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# Chlorella sp. Flour Addition on The Most Preference Level of Cookies

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## Abstract

The development of functional food products is an important strategy to enhance nutritional value while ensuring they remain appealing to consumers. This research aims to evaluate the incorporation of Chlorella flour into cookies as an alternative protein source and functional ingredient, with consumer preference as the primary quality parameter. The research specifically examines the effect of different concentrations of Chlorella flour on the hedonic acceptance of the cookies, whereas previous studies have predominantly emphasized nutritional composition, while evaluation of sensory acceptance at varying Chlorella concentrations in bakery products such as cookies remains unexplored. This research utilized an experimental approach featuring four formulations that included Chlorella flour at addition levels of 0%, 3%, 4% and 5% based on weight relative to the wheat flour used. Sensory evaluation was conducted through a hedonic test assessing color, aroma, texture and taste of the cookies. Based on the results of the research that cookies with Chlorella flour addition between 0% to 5% were generally still acceptable by the panelists. The addition of 4% Chlorella flour was the most preferred treatment among the panelists. Cookies produced with this treatment had a slightly greenish appearance, a slight smell of chlorella flour, compact and crunchy texture, and a balanced sweet taste with a faint Chlorella flavor.

## KEYWORDS

cookies, chlorella, chlorella flour, preference level

## Introduction

Microalgae are single-celled organisms recognized as promising alternative food sources due to their high content of protein, carbohydrates, vitamins, lipids, and minerals. Compared to other single-cell protein sources such as yeast, fungi, and mammals protein, microalgae offer advantages in terms of safety, production efficiency, and simpler cultivation processes (Nur, 2014). Among various microalgae species, Chlorella is one of the most widely cultivated green microalgae and is notable for its high protein content, accounting for approximately 55–60% of its dry weight (Wulandari et al., 2016). The protein composition includes essential amino acids such as leucine, phenylalanine, and tryptophan, which are readily absorbed by the human body (Lordan et al., 2011).

Chlorella is rich in nutrients, which makes it suitable for use as a food product intended for human consumption (Fadila & Widyaningrum, 2023). In addition to its protein content, Chlorella is rich in bioactive compounds, including chlorophyll and carotenoids such as lutein, zeaxanthin,  $\alpha$ -carotene, and  $\beta$ -carotene. These compounds exhibit antioxidant activity and may contribute to the prevention of oxidative damage (Gouveia et al., 2006, 2007).

For hundreds of years, Chlorella has been consumed mainly as a dietary supplement in the forms of tablets or powder (Panahi et al., 2016). Despite its long-

standing use and high nutritional value, the application of Chlorella as an ingredient in processed foods intended for daily consumption remains limited, particularly in widely accepted snack products. Cookies represent a suitable food matrix for functional food development due to their high consumer acceptance, simple processing, and long shelf life resulting from low moisture content (less than 10%) (SNI 2973-2011). However, the development of cookie-based functional foods faces challenges related to nutrient fortification, sensory quality, and ingredient compatibility. Although Chlorella flour has been suggested as a supplementary ingredient in products such as ice cream, bread, biscuits, and milk (Aulia et al., 2016), for example, Kaya et al., (2024) investigated the fortification of Chlorella flour in wet noodles at substitution levels of 0%, 5%, 10%, and 15%, reporting that 15% substitution yielded the highest organoleptic preference. Similarly, Zulistiara et al., (2017) examined the fortification of Chlorella flour in nata production at addition levels of 0 g, 2 g, 4 g, and 6 g, reporting that the highest-quality nata was achieved with 6 g of Chlorella flour. Based on findings from previous studies, although these products differ from cookies, the addition of Chlorella flour in various food products has been shown to influence consumer acceptability. Therefore, further research is needed to determine the extent to which the incorporation of Chlorella flour affects nutritional enhancement and sensory acceptance in cookies (Syahrul & Dewita, 2016; Telepta & Dianan, 2011).

In Indonesia, the utilization of microalgae in commercial food products is not yet widespread (Fadila & Widyaningrum, 2023), and experimental studies evaluating consumer acceptance of microalgae-enriched bakery products remain limited. Although Indonesia has high potential for microalgae production due to its favorable tropical climate and abundant sunlight, existing studies show that research on microalgae as a food ingredient is still emerging and its practical application in mainstream food products has not been widely adopted (Wahyuningtyas et al., 2024). Consumer-based research indicates that microalgae remain an under-researched food ingredient, and governmental support and promotion are needed to strengthen both consumer acceptance and industry engagement.

This limited commercialization is a result of challenges in standardized cultivation, processing techniques, and scaling up production for food applications. Consequently, despite its recognized nutritional potential, systematic evaluation of Chlorella incorporation into cookies formulations in Indonesia, particularly in relation to sensory acceptance and optimal addition levels, remains limited in Indonesia (Chalid et al., 2010; Miranda et al., 2016). Therefore, systematic studies are still needed to evaluate feasible, sensory-acceptable, and commercially

viable applications of microalgae in cookies products to support the development of the functional food industry in Indonesia. This study systematically assesses hedonic acceptance, nutritional enhancement, and natural color characteristics of cookies fortified with varying concentrations of Chlorella flour.

## Methods

### Research Type

This research adopted a quantitative experimental design involving four levels of Chlorella flour addition. The treatments consisted of 0% (control, without Chlorella flour), 3%, 4%, and 5% Chlorella flour based on the total weight of wheat flour. Sensory evaluation was conducted using a hedonic test to assess consumer preference, based on the parameters of appearance (color), aroma, texture, and taste with 20 semi-trained panelists serving as replicates. This number meets the recommended minimum for consumer preference testing in hedonic studies, as sensory evaluation standards suggest that at least 20 panelists are sufficient to obtain reliable preference data. The panelists met standard sensory evaluation requirements, including good health, having no sensory impairments, and being familiar with cookie products (ISO 11136:2014, 2014; Meilgaard et al., 2016).

The panelists were recruited from the Faculty of Fisheries and Marine Sciences, Padjadjaran University, and had previous background in conducting organoleptic evaluations as well as familiarity with the products tested. The purpose of hedonic testing is to assess the level of acceptance or preference of panelists toward a product by scoring method very like (9), like (7), neutral/ordinary (5), dislike (3), very dislike (1) (Hasibuan et al., 2022). The rejection limit for this product is a scale of 3. Accordingly, products with a score equal to or less than 3 are regarded as not preferred by the panelists.

### Research Location

This research of making cookies and test the level of preference was determined at the Fisheries Product Processing Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University.

### Instrumentation or Tools

The equipment used comprised a digital scale, mixer, oven, mixing bowl, baking tray lined with styrofoam plates, hedonic questionnaire sheets, labels, and a camera for documentation. The ingredients used in the cookies formulation included wheat flour, Chlorella flour (Earth Circle Organics brand), powdered sugar, margarine, eggs, skim milk, palm sugar, baking soda, and vanilla. The treatment of adding Chlorella flour as presented in [Table 1](#).

Table 1. Cookies Formulation with the Addition of Chlorella Flour

Ingredients	Treatments			
	A	B	C	D
Chlorella flour (g)	0	3	4	5
Wheat flour (g)	100	100	100	100
Powdered sugar (g)	50	50	50	50
Skim milk (g)	20	20	20	20
Margarine (g)	60	60	60	60
Palm sugar (g)	20	20	20	20
Eggs (grain)	1	1	1	1
Baking powder (g)	0,8	0,8	0,8	0,8
Vanilla (g)	1	1	1	1
Treatment A: No addition of Chlorella flour (control)				
Treatment B: Addition of 3% Chlorella flour				
Treatment C: Addition of 4% Chlorella flour				
Treatment D: Addition of 5% Chlorella flour				

Procedure of Making Cookies Chlorella Flour

All ingredients were prepared and weighed according to the formulation. Margarine, powdered sugar, palm sugar, skim milk, eggs, vanilla, and baking soda were mixed using an electric mixer at medium speed for approximately 5 minutes until a homogeneous mixture was obtained. Wheat flour and Chlorella flour were then added according to the respective treatments and mixed for an additional 3 minutes until a smooth dough was formed. The dough was manually shaped into circular forms and baked at 100 °C for 20 minutes in an oven. The baking temperature of 100 °C was selected based on preliminary trials and supervision guidance to maintain product structure while preserving the functional properties of Chlorella. This baking temperature was intentionally applied to prevent excessive browning and potential degradation of heat-sensitive bioactive compounds in Chlorella flour. After baking, the cookies were cooled at room temperature and packaged in plastic containers.

Data Analysis

The data from hedonic test were analyzed using two-way Friedman ANOVA with a Chi-square test, followed by multiple comparison analysis to evaluate differences between treatments. The pairwise comparison results were finalized through matrix manipulation to determine criterion weights. Bayes method is used to determine several alternative values of criteria and the best treatment. The statistical procedures applied in the Friedman and Chi-square tests are defined by the following formula (Marimin, 2004).

$$x^2 = \frac{12}{bk(k+1)} \sum_{i=1}^t (R_j)^2 - 3b(k+1)$$

Information:

- X2 = Friedman test statistics
- b = Deuteronomy
- k = Treatment
- Rj = Total ranking of each treatment

If the research data shows the same number, the correction factor (FK) is calculated with this formula:

$$FK = 1 - \left\{ \frac{\sum \tau}{bk(k^2 - 1)} \right\} H_o = \frac{x^2}{FK}$$

Ho = The treatment did not show a significant difference at the level of  $\alpha = 0,05$

H1 = The treatment resulted in a significant difference at the level of  $\alpha = 0,05$

If the value of H is less than  $X2 > (k-1)$ , then the null hypothesis Ho is accepted and the alternative hypothesis H1 is rejected, but if  $H > X2 (k-1)$ , then Ho is rejected and H1 is accepted. When H1 is accepted, it means the treatment has a significant difference, and then a multiple comparison test is used to find out which treatments differ, using the following formula:

$$|Ri - Rj| \leq Z \left[ 1 \frac{\alpha}{K(K-1)} \right]$$

Information:

- Ri - Rj : Variation in average rank
- Ri : Mean rank of the i-th sample
- Rj : The average rank for the jth sample
- $\alpha$  : Experiments conducted at a 0.05 error rate
- n : Total number of tests / data
- k : Total number of treatments
- z : Z-table values for multiple comparisons (/k (k-1))

Preference evaluation data were analyzed using the Bayes test, an organoleptic approach employed to compare product evaluation criteria. The calculation results indicate that the criterion with the highest priority value is the most preferred by the panelists.

## Result and Discussion

### Color

The appearance of color is an important parameter of preference level because it is a sensory trait that is first seen by the panelists (Winarno, 2000). The color appearance assessment was carried out to examine panelists' acceptance of the color characteristics of the cookies, with the results presented in Table 2.

According to panelists' evaluations of the color appearance of cookies supplemented with Chlorella flour, the mean preference scores ranged from 1.9 to 2.9, these values represent the averaged results

of a five-point hedonic scale using weighted scores of 9 (very like), 7 (like), 5 (neutral), 3 (dislike), and 1 (very dislike). The highest average value was obtained in the 4% Chlorella flour treatment (2.9), followed by the 3% treatment (2.7), while the lowest score was recorded in the 5% treatment (1.9). Cookies containing 4% Chlorella flour were the most preferred by the panelists, which may be attributed to their slightly greenish color with light green speckles, mild Chlorella aroma, compact structure, crunchy texture, and a balanced sweet taste with a subtle Chlorella flavor. These characteristics contributed to a visually appealing and acceptable color according to the panelists. The color appearance and shape of cookies from all treatments are shown in [Figure 1](#).

Based on the Friedman test at a 95% confidence level, the incorporation of Chlorella flour into cookies did not significantly affect the preference for color appearance., where Fcount (7.12) was smaller than the Ftable value (7.81). The results indicate that there were no significant differences in color preference among the cookie treatments. Significant color change in cookies with 5% treatment was influenced by the addition of chlorella flour which made the color of cookies darker. The green coloration of cookies supplemented with Chlorella flour is derived from the natural pigment chlorophyll present in Chlorella. According to Yasti (2017), increasing the concentration of Chlorella flour results in a darker product color. This is in accordance with [Bang et al., \(2013\)](#) research, which found that Chlorella flour-fortified snakehead fish protein concentrate cookies significantly affected their appearance. The more Chlorella flour added, the greenish the cookies became. Based on this, the more Chlorella flour added, the more greenish the cookies became. However, the color change in these cookies was not significant, making them acceptable to the panelists ([Pangestika et al., 2021](#)).

*Table 2. Average Results of Cookies Color Assessment in Each Treatment*

Treatment (%)	Median	Average
0	7	2.4 a
3	7	2.7 a
4	7	2.9 a
5	5	1.9 a

*Table 3. Average results of Cookies aroma assessment in each treatment*

Treatment (%)	Median	Average
0	7	2.2 a
3	7	2.4 a
4	7	3.0 a
5	7	2.2 a

*Table 4. Average Results of Cookies Texture Assessment in Each Treatment*

Treatment (%)	Median	Average
0	5	1.8 a
3	5	1.8 a
4	9	3.6 b
5	7	2.6 ab

Note: Treatments sharing the same letter indicate no significant difference based on the multiple comparison test at the 5% significance level.

### Aroma

Aroma is a key parameter influencing product acceptance. In the food industry, aroma assessment is regarded as crucial because it can quickly influence consumer perception and product acceptance. The average aroma scores of the cookies are presented in [Table 3](#).

Based on panelists' evaluations of the aroma of cookies supplemented with Chlorella flour, the mean preference scores ranged from 2.2 to 3.0. The highest average aroma preference was observed in the 4% Chlorella flour treatment (3.0), followed by the 3% treatment (2.4), while the lowest scores were recorded in the 0% and 5% treatments (2.2). Cookies containing 4% Chlorella flour exhibited a mild and distinctive Chlorella aroma, whereas cookies without Chlorella flour (0%) showed a neutral aroma dominated by milk and wheat flour, with no characteristic Chlorella scent.

The characteristic aroma of Chlorella flour observed in each treatment was strongly influenced by the concentration of Chlorella flour added to the cookies. Based on Rafika's research (2017), Fortification of Chlorella Flour on The Level of Preference For Instant Porridge with treatments of 0%, 2%, 4%, 6% and 8% resulted in a decreased average value of aroma, this was due to the higher concentration of chlorella flour in instant porridge, the distinctive aroma of Chlorella will be smelled even more. This finding is consistent with the results reported by Helwana et al. (2013) regarding the fortification of Chlorella flour in cookies which affects the aroma of cookies because Chlorella flour is a microalgae which generally has a strong aroma. Based on the Friedman test conducted at the 95% confidence level, the addition of Chlorella flour to cookies significantly affected panelists' preference for cookie aroma, where the Fcount value (5.29) was greater than the F table value (0.99).

Table 5. Average Results of Cookies Taste Assessment in Each Treatment

Treatment (%)	Median	Average
0	6	2.0 a
3	7	2.6 a
4	8	3.1 ab
5	7	2.2 b

Note: Treatments sharing the same letter indicate no significant difference based on the multiple comparison test at the 5% significance level.

Table 6. Chlorella Cookies Criteria Weighting Value

Criteria	Criteria Weight
Color	0,12
Aroma	0,15
Texture	0,19
Taste	0,54

Table 7. Decision Matrix of Chlorella Cookies Assessment by Bayes Method

Treatment (%)	Median Value				Alternative value
	Color	Aroma	Texture	Taste	
0	7	7	5	6	6.08
3	7	7	5	7	6.62
4	7	7	9	8	7.92
5	5	7	7	7	6.76
<b>Criteria Value</b>	0.12	0.15	0.19	0.54	27.38

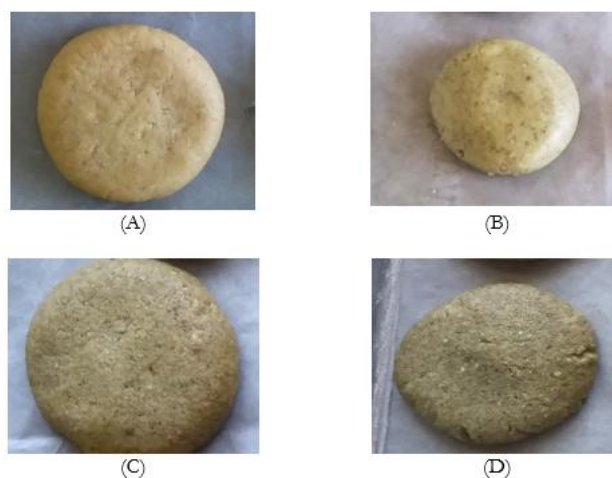


Figure 1. Colour of Cookies (A): 0%; B: 3%; C: 4%; D: 5%

Texture

Texture is one of the most sensitive sensory attributes in food evaluation (Lawless & Heymann, 2010). The texture of a product is generally determined by its water, fat, carbohydrate, and protein composition (Blinova et al., 2015). Texture variations can effect taste perception by modifying the speed of olfactory receptor stimulation of the olfactory receptor cells and salivary glands (Justicia et al., 2012) The average results of observations of the addition of chlorella flour to cookies as presented in Table 4 as follows.

Based on panelists' evaluations of cookie texture following the addition of Chlorella flour, the mean preference scores ranged from 1.8 to 3.6. The highest texture preference was observed in cookies containing 4% Chlorella flour, with an average score of 3.6, followed by the 5% treatment (2.6). In contrast, the lowest preference

scores were recorded in the 0% and 3% treatments, both with mean values of 1.8. Cookies supplemented with 4% Chlorella flour were most preferred due to their moderately dense structure and desirable crunchiness. Conversely, cookies without Chlorella flour (0%) exhibited a more hollow structure and lower crispness, which reduced panelists' acceptance.

The observed differences in texture may be attributed to the water-absorbing (hygroscopic) properties of Chlorella flour. According to Miranda et al. (2018), Chlorella flour exhibits hygroscopic characteristics similar to conventional flour, enabling it to bind water within the cookie matrix. At an optimal level (4%), this property contributes to improved dough structure and texture. However, increasing the concentration to 5% resulted in cookies with a denser and harder texture, likely due to excessive water absorption and

reduced dough expansion during baking, which negatively affected textural acceptability.

At the 95% confidence level, the Friedman test results indicated that the incorporation of Chlorella flour into cookies significantly affected panelists' preference for cookies texture where the  $F_{count}$  value (27.8) was greater than the  $F_{table}$  value (7.81). The results obtained from the test of the multiple comparison follow-up test showed that the 0% and 3% treatments were not significantly different, but significantly different from the 4% and 5% treatments.

#### Taste

Taste is a sensory attribute evaluated through the sense of taste. It also has a significant role in determining consumer preference for a product (Hayati et al., 2014). The results of observations of the addition of Chlorella flour to cookies as presented in Table 5 as follows.

Based on panelists' evaluations of cookie taste following the addition of Chlorella flour, the mean scores ranged from 2.0 to 3.1. The highest mean taste preference score was observed in cookies with 4% Chlorella flour (3.1), followed by the 3% treatment (2.6), while the lowest score was recorded in the control treatment (0% Chlorella flour) at 2.0. Cookies with the addition of 4% Chlorella flour have a characteristic sweet taste evenly and the Chlorella flour feels faint. The sweet taste of cookies comes from the addition of sugar in the manufacturing process. Meanwhile, cookies containing 5% Chlorella flour produced cookies with a stronger characteristic taste of Chlorella flour compared to other treatments.

Chlorella flour addition impacts the sensory taste of cookie products (Stefani et al., 2019). The intensity of the characteristic taste contributed by Chlorella flour in each treatment was strongly influenced by the level of Chlorella flour incorporated into the cookies. The treatment of adding 4% to 5% Chlorella flour decreased the average value, this was because the more Chlorella flour added to the cookies, the more distinctive and dominant Chlorella flour taste. Simanjuntak et al., (2016) stated that the more Chlorella flour added will also give a bitter taste to cookies because Chlorella contains substances that can cause a bitter taste, namely phycocyanin. Based on the Friedman test at the 95% confidence level, the addition of Chlorella flour significantly influenced the taste preference of the cookies where the  $F_{count}$  (9.16) was greater than the  $F_{table}$  value (7.81). The results of the multiple comparison further test analysis showed that the 0% treatment was significantly different from the 3%, 4% and 5% treatments.

#### Bayes method

Relative weight values for the sensory criteria of color, aroma, texture, and taste in Chlorella flour cookies were determined using the Bayes method through pairwise comparisons. This approach was selected because it allows the transformation of subjective sensory judgments into quantitative priority weights while effectively accommodating multiple sensory criteria simultaneously. In addition, the Bayes method is particularly suitable for decision-making based on hedonic data, as it provides a simple and consistent framework for ranking treatments according to overall preference without requiring complex normalization procedures (Faris et al., 2019). The results of the calculation to identify the optimal treatment using the Bayes method, based on the evaluation criteria of color, aroma, texture, and taste of Chlorella flour cookies, are presented in Table 6.

Based on the weighting analysis of the sensory including color, aroma, texture, and taste for Chlorella flour cookies, taste exhibited the highest weight value (0.54),

indicating that it was the most influential factor in panelists product acceptance. Texture was identified as the second most influential criterion, followed by aroma and color. These results demonstrate that taste is the primary determinant of consumer preference; consequently, Chlorella cookies with unfavorable taste are unlikely to be accepted despite satisfactory performance in other sensory attributes.

The Bayes method is an analytical approach used to determine the optimal decision among several alternatives by considering multiple criteria to achieve the best outcome (Marimin, 2004). The results of the Bayesian method calculations for determining the optimal treatment, considering the color, aroma, texture, and taste attributes of Chlorella flour cookies, as presented in Table 7.

Based on the Bayes method calculation, cookies containing 4% Chlorella flour were identified as the most preferred treatment according to the hedonic test results, as they achieved the highest alternative value of 7.92. This was followed by the 5% Chlorella treatment, the 3% treatment, and lastly the 0% treatment. Nevertheless, cookies across all treatments, ranging from 0% to 5% Chlorella flour addition, were still considered acceptable to the panelists.

## Conclusion

Based on the results of the hedonic test, all cookies treatments were generally accepted by the panelists. However, the level of preference indicated that cookies containing 4% Chlorella flour were the most favored relative to other treatments with the highest alternative showing a value of 7.92. Cookies containing 4% Chlorella flour were characterized by a slightly greenish appearance, a mild Chlorella aroma, a compact and crunchy texture, and a balanced sweet taste with a subtle Chlorella flavor.

## Author contributions

All authors made equal contributions to the research process, including the research design, data collection, data analysis, manuscript drafting, and approval of the final manuscript.

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## Conflict of interest

The authors confirm that there are no financial, personal, or institutional conflicts of interest that could have influenced the results or interpretation of this study.

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