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Sago Porridge Enriched with Red Dragon Fruit (*Hylocereus polyrhizus*) Extract: A Functional Food with Enhanced Sensory and Nutritional Properties

I Gede Arie Mahendra Putra[a], Luh Dian Rna Fajarini[a*], Putu Julyantika Nica Dewi[a], Wafi Adizara Muzakki[b], Nur Syamsi Ibrahim[c]

[a]Food Technology, Faculty of Agricultural Technology, Udayana University, Badung, Indonesia
[b]Food Technology, Faculty of Industrial Technology, Institut Teknologi Sumatera, Lampung Selatan, Indonesia
[c]Food Technology, Faculty of Agriculture, Sam Ratulangi University, Manado, Indonesia

[*]Corresponding author, Email: dianrna@unud.ac.id

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ABSTRACT
Sago, one of Indonesia's staple foods, holds significant potential for food diversification due to its high carbohydrate content. However, despite its nutritional benefits, sago consumption remains less popular than corn and potatoes. Sago porridge, a traditional food product, can be developed into a healthy alternative, but its translucent brown color is visually unappealing, affecting consumer acceptance. This study aims to evaluate the optimal concentration of red dragon fruit extract as a natural colorant to enhance the visual appeal of sago porridge. The research method involved testing varying concentrations of red dragon fruit extract (0%, 2%, 4%, 6%) through sensory evaluation and physical analysis. Results showed that a 6% concentration yielded the highest acceptability, with the following physical properties: strawberry red color (L:48.4; a*:70.8; b*:21.5), viscosity of 56,000 mPa·s, texture force of 8.7980 N, and pH of 7.21. This study contributes through the innovative use of red dragon fruit extract as a natural colorant, improving both the visual appeal and nutritional value of sago porridge. The optimal 6% concentration provides a practical reference for local food industries to produce value-added products, supporting food diversification based on local resources and aligning with global trends in healthy, natural foods.*

KEYWORDS
Natural colorant; Physical parameters; Red dragon fruit extract; Sago porridge; Sensory evaluation

1. INTRODUCTION

Sago (*Metroxylon spp.*) is a strategic local carbohydrate source in Indonesia, predominantly composed of carbohydrates (80.45%) and high resistant starch (RS) content, positioning it as a viable rice alternative to reduce reliance on food imports while supporting food security and cultural identity [1], [2]. Its functional advantages, such as higher viscosity and elasticity compared to tapioca attributed to its long-chain amylose-amylopectin structure make it ideal for semi-solid products like porridge [3], [4]. The RS content, correlated with a low glycemic index, also highlights sago's potential as a functional food for individuals with diabetes and obesity [5]. However, due to insufficient product innovation, sago's utilization remains limited compared to corn or potatoes [6]. Although traditional dishes like *Kapurung* and *Bagea* hold significant cultural value, sago porridge is the primary candidate for modernization owing to its balanced nutritional profile and suitability for all age groups [7]. A key challenge lies in its unappealing translucent brown color, necessitating innovative interventions such as integrating natural colorants to enhance market competitiveness.

Red dragon fruit (*Hylocereus polyrhizus*) is a source of betacyanin (10.3 mg/g) a water-soluble pigment with strong antioxidant activity that holds potential as both a natural colorant and functional

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component [8], [9]. However, research on sago innovation has predominantly focused on nutrient fortification [7], texture modification [3], or analog rice formulations with legume flour substitutions [10], [11], without exploring the enhancement of sensory attributes such as color through the integration of natural colorants. This is critical, as the translucent brown color of sago remains a major barrier to consumer acceptance. Furthermore, the synergistic impact of dragon fruit extract with sago porridge on physical properties (viscosity, texture, pH, color stability) has yet to be quantified. Therefore, this study aims to analyze the effect of red dragon fruit extract on the physical properties and sensory acceptance of sago porridge through hedonic testing.

The novelty of this study lies in the integration of red dragon fruit extract as a natural colorant in sago-based products, which synergistically enhances visual appeal through color improvement. The findings are expected to provide: 1) empirical evidence of optimal formulation of red dragon fruit extract for sago pulp products, 2) innovative strategies based on local resources to increase the economic value of sago, and 3) practical recommendations for the food industry in developing sustainable, functional products.

2. MATERIALS AND METHODS

2.1. Materials

The primary material in this study was sago flour Tani Super brand, supplemented with pandan (*Pandanus amaryllifolius*) essence koepoe-koepoe brand, water, salt, sugar, and red dragon fruit (*Hylocereus polyrhizus*) from Badung Market. The tools used are pans, stirring spoons, measuring cups, blenders, filter cloths, dropper pipettes, bowls, plates, teaspoons, tablespoons, knives, and cutting boards. Analytical instruments: pH sensor (smart sensor pH 818), texture analyzer (TAXT.plus), and viscometer (Brookfield).

2.2. Preparation of Sago Porridge

The ingredients used to prepare the sago porridge with the addition of dragon fruit extract include sago flour, dragon fruit extract, pandan essence, sugar, salt, and water, all measured according to the specified formula. The formula for this innovative sago porridge with the addition of dragon fruit extract can be seen in Table 1.

Table 1. Sago porridge formula.

Composition	P0	P1	P2	P3
Dragon fruit extract (%)	0	2	4	6
Sago flour (g)	50	50	50	50
Pandan essence (mL)	1.1	1.1	1.1	1.1
Sugar (g)	4.2	4.2	4.2	4.2
Salt (g)	1	1	1	1
Water (mL)	528	528	528	528

The production of dragon fruit extract was carried out according to a modified method [12]. First, the dragon fruit skin was peeled. Next, 5 g, 10 g, and 15 g of dragon fruit pulp were weighed. Afterward, 1 mL, 2 mL, and 3 mL of water were added, and the mixture was blended for 1 minute until a smooth consistency was achieved. Finally, the mixture was filtered through a cloth, resulting in 6 mL, 12 mL, and 18 mL of dragon fruit extract.

The preparation of sago porridge was based on the research by Winarni et al., (2017) [13] with modifications. The process began with the mixing of sago flour (50 g), sugar (4.2 g), salt (1 g), and pandan essence (1.1 mL). Water (528 mL) was then boiled until it reached boiling point and was gradually poured into the sago flour mixture. Afterward, the mixture was combined with dragon fruit extract and stirred until the porridge turned translucent or achieved a sticky texture, with cooking carried out over medium heat. Once the sago porridge was fully cooked, the cooking process was stopped, and the innovative sago porridge was ready to be served.

2.3. Sensory Evaluation

In this study, sensory evaluation was conducted on innovative sago porridge with added dragon fruit extract, assessing parameters such as color, taste, aroma, texture, and overall acceptance using a 5-point hedonic scale. Twenty students from the Faculty of Agricultural Technology, Udayana University, served as panelists, providing their impressions and preferences for each sensory attribute, which were recorded numerically as detailed in Table 2. Based on the hedonic test data, the most preferred treatment was selected and compared with a control sample through physical analyses (color, pH, texture, and viscosity) to assess product quality. The results provided comprehensive insights into the sensory and physical characteristics of the innovative sago porridge, thereby supporting its potential marketability [14].

Table 2. Criteria and numerical scale hedonic test.

Hedonic scale	Numeric scale
Like	5
Slightly Like	4
Neutral	3
Slightly Dislike	2
Dislike	1

2.4. Color Test

Color analysis in this study was performed using the colorimetry method. The procedure began with the preparation of the product, namely sago porridge, which was subsequently analyzed using a colorimeter. The scale readings were then recorded. The colorimeter functions to determine the color intensity of each sago porridge sample [15].

2.5. pH Test

The pH analysis employed a pH test method using a pH meter to measure hydrogen ion activity. The process started by preparing a sago porridge sample along with distilled water. The pH meter was then immersed in the sample until a stable reading was obtained, after which the measurement was recorded [16].

2.6. Texture Analysis

Texture analysis was carried out using a texture test method with a texture analyzer. Initially, the sago porridge sample to be analyzed was prepared. The texture analyzer was then activated, and its measurement parameters—specifically length and speed—were set. A flat disc probe was used in this analysis because the texture of sago porridge is classified as semi-soft. The instrument was operated, and the resulting data were recorded [17].

2.7. Viscosity Analysis

Viscosity analysis was conducted using a viscosity test method with a viscometer. The procedure began by filling a centrifuge tube with sago porridge and sealing it. The viscometer was then switched on and set to a speed of 20 using a spindle of size 7. After inserting the sago porridge sample into the viscometer, the device was activated. Once the red indicator stabilized, the scale reading was recorded [18].

2.8. Experimental Design and Data Analysis

This study uses a quantitative descriptive method. The treatments involved the addition of dragon fruit extract at four concentration levels, and each treatment was replicated three times, resulting in a total of 12 experimental units. The data obtained is presented in a quantitative descriptive form in tabular form.
P0: 0% dragon fruit extract + 1% pandan essence
P1: 2% dragon fruit extract + 1% pandan essence
P2: 4% dragon fruit extract + 1% pandan essence
P3: 6% dragon fruit extract + 1% pandan essence

3. RESULTS AND DISCUSSION

3.1. Sensory Evaluation of Sago Porridge

Based on the results of sensory evaluation by hedonic test on the color of sago porridge in Figure 1, the average panelists' favorability scores ranged from 2.45 to 4. The P0 treatment (without dragon fruit extract) obtained the lowest score (2.45) because it produced a natural brown color that was less preferred, while the addition of 2–6% dragon fruit extract increased the visual appeal by producing a brighter red color. The highest score (4.6) was achieved in treatment P3 (addition of 6% extract), indicating a positive relationship between extract concentration and panelist preference. This color change is caused by the content of betacyanin, which is a natural pigment in red dragon fruit that belongs to the betalain group. Betacyanin not only provides an attractive red-purple color but also has functional properties such as antioxidant and anticancer, as described in the study [19]. The addition of natural colorants from dragon fruit peels (up to 15%) was preferred over products without colorants, with an emphasis on the role of bright colors in enhancing the visual appeal of food products [20]. Thus, the integration of dragon fruit extract into products such as sago porridge not only improves aesthetics through betacyanin pigments but also enriches nutritional value and health potential, especially through antioxidant mechanisms and the fiber contained therein [19].

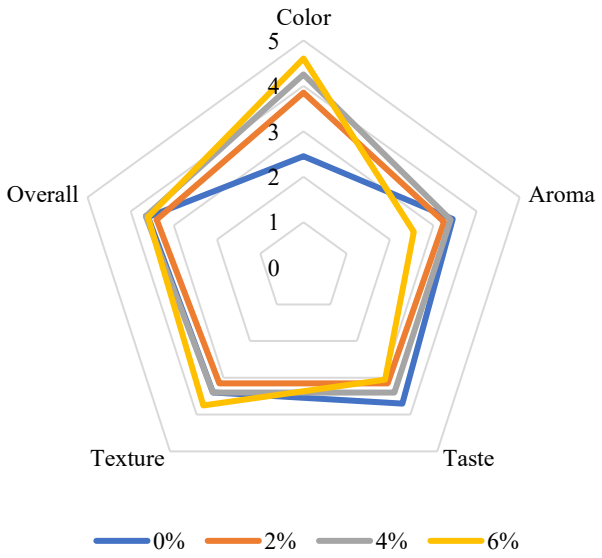

Figure 1. The results of the sago porridge hedonic test.

Based on the hedonic test for the aroma of sago porridge, the average score of panelists ranged from 2.55–3.45, with the P3 treatment achieving the lowest score while the P0 treatment achieved the highest score. The decrease in aroma value in the P3 treatment is thought to be caused by volatile aromatic compounds in dragon fruit that evaporate gradually during the processing. The use of pure dragon fruit in ice cream produced a less favorable aroma than the combination with other ingredients [21]. In addition, the aroma of dragon fruit that panelists do not like is related to the tannin content, which gives the impression of a less pleasant aroma [22]. Thus, although dragon fruit has nutritional and color benefits, its use at high levels can affect aroma preferences due to compound volatility factors and the presence of tannin. In contrast, the higher aroma score in the P0 treatment was due to the pandan essence, which produced a neutral to pleasant aroma. Based on the previous study, the compound 2AP (2-Acetyl-1-pyrroline) in pandan that resembles the aroma of steamed rice becomes more dominant after heating and creates an aroma that panelists like [23]. These results suggest that although dragon fruit provides color and nutritional benefits, it needs special consideration in its use to maintain the aroma quality of the final product.

Based on the hedonic test on the taste of sago porridge, the average score of panelists ranged from 3.05 to 3.07, with the P0 treatment (without the addition of natural coloring) achieving the highest score, while the P3 treatment (addition of 6% dragon fruit extract) obtained the lowest score. Panelists tend to prefer the taste of sago porridge without coloring. Previous studies reported that the addition of 2.5% flower to rice caused a decrease in taste scores in sensory evaluation, indicating that significant visual changes, even though they come from natural ingredients, can reduce consumer acceptance [24]. The addition of natural colorants from dragon fruit in higher concentrations can create complexity between the released compounds and other flavor components, thus lowering hedonic scores [25].

The hedonic test results on texture and acceptability of sago porridge showed that the addition of 6% dragon fruit extract (P3) resulted in the highest texture score (3.75), with an overall texture score range between 3.15–3.75. As illustrated in Figure 1, the use of natural coloring from dragon fruit has a positive impact on the quality of aroma, texture, and consumer acceptability, where sago porridge with dragon fruit extract tends to be preferred. Overall acceptability scores ranged from 3.4 to 3.65 with neutral to mildly favorable criteria, indicating a fairly good although not optimal acceptance. Based on the analysis of the main sensory characteristics (color and texture), the optimal treatment was achieved with the addition of 6% dragon fruit extract (P3), which not only increased the visual appeal through natural pigments but also improved the texture of the product. This finding confirms that the sago porridge innovation with dragon fruit extract can be developed as a functional food product that combines aesthetics, superior texture, and consumer acceptance. This study's results align with the findings of Kumari et al., (2025) [19] and Hasanah et al., (2022) [20] on the effectiveness of betacyanin as a natural colorant. However, the optimal level of dragon fruit extract (6%) in this study is much lower than the 15% concentration used by Hasanah et al., (2022) [20] in beverage products. This difference may be due to the nature of the food matrix in sago pulp (starch-based) which has a higher pigment absorption capacity than liquids, so a low concentration is sufficient to achieve the desired color. In addition, the interaction of betacyanin with sago starch might improve color stability, whereas the interaction between hydrocolloids and starch in dragon fruit might form a network that stabilizes betacyanin [26], [27].

3.2. Physical Properties of Sago Porridge

The best sample is identified based on the results of hedonic tests, especially in color sensory attributes and texture which are the main characteristics of porridge products (innovative sago porridge with the addition of dragon fruit extract). Based on these results, the best treatment is obtained by adding 6% dragon fruit extract to sago porridge. This sample is then analyzed physically using instruments that include measurements of color intensity, viscosity, texture, and pH. The results of physical analysis from the best sample can be seen in Table 3.

Table 3. Physical analysis results.

Physical analysis	Control (P0)	P3 (6%)
Color intensity	Light wood	Strawberry red
	L^*: 52.3	L^*: 48.4
	a^*: 9.6	a^*: 70.8
	b^*: 21.8	B^*: 21.5
Viscosity (mPa·s)	23,000	56,000
pH	6.59	7.21
Texture (N)	2.84	8.79

Color measurement using a colorimeter on sago porridge showed that the addition of 6% red dragon fruit extract affected the color parameters L^*, a^*, and b^*, consistent with the findings of dragon fruit-based ice cream [21]. The L^* value decreased from 52.3 (control) to 48.8 (6% extract), indicating a darkening effect on pigmented food matrices [28]. Meanwhile, the a^* value increased dramatically from 9.6 (control) to 70.8 (6% extract), reflecting a red color intensity that exceeds the reported 0–60 range [29], presumably

due to the high concentration of betacyanin in the extract. These betalain pigments, which are water-soluble and stable at acid-neutral pH [30], not only provide an attractive red-purple color but also have potential as natural dye alternatives with superior antioxidant activity compared to synthetic dyes [31], making them ideal for functional food applications such as sago porridge.

Based on Table 3, the addition of red dragon fruit extract increases the viscosity of sago porridge. This increase is due to the interaction between pectin and natural oligosaccharides in dragon fruit that form a three-dimensional gel structure. This mechanism is supported by the characteristics of dragon fruit pectin with a low degree of methylation (DM: 38–47%), where the few methyl groups ($-OCH_3$) on the galacturonic acid (GalA) chain allow the formation of ionic bonds with calcium (Ca^{2+}) in an egg-box model pattern [32]. Viscosity increases with heating temperature and duration due to stabilization of the gel structure, where pectin and oligosaccharides form a stronger molecular network. The crushing process of dragon fruit releases pectin from the cell wall, which dissolves in the juice and forms a gel matrix binding water and other molecules, thus increasing viscosity [33]. Molecularly, pectin increases viscosity through hydrogen bonding between hydroxyl (-OH) groups and hydrophobic interactions between non-polar regions, which together create a 3D network to trap water molecules and restrict their movement [34].

pH is a critical factor influencing the color of betacyanin pigment and the viscosity of sago porridge. Initially, the sago porridge had a pH of 6.59 (slightly acidic/near neutral). However, after adding 6% dragon fruit extract, the pH increased to 7.21 (weakly alkaline). According to previous studies, betacyanin and anthocyanins in red dragon fruit exhibit pH-dependent color changes: red under acidic conditions (low pH) and blue under alkaline conditions (high pH) [35], [36]. In addition to affecting color, the pH increase also influences viscosity through the ionization mechanism of carboxyl groups (-COOH) in dietary fibers and pectin. At high pH, the ionization of carboxyl groups ($-COO^-$) enhances intermolecular electrostatic repulsion, stiffening polymer chains (pectin) and increasing viscosity [36]. This phenomenon aligns with research on orange pectin [37], where high pH increases molecular chain rigidity and viscosity. Thus, the addition of dragon fruit extract not only shifts the sago porridge color from red to blue but also enhances its thickness through chemical interactions consistent with prior findings.

The addition of red dragon fruit extract to sago porridge significantly increased the texture hardness from 2.84 N to 8.79 N, indicating optimal consistency and viscosity. Two main mechanisms supported this improvement. First, hydrogen interaction between the hydroxyl groups (-OH) of dragon fruit natural pectin and sago starch chains, which strengthens the gel matrix and reduces brittleness [38], [39] and second, stabilization of amorphous regions of starch and formation of additional crystallinity by betacyanin, thereby improving matrix stiffness and rheological properties. The unique gelation properties of sago starch contributed to texture stability [40]. In addition to the texture aspect, the red dragon fruit extract changed the color of the slurry from white, as per the natural characteristics of sago, to an attractive red due to the betacyanin pigment, increasing the visual appeal without synthetic colorants [41]. This combination of texture and color improvement expands the potential application of sago in baby food formulations that require stable consistency and natural color aesthetics [42].

4. CONCLUSION

The study concluded that the addition of 6% red dragon fruit extract (P3) produced sago porridge with the best sensory attributes. For sensory evaluation, the porridge achieved the highest preference scores for its Strawberry Red color (redness intensity: a^* 70.8) and overall acceptance (score 3.65), despite a moderately liked texture (score 3.75). Physically, the formulation exhibited ideal characteristics, including high viscosity (56,000 mPa·s), firm texture (Force: 8.7980 N), and stable pH (7.21), which collectively supported its sensory appeal. To advance this innovation, future studies should optimize heating parameters to prevent syneresis and evaluate shelf-life stability through betacyanin and pectin analysis.

AUTHOR CONTRIBUTION

I Gede Arie Mahendra Putra: Writing (original draft, review & editing), formal analysis, supervision. **Luh Dian Rna Fajarini**: Writing (original draft, review & editing), investigation, formal analysis. **Putu Julyantika Nica Dewi**: Investigation, writing (review & editing), and conceptualization.

Wafi Adizara Muzakki: Writing (review & editing). **Nur Syamsi Ibrahim**: (original draft, review & editing).

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] F. F. Sidiq, D. Coles, C. Hubbard, B. Clark, and L. J. Frewer, "Factors influencing consumption of traditional diets: Stakeholder views regarding sago consumption among the indigenous peoples of West Papua," *Agric. Food Secur.*, vol. 11, no. 1, p. 51, 2022, https://doi.org/10.1186/s40066-022-00390-5.

[2] W. Puspantari, P. T. Cahyana, A. Saepudin, Budiyanto, I. Kurniasari, A. D. Kusumasmarawati, H. Henanto, and M. Untoro, "Sago rice as an environmentally sustainable food," *BIO Web Conf.*, vol. 69, p. 03012, 2023, https://doi.org/10.1051/bioconf/20236903012.

[3] Z. A. Syahariza and H. Y. Yong, "Evaluation of rheological and textural properties of texture-modified rice porridge using tapioca and sago starch as thickener," *J. Food Meas. Charact.*, vol. 11, no. 4, pp. 1586–1591, 2017, https://doi.org/10.1007/s11694-017-9538-x.

[4] M. M. Kamal, R. Baini, S. Mohamaddan, O. S. Selaman, N. A. Zauzi, M. R. Rahman, N. A. Rahman, K. H. Chong, M. F. Atan, N. A. S. A. Samat, S. N. L. Taib, and A. K. Othman, "Effect of temperature to the properties of sago starch," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 206, p. 012039, 2017, https://doi.org/10.1088/1757-899X/206/1/012039.

[5] M. A. Zailani, H. Kamilah, A. Husaini, A. Z. R. A. Seruji, and S. R. Sarbini, "Functional and digestibility properties of sago (*Metroxylon sagu*) starch modified by microwave heat treatment," *Food Hydrocoll.*, vol. 122, p. 107042, 2022, https://doi.org/10.1016/j.foodhyd.2021.107042.

[6] W. Dewayani, Suryani, R. H. Arum, and E. Septianti, "Potential of sago products supporting local food security in South Sulawesi," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 974, no. 1, p. 012114, 2022, https://doi.org/10.1088/1755-1315/974/1/012114.

[7] S. I. Oktafira and B. Setiawan, "Formulasi bubur ready to eat berbasis kacang hijau (*Vigna radiata*) dan beras hitam (*Oryza sativa* L.) sebagai pangan darurat," *J. Ilmu Gizi dan Diet.*, vol. 1, no. 2, pp. 110–118, 2022, https://doi.org/10.25182/jigd.2022.1.2.110-118.

[8] T. W. Lim, R. L. H. Lim, L. P. Pui, C. P. Tan, and C. W. Ho, "Red dragon fruit (*Hylocereus polyrhizus*), a superfruit rich in betacyanins pigments with antioxidative potential for hepatoprotection: A review," *Futur. Foods*, vol. 11, p. 100562, 2025, https://doi.org/10.1016/j.fufo.2025.100562.

[9] I. Tarte, A. Singh, A. H. Dar, A. Sharma, A. Altaf, and P. Sharma, "Unfolding the potential of dragon fruit (*Hylocereus spp*.) for value addition: A review," *eFood*, vol. 4, no. 2, 2023, https://doi.org/10.1002/efd2.76.

[10] S. Sumardiono, B. Budiyono, H. Kusumayanti, N. Silvia, V. F. Luthfiani, and H. Cahyono, "Production and physicochemical characterization of analog rice obtained from sago flour, mung bean flour, and corn flour using hot extrusion technology," *Foods*, vol. 10, no. 12, p. 3023, 2021, https://doi.org/10.3390/foods10123023.

[11] S. Wahjuningsih, H. Haslina, and M. Marsono, "Hypolipidaemic effects of high resistant starch sago and red bean flour-based analog rice on diabetic rats," *Mater. Socio Medica*, vol. 30, no. 4, p. 232, 2018, https://doi.org/10.5455/msm.2018.30.232-239.

[12] K. A. P. Hapsari, I. M. Sugitha, and I. P. Suparthana, "Pengaruh penambahan puree daun kelor (*Moringa oleifera* Lamk.) terhadap karakteristik nugget ikan kembung (*Rastrelliger kanagurta*)," *J. Ilmu dan Teknol. Pangan*, vol. 11, no. 1, p. 123, 2022, https://doi.org/10.24843/itepa.2022.v11.i01.p13.

[13] R. P. Winarni, P. Rindit, S. Umar, Giyatmi, and Ardiansyah, *Produk Pangan Indonesia 2017*. Bogor: Penerbit IPB Press, 2017. [Online]. Available: https://patpi.or.id/wp-content/uploads/2023/04/Ensiklopedia-Produk-Pangan-Indonesia_Jilid-1.pdf.

[14] N. F. Putri, A. S. Aji, V. Aprilia, R. Salfarino, R. B. S. MZ, N. Triwahyuni, and R. K. Triastanti, "Sensory evaluation of gulu naga ijo as a complementary finger food product," *Indones. J. Hum. Nutr.*, vol. 10, no. 2, pp. 105–115, 2023, https://doi.org/10.21776/ub.ijhn.2023.010.02.2.
[15] J. A. Célia, O. Resende, M. S. de Lima, J. S. Correia, K. B. de Oliveira, and K. P. Takeuchi, "Technological properties of gluten-free biscuits from sorghum flour granifero (*Sorghum bicolor* (L.) Moench)," *Food Sci. Technol.*, vol. 42, 2022, https://doi.org/10.1590/fst.29222.
[16] D. W. Dari, L. Alfiatul, and D. Junita, "Karakteristik kimia dan derajat keasaman minuman sari buah pedada (*Sonneratia sp*.) dengan penambahan natrium benzoat," *J. Teknol. Pangan dan Gizi*, vol. 20, no. 1, pp. 35–44, 2021, https://doi.org/10.33508/jtpg.v20i1.2863.
[17] O. D. Indriani and A. N. Khairi, "Physico-chemical characteristics of jelly drink with variation of red dragon fruit peel (*Hylocereus polyrhizus*) and additional sappan wood (*Caesalpinia sappan*)," *J. Agri-Food Sci. Technol.*, vol. 4, no. 1, pp. 37–48, 2023, https://doi.org/10.12928/jafost.v4i1.7069.
[18] L. H. Afrianti, Y. Taufik, and H. Gustianova, "Karaktersitik fisiko-kimia dan sensorik jus ekstrak buah salak (*Salacca edulis* Reinw) varietas bongkok," *Chim. Nat. Acta*, vol. 2, no. 2, 2014, https://doi.org/10.24198/cna.v2.n2.9155.
[19] S. Kumari, D. Thakur, S. Singh, M. Bakshi, and S. K. Singh, "Dragon fruit: Exploring bioactive compounds and their promising role in functional food innovation and value-added products," *J. Food Compos. Anal.*, vol. 141, p. 107370, 2025, https://doi.org/10.1016/j.jfca.2025.107370.
[20] A. Hasanah, N. Nurrahman, and A. Suyatno, "Penambahan ekstrak kulit buah naga terhadap derajat warna, kadar antosianin, aktivitas antioksidan dan sifat sensoris cendol," *J. Pangan dan Gizi*, vol. 12, no. 1, p. 25, 2022, https://doi.org/10.26714/jpg.12.1.2022.25-31.
[21] S. A. Prayitno and A. Rahma, "The sensory evaluation on pumpkin ice cream that formulated by red dragon fruit," *Food Sci. Technol. J.*, vol. 2, no. 2, 2019, https://doi.org/https://doi.org/10.25139/fst.v0i0.2036.
[22] A. E. Putri, M. Murhadi, N. Herdiana, and S. Hidayati, "Effect of adding jackfruit dami (*Artocarpus heterophyllus*) on the sensory and chemical characteristics of red dragon fruit (*Hylocereus polyrhizus*) fruit leather," *J. Keteknikan Pertan. Trop. dan Biosist.*, vol. 12, no. 2, pp. 86–93, 2024, https://doi.org/10.21776/ub.jkptb.2024.012.02.02.
[23] X. Chen, Y. Cao, W. Lan, Z. Gu, W. He, J. He, and L. Zhao, "Quality-driven design of pandan-flavored sponge cake: Unraveling the role of thermal processing on typical pandan aroma," *Foods*, vol. 13, no. 19, p. 3074, 2024, https://doi.org/10.3390/foods13193074.
[24] C. Chusak, J. A. Y. Ying, J. L. Zhien, P. Pasukamonset, C. J. Henry, S. Ngamukote, and S. Adisakwattana, "Impact of *Clitoria ternatea* (butterfly pea) flower on in vitro starch digestibility, texture and sensory attributes of cooked rice using domestic cooking methods," *Food Chem.*, vol. 295, pp. 646–652, 2019, https://doi.org/10.1016/j.foodchem.2019.05.157.
[25] N. Yeasmin, B. R. Sarker, A. Begum, M. Z. U. Al Mamun, Nahidur Rahman, Md. Sujan Hossen, Md. Motalab, and Rahima Akter Sathee, "Fortification of yogurt with red dragon fruit's (*Hylocereus polyrhizus*) peel powder: Effects on comprehensive quality attributes and sensory properties," *Turkish J. Agric. - Food Sci. Technol.*, vol. 11, no. 12, pp. 2300–2307, 2023, https://doi.org/10.24925/turjaf.v11i12.2300-2307.6187.
[26] D. B. Rodriguez-Amaya, "Update on natural food pigments - A mini-review on carotenoids, anthocyanins, and betalains," *Food Res. Int.*, vol. 124, pp. 200–205, 2019, https://doi.org/10.1016/j.foodres.2018.05.028.
[27] G. B. Raj and K. K. Dash, "Development of hydrocolloids incorporated dragon fruit leather by conductive hydro drying: Characterization and sensory evaluation," *Food Hydrocoll. Heal.*, vol. 2, p. 100086, 2022, https://doi.org/10.1016/j.fhfh.2022.100086.
[28] I. D. Kumalasari and A. P. Devira, "Aktivitas antioksidan dan evaluasi sensori kukis tersubstitusi tepung kacang hijau dan tepung kulit buah naga merah," *J. Teknol. dan Ind. Pangan*, vol. 35, no. 1, pp. 67–78, 2024, https://doi.org/10.6066/jtip.2024.35.1.67.
[29] L. O. Rahayu and A. Fidyasari, "Organoleptic and dietary fiber quality of black pigeon pea flour as bioencapsulation material," *J. Inov. Penelit.*, vol. 3, no. 4, pp. 5911–5917, 2022,

https://doi.org/https://doi.org/10.47492/jip.v3i6.1968.
[30] S. Shameena, P. R. G. Lekshmi, P. P. Gopinath, P. Gidagiri, and S. Kanagarajan, "Dynamic transformations in fruit color, bioactive compounds, and textural characteristics of purple-fleshed dragon fruit (*Hylocereus costaricensis*) across fruit developmental stages under humid tropical climate," *Horticulturae*, vol. 10, no. 12, p. 1280, 2024, https://doi.org/10.3390/horticulturae10121280.
[31] G. Kaur, B. Thawkar, S. Dubey, and P. Jadhav, "Pharmacological potentials of betalains," *J. Complement. Integr. Med.*, vol. 15, no. 3, 2018, https://doi.org/10.1515/jcim-2017-0063.
[32] W. Liaotrakoon, N. De Clercq, V. Van Hoed, D. Van de Walle, B. Lewille, and K. Dewettinck, "Impact of thermal treatment on physicochemical, antioxidative and rheological properties of white-flesh and red-flesh dragon fruit (*Hylocereus spp*.) purees," *Food Bioprocess Technol.*, vol. 6, no. 2, pp. 416–430, 2013, https://doi.org/10.1007/s11947-011-0722-4.
[33] T. P. Dao, L. P. U. Nguyen, D. T. Le, T. Y. N. Tran, and P. X. Huynh, "Effects of pectinase treatment on the quality of red dragon fruit (*Hylocereus polyrhizus*) juice," *Int. Food Res. J.*, vol. 30, no. 4, pp. 945–952, 2023, https://doi.org/10.47836/ifrj.30.4.12.
[34] Y. Sato and O. Miyawaki, "Analysis of intermolecular interaction among pectin molecules in aqueous sugar solutions," *Food Sci. Technol. Res.*, vol. 14, no. 3, pp. 232–238, 2008, https://doi.org/10.3136/fstr.14.232.
[35] N. Addion, S. Nola, and Surhaini, "Karakteristik ekstrak kulit buah naga merah (*Hylocereus polyrhizus*) dengan penambahan berbagai kosentrasi asam sitrat sebagai pewarna alami makanan," *J. Teknol. Ind. Pertan.*, vol. 30, no. 2, pp. 228–233, 2020, https://doi.org/10.24961/j.tek.ind.pert.2020.30.2.228.
[36] N. Salma, A. Setiyoko, Y. P. Sari, and Y. Rahmadian, "Effect of wheat flour and yellow pumpkin flour ratios on the physical, chemical properties, and preference level of cookies," *J. Agri-Food Sci. Technol.*, vol. 4, no. 2, pp. 59–70, 2024, https://doi.org/10.12928/jafost.v4i2.7882.
[37] E. Asimakopoulou, T. Goudoulas, I. I. Andreadis, D. G. Fatouros, M. Ahmad, C. Vasiliadou, A. Theocharidou, and C. Ritzoulis, "Analytical rheology as a tool for the structural investigation of citrus pectin," *J. Texture Stud.*, vol. 55, no. 2, 2024, https://doi.org/10.1111/jtxs.12828.
[38] F. Zhu, Y.-Z. Cai, M. Sun, and H. Corke, "Influence of Amaranthus betacyanin pigments on the physical properties and color of wheat flours," *J. Agric. Food Chem.*, vol. 56, no. 17, pp. 8212–8217, 2008, https://doi.org/10.1021/jf801579c.
[39] S. N. N. Makiyah, I. Setyawati, S. N. Rahmadhia, S. Tasminatun, and M. Kita, "Comparison of yam composite cookies sensory characteristic between sugar and stevia sweeteners," *J. Agri-Food Sci. Technol.*, vol. 5, no. 2, pp. 120–133, 2024, https://doi.org/10.12928/jafost.v5i2.10211.
[40] Y. Wang, X. Ou, Q. A. Al-Maqtari, H.-J. He, and N. Othman, "Evaluation of amylose content: Structural and functional properties, analytical techniques, and future prospects," *Food Chem. X*, vol. 24, p. 101830, 2024, https://doi.org/10.1016/j.fochx.2024.101830.
[41] R. Barlina, S. Liwu, L. Trivana, A. P. Manambangtua, and J. Wungkana, "Karakteristik papeda instan pati sagu," *Bul. Palma*, vol. 23, no. 1, p. 51, 2022, https://doi.org/10.21082/bp.v23n1.2022.51-59.
[42] R. Qalbi, S. Giovani, Q. Guo, and N. M. Adelina, "Effect of drying time on physicochemical characteristics of dragon fruit peels powder (*Hylocereus polyrhizus*)," *J. Agri-Food Sci. Technol.*, vol. 4, no. 2, pp. 81–96, 2024, https://doi.org/10.12928/jafost.v4i2.9294.