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OPTIMIZATION OF MORINGA LEAVES (*Moringa oleifera*) DIVERSIFICATION INTO ANTIOXIDANT-RICH MORINGA-NORI FLAKES AS A FOOD SEASONING

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Abstract: This research focuses on optimizing antioxidant-rich Moringa flakes by fine-tuning blanching temperatures and nori content, which are key factors influencing the sensory qualities, antioxidant levels, and sodium content of the final product. Moringa leaves, recognized for their high nutritional value and antioxidant potential, were combined with different concentrations of nori to evaluate their impact on these characteristics. The study employed a factorial design with blanching temperatures of 70°C, 80°C, and 90°C, along with nori levels of 5%, 10%, and 15%, to identify the optimal conditions for creating a nutritionally superior and consumer-friendly food product. Statistical analysis was conducted using t-tests, two-way ANOVA, and Tukey post hoc tests to assess the significance of blanching temperature and nori content on antioxidant activity. The findings revealed that both factors significantly influenced

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the outcomes. Antioxidant activity was best preserved at a blanching temperature of 70°C, as higher temperatures caused degradation of heat-sensitive antioxidants. The optimal antioxidant activity was observed with a 10% nori content. The study concludes that carefully balancing blanching temperature and nori content is crucial for producing Moringa flakes that are rich in antioxidants. These findings offer valuable guidance for food product developers seeking to create health-oriented products with enhanced antioxidant properties, highlighting the importance of precise control over processing parameters. The successful creation of antioxidant-rich Moringa flakes underscores their potential in the health food market, offering a blend of nutritional benefits and consumer appeal.

Keywords: antioxidant activity; blanching temperature; *Moringa oleifera;* nori content; statistical analysis.

2020 AMS Subject Classification: 62P10.

1. INTRODUCTION

Indonesia, known for its rich biodiversity, offers a variety of plants with potential benefits for human health. One notable example is the Moringa leaf (*Moringa oleifera*). Despite its benefits, public awareness about the health advantages of Moringa leaves remains low. These leaves are nutrient-dense and can significantly improve the nutritional value of food products [1]. They contain essential nutrients such as calcium, iron, protein, vitamins A and B, along with other nutritional and antioxidant compounds like flavonoids, tannins, terpenoids, alkaloids, and saponins [2], [3], [4], [5]. Available both fresh and in powdered form, Moringa leaves offer higher nutritional content compared to common sources like milk, spinach, bananas, or carrots [6], [7], [8]. Thus, the comprehensive nutritional profile of Moringa leaves highlights their potential for substantial health benefits. The average total polyphenol content in the stems and leaves of Moringa oleifera is around 2.89% [9], [10], [11], with tannins, measured as tannic acid, present at concentrations up to 2.20% [12]. They also contain significant antioxidant components, particularly isothiocyanates, known for their anti-carcinogenic and antibiotic properties [13], [14]. The flavonoids and phenolic acids in M. oleifera contribute to its use as a dietary supplement [9], [11]. Key flavonoids in Moringa oleifera leaves include various forms of quercetin, apigenin, and kaempferol, along with glycosylated flavonoids formed by the condensation of kaempferol with rhamnose and glucose [9], [11]. According to Folorunso et al. [15] and Moyo et al. [10], Moringa oleifera leaves are also rich in other antioxidant substances such as beta-carotenes (average of 174 mg/kg), vitamin C (average of 7231 mg/kg), and vitamin E (1100 mg/kg). Razis et al. [16] reviewed the potential health benefits of Moringa oleifera, emphasizing its nutritional content and its antioxidant and antimicrobial properties.

Moringa leaves are low in calories, making them an ideal dietary choice for individuals struggling with obesity. Traditionally, these leaves have been used to treat various ailments and are also popular in the cosmetic industry [14], [17], [18]. The high antioxidant levels in Moringa leaves exceed those found in most other ingredients. The presence of folic acid and unsaturated fatty acids in these leaves underscores their potential to address malnutrition. Moringa leaves are often referred to as a "superfood" or "miracle tree" due to the rich nutritional content present in every part of the plant, including the leaves, bark, flowers, fruit, and roots [4], [19]. In developing countries, Moringa leaves are extensively used in food fortification because of their ability to boost the immune system against diseases and toxins [20].

Numerous studies have demonstrated the potential of Moringa leaves. Suhaemi et al. [21] found that adding Moringa leaf flour to nuggets enhances crude protein content while lowering crude fat and total cholesterol levels. Similarly, research by Awi et al. [22] showed that Moringa leaves can serve as a nutritional supplement in the production of salacca jam. The calcium content in Moringa leaf powder exceeds that of fresh leaves, surpassing 400 mg. Additionally, Moringa leaf powder is an effective substitute for iron tablets in treating anemia [23]. Kasolo et al. [7] concluded that Moringa leaves hold significant promise for combating malnutrition due to their rapid growth and ease of cultivation.

Moringa leaves are commonly used as a traditional medicinal plant, often consumed when someone is ill [24], typically in the form of capsules or herbal tea. This limits their consumption and accessibility to meeting the nutritional needs of all groups. Research by Yanti and Nofia [25] indicates that consuming boiled Moringa leaves can impact blood pressure in individuals with hypertension due to their high sodium content. Moringa leaf powder can also be used as a supplement to enhance the nutritional value of food products. Mubarokah and Sumardi [26] innovatively created catfish floss using Moringa leaves, which was found to meet the protein needs of children aged 0-6 years. Food products incorporating Moringa leaves as the main ingredient show increased protein, fiber, nutrient, and antioxidant content. Additionally, consuming an appropriate amount of Moringa leaves has been proven safe [20], [27]. Coello et al. [28] introduced a snack bar formulated with 18% Moringa leaves, serving as a source of protein and micronutrients. Asensi et al. [29] reported that Moringa oleifera is predominantly used in meat, bread, and biscuits products, serving nutritional, industrial, and preservative functions, respectively. Therefore, there is a need for processed products that can reach a wider audience and are easy to consume. Sengev et al. [30] fortified wheat flour bread with 5% Moringa leaves and found a significant increase in protein by 54% and crude fiber content by 56%. Tortilla chips fortified with 1-5% Moringa leaf flour showed higher protein and lipid content. The total phenolic content and antioxidant activity also were significantly improved [31]. Due to their high nutritional value, Moringa leaves help prevent malnutrition and can be used as functional foods because of their high antioxidant content [14], [32].

Despite their nutritional value, Moringa leaves are often less preferred due to their unpleasant aroma. This aroma is attributed to several secondary metabolites, including saponins, tannins, and phytic acid. Saponins impart a bitter taste and possess foaming properties that can affect consumer acceptance of Moringa-based food products. Doerr et al. [33] identified glucosinolates in Moringa leaves as the compounds responsible for their bitter flavor. Consequently, Moringa leaves must undergo a blanching process before further processing. Blanching is a brief heat treatment applied to fruits and vegetables at specific temperatures [34] and durations to retain color and deactivate enzymes that alter color and aroma.

Blanching has been shown to enhance the availability of iron and antioxidant content in Moringa leaves, according to Yang et al. [35]. Fresh Moringa leaves contain nearly 75% moisture content [24]. To preserve nutrients without compromising quality, Moringa leaves can be dried in an oven at low temperatures. Oven-dried Moringa leaves retain more nutrients compared to freezedried leaves. Drying can be accomplished using economical household equipment such as stoves, ensuring a sustainable supply of Moringa leaf nutrients [36]. Commercial drying of Moringa leaves is conducted for microbial decontamination, reducing packaging and carriage costs, and extending shelf life [37], [38]. Ali et al. [24] found that drying in an oven at 50°C effectively preserves the nutrients in Moringa leaves. Another approach is to use additional ingredients like dried shrimp, which can mitigate the undesirable taste and odor of Moringa leaves while providing additional nutritional benefits [39].

Technology for processing raw materials into consumable products is an important part of the agroindustry sector, such as processing coffee [40], cocoa [41], [42] and various other agricultural products. This research builds on the previous study, which resulted in the creation of the first product prototype: Moringa flakes with the addition of dried shrimp [39]. The current research aims to develop Moringa flakes with the addition of dried seaweed as a derivative product of Moringa leaves. This new product is designed to be consumable by all groups. Additionally, it is expected to provide good economic value, enhance competitiveness, and make a positive contribution to the food and health industries. As consumers increasingly seek food products with high dietary value and additional health benefits [31].

2. PRELIMINARIES

2.1. MATERIALS AND APPARATUS

2.1.1. MATERIALS

This study utilizes Moringa leaves obtained from Maguwoharjo, Sleman, along with dried seaweed (nori) as primary components. Additional ingredients comprise fried garlic, fried shallots, chili powder, black pepper, salt, and monosodium glutamate as a flavor enhancer.

2.1.2. APPARATUS

The equipment employed in this study comprises a food dehydrator for drying, Tyler sieves of 20, 30, and 40 mesh sizes, a food chopper, a frying pan, a stove, and various glassware.

2.2. METHODS

2.2.1. PREPARATION

All required equipment and materials for the research were prepared, covering the primary raw ingredients and supplementary components for product development.

2.2.2. PRODUCTION

The production process involved the following steps: Moringa leaves were prepared and then blanched at temperatures of 70°C, 80°C, and 90°C for 5 minutes. After blanching, the Moringa leaves were dried for 10 hours at 60°C using a food dehydrator. The dried Moringa leaves, and nori was then reduced in size using a food chopper and sieved with Tyler sieves of -20+30 mesh and -30+40 mesh sizes. The supporting ingredients also underwent size reduction and sieving with a -20+30-mesh sieve. Fried shallots and fried garlic were mixed with chili powder, black pepper, salt, and flavor enhancers. The dried Moringa leaves, nori, and supporting ingredients were then mixed and roasted for 10 minutes. Finally, the product was cooled to room temperature before analysis and storage.

2.2.3. RESEARCH VARIABLE

The independent variables in this research are the blanching temperature and the amount of added nori. The blanching temperature variable consists of three levels: 70°C, 80°C, and 90°C. The same number of levels applies to the amount of added nori, which are 5%, 10%, and 15%. This results in a total of 9 treatment samples. Additionally, a control sample is created, which is Moringa flakes without any added nori.

2.2.4. PRODUCT ANALYSIS

The analyses performed on this research product were antioxidant activity testing using 2,2-diphenyl-1-picrylhydrazyl (DPPH) [43].

2.2.5. DATA ANALYSIS

The data analysis of the research results was carried out using statistical software SPSS version 27, JASP, and MATLAB. The analysis methods included: a T-test to statistically determine the differences between the control sample and the treatment samples for each analyzed parameter of the product [44] and Two-way ANOVA to assess the effect of the levels of each research variable on the analyzed product parameters, with statistical significance set at $p \leq 0.05$ and Tukey's post-hoc test used to establish and separate means.

3. MAIN RESULTS

To determine the effect of adding nori on the antioxidant activity of the product, a t-test was performed to assess the significance of the differences between the treated samples and the control samples, which consisted of moringa flakes without added nori.

Table 1. T-test of Antioxidant Activity

Analysis	t	df	p	Mean Difference
Antioxidant Act. [%]	5.294	17	5.950e-5*	12.246

*The mean difference is significant at the 0.05 level

The results from Table 1 indicate a significant difference between the sample's antioxidant activity and the control sample, with the actual mean being significantly lower than 76.6%. The mean antioxidant activity and standard deviation for each condition are summarized in Table 2.

Table 2. Result of Antioxidant Activity

Blanching Temperature (°C)	Nori Content (%)	Antioxidant Act. (%)
70	5	68.605±0.26
70	10	45.695±1.43
70	15	71.975±1.49
80	5	68.230±1.20
80	10	60.330±3.06
80	15	69.850±4.49
90	5	70.275±1.09
90	10	50.505±0.22
90	15	73.720±0.06

At a blanching temperature of 70°C, antioxidant activity ranges between 45.695% and 71.975%, with the greatest consistency observed at 5% nori content. Based on Table 6, for a blanching temperature of 80°C, there is greater variability in antioxidant activity, particularly at 10% nori content, which shows the highest standard deviation of 3.069. Antioxidant activity demonstrates high consistency at 90°C with 15% nori content, suggesting that this combination may be optimal for achieving high and stable antioxidant levels. Significant decreases in antioxidant activity at 10% nori content across all blanching temperatures emphasize the need to avoid this nori content level to maintain higher antioxidant levels. These findings can be valuable for developing products with enhanced nutritional benefits. To examine the effects of blanching temperature, nori content, and their interaction, ANOVA analysis was conducted. The result is presented in Table 3.

Table 3. ANOVA of Antioxidant Activity

Cases	Sum of Squares	df	Mean Square	F	p
Blanching Temp.	51.155	2	25.577	6.273	0.020*
Nori Content	1358.279	2	679.140	166.569	7.766e-8*
Blanching Temp. ✻ Nori Content	191.178	4	47.794	11.722	0.001*
Residuals	36.695	9	4.077		

*The mean difference is significant at the 0.05 level

Table 3 shows that blanching temperature has a statistically significant effect on antioxidant activity ($p<0.05$). Similarly, nori content has a highly significant effect on antioxidant activity ($p<0.001$), with a large F-value indicating a strong influence. The interaction between blanching temperature and nori content also significantly affects antioxidant activity.

The findings suggest that variations in nori content greatly influence the antioxidant properties of the product. Therefore, adjusting nori content can be a powerful method to enhance or modify antioxidant activity. While blanching temperature also affects antioxidant properties, its impact is less pronounced compared to that of nori content. The significant interaction ($p = 0.001$) between blanching temperature and nori content indicates that these two factors do not operate independently but instead work together to influence antioxidant activity.

The antioxidant activity of the samples is influenced by both blanching temperature and nori content, though the relationship between these variables and antioxidant activity is not straightforward. Generally, higher nori content appears to enhance antioxidant activity, particularly at the highest temperature tested (90°C). The variability in results, as reflected by the standard deviation in Table 2, indicates that further refinement and control of experimental conditions may be necessary to achieve more consistent outcomes.

Antioxidants, especially those found in plant-based foods, are susceptible to heat-induced degradation. As blanching temperatures rise, these compounds can break down, leading to a decrease in their effectiveness. Table 4 demonstrates a statistically no significant difference in antioxidant activity when the temperature is increased from 80°C to 90°C. This result is consistent with the findings of Wu et al. [45] and Oboh et al. [46], who reported that heat treatment can cause substantial reductions in antioxidant activity due to the degradation of heat-sensitive compounds like phenolics and flavonoids.

Following the ANOVA test, Tukey's post-hoc test was conducted to explore which specific group comparisons are driving the overall effect. The results are presented in Table 4 for blanching temperature and Table 5 for nori content.

Table 4. Tukey’s Post Hoc Test for Blanching Temperature to Antioxidant Activity

Blanching Temperature (°C)		Mean Difference	t	p_{tukey}
70	80	4.045	3.470	0.017*
70	90	2.742	2.352	0.099
80	90	-1.303	-1.118	0.528

*The mean difference is significant at the 0.05 level

Table 5. Tukey’s Post Hoc Test for Nori Content to Antioxidant Activity

Nori content (%)		Mean Difference	t	p_{tukey}
5	10	-16.860	-14.462	4.254e-7*
5	15	2.812	2.412	0.090
10	15	19.672	16.874	1.130e-7*

*The mean difference is significant at the 0.05 level

According to Table 4, the only statistically significant difference in antioxidant activity is observed between the blanching temperatures of 70°C and 80°C, where antioxidant activity increase as the temperature increases from 70°C to 80°C. No significant differences were noted between the other temperature comparisons, indicating that the impact of temperature on antioxidant activity might be more substantial at lower temperature ranges. This finding suggests that the critical temperature range for preserving higher antioxidant activity is around 70°C, with higher temperatures potentially diminishing the beneficial antioxidant properties of the product.

On the other hand, the results from Table 5 indicate that moderate nori content (10%) yields the lowest antioxidant activity, but further increasing the nori content to 15% leads to a significant increase in antioxidant activity.

The absence of a significant difference in antioxidant activity between 80°C and 90°C (as indicated in Table 4) suggests that the most substantial degradation of antioxidants occurs between 70°C and 80°C. Beyond this point, additional heating may not result in a noticeable reduction in antioxidant activity, as the most vulnerable compounds have likely already been degraded. This observation is supported by Xu et al. [47], who found that after a certain temperature threshold, further heating leads to a plateau in the reduction of antioxidant levels in plant-based foods.

The marked reduction in antioxidant activity as nori content rises from 5% to 10% suggests potential drawbacks of over-enriching food products with nori. This is consistent with Subbiah et al. [48] and Turkmen et al. [49], who found that excessive amounts of certain ingredients could diminish their bioactivity, likely due to compound interactions, increased oxidative stress, or degradation during processing [50], [51].

CONCLUSIONS

The study successfully demonstrates that through careful optimization of blanching temperature and nori content, it is possible to produce Moringa flakes that are rich in antioxidants. The results show that blanching temperature has a significant effect, while nori content plays a crucial role in enhancing color and preserving antioxidant activity. Specifically, keeping the blanching temperature at 70°C was found to be optimal for retaining antioxidant properties, as higher temperatures led to a significant decrease in antioxidant levels due to the degradation of heat-sensitive compounds. These findings underscore the importance of precise control over processing parameters to maximize antioxidant retention, ultimately leading to the successful development of antioxidant-rich Moringa flakes with enhanced marketability and nutritional benefits.

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Data supporting this multiyear study cannot be made available due to the study is still ongoing.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

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