

Nutritional and quality properties of nori snack derived from midin (*Stenochlaena palustris*)

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Abstract

This study explores the development of nori snacks from midin (*Stenochlaena palustris*) utilising hot-air drying technology. Midin, an edible fern abundantly found in Sarawak, Malaysia, holds significant potential for use in food products due to its health benefits and economic value. Despite this, its utilisation in food and beverages remains limited and unexplored. The objectives of this research were to determine the nutritional and quality properties of midin nori snacks. This study investigated the impact of varying amounts of midin and tapioca starch on the formulation of midin nori. Different formulations of midin nori snack were prepared, varying the amounts of midin (100 g, 95 g, 90 g, 85 g) and tapioca starch (0 g, 5 g, 10 g, 15 g). Formulations with the addition of tapioca starch (F1, F2 and F3) significantly ($p < 0.05$) have lower moisture, ash, fat and total dietary fibre content compared to the Control, while showing significant ($p < 0.05$) higher carbohydrate content. The water activity of the nori ranges from $0.47 \pm 0.02 a_w$ to $0.50 \pm 0.01 a_w$. Colour analysis showed consistent dark brown hues across all formulations. This study contributes to the exploration and utilisation of midin in the food industry, offering potential for the development of innovative snack products with enhanced nutritional.

1. Introduction

Stenochlaena palustris, commonly known as midin or kelakai, is a wild fern from the *Blechnaceae* family, primarily found in the wetland regions of Southeast Asia, including Borneo and Sumatra. This fern serves as a fundamental component in the diets of various indigenous populations in Borneo, particularly among the Dayak ethnic groups. Midin is often utilised in both salads and cooked dishes, demonstrating its adaptability and versatility in local cuisines (Awang-Kanak and Abu Bakar, 2019; Gunawan-Puteri *et al.*, 2021; Pandiangan *et al.*, 2022).

Rich in essential nutrients, *S. palustris* contains significant levels of vitamins and minerals, including vitamin C, iron, calcium, and an array of antioxidants (Chikmawati *et al.*, 2023; Helsawati *et al.*, 2023). These nutritional attributes have led to its classification as a functional food, recognised for its health benefits. Studies have identified bioactive compounds within the fern, such as flavonoids, alkaloids, and steroids, which are linked to various health benefits, including

antioxidant and anti-inflammatory properties (Kusmardiyani *et al.*, 2016; Marisa *et al.*, 2021; Hendra *et al.*, 2022). The beneficial properties of midin position it as a suitable candidate for inclusion in nutritional supplements and functional foods that are gaining popularity in global markets.

Despite its impressive nutritional and health benefits, *S. palustris* remains an underutilised plant, with limited applications in food and beverages. Underutilised plants are those whose potential has not been fully realised, often thriving in specific local regions while remaining relatively uncommon or unknown on a global scale (Hunter *et al.*, 2019; Shamsudin *et al.*, 2022). Midin, an endemic to Borneo Island, falls into this category (Abdul Wahab *et al.*, 2014; Ndanusa and Siddique, 2020). Although some studies have investigated its use in products such as tea, coffee, cookies, and ice cream, these innovations have not yet gained widespread market acceptance (Hadhiwaluyo *et al.*, 2017; Fahriza *et al.*, 2021; Mahdiyah *et al.*, 2021; Santoso *et al.*, 2022). As the demand for functional and health-promoting foods

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continues to grow, there is an urgent need to explore and develop midin-based products.

The global healthy snacks market, valued at 85.6 billion USD in 2021, is projected to grow at an annual rate of 6.6%, reaching 152.3 billion USD by 2030 (Statista, 2024). This rising interest in health-promoting snacks has led to an increased focus on innovative and nutritious products (Galanakis, 2024). One such option is nori seaweed, which is rich in minerals, vitamins, and antioxidants, making it an excellent choice for health-conscious consumers (Salido *et al.*, 2024). Typically prepared by drying seaweed from the genus *Porphyra*, nori is created through a process that involves collecting, cleaning, and dehydrating the seaweed into thin sheets that are then toasted to enhance their flavour and texture. These sheets are often enjoyed directly or used as wraps for sushi and other dishes (Jung and Yoon, 2017).

While traditional nori remains popular, efforts are underway to develop alternative nori products using ingredients like cassava leaves and various types of microalgae (Herawati and Kamsiati, 2019; Sari *et al.*, 2019; Thunyawannichnonndh *et al.*, 2020). Given its unique nutritional composition and potential health benefits, midin could serve as a viable substitute for traditional nori in snack production. This study aimed to examine the nutritional and quality properties of nori snacks made from midin, utilising varying levels of both midin and tapioca starch.

2. Materials and methods

2.1 Materials

The young fronds of midin ferns were acquired from Sibul Central Market in Sibul, Malaysia. The additional components utilised in the production of nori, such as tapioca starch, white pepper, salt, mushroom seasoning, paprika powder, and sesame oil, were acquired from the local supermarkets in Sibul. The chemicals utilised were analytical grade.

2.2 Midin nori production

The young midin fronds were initially washed with tap water to eliminate any soil or contaminants. After the cleaning procedure, the fronds underwent hot blanching

at a temperature of 100°C for a duration of 30 s in order to maintain their colour and texture. The blanched fronds were then blended to form a uniform mixture. Tapioca starch, mushroom seasoning, paprika powder, white pepper powder, and salt were added to the mixture and mixed completely. Three formulations were created, each containing different amounts of midin and tapioca starch (Table 1). A fourth formulation, which did not contain tapioca starch, was used as the control (Table 1). The resultant blend was heated to a temperature of 80°C for a duration of 2 min in order to improve the binding of the ingredients. Following the cooking process, the mixture was evenly applied in thin layers and then subjected to a drying period of 5 h at 60°C using a hot air-drying oven (NBZ, Malaysia) to achieve the intended crispy texture. After drying, the sheets were cooled at ambient temperature prior to being coated with sesame seed oil. Finally, the sheets were roasted at 150°C for 1 min to develop a characteristic flavour and further enhance their crispness. After roasting, the sheets were cooled at room temperature and then stored in an airtight container with a moisture-absorbent to preserve them until further analysis.

2.3 Proximate analysis

The AOAC INTERNATIONAL (2005) method was employed to assess the levels of crude protein (AOAC Official Method 976.05), crude fat (AOAC Official Method 920.39), and ash (AOAC Official Method 923.03) in the sample. The total carbohydrate content was computed using the difference approach as described by Khan (2019). The total carbohydrate content was obtained by subtracting the sum of the percentages of crude protein, crude fat, ash, and total dietary fibre from 100% after calculating the moisture, fat, protein, ash, and total dietary fibre amounts.

2.4 Total dietary fibre

The total dietary fibre (TDF) was measured using the AOAC Official Method 991.43 procedure, which uses enzymatic-gravimetric analysis with MES-Tris buffer (AOAC INTERNATIONAL, 2005). The alcohol insoluble material (AIM) was prepared by heating and washing samples with ethanol. The residue was dried in an oven at 35°C for 24 h, then crushed into a fine powder

Table 1. Formulation of midin nori.

Type of ingredients (g)	Control	Formulation 1 (F1)	Formulation 2 (F2)	Formulation 3 (F3)
Midin	100	95	90	85
Tapioca starch	0	5	10	15
Mushroom seasoning	1	1	1	1
Paprika powder	1	1	1	1
White pepper powder	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5

and filtered. The enzymatic-gravimetric method involved removing fat from the dried samples using Soxhlet extraction, homogenising them in MES-Tris buffer, and treating them with heat-stable amylase. After reaching 60°C, the samples were treated with protease and amyl glucosidase, raising the pH to 4.7.

The ethanol was then introduced to the samples, allowing them to sit at ambient temperature for one hour to form a precipitate. The resulting solid was then washed using two different concentrations of ethanol: 78% (v/v), 95% (v/v), and 100% acetone. After digestion, the samples were placed in a fume hood and left at room temperature for 5 h to evaporate any residual acetone. The undissolved substance was dried in an oven set at 40°C until it reached a stable weight.

2.5 Determination of water activity

The water activity (a_w) of the samples was measured using the AQUALAB 4TE water activity meter (Addium Incorporation, USA). Once the meter was calibrated, the sample was inserted into the instrument. After the automatic analysis was completed, the a_w value was displayed on the screen.

2.6 Colour measurement

Colour measurement was conducted according to the CR 400 manufacturer's instructions (Minolta Co. Ltd., Japan). Measurements were performed in triplicate for each sample, with calibration using a white colour standard plate (CR 400, Lab*) at the beginning of each session. Results were expressed in the L*, a*, and b* colour space, corresponding to lightness, chromaticity on the green (-) to red (+) axis, and chromaticity on the blue (-) to yellow (+) axis, respectively.

2.7 Statistical analysis

All analytical quantifications were performed in triplicate. An analysis of variance (ANOVA) was performed using IBM SPSS Statistics version 26 to ascertain and compare the mean values. The comparisons were conducted using Duncan's Multiple Range Test (DMRT) with a significance level of $p < 0.05$.

3. Results and discussion

3.1 Proximate content

The analysis of the nutritional composition of midin nori formulations showed notable differences in moisture, ash, crude fat, crude protein, total dietary fibre, and total carbohydrate content across the various formulations (Control, F1, F2, and F3) (Table 2). These findings emphasised the impact of adding tapioca starch to the nori snacks, specifically in relation to the quantities of midin and tapioca starch utilised, on the nutritional composition of the snacks.

The moisture content showed a significant decrease as the amounts of tapioca starch increased, declining from $10.54 \pm 0.17\%$ in the Control formulation to $8.71 \pm 0.22\%$ in F3 ($p < 0.05$). This trend suggested that the inclusion of tapioca starch reduced moisture retention, likely due to the starch's lower hygroscopic nature compared to midin fronds (Lopes *et al.*, 2023). The reduction in moisture content could enhance the texture and prolong the shelf life of the nori snacks. This pattern aligns with the results reported by Huda *et al.* (2022), who examined the attributes of nori snacks produced using chaya leaves and tapioca starch. According to their report, the addition of tapioca starch had a substantial impact on the moisture content and overall quality of the snacks. This suggests that starches can successfully decrease moisture levels in nori formulations (Hunt *et al.*, 2010).

There was a similar trend in the ash content, with a notable decrease from $11.25 \pm 0.05\%$ in the Control group to $5.70 \pm 0.04\%$ in F3 group ($p < 0.05$). The ash content of a food material can be used as an indicator of the amount of minerals featured (Ganogpichayagrai and Suksaard, 2020). The decrease in ash level resulting from the inclusion of tapioca starch can be attributed to the diluting of midin, which is rich in minerals, with starch that contains limited minerals. This discovery is consistent with the anticipated alterations in composition that occur when replacing a mineral-rich component with a less nutritionally dense one. The raw sample of midin, renowned for its abundant minerals, displayed an ash concentration of 13.58% (Chotimah *et al.*, 2022). The results of this investigation were comparable to the ash content seen in raw midin fern.

Table 2. Nutritional properties of midin nori.

Formulation	Moisture (%)	Ash (%)	Crude fat (%)	Crude protein (%)	Total dietary fibre (%)	Total carbohydrate content (%)
Control	10.54 ± 0.17^a	11.25 ± 0.05^a	10.75 ± 0.26^a	6.76 ± 1.34^a	34.8 ± 1.70^a	25.89 ± 1.19^a
F1	8.74 ± 0.36^b	8.74 ± 0.20^b	7.14 ± 0.33^b	4.41 ± 1.53^b	28.5 ± 1.60^b	42.48 ± 1.88^b
F2	8.73 ± 0.00^b	6.68 ± 0.06^c	4.47 ± 3.56^c	4.26 ± 0.15^b	24.9 ± 1.90^b	50.96 ± 3.61^c
F3	8.71 ± 0.22^b	5.70 ± 0.04^d	3.58 ± 0.03^d	4.14 ± 0.30^b	17.7 ± 0.90^c	60.17 ± 0.49^d

Values are presented as mean \pm SD ($n = 3$). Values with different superscripts in the same column are statistically significantly different ($p < 0.05$).

The crude protein content declined from $6.76 \pm 1.34\%$ in the Control formulation to $4.14 \pm 0.30\%$ in F3. However, there were no statistically significant variations in the protein content among the formulations incorporating starch (F1, F2, F3) ($p > 0.05$). This indicates that the inclusion of tapioca starch resulted in a decrease in protein content, with a somewhat uniform impact observed across all amounts of starch. The Control formulation, which contained the highest quantity of midin, exhibited the highest protein content ($p < 0.05$). This finding was similar to that reported by Shada *et al.* (2022) regarding midin incorporation in chicken nuggets. In comparison, Sinurat *et al.* (2024) reported a significantly higher protein content of 12.08 g/100 g in nori seaweed derived from *Ulva lactuca* and *Gracilaria changii*, which is much greater than the protein levels observed in the present study. A study by Masuda *et al.* (2015) emphasised the significance of the protein content in nori snacks, acknowledging the close relationship between the nutritional value of nori and its levels of protein. The study conducted by Siladji *et al.* (2024) also observed that the protein concentration in nori differed depending on the processing techniques and combinations of ingredients. This finding emphasises the importance of meticulous component selection in order to preserve protein levels in snack formulations.

The crude fat level reduced significantly across the formulations, decreasing from $10.75 \pm 0.26\%$ in the Control to $3.58 \pm 0.03\%$ in F3 ($p < 0.05$). This reduction was likely attributed to the low-fat content of both tapioca starch and midin, which is less than 0.1% and 1.47% , respectively, as the formulation increases the amount of midin decreases while the amount of tapioca starch increases (Nisar *et al.*, 2009; Chotimah *et al.*, 2022). Moreover, the fat content in the nori compositions may have been affected by the sesame oil utilised during the glazing process, which probably contributed to the overall fat content of the product. Nevertheless, the act of applying oil while glazing may have resulted in an intricate interplay, wherein the oil permeated the nori, potentially modifying the final fat level. A prior investigation conducted by Mohd Zaher and Ho (2024) also found elevated levels of crude fat in a combination of green tea leaves and vegetable snacks as a result of the utilisation of sesame oil.

Conversely, the total carbohydrate content increased significantly with the incorporation of tapioca starch, rising from $25.89 \pm 1.19\%$ in the Control to $60.17 \pm 0.49\%$ in F3 ($p < 0.05$). This increase was consistent with the high carbohydrate content of tapioca starch, which replaced the lower carbohydrate content of midin in the formulations. The substantial rise in carbohydrate content reflected the substitution of a low-carbohydrate

ingredient with a carbohydrate-dense one. Tapioca starch, obtained from the cassava root, is primarily constituted of carbohydrate, accounting for 80% to 90% of its overall composition (Wongsagon *et al.*, 2005). This makes it a highly valuable source of carbohydrates.

3.2 Total dietary fibre content

The analysis revealed a significant reduction in total dietary fibre content as the level of tapioca starch increased in the midin nori formulations (Table 2). The TDF content reduced significantly from $34.8 \pm 1.70\%$ in the Control formulation to $17.7 \pm 0.90\%$ in F3 ($p < 0.05$). The decrease in TDF was ascribed to the substitution of midin, a plant high in fibre, with tapioca starch, which has significantly lower fibre content. As to the Malaysia Food Regulation (Ministry of Health Malaysia, 1985), for a product to be labelled as a "source of dietary fibre," it must have a minimum of 3 g of dietary fibre per 100 g. To be classified as "high in dietary fibre," it should contain at least 6 g per 100 g. The formulations created in this study, specifically the Control and F1 (with 34.8% and 28.5% TDF content, respectively), surpassed the threshold for being classified as "high in dietary fibre" in a considerable manner.

Nevertheless, when the amount of tapioca starch was raised in formulations F2 and F3, the level of TDF reduced. However, F3 still managed to maintain a substantial amount of dietary fibre at 17.7%, which exceeds the minimal requirement set by regulations. This study revealed that even though the inclusion of tapioca starch led to a decrease in dietary fibre, the midin nori formulations still maintained their significance as a source of dietary fibre. Midin is well acknowledged as an excellent source of dietary fibre, with a documented content of 18.67% (Chotimah *et al.*, 2022). The abundant fibre in midin enhances its health advantages, such as promoting better digestive health and maybe reducing cholesterol levels.

3.3 Water activity

The study of water activity in midin nori formulations reveals significant decreases resulting from the integration of tapioca starch and the drying process at a temperature of 60°C for a duration of 5 h (Figure 1). F1, containing 5 g of tapioca starch, showed a significantly lower water activity than the Control formulation ($p < 0.05$). This indicates that even a modest amount of starch, when combined with complete drying, can successfully decrease moisture levels and improve the product's shelf life. The water activity (a_w) values for the midin nori formulations range from 0.474 ± 0.016 a_w to 0.503 ± 0.012 a_w . The nori snacks have water activity below 0.6 a_w , indicating effective moisture removal and

enhanced microbiological stability (Nemzer *et al.*, 2018). Tapioca starch has a higher water uptake capacity, which can further enhance the stability of snacks by reducing their overall water activity (Rakhshi *et al.*, 2022). The results suggest that the drying method and the deliberate application of tapioca starch are essential factors in reducing water activity, which in turn enhances the stability and quality of midin nori.

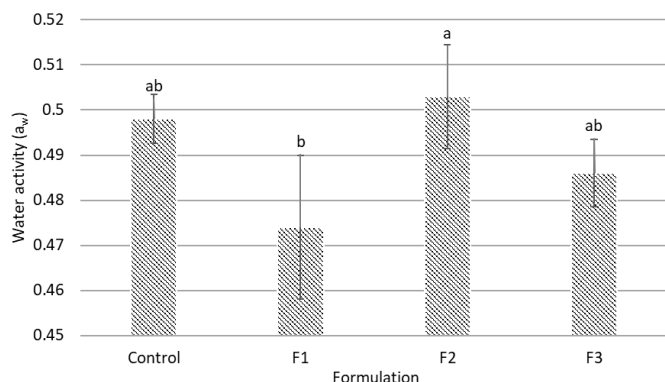


Figure 1. Water activity (a_w) of midin nori. Data is presented as mean \pm SD (n = 3). Bars with different notations are statistically significantly different ($p < 0.05$).

3.4 Colour value

The colour analysis of midin nori formulations indicated that the L^* values, which ranged from 20.57 ± 6.23 to 26.12 ± 1.39 , showed that the nori snacks were predominantly dark brown in colour (Figure 2). The product maintained its dark appearance consistently throughout all formulations, and the observed differences were not statistically significant ($p > 0.05$). A study conducted by Zhang *et al.* (2019) also observed a comparable dark hue in cassava leaf nori, with lightness values varying between 24.92 to 30.23. The red-green chromaticity (a^* values) suggested that the formulations were consistent in redness, with no significant differences ($p > 0.05$) observed. However, the yellow-blue chromaticity (b^* values) demonstrated statistically significant differences ($p > 0.05$) in yellowness, with the

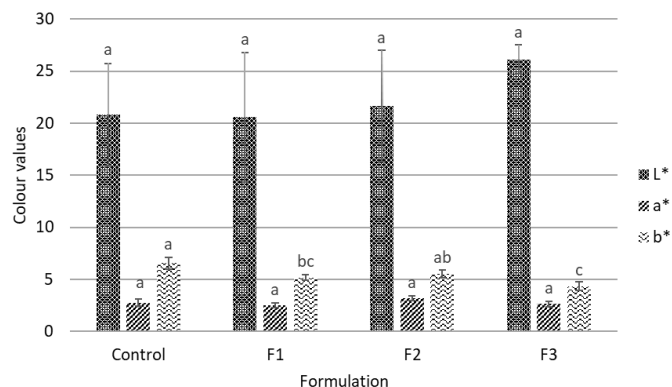


Figure 2. Colour values of midin nori. Data is presented as mean \pm SD (n = 3). Bars with different notations are statistically significantly different ($p < 0.05$).

Control sample being the most yellow and F3 the least yellow. The colour of nori snacks may have been affected by the processing techniques used in their creation. For instance, the application of drying and roasting techniques may have resulted in Maillard reactions, which might intensify the process of browning the product (Berk *et al.*, 2019). In summary, the findings indicated that the nori snacks retained a deep hue irrespective of the amount of tapioca starch or the drying conditions, without any notable influence on the visual attributes caused by these variables.

4. Conclusion

This study evaluated nori snacks made from *S. palustris* (midin) with varying tapioca starch levels. The results demonstrated significant reductions in moisture, ash, and crude fat content, alongside an increase in total carbohydrates with tapioca starch incorporation. Although protein and dietary fibre content decreased, the snacks still maintained high fibre levels. Colour analysis showed consistent dark brown hues across all formulations. Overall, these findings indicate the potential of midin nori snacks as a nutritious alternative to traditional seaweed-based products, deserving further exploration of their texture and shelf-life properties.

Conflict of interest

The authors declare no conflict of interest.

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