

Nutritional profiling of instant analog rice made from edamame and seaweed flours: A mineral perspective

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Abstract. The increasing prevalence of type 2 diabetes mellitus (T2DM), which reached 11.7% in Indonesia in 2023, reflects a growing trend of non-communicable diseases. This indicates the need to strengthen T2DM prevention strategies to reduce metabolic and nutritional risk factors among patients. Micronutrients such as magnesium, calcium, iron, and zinc play important roles in glucose metabolism and insulin sensitivity. The development of nutritionally balanced foods has been explored, specifically instant analog rice made from edamame, which contributes magnesium (600 mg/kg) and zinc (32.8 mg/kg), and seaweed, which provides calcium (3200 mg/kg) and iron (45.6 mg/kg). This study aimed to determine the differences in magnesium, calcium, iron, and zinc content among various formulations of instant analog rice. The research employed a True Experimental design with a Completely Randomized Design (CRD), consisting of four groups: F0 (commercial instant rice) and formulations of edamame flour to seaweed flour ratios, namely F1 (40%:60%), F2 (50%:50%), and F3 (60%:40%). The results showed that calcium and iron contents among the treatment groups were significantly different ($p < 0.05$), while magnesium and zinc contents showed no significant difference ($p > 0.05$). The best formulation was F3, consisting of 60% edamame flour and 40% seaweed flour, with magnesium content of 63 mg/kg, calcium 320 mg/kg, iron 38.49 mg/kg, and zinc 16.41 mg/kg. Comparative analysis between F0 and F3 showed a significant difference in all parameters. These results indicate that instant analog rice based on edamame and seaweed is a promising mineral-rich food ingredient; further research on mineral bioavailability, sensory acceptance, and clinical outcomes is recommended.

1 Introduction

Diabetes mellitus (DM) represents a major global health concern with increasing prevalence across all age groups, projected to affect 738 million adults by 2045 [1]. In Indonesia, DM prevalence rose from 10.9% in 2018 to 11.7% in 2023, reflecting a growing trend of non-communicable diseases associated with nutritional and metabolic risk factors [2]. Type 2 diabetes mellitus (T2DM), the most common form, is closely linked to high intake of sugar and fat, low fiber consumption, and sedentary lifestyle [1]. Management strategies emphasize pharmacological therapy, nutrition education, and dietary interventions to maintain optimal glycemic control and prevent complications [3]. Continuous consumption of low-glycemic index foods has been shown to improve insulin sensitivity, reduce glucose absorption, and decrease HbA1c levels in individuals with T2DM [4].

Patients with T2DM also require adequate intake of micronutrients such as magnesium,

calcium, iron, and zinc. Magnesium improves glycemic control, enhances insulin sensitivity, and reduces the risk of cardiovascular complications [5]. Calcium contributes to the insulin secretion process in pancreatic β -cells [6]. Iron plays a role in insulin secretion and effectiveness as well as blood glucose regulation [7]. Zinc functions as a cofactor for insulin enzymes, participating in insulin receptor phosphorylation, GLUT4 translocation, and insulin storage in the hexameric form within pancreatic β -cell granules [8]. Deficiency or imbalance in these micronutrients can impair insulin sensitivity and glucose metabolism, consequently increasing the risk of diabetes progression [9].

White rice remains the staple food of the Indonesian population, with an average consumption of 81.23 kg per capita per year in 2023 [10]. Although it provides a high energy yield (180 kcal/100 g), white rice has a high glycemic index (GI 64). It contains relatively low amounts of magnesium, calcium, iron, and zinc, which are 21 mg, 25 mg, 0.4 mg, and 0.6 mg per 100 g [11]. This

condition makes it less suitable for individuals requiring controlled blood glucose levels. Therefore, the development of nutrient-enriched analog rice has emerged as a promising alternative. Analog rice, produced from non-rice ingredients through an extrusion process, enables the customization of nutrient composition and functional properties while forming rice-like granules with improved nutritional diversity [12]. Furthermore, the development of instant analog rice enhances convenience, as its porous granules rehydrate easily and allow for faster preparation [13].

Edamame and seaweed are promising local ingredients for formulating instant analog rice. Both are rich in essential minerals such as calcium, iron, and magnesium, and have potential to improve metabolic function and reduce the risk of diabetes [14]. Edamame exhibits antihyperglycemic effects through improved insulin sensitivity [15]. In addition, edamame contains protein, fiber, isoflavones, antioxidants, iron, and zinc, which support metabolic improvement in individuals with T2DM [16]. Soy-based products generally have a low glycemic index and are effective in lowering postprandial blood glucose responses [17]. Every 100 g of edamame flour provides 228 kcal of energy, 22.35 g of carbohydrates, 11.7 g of protein, 2.7 mg of iron, 1.4 mg of zinc, 61 mg of magnesium, and 60 mg of calcium [16].

Seaweed is rich in fiber and bioactive compounds that play important roles in reducing blood glucose and blood pressure [18]. In vitro studies have shown that alginate and phlorotannin extracted from brown seaweeds inhibit α -glucosidase and ACE activities, thereby reducing glucose absorption and blood pressure [19, 20]. Meanwhile, in vivo experiments demonstrated that dietary seaweed supplementation delays gastric emptying and improves postprandial glycemic control in animal and human models [21, 22]. The incorporation of dietary fiber or other functional components into carbohydrate-based foods can effectively lower their glycemic index [23]. Soluble fibers, such as alginate and agar, form viscous gels that delay gastric emptying and reduce glucose diffusion, whereas bioactive compounds like phlorotannins inhibit α -amylase and α -glucosidase activities, slowing starch hydrolysis and postprandial glucose rise. The nutritional composition of seaweed includes 1218 kcal/kg of energy, 255 g/kg of carbohydrates, 45.6 mg/kg of iron, 32.8 mg/kg of zinc, 320 mg/100 g of magnesium, and 2740 mg/100 g of calcium, making it a potential ingredient for functional foods targeted at T2DM patients [24, 25]. Furthermore, as a maritime nation, Indonesia possesses an abundant supply of seaweed exceeding ten million tons each year, which provides a strong foundation for the large-scale development of innovative and sustainable functional food products [26].

To date, no study has specifically investigated the mineral composition, particularly magnesium, calcium, iron, and zinc in instant analog rice formulated with edamame and seaweed. Therefore, this study aims to analyze the magnesium, calcium, iron, and zinc contents of instant analog rice made from edamame and seaweed as a contribution to the development of functional foods and nutritious dietary alternatives for individuals with T2DM.

2 Method

2.1 Tools and Materials

The tools used to make analog rice include digital scale, stove, food dehydrator "ST-32 GETRA", food dehydrator tray, manual pasta press, "Panasonic NR-BL347PS" refrigerator, baking paper, a stainless-steel bowl, thin-wall 500 ml, one one-liter measuring cup, a steamer, a pot, a plate, spatula, spoon, plastic gloves, and vacuum plastic. The tools for analyzed used was Whatman No. 40 filter paper, an air compressor, acetylene gas, calibrated 10 mL and 25 mL volumetric pipettes, dropper pipettes, test sample bottles, an analytical balance, a bulb, a glass stirring rod, a 250 mL Erlenmeyer flask, 100 mL measuring cups and flasks, an electric heater, a glass funnel, and an atomic absorption spectrophotometer with calibrated accessories.

The materials used in this study were seaweed flour from PT. Kappa Carrageenan Nusantara Malang, and edamame flour from Ommah Tepung Organic. Both of the raw materials were then mixed with other ingredients such as tapioca flour (5%), cornstarch (5%), food-grade CMC (0,5%), pandan leaf extract, and water.

2.2 Experimental Design

This research design is a quantitative study conducted using the True Experimental method with a Completely Randomized Design (CRD). It was conducted using a control sample of commercial instant rice of the brand "CJ Heatban Cooked White Rice" with code F0. Then, three treatments were formulated from *Glycine max* L. Merr and *Eucheuma cottonii* flour, based on previous research [27]. The differences were obtained from the comparison of the composition of *Glycine max* L. Merr and *Eucheuma cottonii* flour with formulations F1 (40%:60%); F2 (50%:50%); and F3 (60%:40%). Replication was carried out three times for each treatment, resulting in a total of twelve samples. Data analysis was performed using a One-Way ANOVA test for zinc and a post-hoc LSD test for iron. Meanwhile, for data that were not normally distributed, analysis was performed using the Kruskal-Wallis test for magnesium and

the Mann-Whitney post-hoc test for calcium. After that, the best formulation was selected using the Multiple Attributed method [28]. The final process was to compare the best formulation with the F0 control sample.

2.3 Analysis Method

2.3.1 Atomic Absorption Spectrophotometry (AAS)

Atomic Absorption Spectrophotometry (AAS) is a highly sensitive quantitative method used to analyze metal elements, particularly base cations, by measuring light absorption at specific wavelengths. Its working principle is based on the absorption of radiation by neutral atoms in a free state, where the absorption level is proportional to the number of atoms in the flame. This method is selective, fast, and capable of detecting very small concentrations of elements. The concentration of elements is determined using a regression line equation from a calibration curve, and the process allows for the analysis of several metals at once. In practice, calcium concentration measurements are performed at a wavelength of 422.7 nm, magnesium at 285.2 nm, iron at 248.3 nm, and zinc at 213.9 nm using an air-acetylene flame.

3 Result and Discussion

3.1 Characteristics of Instant Analog Rice

The process of making instant analog rice involves several stages, starting from the selection of ingredients, mixing, and then forming into analog rice [27]. Instantization is carried out from the formed analog rice, followed by further processes, namely steaming, freezing, and drying [29]. Visual and sensory characteristics can be key determinants of consumer acceptance. Color is the most prominent visual cue for the sensory properties of a product [30]. The comparison between the control sample, which is white, and the instant analog rice, which is brown, is due to the different ingredients used in the two products. The increased proportion of edamame flour makes the color more yellowish-brown. The increased proportion of seaweed flour in the sample observed a higher score for seaweed aroma and taste.

3.2 Mineral Analysis

3.2.1 Magnesium

Magnesium is an essential divalent cation that functions as a cofactor for numerous enzymes and stabilizes ATP-dependent processes critical to cellular metabolism. This mineral plays an important role in biochemical pathways, such as macronutrient degradation, oxidative phosphorylation, DNA and protein synthesis, neuromuscular excitability, and regulation of parathyroid hormone (PTH) secretion, which affects diabetes mellitus [31].

Analysis of magnesium levels in various instant analog rice formulations showed no significant differences between formulations ($p > 0.05$). The processing of instant analog rice, which consists of mixing, drying, and boiling, can affect the content of the final product. The findings state that the temperature and acidic pH conditions during the manufacturing process affect the solubility of Mg [32]. Antinutrient activity from raw materials can also affect the final content of instant analog rice, one of which is phytic acid found in legumes, namely edamame. Phytic acid is a negatively charged structure that usually binds to positive charges such as magnesium. This creates a complex bond and reduces the bioavailability of absorption [33]. This is one of the causes of mineral ions deficiency in humans, as it is the most effective antinutrient in food.

3.2.2 Calcium

Calcium is one of the minerals that greatly affects human health, especially bone health. The results showed that the highest calcium concentration was found in formulation F2 (3800 mg/kg). The highest calcium concentration was observed in F2 (3800 mg/kg), while the lowest was found in F2 (3200 mg/kg). Seaweed is one of the sources that contributes significantly to the calcium content in instant analog rice. It is mentioned that seaweed from the sea, especially green algae, is rich in calcium [34].

From the data obtained, the calcium content decreased in sample F1 with the highest amount of seaweed flour formulation. The decrease in calcium content may have occurred due to the repeated drying of the product [35]. Another factor that caused the calcium content to be lower than that of the ingredients was the interaction between the two ingredients, particularly the use of edamame flour. Edamame is a type of legume (young soy) that contains phytic acid, a form of antinutrient, which can bind with calcium ions to form insoluble complexes, thereby reducing bioavailability in the product [36].

Table 1. Mineral Analysis of Instan Analog Rice

Parameters	Formulations			
	F0	F1	F2	F3
Magnesium (mg/kg)	0,002 (0,0017;0,002)	0,060(0,06;0,07)	0,070(0,07;0,07)	0,060(0,06;0,07)
Calcium (mg/kg)	0,020 (0,020;0,020)	0,370(0,36;0,38) ^b	0,380(0,38;0,38) ^b	0,320(0,31;0,33) ^a

Additional information:

- Data Magnesium and Calcium are presented as the median of 3 replicates (min;max)
- Different superscripts in the same column indicate significant differences ($\alpha < 0.05$)
- F1, F2 and F3 are instant analog rice formulations using *Glycine max L. Merr* and *Eucheuma cottonii* with respective ratios (40%:60%); (50%:50%); and (60%:40%).

3.2.3 Iron

Iron is one of the essential minerals involved in various physiological functions, particularly in oxygen transport and hemoglobin synthesis [7]. As shown in Figure 1, the iron content in formulation F3 differed significantly ($p < 0.05$) from that in F1 and F2. The highest iron concentration was observed in F3 (38.49 ± 13.50 mg/kg), while the lowest was found in F2 (17.59 ± 1.71 mg/kg). Iron content is influenced by processing techniques such as heating, drying, and boiling [37, 38, 39].

In this study, the production of instant analog rice involved mixing, drying at 50 °C for 8 h, steaming at 100 °C for 60 min, and a second drying process at 50 °C for 3 h 30 min. These treatments decreased iron levels due to leaching into the steaming water and oxidation of Fe²⁺ to the less stable Fe³⁺ form [37]. This finding is consistent with the results reported by [40], who observed that the rate of iron release at 50 °C was initially low but increased significantly with prolonged heating time. Heating at 97 °C for 60 min led to an iron release ranging from 4.91 to 6.07 mg/L [40]. Additionally, heat exposure can induce protein denaturation and polysaccharide degradation, leading to the formation of iron-protein or iron-fiber complexes that are difficult to quantify using SSA [38]. The dehydration process can further promote mineral diffusion from the food matrix, thereby reducing measurable iron concentrations in the final product [39].

3.2.4 Zinc

Zinc is another essential mineral that plays a crucial role in supporting numerous biological processes such as immune function, enzymatic reactions, DNA synthesis, and cellular growth and development [8]. As shown in Figure 1, zinc content did not differ significantly ($p < 0.05$) among the formulations. The highest zinc concentration

was recorded in F3 (16.41 ± 1.64 mg/kg), while the lowest was found in F1 (14.50 ± 1.23 mg/kg).

Compared to the raw materials, the zinc content in instant analog rice was relatively lower. According to [16] the zinc content of edamame flour is 14 mg/kg, whereas seaweed flour, as reported by [24], contains up to 32.8 mg/kg. This reduction may be attributed to the steaming process, which induces mineral leaching into the condensate or surface moisture layer [41]. Heat and humidity during steaming can weaken the binding of minerals within the food matrix, thereby facilitating the migration of zinc into the aqueous medium that is typically discarded [42]. Several studies have reported that mineral retention in steamed foods ranges from 80 to 100%, indicating that mineral loss accounts for approximately 0–20% of the initial content [43].

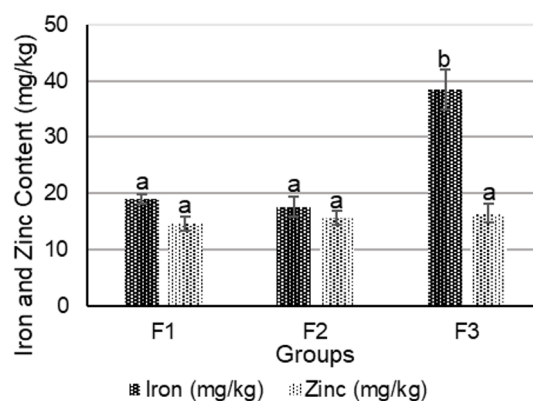


Figure 1. Iron and Zinc Content of Instan Analog Rice

1.1 Best Formulation

The best formulation was calculated for the parameters magnesium, calcium, iron, and zinc using the Zeleny method, with the following results: F1=0.219; F2=0.200; F3=0.105. Based on the

data, F3 was the best formulation for making instant analog rice.

1.2 Best Formulation with Control

Further analysis was conducted by comparing the magnesium, calcium, iron, and zinc contents of the best formulation (F3) with the iron and zinc contents of the control product (F0). Based on Table 1, formulation F3 exhibited significantly different levels of magnesium, calcium, iron, and zinc ($p < 0.05$) compared to the control (F0). Edamame is known to contain moderate amounts of magnesium, calcium, iron, and zinc, along with absorption-promoting compounds such as protein, vitamin C, and specific amino acids that facilitate mineral bioavailability. Seaweed, particularly *Eucheuma cottonii*, is naturally rich in magnesium, calcium, and iron, and also provides a relatively high zinc content [16, 24]. The combination of these two ingredients enables a superior mineral profile compared to white rice-based products, which tend to lose most micronutrients due to extensive milling and processing [44]. Therefore, it can be concluded that the low moisture content and the incorporation of edamame and seaweed in the analog rice formulation substantially contribute to increased mineral density. This finding underscores the potential of instant analog rice as a superior alternative food source in providing iron and zinc compared with conventional rice-based products.

4 Conclusion

The results showed that the best formulation was F3, with magnesium, calcium, iron, and zinc at 630 mg/kg, 3200 mg/kg, 38.49 mg/kg, and 16.41 mg/kg, respectively. Other tests, such as raw-material testing, need to be conducted to determine the initial composition of the materials used, thereby further strengthening the research results. Analog instant rice made from edamame flour and seaweed has strong potential as a functional food for supporting the management of type 2 diabetes (T2DM).

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References

1. IDF. (2021). *IDF Diabetes Atlas 10th edition*.
2. Kementerian Kesehatan RI. (2023). *Survei Kesehatan Indonesia (SKI)*.
3. WHO. (2024). *Guidance On Global Monitoring for Diabetes Prevention and Control*. CC BY-NC-SA 3.0 IGO.
4. Ojo, O., Ojo, O. O., Adebowale, F., & Wang, X.-H. (2018). The Effect of Dietary Glycaemic Index on Glycaemia in Patients with Type 2 Diabetes: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Nutrients*, 10(373), 1–15. <https://doi.org/10.3390/nu10030373>.
5. Liu, Z., & Sun, X. (2020). A Critical Review of the Abilities, Determinants, and Possible Molecular Mechanisms of Seaweed Polysaccharides Antioxidants. *International Journal of Molecular Sciences*, 21(7774), 1–20. <https://doi.org/doi:10.3390/ijms2120777>.
6. Dastgerdi, A. H., Rad, M. G., & Soltani, N. (2022). The Therapeutic Effects of Magnesium in Insulin Secretion and Insulin Resistance. *Advanced Biomedical Research*, 11(54), 1–11. <https://doi.org/10.4103/abr.abr>.
7. Harrison, A. V, Lorenzo, F. R., & McClain, D. A. (2023). Iron and the Pathophysiology of Diabetes. *Annu Rev Physiol*, 85, 339–362. <https://doi.org/10.1146/annurev-physiol-022522-102832.Iron>.
8. Ahmad, R., Shaju, R., Atfi, A., & Razzaque, M. S. (2024). Zinc and Diabetes: A Connection between Micronutrient and Metabolism. *Cells*, 13, 1359. <https://doi.org/doi.org/10.3390/cells13161359>.
9. Soetedjo, N. N. M. (2025). The role of nutrition in various endocrine and metabolic diseases. *Clinical Nutrition Open Science*, 62(38), 164–188. <https://doi.org/10.1016/j.nutos.2025.05.015>.
10. Badan Pangan Nasional, 2024. Rata-rata Konsumsi per Jenis Pangan Penduduk Indonesia Nasional Update Tahun 2024, Jakarta: Badan Pangan Nasional, Diakses 15 Oktober 2024 pada <https://www.satudata.badanpangan.go.id>.
11. Kemenkes RI. (2019). *Tabel Komposisi Pangan Indonesia*.
12. Chaturvedi, S., & Manickavasagan, A. (2024). Trends in Food Science & Technology Rice analogues: Processing methods and product quality. *Trends in Food Science & Technology*, 148, 104493. <https://doi.org/10.1016/j.tifs.2024.104493>.
13. Gupta, R. K., Gangoliya, S. S., & Singh, N. K. (2015). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of Food Science and Technology*, 52(2), 676–684. <https://doi.org/10.1007/s13197-013-0978-y>.

14. Rosiana, N. M., & Amareta, D. I. (2016). Karakteristik Yogurt Edamame Hasil Fermentasi Kultur Campuran Bakteri Asam Laktat Komersial Sebagai Pangan Fungsional Berbasis Biji-Bijian. Seminar Hasil Penelitian Dan Pengabdian Masyarakat Dana BOPTN Tahun, 16(2), 33–37. <https://doi.org/10.25047/jii.v16i2.288>.
15. Aghora, T. S., Thangam, M., & Patil, N. (2023). *Legume Vegetables for Human Nutrition and Entrepreneurship* (B. Singh & P. Kalia (eds.)). Springer. <https://doi.org/https://doi.org/10.1007/978-981-19-9016-8>.
16. Pardeshi, P. P., Sonkamble, P. A., Rathod, D. R., Gangtore, D. R., Jadhav, P. V., Sakhare, S. B., Nandanwar, R. S., & Varghise, P. (2024). Characterization of vegetable soybean (Edamame) germplasm and assessment of optimal food quality traits. *Indian Journal of Genetics and Plant Breeding*, 84(3), 482–491. <https://doi.org/10.31742/ISGPB.84.3.19>.
17. Ijarotimi, O. S., Fakayejo, D. A., & Oluwajuyitan, T. D. (2021). Nutritional Characteristics, Glycaemic Index and Blood Glucose Lowering Property of Gluten-Free Composite Flour from Wheat (*Triticum aestivum*), Soybean (*Glycine max*), Oat-Bran (*Avena sativa*) and Rice-Bran (*Oryza sativa*). *Applied Food Research*, 1(2), 100022. <https://doi.org/10.1016/j.afres.2021.100022>.
18. Kim, Y. R., Park, M. J., Park, S., & Kim, J. Y. (2023). Brown Seaweed Consumption as a Promising Strategy for Blood Glucose Management: A Comprehensive Meta-Analysis. *Nutrients*, 15, 4987. <https://doi.org/https://doi.org/10.3390/nu15234987>.
19. Shannon, E., Conlon, M., & Hayes, M. (2023). In Vitro Enzyme Inhibitory Effects of Green and Brown Australian Seaweeds and Potential Impact on Metabolic Syndrome. *Journal of Applied Phycology*, 893–910. <https://doi.org/10.1007/s10811-022-02900-1>.
20. Cho, C., Lu, Y., Kim, M., Jeon, Y., & Lee, S.-H. (2022). Therapeutic Potential of Seaweed-Derived Bioactive Compounds for Cardiovascular Disease Treatment. *Applied Science*, 12, 1025. <https://doi.org/https://doi.org/10.3390/app12031025>.
21. Bocanegra, A., Macho-González, A., Garcimartín, A., Benedí, J., & Sánchez-Muniz, F. J. (2021). Whole Alga, Algal Extracts, and Compounds as Ingredients of Functional Foods: Composition and Action Mechanism Relationships in the Prevention and Treatment of Type-2 Diabetes Mellitus. *International Journal of Molecular Sciences Review*, 22(3816), 1–39. <https://doi.org/https://doi.org/10.3390/ijms22033816>.
22. Lu, L. W., & Chen, J. (2022). Seaweeds as Ingredients to Lower Glycemic Potency of Cereal Foods Synergistically — A Perspective. *Foods*, 11(714), 1–24. <https://doi.org/https://doi.org/10.3390/foods1105071>.
23. Pede, G. Di, Dodi, R., Scarpa, C., Brighenti, F., Asta, M. D., & Scazzina, F. (2021). Glycemic Index Values of Pasta Products: An Overview. *MDPI*, 10(2541), 1–16. <https://doi.org/https://doi.org/10.3390/foods10112541>.
24. Circuncisão, A. R., Catarino, M. D., Cardoso, S. M., & Silva, A. M. S. (2018). Minerals from macroalgae origin: Health benefits and risks for consumers. *Marine Drugs*, 16(11), 1–30. <https://doi.org/10.3390/md16110400>.
25. Cotas, J., Lomartire, S., Pereira, L., Valado, A., Marques, J. C., & Gonçalves, A. M. M. (2024). Seaweeds as Nutraceutical Elements and Drugs for Diabetes Mellitus: Future Perspectives. *Marine Drugs*, 22(168), 1–22. <https://doi.org/https://doi.org/10.3390/md22040168>.
26. Basyuni, M., Puspita, M., Rahmania, R., Albasri, H., Pratama, I., Purbani, D., Aznawi, A. A., Mubaraq, A., Mustaniroh, S. S. Al, Menne, F., Rahmila, Y. I., Iii, S. G. S., Susilowati, A., Larekeng, S. H., Ardli, E., & Kajita, T. (2024). Current biodiversity status, distribution, and prospects of seaweed in Indonesia: A systematic review. *Heliyon*. Current biodiversity status, distribution, and prospects of seaweed in Indonesia: A systematic review. *Heliyon*, 10(10), e31073. <https://doi.org/10.1016/j.heliyon.2024.e31073>.
27. Setiawan, E. C., Puspitasari, D. A., Kirana, S., Alfani, M. N. R., Imam, A. W. N., & Widyanto, R. M. (2022). Kandungan Gizi dan Uji Organoleptik Beras Analog Kedelai Edamame dan Rumput Laut. *Indonesian Journal of Human Nutrition*, 9(1), 1–15. <https://doi.org/https://doi.org/10.21776/ub.ijhn.2022.009.01.1>.
28. Zeleny, M. (1982). Multiple Criteria Decision Making: Eight Concepts of Optimality. *Human Systems Management*, 17(2), 97–107. [https://doi.org/10.1016/0165-0114\(95\)00165-4](https://doi.org/10.1016/0165-0114(95)00165-4).
29. Kurniasari, I., Kusnandar, F., & Budijanto, S. (2020). Karakteristik Fisik Beras Analog Instan Berbasis Tepung Jagung dengan Penambahan k-Karagenan dan Konjak. *AgriTECH*, 40(1), 64–73. <https://doi.org/10.22146/agritech.47491>.
30. Spence, C. (2015). On the psychological impact of food colour. *Flavour*, 4(1), 1–16. <https://doi.org/10.1186/s13411-015-0031-3>.
31. Schuchardt, J. P., & Hahn, A. (2017). Intestinal Absorption and Factors Influencing Bioavailability of Magnesium - An Update. *Bentham Science*, 13, 260–278.

- <https://doi.org/10.2174/1573401313666170427162740>.
32. Handayani, K. R., Yuyun, Y., & Jamaluddin. (2020). Pengaruh Media Perebusan Terhadap Komposisi Mineral Kerang Air Tawar Meti (*Batissa violacea* Lamarck, 1818). *Jurnal Farmasi Galenika (Galenika Journal of Pharmacy) (e-Journal)*, 6(2), 328–337. <https://doi.org/10.22487/j24428744.2020.v6.i2.15199>.
33. Samtiya, M., Aluko, R. E., & Dhewa, T. (2020). Plant Food Anti-Nutritional Factors and Their Reduction Strategies: An Overview. *Food Production, Processing and Nutrition*, 2(6), 1–14.
34. Xu, Y., Ye, J., Zhou, D., & Su, L. (2020). Research Progress on Applications of Calcium Derived From Marine Organisms. *Scientific Reports*, 10(18425), 1–8. <https://doi.org/10.1038/s41598-020-75575-8>.
35. Sampebua, D., Sukainah, A., & Yanto, S. (2021). Pembuatan Stik Berbahan Dasar Tepung Tulang Ikan Bandeng (*Chanos chanos*) dan Bubur Rumput Laut (*Euचेuma cottonii*). *Jurnal Pendidikan Teknologi Pertanian*, 7(1), 11–20.
36. Akond, A. S. M. G. M., Crawford, H., Berthold, J., Talukder, Z. I., & Hossain, K. (2018). Minerals (Zn, Fe, Ca and Mg) and Antinutrient (Phytic Acid) Constituents in Common Bean. *Physiology & Behavior*, 6(3), 235–243. <https://doi.org/10.3923/ajft.2011.235.243.Minerals>.
37. Malathi, V. M., Sehwat, R., Seth, D., Pravitha, M., Venkateswarlu, R., Subeesh, A., Krishnan, V., & Satyavathi, C. T. (2025). Heat matters : role of thermal processing on millet composition , digestibility , bioaccessibility and bioavailability. *European Food Research and Technology*, 1–29. <https://doi.org/https://doi.org/10.1007/s00217-025-04911-x>.
38. Liu, J., Zhang, L., & Chen, Z. (2023). Impact of Heat Treatment on Protein–Mineral Interactions in Cereal-Based Foods. *LWT – Food Science and Technology*, 181, 114753.
39. Wang, Q., Qi, J., Wang, S., Xu, J., & Yang, Y. (2020). Cold Regions Science and Technology Effect of Freeze-Thaw on Freezing Point of a Saline Loess. *Cold Regions Science and Technology*, 170, 102922. <https://doi.org/10.1016/j.coldregions.2019.102922>.
40. Shi, C., Zhe, G., Ding, X., Meng, Q., Li, J., & Deng, L. (2024). Current Research in Food Science Effect of Cooking Conditions on Iron Release from Pots and Development of Kinetic Models for Iron Supplementation in Nips. *Current Research in Food Science*, 9(June), 100830. <https://doi.org/10.1016/j.crfs.2024.10083>.
41. Huertas, R., Allwood, J. W., Hancock, R. D., & Stewart, D. (2022). Iron and Zinc Bioavailability in Common Bean (*Phaseolus Vulgaris*) is Dependent on Chemical Composition and Cooking Method. *Food Chemistry*, 387, 132900. <https://doi.org/10.1016/j.foodchem.2022.132900>.
42. Alshallash, K. S., Shahat, M., Ibrahim, M. I., Hegazy, A. I., Hamdy, A. E., Elnaggar, I. A., Elwahed, A. E. N. A., & Taha, I. M. (2023). The Effect of Different Processing Methods on the Behavior of Minerals Content in Food Products. *Journal of Ecological Engineering*, 24(3), 263–275. <https://doi.org/https://doi.org/10.12911/22998993/158783>.
43. Bogнар, A. (2022). *Tables on Weight Yield of Food and Retention Factors of Food Constituents or The Calculation of Nutrient Composition of Cooked Foods (Dishes)*. Karlsruhe: Federal Research Centre for Nutrition.
44. Ahmed, Z. (2025). A Review on the Impact of Cooking Methods and Rice Varieties on Nutritional Value. *IPS Journal of Nutrition and Food Science*, 4(3), 555–560. <https://doi.org/https://doi.org/10.54117/5vaksr64>.