Characteristics of Nori Moringa Leaves with Suweg (*Amorphophallus campanulatus*) Starch Addition

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ABSTRACT

Nori is a thin sheet made from dried *Porphyra* seaweed, which grows only in subtropical climates, posing challenges to its availability in Indonesia. To address this limitation, diversification of nori with other ingredients such as moringa leaves becomes imperative. Moringa leaves are used due to their green color, high nutritional content, and easy availability. A binder and gel-forming agent containing high amylopectin are also needed to achieve a high-quality and compact nori texture. Suweg is an underutilized gel-forming agent with high amylopectin content. Therefore, this research aimed to characterize moringa leaf nori supplemented with suweg starch (*Amorphophallus campanulatus*) at concentrations of 0%, 1.25%, 2.5%, 3.75%, and 5%. The results indicated that suweg starch influenced tensile strength, thickness, water content, water activity, ash content, and protein, as well as sensory tests for color, aroma, brittleness, and taste, while crude fiber content was not affected. Based on sensory, physical, and chemical tests the best nori was achieved with the addition of 1.25% suweg starch. The result of characterization of this nori included a tensile strength of 355.90 gf, thickness 0.0145 mm, water content 15.50%, water activity value 0.645, ash content 15.30%, protein content 9.88%, and crude fiber of 2.18%. The sensory evaluation showed that the nori had a green color (3.1), a subtle leafy aroma (3.1), slightly broken (2.9), and a slightly bitter taste (3.2) with preference scores categorized as preferred (3.5), slightly favored (3.3), favored (3.7), and moderately liked by the panelists (score 3.3), respectively. The resulting nori has a thinner thickness and lower tensile strength than commercial products

Keywords: Moringa leaf; nori; *porphyra*; starch suweg

INTRODUCTION

Nori is a consumable thin seaweed sheet derived from purplish seaweed, which belongs to the *phylum Rhodophyta* (red algae) (KBBI, 2016). The main raw material used in nori production is the red seaweed species Porphyra, which only grows in subtropical climates. Currently, the consumption rate has significantly increased in Indonesia, leading to a rise in nori imports (Sholitan et al., 2017). Consequently, an opportunity for diversifying nori production is presented using locally available raw materials in the country (Agusta et al., 2017). Moringa leaves have emerged as a viable alternative raw material due to their green color similar to Porphyra, easy cultivation, and availability (Aminah et al., 2015). These leaves also contain high fiber content (7.92%) and protein (22.75%) (Melo et al., 2013), as well as a significant amount of vitamin C, specifically 220 mg per 100 g of material (Krisnadi, 2015). Widyastuti et al. (2020) created artificial nori using moringa leaves as the raw material, where the formation of the sheets requires gel-forming and binding

agents such as CMC, agar, and tapioca. The best nori was achieved using CMC as the binding agent at 5%, characterized by dark green, not brittle (score 1.66), and strong brittleness (score 2.20), overall preferred compared to tapioca and agar (score 3.62).

Widyastuti et al. (2020) created artificial moringa leaf nori using CMC, which resulted in a dark green, brittle, and easily breakable texture. To improve these qualities, efforts were made by making artificial moringa leaf nori using a different binding and gel-forming agent, namely suweg starch. Suweg (*Amorphophallus campanulatus*) is a starchy tuber with a relatively high starch content of 83.86%, comprising 24.91% amylose and 58.95% amylopectin content (Pramesti et al., 2015), higher compared to tapioca (51.95%), thereby possessing enhanced binding capabilities. However, suweg starch has a setback value of 550 cP, compared to tapioca at 735 cP (Richana & Sunarti, 2004), resulting in a robust product that is not as firm as tapioca. According to Lestari et al. (2015), the setback value influences the hardness level of the product. When the setback value was lower, the nori product was sturdy with reduced firmness compared to tapioca. Furthermore, it also lowers cholesterol with blood sugar levels and possesses a neutral taste, making it easily combinable with various food ingredients (Lianah et al., 2018). This research aimed to determine the effect of adding suweg starch at different concentrations of 0%, 1.25%, 2.5%, 3.75%, and 5% on the quality characteristics of Moringa nori leaves to achieve optimal results.

METHODS

Materials

In this research, the materials used to create nori were moringa leaves, suweg starch (*Amorphophallus campanulatus*) (Sukhija et al., 2015) water, salt (Regina), sugar (Gulaku), carrageenan (carrageenan Kappa refine/Premium), and garlic powder (Koepoe koepoe). The materials used for analysis (technical grade) included SeO_2, K_2SO_4 (Merck), $CuSO_4.5H_2O$ (Merck), H_2SO_4 (Merck, 98%), NaOH (Merck), Phenol Phtalein, H_3BO_3 (Merck, 99,8%), HCl (Merck, 37%), and Whatman filter paper No. 541.

The tools used in the process of making moringa leaf nori included a scale, measuring glass, mixing bowl, pot, hotplate thermo scientific SP142025Q Cimarec, oven blower memmert ULE 400 made in Germany, heat-resistant plastic, 60-mesh sieve, and thermometer. Meanwhile, the tools used for testing include a texture analyzer (TAXT21), micrometer screw, analytical balance, Sinauba WA-360 aw meter, oven, burner, furnace, desiccator, and Kjeldahl flask.

Research methods

An experimental design was used, employing a *Completely Randomized Design* (CRD) with 1 factor and 5 levels, conducted in 3 replications. The factor was the addition of suweg starch at different concentrations, namely 0%, 1.25%, 2.5%, 3.75%, and 5%.

The Process of Making Moringa Nori Leaves

The process of making moringa nori leaves referred to (Widyastuti et al., 2020), with modifications. In this research, the Moringa leaves were used in dark green color and separated from the stalks, followed by weighing 100 g and washing with clean running water. Subsequently, the leaves were blanched with hot steam at 80 °C for 5 minutes, and crushed with the addition of water (Moringa leaves: water = 1:13 w/v) using a blender at high speed for 2 minutes. A total of 1000 g of crushed samples were weighed (w/w) and mixed with 0.5% carrageenan, 0.25% granulated sugar, 0.25% salt, 0.33% garlic powder, and suweg root starch (0%; 1.25%; 2.5%; 3.75%, dan 5%) separately. The mixture was heated to a temperature of 80 °C, maintained for 5 minutes, and cooled to room temperature (25-27 °C) for 1 minute. Making nori sheets is done by pouring 250 mL of the mixture into a baking pan measuring $30x24$ cm^2 covered with heat-resistant plastic for each treatment. After that, the dough is dried in an oven at 40 °C for 24 hours.

Sample testing technique

The quality of nori was determined based on the tensile strength test with the TAXT21 texture analyzer with a minimum length of 22 cm and a width of 1.5 cm, for each determination 1 sample sheet is required. The thickness was measured using a micrometer screw, with a length of 2 cm and a width of 2 cm at five points in each sample (Sari et al., 2019). The water content was determined using the oven method at a temperature of 105 ºC until it reaches a stable weight ($\pm$5 hours) and the ash content determined by the ashing process at a temperature of 550 ºC until it becomes white ash (AOAC, 2012). The aw value was measured by Shibaura a_w meter WA-360. The aw standard used for NaCl is 0.7509 and K2SO4 is 0.97 (30 ºC) (Putri et al., 2018), while protein content used the Kjeldahl method. Furthermore, the crude fiber content involved dissolving samples in acids and bases based on SNI 01-2891-1992 (BSN, 1992), sensory tests involved score and hedonic tests based on SNI 01-2346-2006 (BSN, 2006). The parameters tested were color, aroma, fracture ease, and taste quality scores. The panelists used were 20 Food Technology students who had received sensory courses.
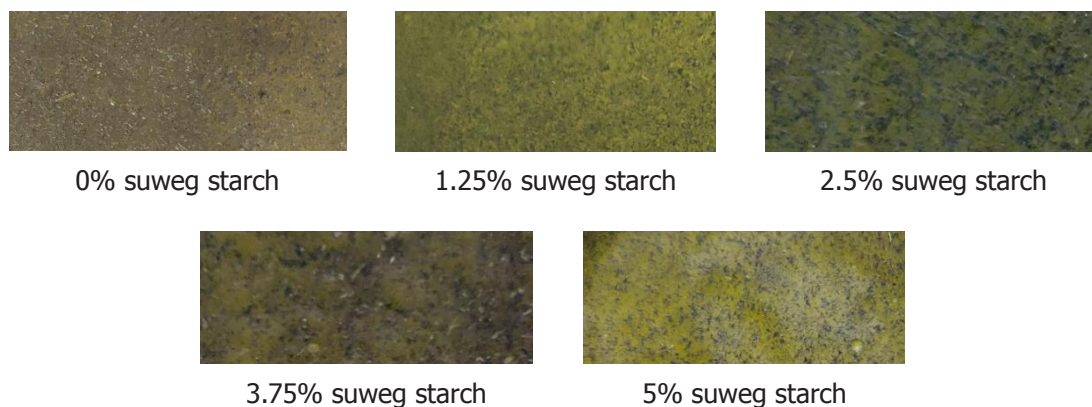
0% suweg starch

1.25% suweg starch

2.5% suweg starch

3.75% suweg starch

5% suweg starch

Figure 1. The fifth photo of Moringa nori

Data analysis

The data were analyzed using Analysis of Variance and when there was a significant (α=0.05) or very significant (α=0.01) effect of each treatment, the *Duncan Multiple Range Test* (DMRT) was performed with a 95% confidence level (α=0.05).

RESULTS AND DISCUSSION

The qualities of Moringa nori is determined based on physical, chemical, microbiological and sensory tests. The fifth photo of Moringa nori can be seen in Figure 1.

Tensile Strength

Tensile strength is the maximum pulling force that a sample can withstand during the measurement before it begins to tear (Sari et al., 2019). As shown in Figure 2, the tensile strength value of moringa leaf nori is 115.53 – 980.63 gf which is in this research increased with higher concentrations of suweg starch.

The results of the difference test indicated that the addition of suweg starch had a highly significant effect ($p<$ 0.01) at the α = 0.01 level on the tensile strength of nori. The increase in suweg starch concentration led to a rise in the content of amylose in the suspension. This enhanced the number of hydroxyl groups, thereby strengthening gel formation and resulting in a rigid film (Hatmi et al., 2020). Tensile strength was influenced by starch during the heating and cooling processes, where hydrogen atoms formed interactions with amylose to create a gel, followed by the formation of cross-linking aggregation and a three-dimensional structure, producing a stronger and less brittle gel (Ramasari et al., 2019). Moringa nori added with suweg with a concentration of 0 – 3.75% had a lower tensile strength (115.53-864.24 gf) than commercial products (890 gf) (Riyanto et al., 2014), but nori added with suweg concentration of 5% produced a higher tensile strength (980.63 gf).
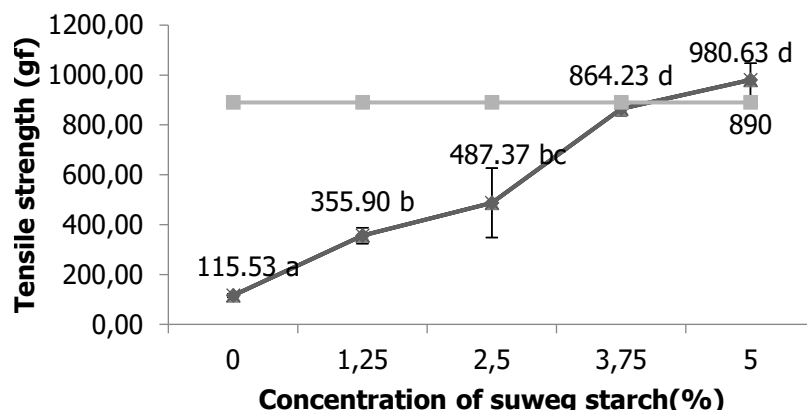
Description: the mean value followed by different letters indicates a very significant difference ($p<$0.01)

Figure 2. Graph of nori tensile strength (gf)
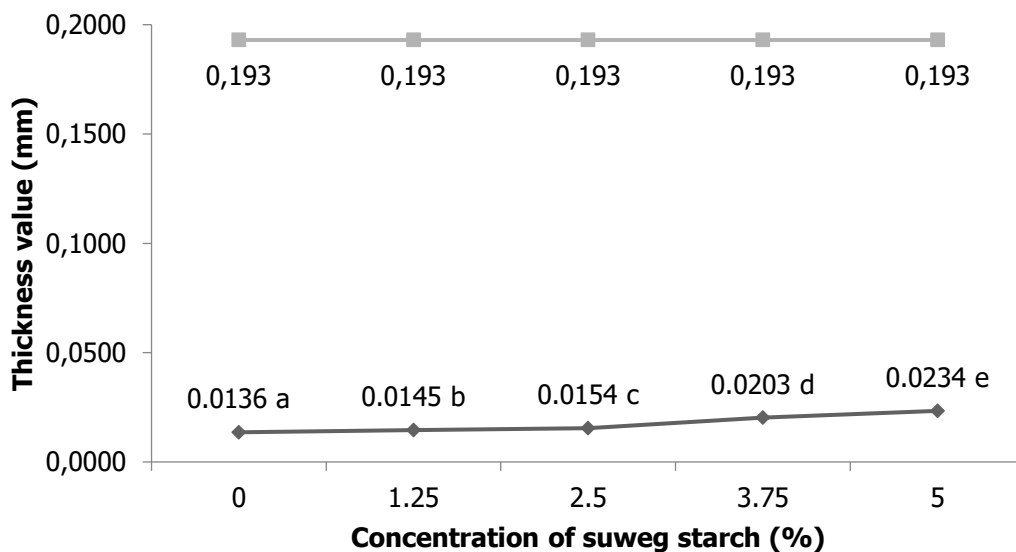
Description: The mean value, followed by different letters indicated a very significant difference ($p<0.01$)

Figure 3. Graph of nori thickness values (mm)

Thickness

The thickness value of Moringa nori leaves with the addition of different suweg tuber starch resulted in different thicknesses. Figure 3 showed that a higher concentration of suweg tuber starch yielded greater thickness of the Moringa leaf nori.

The results of the different tests showed that the addition of suweg starch had a very significant effect ($p<0.01$) at the level ($α=0.01$) on the nori thickness. According to (Sari et al., 2019), the difference in thickness of the nori was affected by the total amount of solids in the dough due to the amylopectin content in the suweg starch. Amylopectin in starch caused the viscosity of the nori dough to be higher, thereby increasing the concentration of the polymer matrix constituents, the total dissolved solids, and thickness (Syarifuddin & Yunianta, 2015). When the total solids in the solution increased, the resulting nori became thicker, with more thickness being achieved during the drying process (Rahmawati et al., 2019). According to Bertuzzi et al. (2012), the thickness of the nori affected the tensile strength, indicating that the thicker the layer, the higher the tensile strength. Hatmi et al. (2020) also reported that the increase in thickness was proportional to a higher concentration of starch added. This was because, in the same volume, the number of constituent polymers and the total dissolved solids that form the coating increased. Meanwhile, the resulting moringa nori had a smaller average thickness value compared to Moringa nori with the addition of carrageenan and arrowroot starch (1%:3%), namely 0.0215 mm

(Isnaini, 2018). Moringa nori with the addition of 0-5% suweg starch has a thickness value were lower (0.0136 – 0.0234 mm) than the commercial nori (0.193 mm) (Riyanto et al., 2014).

Water content

The water content of moringa nori with the addition of different suweg starch ranged from 12.87-17.91%. As shown in Table 1, it was discovered that a higher concentration of suweg starch resulted in lower nori water content. The decrease in water content was due to the higher concentration of starch, which increased the number of hydroxyl groups and enhanced the ability of starch to absorb water. According to Syarifuddin & Yunianta (2015), increasing the concentration of suweg tuber starch increased the number of water bonds with amylopectin that made up the material matrix, thereby reducing the amount of free water left in the material network. The amylopectin affected the water content of nori, with higher amylopectin content resulting in lower water content of the product. Moringa leaf nori with the addition of arrowroot starch had a higher water content of 12.12% as reported by (Isnaini, 2018), compared to (12.87-17.91%) obtained in this research. This was because the amylopectin content of arrowroot starch was higher (73.46%) than suweg (58.95%). The water content of suweg leaf nori added with pectin ranged from 2.47% - 4.15%, where a higher pectin concentration resulted in lower nori water content. This was because pectin had a high ability to bind water (Innayatuhibbah et al., 2018). According to Ramasari

Table 1. Chemical quality of Moringa leaf nori added with suweg starch

Suweg starch (%)	Water content (%)	Water activity	Ash content (%)	Protein content (%)	Crude fiber content (%)
0.00	17.91±0.68[a]	0.68±0.02[a]	18.58±2.34[a]	15.44±1.67[a]	2.11±1.00
1.25	15.50±0.48[bc]	0.65±0.01[bd]	15.30±0.52[b]	9.88±0.21[cd]	2.18±0.15
2.50	14.60±0.33[c]	0.64±0.01[d]	11.14±0.41[cd]	11.72±0.34[bc]	1.28±0.12
3.75	13.33±1.02[de]	0.67±0.01[bc]	9.00±1.05[de]	8.48±0.93[de]	1.58±0.94
5.00	12.87±0.36[e]	0.67±0.01[bc]	7.85±0.93[e]	6.87±1.36[e]	1.32±0.18

Description (superscript): Different letters in the same column indicate a significantly difference ($p<0.05$)

et al. (2019), higher nori water content yielded lower crispness, and vice versa. Moringa nori with the addition of 0-5% suweg starch had a water content (12.87-17.91 %) were higher than the commercial nori (8.44 %) (Riyanto et al., 2014).

Water Activity (Aw)

Water activity (aw) represents the amount of free water available for microbial growth, leading to a deterioration in the quality of food materials (Andarwulan et al., 2011). In this research, the addition of different amounts of suweg starch resulted in water activity values ranging from 0.64 to 0.68. As shown in Table 1, the aw values remained relatively consistent with increasing concentrations of added suweg starch. Generally, microorganisms require varying water activity levels for growth, where bacteria grow at an aw of 0.90, yeast at 0.80-0.90, and mold at 0.60-0.70 (Faridah et al., 2013). The aw values obtained were within the range of 0.64-0.68, indicating the potential for mold growth. The water activity values obtained by Riyanto et al. (2014) on myofibrillar protein-based edible film from tilapia fish were lower compared to moringa leaf nori, ranging from 0.46 to 0.58, while the water activity of commercial nori was 0.68 and this value was relatively the same as Moringa nori.

Ash Content

Measurement of the ash content in the nori was carried out to determine the amount of mineral composition in the product. The resulting ash was composed of various types of minerals with varying compositions, based on the type and source of food used (Andarwulan et al., 2011). The results showed that Moringa nori leaves added with suweg starch had an ash content ranging from 7.85-18.58%. This indicated that higher suweg starch, resulted in lower ash content. Suweg starch exhibited an ash content of 2.5% (Richana & Sunarti, 2004), which was lower

than Moringa leaves at 13.02% (Melo et al., 2013), with higher concentrations of suweg starch resulting in lower nori ash content. Furthermore, nori ash content of *Gracillaria sp.* and *kolang kaling* ranged from 26.87% – 30.75% (Sari et al., 2019) due to an ash content of 38.91% (Syarifuddin et al., 2012). Moringa nori with the addition of 0-5% suweg starch had an ash content (7.85-18.58%) were relatively higher than the commercial nori (8.44 %) (Riyanto et al., 2014).

Protein Content

The addition of different suweg tuber starch produced different levels of nori protein, which ranged from 6.87% -15.44%. Based on Table 1, the data showed that a higher concentration of suweg starch resulted in lower protein content of artificial nori in Moringa leaves. This was because the protein content of suweg starch was 6.02% (Richana & Sunarti, 2004), which was lower than the fresh Moringa leaves at 22.75% (Melo et al., 2013). Compared to the nori algae *Hypnea saidana* and *Ulva conglubata* (Lalopua, 2017), the protein content of artificial nori from Moringa leaves added with suweg starch was higher, at 6.87% -15.44% and 1.36% respectively. Moringa nori with the addition of 0-5% suweg starch had a protein content (6.87 – 15.44 %) were lower than the commercial nori (42.50 %) (Riyanto et al., 2014).

Crude Fiber Content

The fiber content of the nori produced ranged from 1.28% -2.18% (Table 1), with a relative decrease in crude fiber at higher concentrations of suweg starch. This was because the crude fiber content in suweg starch according to Richana & Sunarti (2004) was 0.33%, while the fiber content in Moringa leaves, as stated by Melo et al. (2013), was 7.92%. This indicated that a higher concentration of suweg starch resulted in lower crude fiber content in nori. Lalopua (2017) also showed that the crude fiber content of the nori algae *Hypnea*

saidana and *Ulva conglubata* was 4.09%, indicating a value greater than the crude fiber of the nori produced in this research (1.28% - 2.18%). Pade & Bulotio (2019) stated that the crude fiber content of *Gracilaria sp.* nori seaweed with the nitrification of Moringa leaves was 4.6% - 5.1%.

Organoleptic Quality

Quality score test

The addition of different suweg concentrations indicate a significant difference (p<0.05) on color quality, fragrance quality, breakability quality, and taste quality. The color quality of Moringa nori leaves ranged from a score of 3.0 – 3.6 (green – brownish green), where a higher concentration of suweg starch caused the nori color greener (Table 2). According to Utomo & Ginting (2021), suweg starch had a brightness level of 70.53-81.63, which significantly contributed to a change in the color of the nori from brownish green to green. The brownish-green color of nori without suweg starch was caused by the chlorophyll pigment found in Moringa leaves, which turned brown when heated. This color change occurred because heating at a temperature of 60°C caused proteins to denature, resulting into breakdown of the protein-chlorophyll complex bonds. When heated, the hydrogen atoms were released, causing the protein to become acidic, leading to the release of the Mg metal in the chlorophyll and the formation of pheophytin characterized by a slightly brownish color change (Arfandi et al., 2013).

The aroma of food products comes from volatile compounds in food, which enter the nasal cavity when inhaled and are felt by the olfactory system. Due to their volatility, aroma compounds can easily reach the olfactory system above the nasal cavity and need sufficient concentration to interact with olfactory receptors (Tarwendah, 2017). In this research, the aroma of nori ranged from 2.8 to 3.3 (slightly unpleasant aroma), while the unpleasant tended to decrease with a higher concentration of suweg starch, as shown in Table 2. Kandekar & Abhang (2020) reported that suweg tuber starch had no aroma, leading to the dominance of the unpleasant aroma produced by Moringa nori leaves. This unpleasant aroma occurred because Moringa leaves contained saponins (Indriasari et al., 2016) lip oxidase enzymes, which hydrolyzed or decomposed fat into unpleasant aroma compounds (Jannah et al., 2018).

The ease of breaking of Moringa nori leaves ranged from a score of 2.3 – 4.2 (easily broken – not easily broken). As presented in Table 2, the higher concentration of suweg starch resulted in easily broken nori produced. Moreover, the higher the suweg starch, the higher the amylose content, causing an increase in the number of hydroxyl groups, leading to a stiffer film layer that offered resistance to biting (Karmakar et al., 2014 and Hatmi et al., 2020). Furthermore, suweg starch had a setback value of 550 cP (Richana & Sunarti, 2004), which was not excessively high to produce sturdy nori products (Lestari et al., 2015). This was in line with the nori tensile strength test, where higher starch concentration increased the tensile strength value produced.

The taste of artificial Moringa nori leaves ranged from a score of 3.0-4.0 (slightly bitter-not bitter). As shown in Table 2, a higher concentration of suweg starch produced artificial Moringa nori leaves that were not bitter. This was because suweg starch had a bland taste (Kandekar & Abhang, 2020), causing a decrease

Table 2. Test the quality score of Moringa nori leaves added with suweg starch

Parameter	Suweg starch concentration				
	0%	1.25%	2.5%	3.75%	5%
Color Quality	3.6±0.20[a]	3.1±0.08[b]	3.1±0.22[b]	3.2±0.08[bc]	3.0±0.19[b]
Fragrance Quality	2.8±0.10[a]	3.1±0.26[b]	3.3±0.08[b]	3.3±0.10[b]	3.3±0.08[b]
Breakability quality	2.3±0.36[a]	2.9±0.43[ab]	3.5±0.13[c]	3.8±0.06[cd]	4.2±0.13[d]
Taste quality	3.0±0.15[a]	3.2±0.08[ab]	3.5±0.03[c]	3.9±0.13[d]	4.0±0.15[d]

Description (superscript): Different letters in the same line indicate a significantly difference (*p*<0.05)
Score Description:
Color quality: 1 = whitish green, 2=yellowish green, 3=green, 4=brownish green, 5=dark green, Aroma quality: 1=very unpleasant aroma, 2= aroma bad, 3=slightly aroma bad, 4=does not aroma bad, 5 = very odorless, Ease of fracture quality: 1 = very easy to break, 2 = easy to break, 3=rather easy to break, 4=not easy to break; 5=very unbreakable, Taste quality: 1=very bitter, 2=bitter, 3=bit bitter, 4=not bitter, 5=very not bitter.

Table 3. Hedonic test results of artificial nori moringa leaves (score)

Parameter	Suweg starch concentration				
	0%	1.25%	2.5%	3.75%	5%
Color	3.2±0.10	3.5±0.05	3.4±0.22	3.5±0.06	3.4±0.10
Aroma	3.0±0.05[a]	3.3±0.09[bd]	3.2±0.09[cd]	3.4±0.03[c]	3.2±0.13[d]
Ease of breaking	3.4±0.15[a]	3.7±0.05[b]	3.5±0.13[ab]	3.4±0.13[a]	3.0±0.10[c]
Taster	3.0±0.08[a]	3.3±0.06[b]	3.5±0.05[c]	3.4±0.03[bc]	3.4±0.08[bc]

Note: Different letters in the same line indicate a significantly difference ($p < 0.05$)
Score description: 1=dislike very much, 2=dislike, 3=rather like, 4=like, 5 = really like

in the bitter taste of nori as the concentration of suweg starch increased. The bitter taste in nori was due to the presence of tannins (Jannah et al., 2018) and saponins (Indriasari et al., 2016) in Moringa leaves.

Hedonic Test

The preference of panelists for a product holds significant importance, a product cannot be commercialized when it is not liked. In this research, the preference of panelists for Moringa nori products added with suweg starch was shown in Table 3. Based on the results, the level of color preference ranged from a score of 3.2-3.5 (rather like it), exhibiting a high interest in greener nori. The highest preference was given to the addition of 1.25% suweg starch, as presented in Table 1.

The preference panelists for aromas ranged from a score of 3.0-3.3 (rather like), as shown in Table 3, This indicated that the preference increased as the unpleasant odor decreased (Table 2). The addition of suweg starch concentration, which had no aroma reduced the unpleasant aroma of nori, thereby increasing preference.

For the ease of breaking nori, the preference of panelists ranged from 3.0-3.7 (rather like it), where the highest occurred at the suweg starch concentration of 1.25%. Table 3 showed that the higher the concentration of suweg starch added, the lower the preference. This was because higher suweg starch rendered the nori more resistant to breaking (Table 2). Hatmi et al. (2020) stated that the higher concentration of suweg starch resulted in a stronger formation and less easily torn nori sheets.

The preference of panelists for the taste of Moringa nori leaves ranged from a score of 3.0-3.5 (somewhat liked), where the preference score increased with the higher concentration of suweg starch at 2.5% (Table 3). The increase in preference was in line with the decrease in the bitter taste of nori (Table 2).

CONCLUSION

In conclusion, this research showed that the best quality of Moringa nori leaves was determined based on the quality score and preference test of the panelists, tensile strength test, moisture content, and aw values, namely the addition of 1.25% suweg starch. The resulting nori was characterized by tensile strength 355.90 gf, thickness 0.0145 mm, moisture content 15.50%, water activity value 0.645, ash content 15.30%, protein content 9.88%, and crude fiber content 2.18%. The sensory evaluation showed that the nori exhibited a green (3.1), slightly unpleasant (3.1), slightly broken (2.9), and a bitter taste (3.2), with preference scores categorized as preferred (3.5), slightly favored (3.3), favored (3.7), and moderately liked by panelists (3.3), respectively. The best Moringa nori from this research had lower quality than commercial nori because it has lower tensile strength, thickness, and protein content with a higher water content.

CONFLICT OF INTEREST

There is no conflict of interest from various parties regarding this research.

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