freezer and subsequently sliced into thin pieces of uniform thickness. The slices were dried under direct sunlight for 1–3 days until completely dehydrated and then stored in plastic packaging prior to magnesium and potassium analysis. The equipment used in this study included a digital balance, knife, tray, steamer, stove, mortar and pestle, analytical balance, fume hood, Erlenmeyer flasks, graduated cylinders, funnels, and an Atomic Absorption Spectrophotometer (AAS).

Sample Digestion Procedure

Sample preparation began by accurately weighing 1 g of the cracker sample using an analytical balance, and the sample mass was recorded for subsequent calculations. The sample was then transferred into an Erlenmeyer flask, followed by the gradual addition of 3 mL of concentrated nitric acid (HNO_3) and 1 mL of hydrochloric acid (HCl). The mixture was heated on a hot plate or heating block at 80–90°C for approximately 1–3 hours until a clear solution was obtained, indicating complete digestion of the sample matrix. After the heating process was completed, the solution was allowed to cool to room temperature and then filtered to remove any insoluble residues. Distilled water was added to the filtrate to obtain a predetermined final volume, generally 50 mL. The resulting filtrate was subsequently used for the determination of magnesium (Mg) and potassium (K) concentrations using Atomic Absorption Spectrophotometry (AAS).

Preparation of Magnesium (Mg) Calibration Curve

A magnesium (Mg) standard solution with a concentration of 1000 ppm was diluted to 100 ppm in a 25 mL volumetric flask, and the volume was adjusted to the calibration mark with distilled water. Aliquots of 0, 0.5, 1.0, 1.5, 2.0, and 2.5 mL of the 100 ppm working solution were then transferred into separate 10 mL volumetric flasks and diluted to volume with distilled water to obtain standard solutions with concentrations of 0, 5, 10, 15, 20, and 25 ppm, respectively. The absorbance of each standard solution was measured using Atomic Absorption Spectrophotometry (AAS) at a wavelength of 285.3 nm. The absorbance data obtained were subsequently used to construct a calibration curve and determine the linear regression equation using Microsoft Excel.

Preparation of Potassium (K) Calibration Curve

A potassium (K) standard solution with a concentration of 1000 ppm was diluted to 100 ppm in a 25 mL volumetric flask, and the volume was adjusted with distilled water to the calibration mark. Aliquots of 0, 0.5, 1.0, 1.5, 2.0, and 2.5 mL of the 100 ppm solution were then transferred into separate 10 mL volumetric flasks and diluted to volume with distilled water, resulting in standard solutions with concentrations of 0, 5, 10, 15, 20, and 25 ppm, respectively. The absorbance of the standard solutions was measured using Atomic Absorption Spectrophotometry (AAS) at a wavelength of 766.5 nm. The absorbance values obtained were used to construct the calibration curve and calculate the corresponding linear regression equation using Microsoft Excel.

Data Analysis

The measurement data obtained from the series of standard solutions were subsequently used to construct magnesium and potassium calibration curves using the calibration curve method. According to Noftia et al. (2019), the preparation of a standard calibration curve is based on the relationship between concentration (C) and absorbance (A), which is used to determine the slope and intercept values of the linear regression equation. The concentration of the sample can then be calculated by substituting the measured absorbance value into the regression equation in Beer–Lambert Law:

$$Y = ax + b$$

Where:
Y = sample absorbance value
x = sample concentration
a = slope of the regression line
b = intercept of the regression line

Based on the results of the linear regression analysis, the concentration of the sample was subsequently determined using the following equation:

$$\text{Metal Content (mg/g)} = \frac{(\text{C} \times \text{V} \times \text{DF})}{\text{W}}$$

Where:
C = concentration of the sample obtained from the regression equation (mg/L)
V = final volume of the sample solution (mL)
DF = dilution factor
W = sample weight (g)

RESULTS AND DISCUSSION

Magnesium and Potassium Calibration Curves

The measurement results of the magnesium standard solutions obtained using Atomic Absorption Spectrophotometry (AAS) were presented in the form of a calibration curve. Six standard magnesium solutions with different concentrations were prepared for quantitative analysis using AAS. The absorbance values recorded were 0.248 at 0.1 ppm, 0.844 at 0.5 ppm, 1.589 at 1.0 ppm, 2.333 at 1.5 ppm, 3.078 at 2.0 ppm, and 3.823 at 2.5 ppm. The results demonstrated that absorbance increased with increasing magnesium concentration, indicating a direct relationship between the two variables. Based on the concentration and absorbance data, a linear regression equation of y = 0.0669x + 0.6714 was obtained for the magnesium standard solutions, with a correlation coefficient (R^2) of 0.9996. This high coefficient of determination indicates an excellent linear relationship between magnesium concentration and absorbance. The calibration curve therefore satisfies the requirements of the Beer–Lambert law, which states that absorbance is directly proportional to analyte concentration within a specific concentration range (Figure 2).

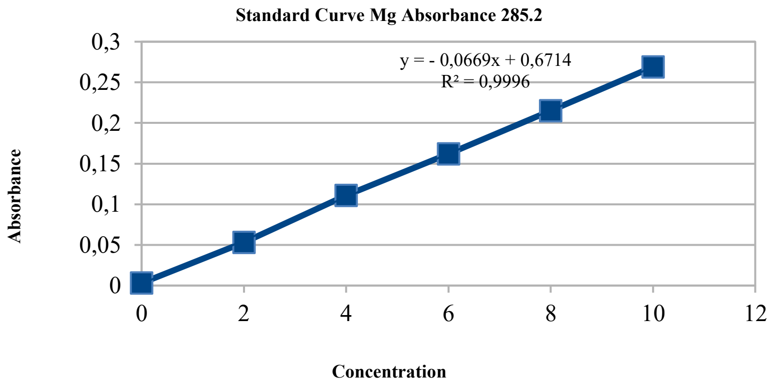

Figure 2. Magnesium (Mg) calibration curve.

The measurement results of the potassium standard solutions using Atomic Absorption Spectrophotometry (AAS) were presented in the form of a calibration curve. Six potassium standard solutions with different concentrations were prepared for quantitative analysis. The absorbance values obtained were 0.020 at 0.1 ppm, 0.187 at 0.5 ppm, 0.396 at 1.0 ppm, 0.605 at 1.5 ppm, 0.815 at 2.0 ppm, and 1.024 at 2.5 ppm. These results indicate that absorbance increased as the concentration of potassium increased, demonstrating a direct proportional relationship between concentration and absorbance. Based on the concentration and absorbance data, the linear regression equation for the potassium standard solutions was determined to be y = 0.0506x + 2.3918, with a correlation coefficient (R^2) of 1.0000. This value indicates a perfect linear relationship between potassium concentration and absorbance, confirming excellent calibration linearity. The observed relationship is consistent with the Beer–Lambert law, which states that absorbance is directly proportional to analyte concentration within a given concentration range (Figure 3).

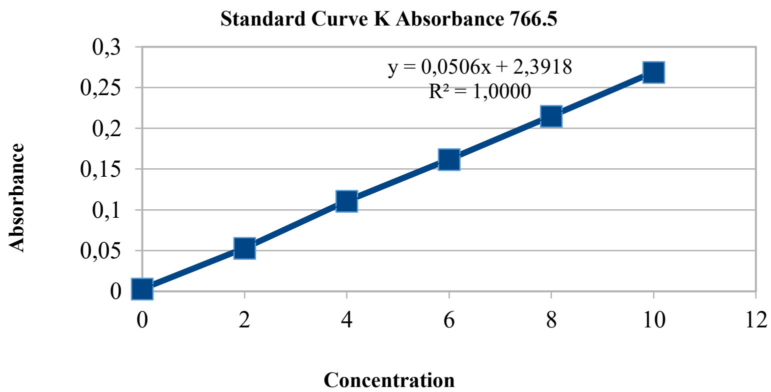

Figure 3. Potassium (K) calibration curve.

Analysis of Magnesium and Potassium Contents in Crackers

The magnesium and potassium contents of the *Moringa oleifera* leaf crackers were analyzed using two replications for each sample at every treatment level. The results of the replicate measurements were averaged to obtain the mean mineral content for each treatment. The average magnesium content was 0.06 mg/g in the control treatment (P0), increased to 0.08 mg/g in P1, reached 0.09 mg/g in P2, and subsequently decreased slightly to 0.08 mg/g in P3. In contrast, the average potassium content increased progressively across treatments, from 0.83 mg/g in P0 to 1.11 mg/g, 1.49 mg/g, and 1.84 mg/g in P1, P2, and P3, respectively (Table 1).

Table 1. Magnesium and potassium contents of crackers.

Sample	Mg (mg/g)	Mean (Mg)	K (mg/g)	Mean (K)
P0 (0%)	0.06	0.06	0.79	0.83
	0.06		0.87	
P1 (5%)	0.08	0.08	1.13	1.11
	0.07		1.08	
P2 (10%)	0.09	0.09	1.49	1.49
	0.09		1.49	
P3 (15%)	0.09	0.08	1.75	1.84
	0.06		1.93	

Statistical Data Analysis

The statistical analysis was performed using One-Way Analysis of Variance (ANOVA) to evaluate the effect of *Moringa oleifera* leaf flour supplementation on the magnesium and potassium contents of the crackers. The results indicated that the significance value for magnesium was 0.377 ($p > 0.05$), demonstrating that the addition of moringa leaf flour did not produce a statistically significant effect on the magnesium content of the crackers. Although a slight increase in magnesium concentration was observed across the treatments, the magnitude of this increase was not sufficient to generate a significant difference among treatment groups. The significance value for potassium was 0.001 ($p < 0.05$), indicating a statistically significant effect of moringa leaf flour supplementation on the potassium content of the crackers. This result confirms that increasing the concentration of *Moringa oleifera* leaf flour significantly enhanced the potassium levels in the final product. The findings suggest that potassium enrichment was more responsive to moringa leaf fortification than magnesium enrichment under the conditions of this study. While the incorporation of *Moringa oleifera* leaf flour tended to increase both magnesium and potassium contents, only the increase in potassium was statistically significant. These results support the potential use of moringa leaf flour as a natural fortification ingredient for improving potassium content in crackers and enhancing their nutritional value as a healthy snack alternative, as presented in Table 2.

Table 2. One-Way ANOVA for Magnesium (Mg) and Potassium (K).

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Magnesium	Between Groups	,001	3	,000	1,350	,377
	Within Groups	,001	4	,000		
	Total	,002	7			
Potassium	Between Groups	1,175	3	,392	72,660	,001
	Within Groups	,022	4	,005		
	Total	1,197	7			

Discussion

The addition of *Moringa oleifera* leaf flour to crackers was intended to enhance their mineral content, particularly magnesium (Mg) and potassium (K), thereby improving the nutritional value of the final product compared with conventional crackers. *Moringa oleifera* leaves are known to contain a wide range of essential nutrients, including minerals, vitamins, proteins, and antioxidant compounds that provide various health benefits. As the concentration of moringa leaf flour incorporated into the cracker formulation increased, the mineral content of the product also tended to increase. This finding indicates that moringa leaves have considerable potential as a natural fortification ingredient derived from local food resources. The enhancement of mineral content in the crackers is influenced by the composition of the ingredients used during the production process. Furthermore, the utilization of moringa leaf flour as a supplementary ingredient may serve as an alternative strategy for the development of functional foods that are not only acceptable to consumers but also contribute to meeting daily nutritional requirements (Sultana, 2020; Gopalakrishnan et al., 2016).

The determination of magnesium and potassium contents in this study was carried out using Atomic Absorption Spectrophotometry (AAS) due to its high sensitivity and accuracy in mineral analysis. Prior to measurement, the cracker samples underwent a digestion process using a mixture of nitric acid and hydrochloric acid to dissolve and release the minerals present in the sample matrix. The resulting digested solutions were subsequently analyzed using AAS at specific wavelengths corresponding to each mineral. Calibration curves were employed to establish the relationship between the concentrations of standard solutions and their absorbance values, enabling quantitative determination of mineral concentrations in the samples. This analytical method was selected because it provides accurate results and exhibits excellent linearity over the concentration ranges tested. Therefore, AAS was considered an effective technique for determining the magnesium and potassium contents of *Moringa oleifera* leaf crackers in this study (Gandjar & Rohman, 2018).

Magnesium and potassium are essential minerals that play important roles in maintaining normal physiological functions of the human body. Magnesium is involved in numerous enzymatic activities, supports muscle and nerve function, and contributes to the maintenance of bone health and cardiovascular function. Potassium, on the other hand, is essential for maintaining fluid balance, facilitating nerve impulse transmission, and regulating blood pressure within the normal range (Gandjar & Rohman, 2018). The presence of magnesium and potassium in *Moringa oleifera* leaf crackers indicates that this product has the potential to serve as a nutritious snack that can contribute to meeting daily mineral requirements. Adequate intake of magnesium and potassium is essential for maintaining optimal metabolic function, whereas deficiencies of these minerals may lead to various health problems, including muscle weakness, cardiac arrhythmias, hypertension, and nervous system disorders. Therefore, the utilization of moringa leaves as a food fortification ingredient is expected to improve the nutritional quality of local food products (Ferreira et al., 2020; Siddiqui et al., 2024).

The magnesium and potassium contents of the crackers were influenced by several factors, particularly the processing conditions applied during the study and the concentration of *Moringa oleifera* leaf flour incorporated into the formulation. Moringa leaves are recognized as a rich source of essential minerals, including magnesium and potassium. Previous studies have reported that dried Moringa leaf powder contains substantial amounts of magnesium and potassium, making it a valuable ingredient for enhancing the nutritional quality of food products. As the proportion of Moringa leaf flour increased in the cracker formulation, the mineral contribution from the leaves also increased, resulting in higher magnesium and potassium contents in the final product. This trend is consistent with the findings of the present study, where treatments containing higher levels of Moringa leaf flour generally exhibited greater mineral concentrations than the control treatment. However, the magnitude of the increase differed between magnesium and potassium. Potassium showed a more pronounced increase, whereas magnesium increased to a lesser extent and did not differ significantly among treatments. This difference may be attributed to the lower retention of magnesium during processing and its interaction with antinutritional compounds such as phytates and oxalates, which can reduce mineral availability. Processing stages such as steaming, heating, drying, and frying may also result in partial mineral losses through leaching or thermal effects. In contrast, potassium is relatively stable during thermal processing and therefore tends to be retained more effectively in the final product. Furthermore, the uniformity of cracker size and shape may influence mineral retention, as variations in heat exposure can affect nutrient stability among treatments. Therefore, maintaining consistency in formulation and processing conditions is essential to ensure reliable and accurate experimental results (Rousseau et al., 2019; Melse-Boonstra, 2020).

Crackers supplemented with *Moringa oleifera* leaf flour can be classified as a nutritious snack because they contain essential minerals that are beneficial to human health, particularly magnesium and potassium. The crackers function not only as a snack food but also as a functional food product that may contribute to meeting daily mineral requirements. The incorporation of moringa leaf flour into crackers represents an effort to develop healthier local food products with greater nutritional value than conventional crackers, which are generally composed primarily of carbohydrates. In addition to minerals, moringa leaves contain vitamins, proteins, and antioxidant compounds that further support human health. Moringa-based food products therefore have considerable potential as healthy snack alternatives that are acceptable to consumers due to their favorable sensory characteristics and the wide availability of raw materials. Consequently, the utilization of moringa leaves as a food fortification ingredient may contribute to the diversification of local food products while simultaneously improving community nutritional status in a sustainable manner (Saini et al., 2016; Sultana, 2020).

CONCLUSIONS

The addition of *Moringa oleifera* leaf flour exhibited different effects on the magnesium (Mg) and potassium (K) contents of the crackers. Statistical analysis revealed that the supplementation of moringa leaf flour did not have a significant effect on magnesium content, with a significance value of 0.377 ($p > 0.05$), although a descriptive increase in Mg levels was observed across treatments. In contrast, potassium content increased significantly, as indicated by a significance value of 0.001 ($p < 0.05$). This increase demonstrates that higher concentrations of *Moringa oleifera* leaf flour resulted in greater potassium levels in the cracker products. Therefore, *Moringa oleifera* leaf flour shows considerable potential as a fortification ingredient for improving the nutritional quality of crackers, particularly by enhancing their potassium content and supporting their development as a nutritious snack alternative.

Acknowledgements: The authors would like to express their sincere gratitude to Tadulako University for the institutional support and facilities provided during the conduct of this research.

Authors' Contributions: Conceptualization, Desi contributed to conducting the research, collecting and analyzing data, and preparing the manuscript. Abd. Hakim Laenggeng and Masrianih supervised the research methodology and revised the article. Musdalifah Nurdin, Raya Agni, and I Nengah Kundera contributed to data analysis, evaluation of results, and manuscript improvement. All authors approved the final version of the article.

Competing Interests: The author states that there are no competing interests.

REFERENCES

Arfaoui, L. (2021). Dietary Plant Polyphenols: Effects of Food Processing on Their Content and Bioavailability. Molecules, *26*(10), 2959. https://doi.org/10.3390/molecules26102959

Arminiati, N. P., Komang Wiardani, N., Ayu, G., & Kusumayanti, D. (2022). Studi Kepustakaan Asupan Natrium dan Kalium dengan Tekanan Darah pada Penderita Hipertensi. *Journal of Nutrition Science*, *11*(3), 1–4. https://doi.org/10.33992/jig.v11i3.1215

Dinicolantonio, J. J., Liu, J., & Keefe, J. H. O. (2018). Magnesium For the Prevention and Treatment of Cardiovascular Disease. Open Heart. 1–10. https://doi.org/10.1136/openhrt-2018-000775

D'Elia, L., Barba, G., Cappuccio, F. P., dan Strazzullo, P. 2019. Potassium Intake, stroke, and Cardiovascular Disease: A Meta-Analysis of Prospective Studies. Nutrients, *11*(10), 2482. https://doi.org/10.3390/nu11102482

Elvira, I., Baihaqi, Faradilla, R. H. F., Rejeki, S., & Suci, I. A. (2024). Pengaruh Metode Pengolahan Terhadap Kadar Air, Kadar Abu, Dan Kandungan Vitamin C Daun Kelor (Moringa oleifera). *Jurnal Agrosains*, *17*(1). https://doi.org/10.54035/agrosains.v17i1.446

Febrianty, A. M., Tamrin, T., Kuncoro, S., & Warji, W. (2023). Mempelajari Sifat Fisik Kerupuk Berbahan Tepung Melinjo dan Tepung Gaplek. *Jurnal Agricultural Biosystem Engineering*, *2(*2), 298–304. http://dx.doi.org/10.23960/jabe.v2i2.7483

Ferreira, J. P., Butler, J., Rossignol, P., Pitt, B., Anker, S. D., Kosiborod, M., Lund, L. H., Bakris, G. L., Weir, M. R., & Zannad, F. (2020). Abnormalities of Potassium in Heart Failure. *Journal of the American College of Cardiology*, *75*(22), 2836–2850. https://doi.org/10.1016/j.jacc.2020.04.021

Flora, R., Nisya, K. Z., Yuliana, I., & Sugito. (2022). Nutrient and Hedonic Value in Cookies with Moringa oleifera Fortification. *Indonesian Journal of Nutrition and Dietetics*, *10*(2), 71–78. https://doi.org/10.21927/ijnd.2022.10(2).71-78

Gandjar, I. G., & Rohman, A. (2018). *Kimia Farmasi Analisis*. Pustaka Pelajar.

Ghozali, I. (2018). *Aplikasi Analisis Multivariate dengan Program IBM SPSS 25*. Universitas Diponegoro.

Gopalakrishnan, L., Doriya, K., & Kumar, D. S. (2016). Moringa oleifera: A Review on Nutritive Importance and its Medicinal Application. *Food Science and Human Wellness*, *5*(2), 49–56. https://doi.org/10.1016/j.fshw.2016.04.001

Hartono. (2012). *Statistik Untuk Penelitian*. Yogyakarta: Pustaka Pelajar.

Husain, M. F., Limonu, M., & Antuli, Z. (2025). Karakteristik Fisikokimia Kerupuk Tepung Jagung dengan Penambahan Daging Ikan Betok (Anabas Testudineus*). Jambura Journal of Food Technology*, *4(*2), 139–148. https://Doi.Org/10.37905/Jjft.V4i2.13899

Jami, S. R., Fatimah-Muis, S., Syauqy, A., Tjahjono, K., & Anjani, G. (2022). Effect of Moringa oleifera Leaf Flour Supplementation on Total Antioxidant Content of Sprague Dawley Rat Serum Given High-Fat Diet. *Jurnal Gizi Indonesia*, *10*(2), 141–149. https://doi.org/10.14710/jgi.10.2.141-149

Meireles, D., Gomes, J., & Lopes, L. (2020). A Review of Properties, Nutritional and Pharmaceutical Applications of Moringa oleifera: Integrative Approach on Conventional and Traditional Asian Medicine. *Journal of Food Science and Technology*, *20*(4), 495–515. https://doi.org/10.1007/s13596-020-00468-0

Melse-Boonstra, A. (2020). Bioavailability of Micronutrients from Nutrient-Dense Whole Foods: Zooming in on Dairy, Vegetables, and Fruits. Frontiers in Nutrition, *7*, 101. https://doi.org/10.3389/fnut.2020.00101

Montgomery, D. C. (2020). *Design and Analysis of Experiments*. (10th ed.). Wiley.

Noftia, Tutik. Dan Ariska, R. W. (2019). Penetapan Kadar Logam Timbal (Pb) dan Seng (Zn) pada Margarin dengan Metode Spektrofotometri Serapan Atom. Jurnal Farmasi Malahayati. *2*(1), 24-32.

Pakpahan, N., & Nelinda. (2019). Studi Karakteristik Kerupuk: Pengaruh Komposisi dan Proses Pengolahan. *Teknologi Pengolahan Pertanian*, *1*(1), 28-38. http://doi.org/10.1016/j.regsciurbeco.2008.06.005%0A

Rizqiya, N., Putri, A. R., & Sari, D. (2023). Analisis Hubungan Konsumsi Makanan Siap Saji, Jajan, dan Kebiasaan Sarapan dengan Gizi Lebih Pada Anak Sekolah Dasar. *Muhammadiyah Journal of Nutrition and Food*, *5*(2), 114–120. https://doi.org/10.24853/mjnf.5.2.114-120

Rosvita, N. C., Widajanti, L., dan Pangestuti, D. R. (2018). Hubungan Tingkat Konsumsi Kalsium, Magnesium, Status Gizi (IMT/U), dan Aktivitas Fisik dengan Kram Perut Saat Menstruasi Primer pada Remaja Putri (Studi di Sekolah Menengah Atas Kesatria 2 Kota Semarang Tahun 2017). *Jurnal Kesehatan Masyarakat*, *6*(5), 519–525. DOI: https://doi.org/10.14710/jkm.v6i1.19955

Rousseau, S., Kyomugasho, C., Celus, M., Hendrickx, M. E. G., & Grauwet, T. (2019). Barriers Impairing Mineral Bioaccessibility and Bioavailability in Plant-Based Foods and the Perspectives for Food Processing. Critical Reviews in Food Science and Nutrition, *60*(5), 826–843. https://doi.org/10.1080/10408398.2018.1552243

Sá, A. G. A., Moreno, Y. M. F., & Carciofi, B. A. M. (2019). Food Processing for the Improvement of Plant Proteins Digestibility. *Critical Reviews in Food Science and Nutrition*, *60*(20), 3367–3386. https://doi.org/10.1080/10408398.2019.1688249

Saini, R. K., Sivanesan, I., & Keum, Y. S. (2016). Phytochemicals of Moringa oleifera: A review of their nutritional, therapeutic and industrial significance. *Biotech*, *3*(6), 203. https://doi.org/10.1007/s13205-016-0526-3

Siddiqui, R. W., Muhammad, S., Nishat, H., Alzaabi, A. A., Alzaabi, F. M., Siddiqui, T. W., & Siddiqui, S. W. (2024). The Connection Between Magnesium and Heart Health: Understanding Its Impact on Cardiovascular Wellness, 1*6*(10). https://doi.org/10.7759/cureus.72302

Sultana, S. (2020). Nutritional and Functional Properties of Moringa oleifera. Metabolism Open, *8*, 100061. https://doi.org/10.1016/j.metop.2020.100061

Vinceti M, Filippini T, Crippa A, de Sesmaisons A, Wise LA, Orsini N. Meta-Analysis of Potassium Intake and the Risk of Stroke. J Am Heart Assoc. 2016 Oct *65*(10):e004210. https://doi.org/10.1161/jaha.116.004210

Verghese, M., Willis, S., Boateng, J., Gomaa, A., & Kaur, R. (2021). Effect of Food Processing on Antioxidant Potential, Availability, and Bioavailability. *Annual Review of Food Science and Technology*, *12*, 307–329. https://doi.org/10.1146/annurev-food-062420-105140

Wahdah, N., Sari, M., & Hidayat, R. (2022). Preferensi Mahasiswa Terhadap Makanan Tradisional dan Perbandingannya dengan Pangan Siap Saji. *Jurnal Manajemen & Pangan Indonesia*, *9*(2), 58–66. https://doi.org/10.29244/jmpi.2022.9.2.58