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Optimization of Blanching Temperature and Nori Incorporation in the Production of Moringa oleifera-Based Food Seasoning

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Abstract. *The utilisation of moringa leaves as a functional food ingredient is constrained by nutrient losses during thermal processing and limited sensory acceptability due to undesirable flavour characteristics. Optimising blanching conditions while incorporating umami-rich nori is therefore essential to improve antioxidant retention, nutritional quality, and consumer acceptance of moringa-based seasonings. This study aimed to optimise blanching temperature and nori incorporation in the formulation of moringa flake (Bon Kelor), a functional food seasoning. A factorial experimental design was employed with three blanching temperatures (70°C, 80°C, and 90°C) and three levels of nori (5%, 10%, and 15%). Analyses included antioxidant activity (DPPH), proximate composition, sodium content, and hedonic sensory evaluation. The results showed significant effects of both blanching and nori concentration on antioxidant activity, macronutrient levels, and organoleptic properties ($p < 0.05$). The best formulation was obtained at 90°C with 15% nori, featuring high antioxidant activity (73.72%), protein (18.34%), and energy (370.39 kcal/100 g). The by-difference method revealed increased carbohydrate content with nori addition, attributed to water-soluble polysaccharides. Sensory analysis confirmed high panellist acceptance for colour, aroma, and taste. Blanching enhanced nutrient retention, reduced moisture, and improved flavour. In summary, combining thermal treatment with seaweed enrichment offers a valuable strategy to produce nutritious and acceptable moringa-based food products.*

Keywords: *Antioxidant Activity; Blanching Temperature; Functional Food; Moringa Flake; Nori Enrichment.*

Type of the Paper: Regular Article.

1. Introduction

Moringa oleifera is a perennial shrub that can grow to a height of 7 to 11 metres. It thrives across a broad range of altitudes, from lowland areas up to approximately 700 metres above sea level. This wide adaptability enables the plant to be cultivated under diverse environmental conditions throughout Indonesia [1]. *Moringa oleifera* is wellknown for its remarkable nutritional and functional properties. Despite the abundance and nutritional potential of moringa in Indonesia, public awareness and utilisation remain low. Most uses are limited to traditional medicine or herbal teas, which narrows their accessibility and limits their nutritional impact on the general population [2]. One promising strategy to enhance its use involves processing leaves into semi-finished products, such as moringa leaf powder. This powder can serve as a nutritious base ingredient for various innovative food and beverage products with substantial economic value. Consequently,

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processing moringa leaves into powder not only adds value but also contributes to the diversification of nutrient-dense food products [3].

Moringa oleifera is often referred to as the 'tree of life' due to its rich chemical composition, which encompasses over a hundred bioactive compounds—including alkaloids, flavonoids, anthraquinones, vitamins, glycosides, and terpenes—alongside unique isolates such as muramoside A&B and niazimin A&B. These compounds have been shown to exert antioxidant, anticancer, antihypertensive, hepatoprotective, and nutritional activities [4]. Despite this extensive phytochemical profile and a long history of traditional use, the scientific adoption and commercialization of moringa remain limited. This research therefore focuses on processing moringa leaves into a value-added seasoning (Bon Kelor), using blanching to preserve heat-sensitive bioactives while enhancing flavour and nutritional synergy through the incorporation of nori as a natural umami-rich additive.

In Indonesia, seaweed is predominantly used as a source of hydrocolloids such as agar, carrageenan, and alginate—essential compounds widely employed in both food and non-food industries. Seaweed is a highly valuable biological resource with vast potential across numerous sectors. One species with promising applications is *Ulva lactuca* L., commonly known as sea lettuce. Belonging to the green algal group (Chlorophyta), *Ulva lactuca* grows abundantly in various aquatic ecosystems in Indonesia, including coastal, marine, brackish, and rocky environments. Natural populations are especially abundant along coastlines such as Pidakan Beach in Pacitan, East Java, and Kukup Beach in Gunung Kidul, Yogyakarta [5].

Blanching is a thermal pre-treatment process commonly applied before drying, particularly in fruit and vegetable processing. Typically performed at temperatures ranging from 75°C to 95°C, the primary objective of blanching is to inactivate enzymatic activities that may lead to discolouration, texture degradation, and off-flavours. This step is essential for maintaining the quality and stability of food products. In the case of moringa leaf powder production, blanching is used not only to inactivate degradative enzymes but also to reduce microbial load, accelerate drying, and eliminate undesirable raw leaf odour [6].

Previous studies have reported that thermal treatments significantly affect the quality of moringa leaves. Specifically, Wickramasinghe et al. [7] demonstrated that steam blanching for three minutes effectively preserves the vibrant green colour and minimises the loss of ascorbic acid, which is crucial for sensory appeal and nutritional integrity. Beyond basic nutrients, Moringa oleifera is recognised for its complex phytochemical profile. As reviewed by Pareek et al. [4], these leaves serve as a potent source of bioactive compounds, including flavonoids (such as quercetin and kaempferol) and phenolic acids, which contribute to their significant pharmacological activities and antioxidant capacity. To complement these properties, this study incorporates nori (*Ulva lactuca L.*) as a functional ingredient. According to Peñalver et al. [8], seaweeds are not only rich in essential minerals and vitamins but also contain unique polysaccharides and polyphenols that enhance the health-promoting properties of food products. The synergy between moringa's bioactive profile and nori's nutritional density provides a robust basis for developing a high-value functional seasoning.

In this study, a moringa-based seasoning (Bon Kelor) was developed using blanching treatments at varying temperatures of 70, 80, and 90°C to evaluate the heat tolerance of moringa leaves. This research builds upon a previous study by Wadjong et al. [9] that used dried shrimp (ebi) as an additive at concentrations of 10%, 20%, and 30% to enhance the savory (umami) profile and mask the inherent 'grassy' aroma of moringa leaves. Their findings indicated that while dried shrimp significantly improved consumer preference and protein content, the optimization of blanching time was critical to maintaining the final product's quality. Building upon this concept, the present study introduces nori (*Ulva lactuca L.*) as an alternative natural umami agent. Unlike animal-based additives, nori offers a unique combination of marine polysaccharides and antioxidants, providing a distinct functional dimension to the seasoning formulation.

Moreover, blanching—applied as a key pre-treatment step at three temperature levels (70, 80, and 90°C)—was employed, as temperature variation is known to affect the retention of heat-sensitive nutrients in moringa leaves [10]. Recent research has also demonstrated that blanching can modify the physicochemical and mineral profiles of seaweeds, thereby influencing both nutritional value and sensory characteristics [11]. By optimising these parameters, this research aims to develop a nutrient-dense, antioxidant-rich, and organoleptically acceptable moringa–nori seasoning (Bon Kelor) suitable for a broad range of consumers. Although the nutritional and functional potential of *Moringa oleifera* for food product development has been widely recognised, studies integrating optimised thermal processing with seaweed enrichment to enhance antioxidant activity, nutritional density, and sensory quality in moringa-based seasonings remain limited [12].

The purpose of this study is to evaluate and optimise the effects of blanching temperature and nori incorporation on the physicochemical, antioxidant, and sensory characteristics of a moringa-based food seasoning.

2. Materials and Methods

2.1. Equipment and Materials

The equipment used in this study included an analytical balance, a blender, a sieve, and a stove for the primary processing of samples. Additional instruments used for laboratory analyses comprised an oven, porcelain crucibles, a desiccator, beakers, volumetric flasks, Kjeldahl flasks, drop pipettes, volumetric pipettes, burettes, and Erlenmeyer flasks. Each piece of equipment was used in accordance with the specific requirements of the respective analytical procedures.

The main raw materials used in the formulation of Bon Kelor seasoning included moringa leaves (*Moringa oleifera*), dried seaweed (nori), shallots, garlic, chilli, sugar, salt, and flavour enhancers. Reagents and chemicals used for laboratory analysis consisted of Bon Kelor samples, PA-grade methanol, 2,2-diphenyl-1-picrylhydrazyl (DPPH), distilled water (aquadest), 5% potassium chromate (K_2CrO_4), and 0.1 N silver nitrate ($AgNO_3$), all provided by CV Chem-Mix Pratama, Yogyakarta.

2.2. Experimental Design

The experimental design used in this study followed a completely randomized design (CRD) involving two independent variables: blanching temperature and nori content. The first factor, nori content, consisted of three treatment levels: 5% (N1), 10% (N2), and 15% (N3), corresponding to 5 g, 10 g, and 15 g of dried nori, respectively. The second factor, blanching temperature, also consisted of three levels: 70°C (S1), 80°C (S2), and 90°C (S3).

Each combination of the two factors was tested in duplicate, resulting in a total of 18 experimental units. This factorial design allowed for the evaluation of both the main effects and interaction effects of blanching temperature and nori concentration on the physicochemical and sensory characteristics of the developed Bon Kelor product.

2.3. Research Procedure

2.3.1. Moringa Leaf Processing

The preparation of Bon Kelor began with the selection of fresh moringa leaves (Moringa oleifera), identified by their dark green colour as an indicator of quality [13]. The leaves were carefully separated from the stems and sorted to ensure uniformity and to exclude any damaged material. After sorting, the leaves were thoroughly washed to remove any dirt or debris.

Next, the leaves were blanched at predetermined temperature levels: 70°C (S1), 80°C (S2), and 90°C (S3), according to the experimental treatment design. After blanching, the leaves were drained and then oven-dried for 6 to 10 hours until they reached a brittle texture suitable for manual crushing. Once dried, the leaves were sifted using a -30+40-mesh sieve, and only the fraction that passed through 30 mesh but was retained on 40 mesh was used for further formulation.

2.3.2. Nori Processing

Dried seaweed (nori) was coarsely ground using a blender and subsequently sieved using the same mesh system. The fraction retained between 30 and 40 mesh was selected for incorporation into the seasoning formulation.

2.3.3. Seasoning Ingredient Preparation

The additional ingredients consisted of 15 g of garlic, 25 g of shallots, and 4 g of chilli powder. The garlic and shallots were deep-fried until dry and crisp, then coarsely ground and sieved using a -30+40-mesh sieve, with the retained fraction used in the final mix. The resulting mixture was then combined with chilli powder, ground pepper, and salt according to the requirements of the formulation [13].

2.3.4. Formulation of Bon Kelor Seasoning

To produce Bon Kelor, 50 g of dried moringa leaf powder, 50 grams of seasoning ingredients, and nori at the designated treatment levels (N1: 5 g, N2: 10 g, N3: 15 g) were used. The mixing process began with the moringa leaf powder, followed by the addition of nori and the seasoning components. The entire mixture was pan-roasted for approximately 5 to 7 minutes to enhance flavour integration and reduce moisture content. After roasting, the product was allowed to cool to room temperature before being packaged and subjected to further analysis.

2.4. Analytical Procedures

2.4.1. Antioxidant Activity Analysis

The antioxidant activity of the Bon Kelor samples was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. Approximately 1 g of sample was extracted using PA-grade methanol, and the extract was reacted with a DPPH solution. The mixture was incubated in the dark at room temperature for 30 minutes. The absorbance was measured at 517 nm using a UV-Vis spectrophotometer. The percentage of antioxidant activity was calculated by comparing the absorbance of the sample against that of a control solution [14].

While the DPPH assay provides a reliable and rapid screening of the free radical scavenging capacity of Bon Kelor, it is important to acknowledge that the measured antioxidant capacity can vary depending on the specific assay employed. The DPPH method primarily measures the ability of compounds to transfer hydrogen atoms or electrons in an organic solvent system (methanol). However, it may not fully capture the activity of lipophilic antioxidants or those acting through different mechanisms, such as metal chelation or oxygen radical absorbance [7]. Therefore, the results reported here represent a specific chemical response under the test conditions employed.

2.4.2. Sodium Chloride (NaCl) Content Analysis

The titrimetric method was used to determine the NaCl content. A known weight of the sample was homogenised in distilled water, and 5% potassium chromate solution was added as an indicator. The solution was titrated with 0.1 N silver nitrate ($AgNO_3$) until a reddish-brown endpoint appeared, indicating the formation of silver chromate. The NaCl concentration was then calculated based on the volume of $AgNO_3$ used in the titration [15].

2.4.3. Proximate Composition Analysis

The proximate composition including moisture, ash, protein, fat, and crude fibre, was analysed in accordance with Association of Official Analytical Chemists (AOAC) methods:

a. Moisture content was determined by oven-drying the sample at 105°C until a constant weight was achieved.
b. Ash content was measured by incinerating the sample in a muffle furnace at 550°C.
c. Crude protein was analysed using the Kjeldahl method, involving digestion, distillation, and titration, followed by conversion using a nitrogen-to-protein factor.
d. Fat content was determined via Soxhlet extraction using a suitable organic solvent (e.g., diethyl ether).
e. Crude fibre was measured using acid and alkaline digestion methods, with residues incinerated to determine the fibre mass.
f. Carbohydrates were measured by the by-difference method. The carbohydrate value represents a calculated remainder rather than a direct measurement. Consequently, any cumulative analytical errors in the measurement of moisture, ash, protein, and fat are reflected in the final carbohydrate percentage.

2.4.4. Energy Content (Caloric Value)

The total energy content of the samples was calculated using the Atwater general factor system, based on the macronutrient composition obtained from the proximate analysis [16].

2.4.5. Sensory Analysis

The sensory evaluation of the Bon Kelor (moringa flake) samples was conducted to assess consumer acceptability based on three key attributes: colour, taste, and aroma [17]. The evaluation was performed using the hedonic test method, following standard sensory analysis protocols for food products.

A total of 20 untrained panellists, familiar with food products but not professionally trained in sensory science, were recruited for the analysis. Each panellist was provided with coded samples representing the various treatment combinations (blanching temperature and nori concentration). The samples were presented in randomised order to avoid order bias. Panellists rated their preference for each attribute (colour, taste, and aroma) independently. The hedonic scale used was a 7-point scale to assess the panellists' preference for colour, aroma, and taste. The scale was anchored as follows: 1 = dislike extremely; 2 = dislike; 3 = dislike slightly; 4 = neither like nor dislike; 5 = like slightly; 6 = like very much; and 7 = like extremely. A score of 4 represented the threshold of acceptance, while scores above 4 indicated positive consumer preference.

3. Results and Discussion

Based on Table 1, the incorporation of nori into moringa flakes significantly enhanced the antioxidant activity, reaching up to 73% in the sample blanched at 90°C with 15% nori addition. This result highlights the synergistic effect of blanching and nori enrichment on the antioxidant capacity of the product. The observed increase is consistent with previous findings by Afrin et al. [18], who reported that nori exhibits high intrinsic antioxidant activity, ranging between 50% and 75%. Therefore, its inclusion contributes additional bioactive compounds, particularly phenolics and flavonoids, to the moringa-based formulation.

Moreover, this supplementation complements the already substantial antioxidant profile of moringa leaves, which has been reported to range from 42% to 60% [19]. The combined presence of antioxidants from both ingredients likely contributes to the enhanced radical scavenging activity observed in this study, especially under high-temperature blanching conditions that may facilitate the release of bound antioxidant compounds from the plant matrix. In *moringa oleifera* leaves, a significant portion of phenolic compounds is naturally esterified or bound to structural polysaccharides (cellulose and hemicellulose) and proteins within the cell wall [7]. High-temperature blanching conditions facilitate the release of these bound antioxidant compounds by breaking the covalent and non-covalent bonds that anchor them to the cell matrix, thereby increasing their solubility and bioavailability in the extract [20].

However, the absence of a negative control group (e.g., unblanched moringa or formulations with 0% nori) represents a limitation in providing a baseline for the absolute impact of these factors. Future research should incorporate such controls to quantify more precisely the magnitude of change in antioxidant retention and umami enhancement compared with the raw, untreated plant matrix.

Table 1. Physiochemical analysis of moringa flakes incorporated with nori.

Blanching Temp.[ºC]	Nori [%]	Antioxidant Act. [%]	Sodium [%]	Moisture [%]	Ash [%]	Protein [%]	Fat [%]	Crude Fibre [%]	Carbohydrate [%]	Energy [kcal.100g^{-1}]
70	5	68.61	1.36	6.46	6.51	16.08	17.02	22.77	31.15	342.66
80	5	68.23	1.22	6.62	5.57	15.79	18.17	19.23	34.61	365.18
90	5	70.28	1.30	6.58	5.32	16.61	18.34	21.56	31.59	358.38
70	10	45.70	1.43	7.07	6.67	15.23	16.22	22.62	32.19	335.73
80	10	60.33	1.25	6.11	5.46	16.80	18.34	19.26	34.03	368.79
90	10	50.51	1.28	6.31	5.90	17.33	19.13	20.56	30.77	365.69
70	15	71.97	1.38	7.27	6.45	16.13	17.66	18.29	34.22	360.42
80	15	69.85	1.29	6.48	5.86	17.49	18.27	19.51	33.05	366.25
90	15	73.72	1.32	3.76	5.83	18.34	18.58	21.28	32.20	370.39
SNI 9228:2023				max 8	max 10	15-19				

All moringa flake samples produced in this study met the Indonesian National Standard (SNI 9228:2023) for dried moringa leaves, despite undergoing thermal processing via blanching and roasting. Among all treatments, the sample blanched at 90°C with 15% nori addition yielded the optimal nutritional profile, characterised by the lowest moisture content and the highest levels of antioxidant activity, protein, and energy. The retention of these nutrients post-processing highlights the feasibility of this product as a nutritious food alternative, particularly beneficial for children, who require high-density functional foods for optimal development. Furthermore, the elevated antioxidant activity suggests a functional role in counteracting free radicals, supporting the product's potential as a natural antioxidant source.

Fig. 1. Moringa flake (Bon Kelor) product incorporated with nori.

A sensory evaluation was also conducted on selected samples, assessing colour, taste, and aroma attributes. The visual appearance of the final moringa flake (Bon Kelor) seasoning, which incorporates nori to achieve a uniform and appealing texture is shown in Fig. 1. As presented in Table 2, the highest panellist preference scores were observed in the same treatment group (90°C blanching and 15% nori), achieving an average overall acceptance score of 6.58 out of 7. The blanching process was effective in preserving the natural green colour of moringa leaves through enzyme inactivation, which prevented enzymatic browning. Additionally, blanching contributed to the reduction of undesirable volatile compounds, thus minimising the characteristic 'grassy' odour of moringa [9].

The inclusion of nori not only enhanced the flavour complexity but also introduced marine umami notes, effectively masking any residual off-flavours. The colour similarity between dried moringa and nori produced a visually appealing deep green tone, further contributing to panellist acceptance. This mutual enhancement between moringa and nori components demonstrates a synergistic formulation effect, reinforcing the product's sensory appeal and functional value.

Table 2. Sensory analysis results.

Blanching Temp. [ºC]	Nori [%]	Colour	Aroma	Taste	Average
70	5	5.43	5.58	5.63	5.54
80	5	5.68	5.90	5.83	5.80
90	5	5.80	6.03	6.00	5.94
70	10	5.58	5.83	5.35	5.58
80	10	5.73	6.00	5.85	5.86
90	10	5.98	6.45	5.98	6.13
70	15	5.85	5.90	5.38	5.71
80	15	5.55	5.93	5.65	5.71
90	15	6.53	6.70	6.53	6.58

To determine the effects of blanching temperature and nori concentration on the physicochemical and sensory characteristics of the Bon Kelor product, a two-way analysis of variance (ANOVA) was performed. The summary of the ANOVA results is presented in Table 3. For response variables showing statistically significant differences ($p < 0.05$), Duncan's multiple range test (DMRT) was subsequently conducted as a post hoc analysis to identify which treatment levels differed significantly. The results of the Duncan test are presented in Table 4 for the effect of blanching temperature and in Table 5 for the effect of nori concentration.

As illustrated in Fig. 2, the interaction between blanching temperature and nori concentration had a noticeable influence on the antioxidant activity of Bon Kelor. Generally, higher blanching temperatures (90°C) were associated with an increase in antioxidant activity, particularly when combined with the higher nori concentration (15%). This suggests that thermal processing at elevated temperatures may enhance the release of antioxidant compounds, especially in formulations with abundant phenolic sources such as nori [21].

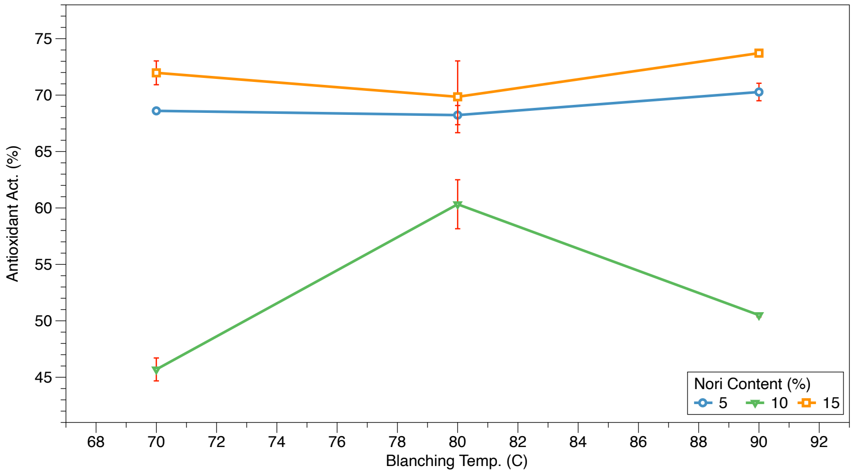

Fig. 2. Antioxidant activity of moringa flake along blanching temperature variation.

However, an unexpected decrease in antioxidant activity was observed in the 10% nori sample at 90°C, diverging from the overall trend. This reduction may be attributed to compound interactions or thermal degradation affecting extractability, as previously discussed.

Overall, samples containing 15% nori consistently yielded the highest antioxidant activity, especially when subjected to 90°C blanching, indicating a synergistic effect between thermal treatment and bioactive compound availability [22]. In contrast, lower nori concentrations (5% and 10%) demonstrated less consistent results, with antioxidant activity varying more irregularly across temperature treatments. This instability may reflect the limited buffering capacity of antioxidant systems at lower additive levels when exposed to heat. These results underscore the importance of optimising both ingredient concentration and processing conditions to maximise functional properties such as antioxidant capacity in value-added food products.

Table 3. The two-way ANOVA results.

Analysis	Antioxidant Act.	Sodium	Moisture	Ash	Protein	Fat	Crude Fibre	Carbohydrate	Energy	Sensory - Colour	Sensory - Aroma	Sensory - Taste
Blanching Temp.	<0.01**	0.064	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	0.002**	<0.01**	0.295
Nori	0.02*	0.819	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**
Interaction	<0.01**	0.884	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	0.004**	0.008**	0.009**

Notes: * = variable shown significant difference; ** = variable shown very significant difference

Table 4. Duncan's Multiple Range Test post hoc for blanching temperature.

Blanching Temp. (ºC)		Antioxidant Act.	Sodium	Moisture	Ash	Protein	Fat	Crude Fibre	Carbohydrate	Energy	Sensory - Colour	Sensory - Aroma	Sensory - Taste
70	80	*	-	*	*	*	*	*	*	*	-	*	-
70	90	*	-	*	*	*	*	-	*	*	*	*	-
80	90	-	-	*	-	*	*	*	*	-	*	-	-

Notes: * = variable shown significant difference; - = variable shown no significant difference

Table 5. Duncan's Multiple Range Test post hoc for nori content.

Nori (%)		Antioxidant Act.	Sodium	Moisture	Ash	Protein	Fat	Crude Fibre	Carbohydrate	Energy	Sensory - Colour	Sensory - Aroma	Sensory - Taste
5	10	*	-	-	*	*	-	*	-	-	-	*	*
5	15	*	-	*	*	*	*	*	*	*	*	*	*
10	15	*	-	*	-	*	*	*	*	*	*	*	*

Notes: * = variable shown significant difference; - = variable shown no significant difference

Aqueous processing enhances the release of antioxidant and phenolic compounds, suggesting strong potential for functional synergy when incorporated into plant-based food matrices [23,24].

According to the ANOVA results presented in Table 3, the sodium content of moringa flake products was significantly affected by both blanching temperature and nori concentration. As shown in Fig. 3, sodium levels decreased slightly when the blanching temperature was increased from 70°C to 80°C across all nori concentrations. This reduction may be attributed to the leaching of sodium into the blanching water, a phenomenon that becomes more pronounced at higher temperatures and with longer blanching durations.

Interestingly, a slight rebound in sodium content was observed at 90°C, which could be due to cellular breakdown and moisture loss, thereby concentrating residual sodium in the final product. This result suggests a complex interaction between leaching dynamics and solid concentration effects under high-temperature conditions.

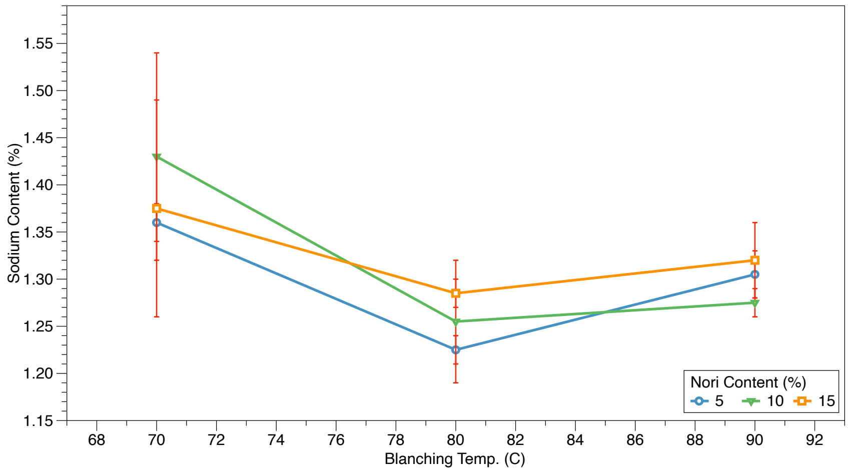

Fig. 3. Sodium content of moringa flake along blanching temperature variation.

In terms of nori concentration, increasing the proportion of nori from 5% to 15% led to a progressive rise in sodium content at all blanching temperatures. This trend is expected, given that nori is naturally rich in sodium—a key mineral in marine algae [25]. Thus, higher nori inclusion directly contributes to a greater overall sodium concentration in the product. These findings indicate that sodium content of the final product is influenced by both ingredient composition and processing conditions and should be carefully considered, particularly if the product is to be marketed as a functional food for populations requiring sodium control.

As shown in Table 4 and Fig. 4, increasing the blanching temperature had a significant effect on the moisture content of the moringa flake products. A consistent decrease in moisture content was observed with each increment in blanching temperature, with the most notable reduction occurring at 90°C, particularly in samples containing 15% nori. This is attributed to the intensified evaporation of water at higher temperatures, which facilitates greater moisture loss from the matrix during drying [26].

Nori, a dehydrated seaweed product, possesses a high water-binding capacity, especially at lower temperatures such as 70°C. However, at elevated blanching temperatures, the absorbed water in nori is rapidly volatilised, leading to a substantial decline in moisture retention at 90°C. This effect is magnified when higher proportions of nori are used, owing to the greater initial water uptake and subsequent loss during the heating and drying phases. The interaction between these two factors suggests that optimising blanching conditions is crucial for achieving desirable moisture levels in the final product, particularly for ensuring product stability, shelf life, and texture.

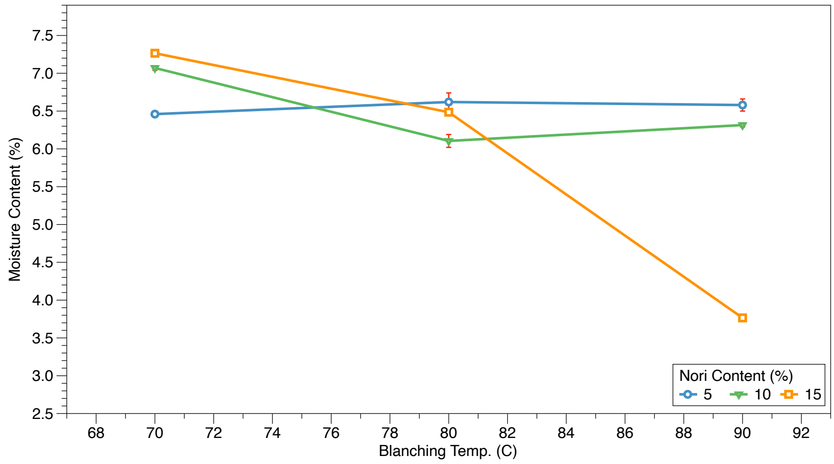

Fig. 4. Moisture content of moringa flake along blanching temperature variation.

The ash content of moringa flake products was significantly influenced by both blanching temperature and nori concentration, as shown in Fig. 5. Although blanching does not degrade minerals, elevated blanching temperatures can lead to the leaching of water-soluble minerals into the blanching medium, especially when the blanching is prolonged or involves a high water volume. This leaching effect can result in a reduction in total ash content, as part of the mineral fraction is lost during processing.

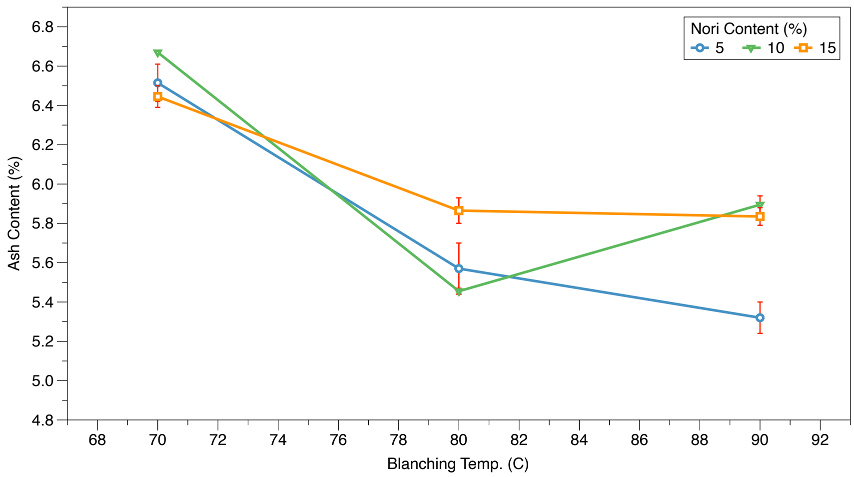

Fig. 5. Ash content of moringa flake along blanching temperature variation.

These findings are supported by Reis [27], who demonstrated that higher blanching temperatures (e.g., 90°C) and longer durations promote the dissolution of essential minerals such as sodium and potassium into the blanching water, thereby reducing the residual mineral content of the processed product.

In contrast, the addition of nori significantly increased the ash content of the final product across all temperature levels. Nori is well documented as a mineral-rich seaweed, particularly abundant in elements such as calcium, magnesium, phosphorus, iron, iodine, and sodium. These minerals are thermally stable and not degraded during typical food processing conditions. Thus, higher concentrations of nori in the formulation result in a direct increase in ash content, reflecting the elevated total mineral content. This agrees with Premarathna et al. [28], who reported that edible seaweeds, including nori (*Porphyra spp.*), typically contain 10–15% ash by dry weight. Therefore, increasing the proportion of nori in food products can significantly enhance the mineral profile, improving nutritional quality without compromising heat-sensitive nutrients.

As illustrated in Fig. 6, the protein content of moringa flake products showed a clear increasing trend with both rising blanching temperatures and higher nori concentrations. Across all levels of nori addition (5%, 10%, and 15%), protein content increased progressively as the blanching temperature rose from 70°C to 90°C. This enhancement can be attributed to the naturally high protein content of nori, a seaweed known to contain between 25–50% protein by dry weight [29,30]. Therefore, increased inclusion of nori proportionally raised the total protein levels in the final product.

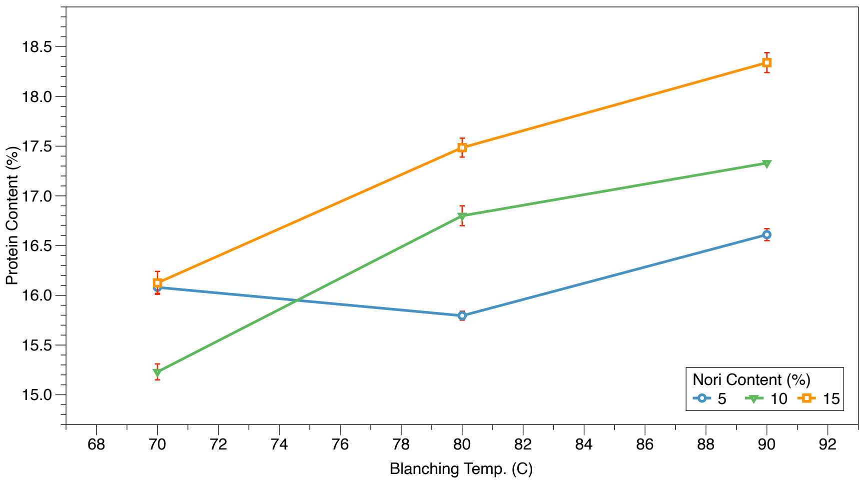

Fig. 6. Protein content of moringa flake along blanching temperature variation.

Although blanching is a thermal process that can cause protein denaturation, it does not necessarily reduce total protein content. According to Knez et al. [31], short-duration blanching at moderate temperatures is unlikely to cause significant protein loss. Instead, thermal denaturation of proteins can have beneficial effects, such as improving digestibility and bioavailability by unfolding protein structures, thereby enhancing enzymatic access during digestion. These results suggest that optimised blanching combined with protein-rich nori not only preserves the protein integrity of moringa flakes but may also improve their functional and nutritional value. This finding is particularly important for product development targeted at populations with higher protein requirements, such as children, vegetarians, and the elderly.

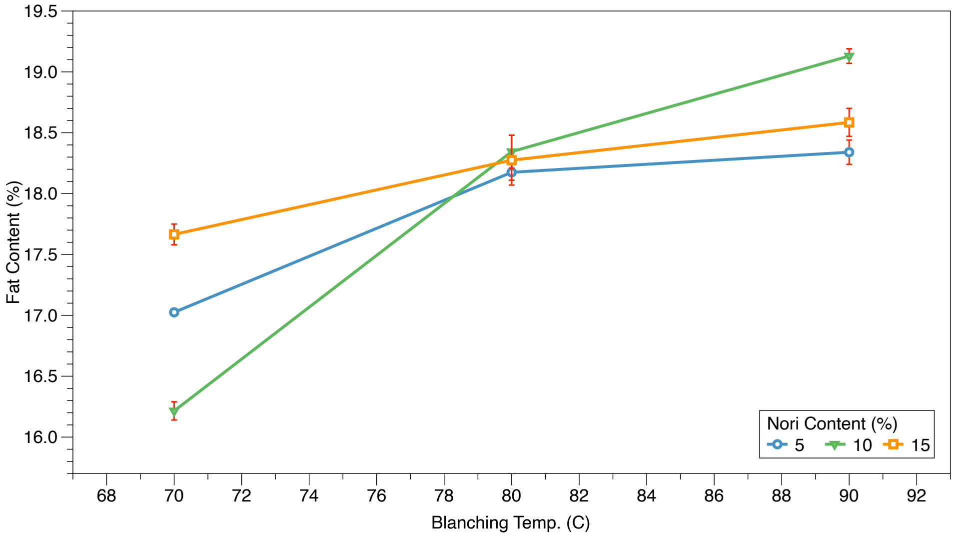

Fig. 7. Fat content of moringa flake along blanching temperature variation.

As shown in Fig. 7, the fat content of Moringa flake products increased with both elevated blanching temperatures and higher concentrations of nori. This rise in fat content is attributed to structural modifications in the cellular matrix during the blanching process, which enhances lipid release and affects the final fat composition of the product [27]. Blanching, particularly at higher temperatures, can disrupt cell wall integrity, thereby facilitating the extraction of lipids that might otherwise remain bound within the plant matrix. These findings are consistent with the report by Akomea-Frempong et al. [32], who demonstrated that high-temperature blanching increased the measurable fat content in various food products, including marine vegetables such as kelp. The same phenomenon appears to occur in this study, suggesting that thermal treatment plays a key role in enhancing lipid availability.

In addition, increasing the percentage of nori in the formulation significantly elevated the fat content of moringa flakes. Nori contributes naturally occurring lipids, including polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), both of which belong to the beneficial omega-3 fatty acid group. These essential fatty acids are known for their anti-inflammatory and cardioprotective properties and are rarely found in terrestrial plant sources [32]. Therefore, the observed increase in fat content reflects both the thermal effect of blanching and the nutritional contribution of nori. These results suggest that nori-enriched moringa flakes not only provide improved flavour and functional properties but may also serve as a plant-based source of essential fatty acids.

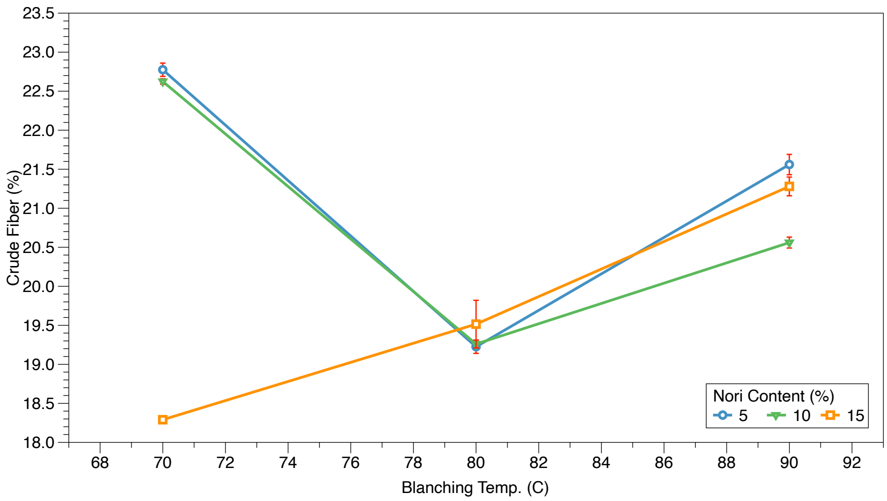

Fig. 8 Crude fibre content of moringa flake along blanching temperature variation.

The crude fibre content of moringa flake products was significantly influenced by both blanching temperature and nori concentration, as depicted in Fig. 8. A general decline in fibre content was observed with increasing blanching temperatures, particularly at higher nori concentrations (10% and 15%). This suggests that, although nori contributes dietary fibre to the product, high-temperature blanching may induce partial solubilisation or degradation of fibrous components, leading to reduced measurable fibre content. This observation aligns with earlier findings by Reis [27] and Osundunakin et al. [33] ,which report that thermal processing of vegetables and seaweeds can cause cell wall softening and loss of soluble dietary fibres into the blanching medium. The mechanical disruption of cell structures at elevated temperatures facilitates the leaching of soluble fibres, particularly pectins and hemicelluloses, thereby lowering the residual fibre measured post-processing.

Nonetheless, despite some loss due to blanching, nori itself is a rich source of dietary fibre, especially insoluble fibres such as cellulose and alginates. Thus, increasing the proportion of nori in the formulation resulted in a net increase in fibre content at all blanching temperatures. This highlights the dual influence of processing conditions and formulation strategy on the fibre profile of the final product. These results indicate that while blanching may reduce fibre content to some extent, incorporating high-fibre ingredients like nori can compensate for such losses and contribute to the dietary fibre enrichment of functional food products [34].

As shown in Fig. 9, the carbohydrate content of moringa flake products was significantly influenced by both blanching temperature and nori concentration. In this study, carbohydrate levels were determined using the by-difference method, a standard approach in proximate analysis, in which the carbohydrate content is estimated by subtracting the sum of moisture, protein, fat, ash, and fibre from 100% of the total composition. This method captures both structural carbohydrates and soluble polysaccharides, though it may also reflect shifts due to changes in other proximate components.

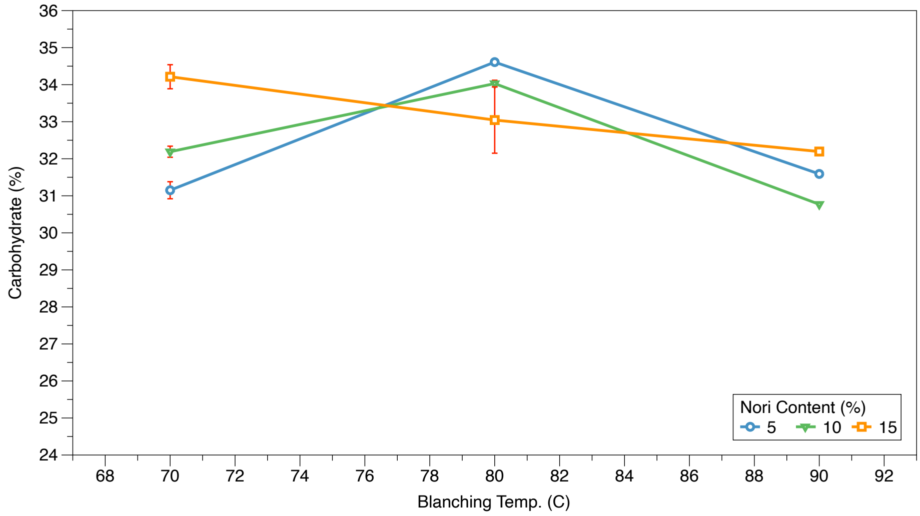

Fig. 9 Carbohydrate content of moringa flake along blanching temperature variation.

An increase in nori concentration from 5% to 15% resulted in a gradual rise in calculated carbohydrate content. This can be attributed to the polysaccharide composition of nori, which includes water-soluble compounds such as porphyran, ulvan, and rhamnose-rich polysaccharides. These components not only elevate the carbohydrate profile but also contribute functional bioactivities, particularly prebiotic effects that support gastrointestinal health [8].

Blanching temperature also played a role in carbohydrate dynamics. At moderate temperatures, blanching may improve the extractability and solubility of certain polysaccharides, thereby enhancing the apparent carbohydrate content. However, at higher blanching temperatures (e.g., 90°C), the potential for thermal degradation of labile sugars and leaching of water-soluble carbohydrates into the blanching medium becomes more pronounced [35,36]. This may explain the inconsistent fluctuations observed at higher temperatures for certain nori levels.

It is important to note that starch, while generally thermally stable, can undergo gelatinisation or structural alterations under heat, potentially affecting the by-difference calculation due to changes in moisture retention and fibre interaction. Thus, shifts in carbohydrate values under different treatments are partly indirectly influenced by the compositional changes in protein, moisture, and fibre fractions. Despite these variations, the inclusion of nori enhances the nutritional value of moringa flakes by contributing complex carbohydrates with functional potential, supporting their application as a fibre-rich, gut-friendly food supplement.

As presented in Table 4 and Table 5, blanching temperature and nori concentration significantly influenced the energy content of the moringa flake products ($p < 0.05$). An increasing trend in caloric value was observed in response to higher blanching temperatures and greater levels of nori addition, as illustrated in Fig. 10.

This increase in energy content is primarily associated with changes in proximate composition, particularly in protein, fat, and carbohydrate levels, which directly contribute to total caloric value. Blanching at elevated temperatures resulted in moisture reduction, which in turn concentrated the macronutrients per unit mass, thus enhancing energy density. Moreover, thermal treatment may improve the extractability and availability of energy-yielding compounds such as lipids and carbohydrates, thereby contributing to an increase in caloric content [27,37].

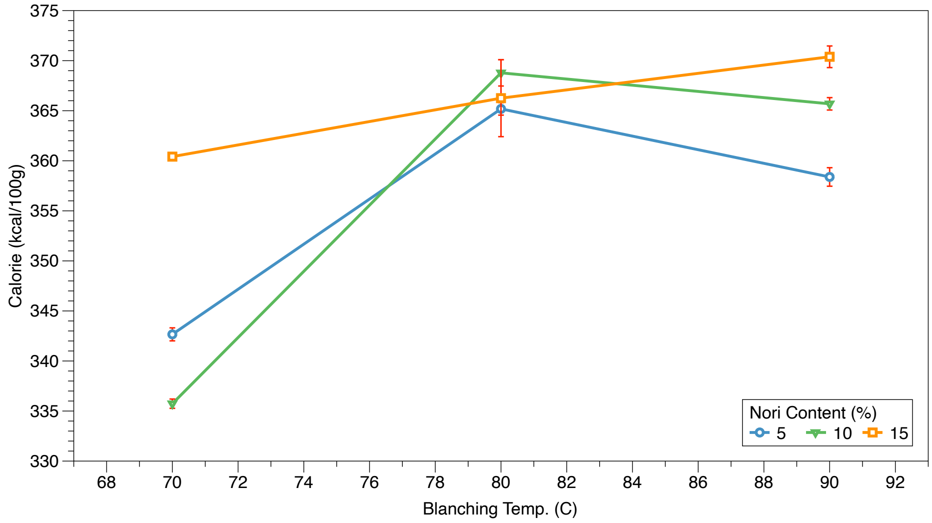

Fig. 10 Energy value of moringa flake along blanching temperature variation.

Nori is inherently rich in macronutrients, including essential fatty acids, complex carbohydrates, and high-quality protein, all of which contribute substantially to the total energy of the final product. As the percentage of nori increased from 5% to 15%, the cumulative effect of these macronutrients led to a marked elevation in the energy values of the moringa flakes [35,36].

Minimal thermal processing, such as blanching can significantly alter the physicochemical and sensory characteristics of seaweed-based ingredients, thereby influencing their suitability for food formulation [38].

These results suggest that the strategic combination of blanching optimisation and nori enrichment can be effectively used to develop nutrient-dense, high-energy food products suitable for dietary applications requiring enhanced caloric intake, such as for children, athletes, or individuals experiencing undernutrition.

4. Conclusions

This study demonstrates that blanching temperature and nori concentration significantly influence the physicochemical, antioxidant, and sensory properties of moringa-based seasoning. The optimal formulation, involving blanching at 90°C with 15% nori, achieved the highest antioxidant activity (73.72%), protein content (18.34%), and energy value (370.39 kcal/100 g), while also meeting the Indonesian National Standards (SNI 9228:2023) for dried moringa products. This combination effectively preserves bioactive compounds and maximises nutritional density through the addition of seaweed-based protein, polysaccharides, and essential fatty acids. Furthermore, this treatment yielded the highest consumer acceptance (6.58 out of 7.00), as blanching reduced the characteristic odour of moringa while nori contributed a desirable umami taste profile.

Despite these promising results, several limitations should be acknowledged. The absence of a negative control group (e.g., unblanched moringa or 0% nori) limits the quantification of absolute changes in antioxidant retention and sensory enhancement. Additionally, the DPPH assay captures only specific radical scavenging mechanisms, and the use of untrained panellists may introduce variability in sensory evaluation. Future research should incorporate appropriate controls, explore alternative blanching methods (e.g., steam blanching), and evaluate the long-term storage stability of the product. In vivo studies are also recommended to validate the functional health benefits of this moringa–nori seasoning.

Abbreviations

$AgNO_3$	Silver nitrate
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
Cal	Calorie
CRBD	Completely Randomized Block Design
DHA	Docosahexaenoic Acid
DMRT	Duncan’s Multiple Range Test
DPPH	2,2-Diphenyl-1-picrylhydrazyl
EPA	Eicosapentaenoic Acid
NaCl	Sodium chloride
PUFAs	Polyunsaturated Fatty Acids
SNI	Indonesian National Standard (Standar Nasional Indonesia)
UV–Vis	Ultraviolet–Visible (spectrophotometer)

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The datasets include raw physicochemical measurements, sensory evaluation scores, and statistical analysis outputs generated during the current study and are not publicly available due to institutional data management policies.

CRediT authorship contribution statement

Mohammad Prasanto Bimantio: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing original draft, Visualization. **Aap Hidayah Maesa:** Investigation, Methodology, Resources, Data curation, Writing data. **Reza Widyasaputra:** Supervision, Project administration, Validation, Writing and editing.

Declaration of Competing Interest

The authors of this manuscript declare no conflict of interest or competing interest.

Declaration of Use of AI in the Writing Process

The author(s) used Gemini during the preparation of this manuscript to improve grammar, paraphrase text, and translation. After using the tool/service, the author(s) carefully reviewed and edited the content and take full responsibility for the content of the publication.

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