



CHECK-ALL-THAT-APPLY (CATA) METHOD FOR DETERMINING VARIATIONS IN SENSORY ATTRIBUTES OF SEAWEED-ANALOG RICE MADE FROM *Eucheuma cottonii* AND *Ulva* sp.

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Abstract

Seaweed contains high levels of water-soluble fiber, particularly in species such as *Hypnea* spp., *Ulva lactuca*, and *Eucheuma cottonii*, which provide health benefits, including the prevention of colon cancer, hypercholesterolemia, diabetes, and liver disease. Seaweed has potential as an ingredient in analog rice products. This study aimed to determine the sensory attributes and preference profiles of analog rice made from *E. cottonii* and *Ulva* sp. using the check-all-that-apply (CATA) method. The seaweed analog rice formulations consisted of 20% *E. cottonii*, 13.2% *E. cottonii*, and 6.8% *Ulva* sp.; 6.8% *E. cottonii* and 13.2% *Ulva* sp.; and 20% *Ulva* sp., with all percentages based on rice flour weight. Four analog rice formulations were compared with conventional rice as a control. Sensory evaluation was conducted with 40 trained panelists covering appearance, color, texture, aroma, and taste parameters. Data were analyzed using Cochran's Q test, frequency analysis, and correspondence analysis (CA). The results showed significant differences among the formulations, particularly in color attributes, texture maturity, seaweed aroma, and grain integrity. Mapping through CA and PCoA revealed that sample B393 (20% *E. cottonii*) was the formulation closest to the ideal profile, characterized by a white color, cooked and soft texture, neutral to fresh seaweed aroma, and intact grain shape. Penalty analysis identified cooked and soft textures, white or cream color, and pleasant food aroma as essential "must have" attributes, while floury aroma and hard texture were classified as "must not have." Overall, the CATA method combined with multivariate analysis proved effective in identifying key drivers of liking and determining the most preferred seaweed-based analog rice formulation for product development.

Keywords: cochran's Q test, correspondence analysis, ideal profile, principal coordinate analysis, sensory

Metode *Check-All-That-Apply* (CATA) untuk Menentukan Variasi Atribut Sensori pada Beras Analog Rumput Laut dari *Eucheuma cottonii* dan *Ulva* sp.

Abstrak

Rumput laut mengandung serat larut air tinggi, terutama pada spesies *Hypnea* sp., *Ulva lactuca*, dan *Eucheuma cottonii*, yang bermanfaat dalam mencegah kanker usus besar, hiperkolesterolemia, diabetes, dan penyakit hati. Rumput laut berpotensi sebagai bahan baku dalam beras analog. Tujuan penelitian ini adalah menentukan atribut sensori dan profil preferensi beras analog dari rumput laut *E. cottonii* dan *Ulva* sp. menggunakan metode *check-all-that-apply* (CATA). Formulasi beras analog rumput laut, yaitu *E. cottonii* 20%, *E. cottonii* 13,2% dan *Ulva* sp. 6,8%, *E. cottonii* 6,8% dan *Ulva* sp. 13,2%, dan *Ulva* sp. 20%. Semua persentase dari formula berdasarkan berat tepung beras. Empat formula beras analog dibandingkan dengan beras konvensional sebagai kontrol. Evaluasi sensori dilakukan terhadap 40 panelis terlatih meliputi parameter ketampakan, warna, tekstur, aroma dan rasa. Data dianalisis menggunakan uji Cochran's Q, analisis frekuensi dan analisis koresponden. Hasil penelitian menunjukkan adanya perbedaan nyata antar formulasi, terutama pada atribut warna, kematangan tekstur, aroma rumput laut, dan keutuhan butiran. Pemetaan melalui CA dan PCoA mengungkapkan bahwa sampel B393 (20% *E. cottonii*) merupakan formulasi yang paling mendekati profil ideal, ditandai oleh warna putih, tekstur matang dan lembut, aroma rumput laut netral hingga segar, serta bentuk butiran yang utuh. Penalty analysis mengidentifikasi tekstur matang dan lembut, warna putih atau krem, dan aroma pangan yang menyenangkan sebagai atribut wajib (*must have*), sedangkan aroma tepung dan tekstur keras sebagai atribut yang harus dihindari (*must not have*). Secara keseluruhan, metode CATA yang dipadukan dengan analisis multivariat terbukti efektif dalam mengidentifikasi atribut penentu kesukaan dan menentukan formulasi beras analog rumput laut yang paling disukai untuk pengembangan produk.

Kata kunci: analisis koordinat utama, analisis korespondensi, profil ideal, sensori, uji Cochran's Q

INTRODUCTION

Analog rice is a rice-like product developed from one or more carbohydrate sources and shaped to resemble traditional rice grains (Budijanto & Yuliyanti, 2012; Mishra *et al.*, 2012). Various non-rice raw materials have been used in its production, including composite flours with agar paste and *Gracilaria* seaweed slurry (Damat *et al.*, 2020) and cassava or sorghum flours enriched with *Eucheuma cottonii* seaweed (Budijanto & Yuliyanti, 2012; Setiawati *et al.*, 2014). Indonesia, one of the world's largest seaweed producers, harvested nearly 10 million tons of wet seaweed in 2022, predominantly *Eucheuma* species (KKP, 2022). Seaweed's short cultivation cycle and nutritional richness, particularly its high soluble fiber content of up to 55% dry weight in species such as *Hypnea* sp. and *Ulva lactuca*, make it an attractive raw material for analog rice. Water-soluble fibers, such as carrageenan and

alginate, have been associated with reduced risks of colon cancer, diabetes, liver disease, and hypercholesterolemia (Mohamed *et al.*, 2012; Peñalver *et al.*, 2024).

Given its nutritional potential, seaweed has been incorporated into analog rice to enhance its fiber content and functional properties, with extrusion and blending techniques widely applied (Setiawati *et al.*, 2014; Patria *et al.*, 2020). Analog rice aims to replicate the nutritional, textural, and sensory attributes of conventional rice while serving as an alternative staple food (Adicandra & Estiasih, 2016). However, seaweed contributes distinctive sensory attributes, including umami flavor, chewy texture, and mineral fishy notes, which may influence consumer acceptance of the final product. To address this challenge, advanced sensory methods, such as check-all-that-apply (CATA), have been increasingly employed to map consumer perceptions of novel foods. CATA



provides rapid and reliable results compared to conventional descriptive methods (Tiepo *et al.*, 2016; Giacalone & Jaeger, 2023) and has proven effective for innovative products based on alternative ingredients such as seaweed (Alcantara & Freitas-Sá, 2018; Lu *et al.*, 2021; Rabitti *et al.*, 2024).

CATA has been widely applied to plant-based foods (Lee & Ju, 2024), fish products (Belusso *et al.*, 2016), chocolate, beverages (Amorim *et al.*, 2023), coffee (Espitia-lópez *et al.*, 2019), and fish broth seaweed snacks (Mindarwati *et al.*, 2024). It has also been recommended for consumer segmentation (Hussain, 2019) and to reduce market failure risks for unfamiliar products (Granato *et al.*, 2020; Lough *et al.*, 2008; Krus & Grantham, 2011; Neumann *et al.*, 2012). However, no previous study has combined CATA with seaweed-based analog rice, creating a significant research gap. A prior study on seaweed analog rice primarily assessed the physicochemical and nutritional properties using hedonic tests (Setiawati *et al.*, 2014; Yulviatun *et al.*, 2022).

The novelty of this study lies in the integration of the CATA method with Cochran's Q, correspondence analysis, PCoA, and a penalty analysis. This study applied these combined sensory approaches for the first time to evaluate analog rice formulated with *E. cottonii* and *Ulva* sp. This study systematically identified ideal and undesirable sensory attributes based on consumer perceptions. The most optimal formulation was determined through comprehensive sensory mapping. This approach distinguishes the study from previous research, which mainly focused on physicochemical characteristics and simple hedonic tests without advanced sensory profiling. This study aimed to determine the sensory attributes and preference profiles of analog rice made from *E. cottonii* and *Ulva* sp. using the check-all-that-apply (CATA) method.

MATERIALS AND METHODS

Preparation of Seaweed Flour

The materials used in this study were *E. cottonii* seaweed from the waters of Sukabumi–West Java and *Ulva* sp. seaweed from Gunung

Kidul Beach. The seaweed was prepared by washing and soaking it in clean water to remove sand and other impurities present in the raw material. *E. cottonii* seaweed was prepared as a puree. The seaweed preparation was modified according to Dyas (2023). *Ulva* sp. seaweed was dried at a temperature of 50–60 °C (Rahmat *et al.*, 2018). The dried seaweed was mashed (powdered) with a blender, sifted (80 mesh), stored in a sealed container, and protected from sunlight.

Processing of Seaweed Analog Rice Top of Form Bottom of Form Processing

All the ingredients were weighed according to the composition, while the broken rice was thoroughly washed, drained, aerated for approximately 30 min, ground using a blender, and then mixed with seaweed according to the formulation until homogeneous using a mixer. The dough is then placed into a *double-screw* extruder until it forms rice grains. Analog rice granules were then dried at a temperature of 70–80°C for 3 h until the moisture content reached approximately 10%. Analog rice processing was modified according to the procedure described by Amrizal *et al.* (2024). The analog rice formulations are presented in Table 1, with rice flour at 80%, while the remaining 20% consisted of variations in seaweed formulations using *E. cottonii* and *Ulva* sp.

Sample Presentation

The cooking process of analog rice begins by weighing the required amount of analog rice, followed by washing it once with clean water. The analog rice was then boiled in water at a 1:1 ratio (w/v) for 5 min. After boiling, the remaining water was discarded, and the analog rice was drained. Subsequently, it is steamed in a preheated steamer with boiling water for approximately 20–30 min until fully cooked, achieving a soft and tender texture with no hard particles remaining (Abhilasha *et al.*, 2021). Each sample was presented on a paper plate and labeled with a different three-digit random number. Mineral water was served to the panelists to neutralize

Table 1 Samples of seaweed analog rice and commercial rice were used in the study

Code	Formulation
B425	Commercial analog rice
B393	Seaweed analog rice (rice flour 1 part (e.g 1000 g), <i>Eucheuma cottonii</i> seaweed, 20% of rice flour).
B127	Seaweed analog rice (rice flour 1 part (e.g 1000 g), <i>Eucheuma cottonii</i> seaweed 13.2% and <i>Ulva</i> sp. 6.8% of rice flour).
B981	Seaweed analog rice (rice flour 1 part (e.g 1000 g), <i>Eucheuma cottonii</i> seaweed 6.8% and <i>Ulva</i> sp. 13.2% of rice flour).
B653	Seaweed analog rice (rice flour 1 part (e.g 1000 g), <i>Ulva</i> sp. seaweed, 20% of rice flour).

their taste buds during sample changeover. Forty semi-trained panelists involved were 40 semi-trained panelists.

Determination of Sensory Attributes of Seaweed Analog Rice

The sensory attributes of the seaweed analog rice were determined through a focus group discussion (FGD) conducted by three researchers and two senior students in fishery technology. The focus group discussion (FGD) was conducted with students and lecturers from the Fisheries Polytechnic, specifically from the Fishery Product Processing study program, who had regular experience in conducting sensory evaluations as part of their practical training and internal campus activities (Johansson, 2021). Although the participants were not experts in analog rice, they possessed relevant sensory assessment skills, including familiarity with evaluating the appearance, aroma, texture, and taste of various food products. Their background in food processing and routine exposure to organoleptic testing ensured that the sensory attributes generated during the FGD were aligned with the actual characteristics of the seaweed-based analog rice sample. This composition of personnel supports the validity of the identified attributes and ensures that the FGD outcomes reflect informed sensory observations. The FGD procedure began by providing five samples of seaweed analog rice, each with a different code (three-digit

number), and then asking the panelists to feel the attributes that appeared for each panelist. Furthermore, the data were collected and discussed again by all panelists to determine the attributes most likely to be present in the samples, as well as the attributes that are understood by consumers. The attributes generated from the FGDs were used for check all that apply (CATA) testing.

Sensory Testing with the CATA Method

The panelists were 40 fishery technology students. The panelists in this study were recruited from Fisheries Polytechnic cadets enrolled in the Fishery Product Processing study program, who were accustomed to conducting sensory evaluations of various food products through routine practicums and internal campus training. Panelist selection was based on their experience in organoleptic quality assessment, ability to recognize basic sensory attributes, and willingness to complete all stages of evaluation. Prior to testing, the panelists received instructions on the CATA procedure, definitions of each attribute, and guidelines for completing the evaluation form to ensure consistency in assessment (Espitia-lópez *et al.*, 2019). A total of 40 panelists, both males and females aged 18–40 years, participated in the study. These demographic details are provided to enhance data transparency and clarify the capacity of the panelists as a semi-trained group suitable for sensory analysis in this study.



The initial stage involved filling in personal biodata, namely, name, gender, and age. Before tasting the samples, the panelists were directed to fill out a questionnaire containing questions about seaweed analog rice based on consumer perceptions. The panelists were asked to check the attributes that were considered ideal for seaweed analog rice in the questionnaire. The list of attributes was based on the results of the previous FGD. The next test was to determine the attributes of each sample by tasting. The panelists were given 5 plates of seaweed analog rice samples, each labeled with a three-digit code, to taste and assess each attribute listed in the questionnaire. If an attribute was not present in the sample, it was not included in the questionnaire.

Data Analysis

The XLSTAT 2023 Addinsoft software with CATA analysis and preference mapping capabilities was used to analyze the data. Cochran's Q test, principal coordinate analysis (PCoA), correspondence analysis (CA), and Penalty Analysis were among the data analysis methods used in CATA. A contour map featuring color zones and percentages was part of the data analysis produced by preference mapping tools. To enhance methodological clarity, the description of the statistical analyses was supplemented by specifying the significance threshold used in this study. All analyses were performed using XLSTAT 2023 (addinsoft), including Cochran's Q test, principal coordinate analysis (PCoA), correspondence analysis (CA), and penalty analysis, and were interpreted using a significance level of $p < 0.05$. In particular, Cochran's Q test applied this p-value threshold to determine whether the differences among the sensory attributes selected by the panelists were statistically significant.

RESULT AND DISCUSSION

Sensory Attributes Based on FGD

Sensory attributes are a set of words that can be used to explain a food product's sensory attributes. featured a contour plot with percentages and color zones. In detail, the sensory attributes, which include color/

appearance, texture, aroma, and taste (Pereira *et al.*, 2021; Ruiz-Capillas & Herrero, 2021) as shown in Table 2, which shows that the FGD results for 5 seaweed analog rice products are 32 sensory attributes. In this study, all 32 sensory attributes generated from the FGD were used directly in the CATA questionnaire without any additional selection process, ensuring that the attribute list from the FGD was identical to the attributes evaluated by panelists in the CATA test.

The attributes of seaweed analog rice are influenced by the various compounds it contains in seaweed analog rice. Bahlawan *et al.* (2023) explained that aroma is an important parameter for consumer acceptance. The sensory attributes identified in the FGD (color, aroma, taste, and texture) were influenced by the composition and processing of the seaweed analog rice. The aroma of the product was affected by the raw materials and thermal reactions during cooking, particularly the Maillard reaction, which contributes to the development of characteristic odors. The Maillard reaction, which denatures proteins, occurs during the cooking of seaweed analog rice (Ding *et al.*, 2020). The addition of *Ulva* seaweed influenced the color by producing a greener appearance, whereas enzymatic browning during the processing of seaweed analog rice contributed to the development of brownish hues (Moon *et al.*, 2020). The taste attributes remained similar to those of conventional rice, indicating that the addition of seaweed did not significantly alter the flavor. The texture characteristics, ranging from soft to slightly crumbly, were influenced by the seaweed content, cooking conditions, and extrusion parameters. These factors collectively shape the key sensory properties of seaweed-based analog rice. The addition of seaweed contributes to the chewiness and softness of rice from seaweed analog rice (Mamat *et al.*, 2014).

Sensory Profile of Seaweed Analog Rice

Many studies have used the CATA approach. A study by Kim *et al.* (2023) used the CATA method to evaluate the taste of foreign and domestic coffee products in China. CATA

Table 2 Sensory attributes of seaweed analog rice based on FGD

Attributes	Description
Color	
White	Rice that has a clean, uniform white color, free from spots or other discolorations.
Clear/translucent	The rice grains have a semi-translucent appearance, allowing light to partially pass through them, creating a soft, transparent effect.
Brown	A darker and richer brown color, giving a strong and solid appearance.
Light brown/ cream	A light and soft brown color.
Light yellow	A very light yellow color, almost approaching white.
Light green	A light green color resembling fresh leaf shoots, reflecting a natural impression and rich in chlorophyll, possibly due to the pigment content from natural ingredients mixed into the rice.
Dark green	A dark green color similar to mature or aged leaves.
Appearance	
Oval size	The rice grains are oval-shaped with slightly pointed or slightly rounded ends.
Big size	Rice with a large size and weight that feels more solid when held.
Small size	Rice grains are small, giving a light, quick-cooking impression.
Flattened shape	An oval, flattened shape with a wider dimension than its thickness.
Whole shape	Rice grains that are still in their original form, without cracks or damage.
Broken shape	Rice with grains that have cracks or breaks, giving an uneven appearance.
Texture	
Hard	Rice with a hard texture, with grains that feel coarse and dense when chewed.
Soft	Cooked rice with a soft texture that allows the grains to soften easily when chewed.
Mushy	Rice grains that are overly mushy due to absorbing too much water give a full and slightly watery impression.
Crumbled/broken	Cooked rice in a crumbled condition, resulting in irregular grains.
Half-cooked	Cooked rice grains with a texture that is not fully soft, where some parts of the rice still feel slightly hard or not completely cooked.
Cooked	Rice with a uniformly soft texture throughout the grains, with no hard or undercooked parts, indicating consistent doneness.



Table 2 (cont.)

Attributes	Description
Porridge-like	Cooked rice grains with a very mushy and cohesive texture, resulting in a consistency similar to porridge or fully softened rice.
Slightly chewy	Cooked rice with a slightly chewy consistency, where the grains are not completely broken down and have a slight resistance when bitten.
Very chewy	Cooked rice grains with a dense and very chewy texture, giving a firm impression and not easily breaking apart when chewed.
Slimy	Cooked rice grains with a slimy appearance, where the liquid from the rice makes them feel slippery and wet.
Aroma	
Food aroma	Cooked rice that emits an appetizing aroma, giving a strong and enticing fragrance, enhances the appeal of the dish.
Odorless	Cooked rice with a neutral and unobtrusive smell, where there is no distinctive aroma that stands out.
Seaweed aroma	Cooked rice containing seaweed produces a natural sea aroma.
Rice flour aroma	Cooked rice containing rice flour may produce an aroma similar to that of rice flour.
Pandan aroma	Cooked rice with a pandan aroma produces a scent similar to fresh pandan leaves.
Musty/ rancid	Cooked rice grains with a musty smell often indicate a rotten or rancid odor, similar to the smell of food that has spoiled or is no longer fresh.
Spoiled/stale	Cooked rice with a stale smell emits a foul and sour aroma, similar to the smell of food that has undergone decomposition or fermentation.
Neutral	Cooked rice with a neutral smell has an almost imperceptible aroma, indicating that there is no prominent scent from the rice.
Taste	
Sweet	Cooked rice with a sweet taste shows the presence of a natural sweetness that comes from the rice starch.

allows researchers to collect sensory profiles from coffee samples more efficiently than traditional consumer surveys do. According to Ciappini & Arias (2023), the CATA method is effective in describing the sensory attributes of products, including honey.

The CATA method is a sensory analysis technique that relies on consumer perception

to gather information about the attributes of the food product being tested. Untrained panelists can participate in this analysis by choosing words or phrases from a list that appropriately describes the sample (Pramudya & Seo, 2018). Market research and product characterization frequently employ the CATA approach in conjunction with hedonic sensory

systems (Belusso *et al.*, 2016). The CATA method produces data in the form of sensory profile characteristics of seaweed analog rice, with the results of the analysis including Cochran's Q test and correspondence analysis (CA) (Sourial *et al.*, 2013). Comparing sensory qualities of each sample at a 5% significance level is the outcome of Cochran's Q test, which uses multiple pairwise comparisons and Marascuilo's crucial difference approach. The goal of Cochran's Q Test is to find substantial variations between samples for each attribute (Espitia-lópez *et al.*, 2019). The results of Cochran's Q Test are shown in Table 3.

The Cochran's Q test results for the seaweed analog rice products yielded p-values indicating the comparison of each sample across sensory attributes. A p-value <0.0001%

indicated a significant difference between the attributes (Espitia-lópez *et al.*, 2019). The CATA sensory test results revealed that out of the 32 attributes evaluated, 15 attributes, particularly in terms of color and texture, showed significant differences among the five seaweed analog rice samples. Sample B393 was perceived as the whitest, B425 had the softest texture, and B393 was mushier. Meanwhile, most aroma attributes did not show meaningful variation, leading to the conclusion that formulation differences had a greater impact on the visual and textural perceptions of the product than on its aroma.

The optimal product was analyzed using correspondence analysis (CA), which correlated the sensory attributes with the product samples. The biplot, which explained

Table 3 Results of Cochran's Q test and Sheskin post-hoc test on seaweed analog rice samples

Attributes	p-value	B425	B393	B127	B981	B653
Color						
White	<0.0001	0.300 ^{ab}	0.575 ^b	0.150 ^a	0.150 ^a	0.250 ^a
Clear/translucent	0.700	0.000 ^a	0.025 ^a	0.000 ^a	0.025 ^a	0.000 ^a
Brown	0.004	0.025 ^a	0.000 ^a	0.125 ^a	0.150 ^a	0.100 ^a
Light brown/ cream	<0.0001	0.500 ^b	0.225 ^{ab}	0.100 ^a	0.000 ^a	0.050 ^a
Light yellow	0.118	0.100 ^a	0.050 ^a	0.025 ^a	0.025 ^a	0.150 ^a
Light green	0.077	0.025 ^a	0.050 ^a	0.050 ^a	0.125 ^a	0.125 ^a
Dark green	0.002	0.075 ^a	0.100 ^a	0.375 ^a	0.275 ^a	0.225 ^a
Appearance						
Oval size	0.001	0.000 ^a	0.000 ^a	0.225 ^a	0.250 ^a	0.150 ^a
Big size	0.478	0.225 ^a	0.200 ^a	0.200 ^a	0.175 ^a	0.275 ^a
Small size	0.042	0.075 ^a	0.000 ^a	0.000 ^a	0.050 ^a	0.000 ^a
Flattened shape	0.416	0.025 ^a	0.000 ^a	0.025 ^a	0.000 ^a	0.000 ^a
Whole shape	0.933	0.000 ^a	0.025 ^a	0.025 ^a	0.025 ^a	0.025 ^a
Broken shape	0.012	0.075 ^a	0.100 ^a	0.050 ^a	0.050 ^a	0.225 ^a
Texture						
Hard	<0.0001	0.025 ^a	0.000 ^a	0.175 ^a	0.150 ^a	0.175 ^a
Soft	<0.0001	0.550 ^c	0.225 ^{ab}	0.450 ^{bc}	0.475 ^{bc}	0.275 ^{abc}



Table 3 (cont.)

Attributes	p-value	B425	B393	B127	B981	B653
Mushy	<0.0001	0.100 ^a	0.450 ^{bc}	0.125 ^a	0.225 ^{ab}	0.225 ^{ab}
Crumbled/broken	0.018	0.150 ^a	0.125 ^a	0.050 ^a	0.050 ^a	0.025 ^a
Half-cooked	0.093	0.100 ^a	0.000 ^a	0.050 ^a	0.025 ^a	0.025 ^a
Cooked	0.038	0.000 ^a	0.050 ^a	0.100 ^a	0.100 ^a	0.025 ^a
Porridge-like	0.005	0.250 ^a	0.225 ^a	0.150 ^a	0.125 ^a	0.300 ^a
Slightly chewy	0.173	0.050 ^a	0.100 ^a	0.025 ^a	0.025 ^a	0.025 ^a
Very chewy	0.639	0.225 ^a	0.200 ^a	0.175 ^a	0.175 ^a	0.200 ^a
Slimy	0.352	0.000 ^a	0.000 ^a	0.000 ^a	0.025 ^a	0.025 ^a
Aroma						
Pleasant food aroma	0.015	0.275 ^a	0.275 ^a	0.275 ^a	0.375 ^a	0.425 ^a
Odorless aroma	0.002	0.100 ^a	0.100 ^a	0.075 ^a	0.075 ^a	0.200 ^a
Seaweed aroma	0.030	0.125 ^a	0.050 ^a	0.050 ^a	0.150 ^a	0.150 ^a
Rice flour aroma	<0.0001	0.550 ^b	0.475 ^b	0.500 ^b	0.325 ^{ab}	0.225 ^{ab}
Pandan aroma	0.543	0.025 ^a	0.075 ^a	0.050 ^a	0.050 ^a	0.025 ^a
Stale aroma	0.155	0.000 ^a	0.050 ^a	0.075 ^a	0.050 ^a	0.000 ^a
Sour/spoiled aroma	0.629	0.000 ^a	0.000 ^a	0.025 ^a	0.025 ^a	0.025 ^a
Neutral aroma	0.005	0.925 ^a	0.725 ^a	0.850 ^a	0.900 ^a	0.725 ^a
Taste						
Sweet	0.000	0.025 ^a	0.200 ^a	0.125 ^a	0.050 ^a	0.025 ^a

Note: B425: commercial analog rice; B393: seaweed analog rice (rice flour, *E. cottonii* seaweed, 20% of rice flour); B127: Seaweed analog rice (rice flour, *E. cottonii* seaweed 13.2% and *Ulva* sp. 6.8% of rice flour); B981: Seaweed analog rice (rice flour, *E. cottonii* seaweed 6.8% and *Ulva* sp. 13.2% of rice flour); B653: Seaweed analog rice (rice flour, *Ulva* sp. seaweed, 20% of rice flour).

82.23% of the data variability along the x- and y-axes, divided the six samples into four quadrants (Figure 1). CA highlighted the relationships between samples formulated with *E. cottonii* and *Ulva* sp. and the corresponding sensory characteristics, summarizing the data while identifying the underlying factors influencing sensory perception in sustainable seaweed analog rice.

The panelists conducted a sensory evaluation of samples B425, B393, B127, B981, and B653. Attributes such as color, large rice grain size, firm texture (unripe), neutral

smell, and mushy texture (ripe) were linked to code B425. Code B393 was associated with the white color and ripe texture. Attributes including brown and light to dark green color, half-cooked, and broken shape (hard) were related to codes B127, B981, and B653. Panelist responses to samples containing *Ulva* sp. and *Eucheuma cottonii* varied depending on the cooking time and seaweed type. Three product groups emerged from the CATA attribute responses: (1) B425, (2) B393, and (3) B127, B981, and B653. The X(F1) axis contributed 45.19% of the variance, indicating

that *the proportions of E. cottonii and Ulva sp.* influence sensory perception. The eigenvalues and inertia percentages presented in Table 4 are further visualized in Figure 1 using a scree plot to clarify the variance explained by each CA dimension.

The results of the correspondence analysis (CA) showed that the five dimensions (F1–F5) had different eigenvalues and inertia percentages, with F1 and F2 providing the largest contributions to explaining the variability of the data. In the table, F1 explained 45.19% of the variability, followed by F2 with 37.039%, indicating that these two dimensions together accounted for 82.23% of the total data variation and were therefore the most relevant for interpreting the biplot. The remaining dimensions, F3 (10.10%), F4 (5.448%), and F5 (2.223%), contributed minimal additional information. This is supported by the scree plot, which shows a steep decline from F1 to F2 and a more gradual decrease in the subsequent dimensions, indicating that the information contributed beyond F2 is not significant. Thus, the CA interpretation should focus on F1 and F2, as these two dimensions are the most representative in describing the relationships among the samples and sensory attributes in the biplot.

Furthermore, correspondence analysis (CA) was used to map ideal attributes based on panelist perception (Ares *et al.*, 2010). The CA biplot (Figure 1) illustrates the relationships among the samples, ideal rice, and sensory attributes (Hunaefi & Marusiva, 2021). Ideal attributes are defined as those closest to the ideal point on the map (Sourial *et al.* 2013). Ideal rice was described by the panelists as sweet, soft, neutral in aroma, with a fresh seaweed aroma, and intact in shape. Figure 2 shows that none of the product samples

completely matched the ideal attributes, although B393 and B653 were the closest. B393, containing *E. cottonii*, had attributes of a white color and ripe texture. B653, with *Ulva sp.*, was associated with the whole shape and seaweed aroma.

The results of the principal coordinate analysis (PCoA) are shown in Figure 3. The correlation map between sensory attributes and liking scores in Figure 2 reveals a clear pattern of panelist preferences for seaweed-fortified analog rice. The position of the “liking” point in the upper right quadrant indicates that panelist preference is significantly and positively correlated with attributes located in the same quadrant. Attributes such as “sweet,” “brown,” “cream,” “food fragrant whole cooked,” and “big size white” were consistently associated with samples that received the highest sensory ratings. This suggests that panelists tend to prefer analog rice with appealing color (brown to cream), large and whole grains, a characteristic cooked rice aroma, and a slightly sweet flavor. These characteristics likely mimic the preferred qualities of conventional rice, thereby enhancing the consumer acceptance of the analog product.

Conversely, attributes located in the lower left quadrant, such as “mushy,” “half cooked,” and “neutral,” showed a negative correlation with liking. This implies that samples perceived as having a texture that is too soft, undercooked, or bland taste tend to be less preferred. This finding aligns with earlier sensory results, where formulations with excessive seaweed addition (e.g., >20% *E. cottonii* or combinations with *Ulva sp.*) were reported to have a chewier and stickier texture, which may approach the perception of “mushiness” or be deemed less ideal by some panelists.

Table 4 Eigenvalues, inertia percentages, and cumulative variance explained across dimensions in correspondence analysis

	F1	F2	F3	F4	F5
Eigenvalue	0.134	0.109	0.030	0.016	0.007
Inertial (%)	45.189	37.039	10.101	5.448	2.223
Cumulative (%)	45.189	82.229	92.329	97.777	100.000

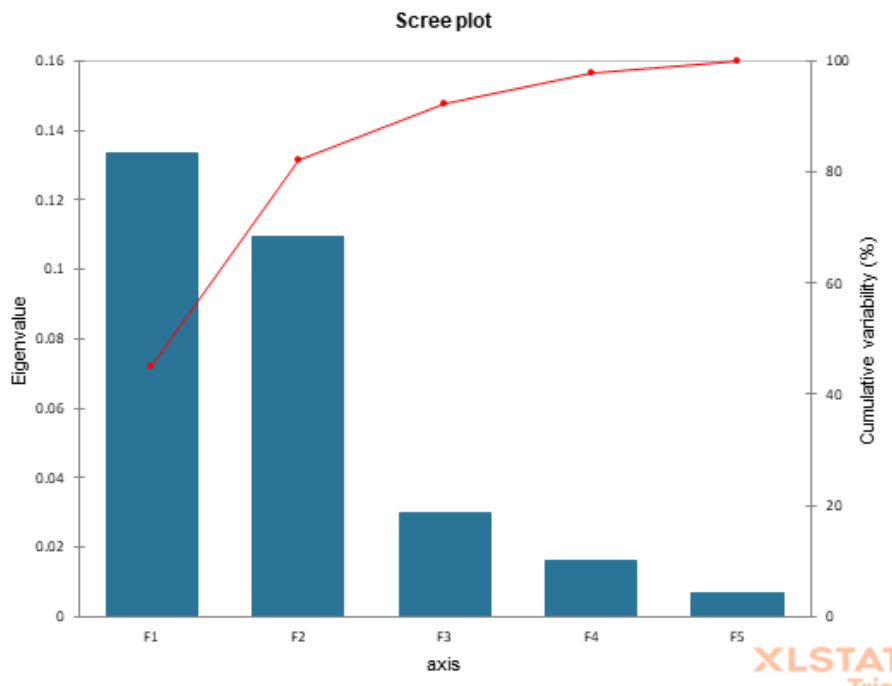


Figure 1 Screen plot displaying eigenvalues and cumulative variance explained for the five CA dimensions

This interpretation reinforces the conclusion that formulation B393 (20% *E. cottonii*) is the most optimal, not only because of its quantitatively highest liking score but also because its sensory profile aligns most closely with the cluster of preferred attributes: it offers a balanced color, grain size, and acceptable aroma, without being dominated by the less desirable “mushy” or “neutral” characteristics. Thus, this correlation analysis not only identifies the key drivers of consumer acceptance but also provides formulation guidance for optimizing the sensory characteristics of functional seaweed-based analog rice.

The next analysis is the penalty analysis, which is used as the basis of product development and focuses on which attributes can affect overall product acceptance (Lee, 2020). The resulting five categories of attribute groups in the XLSTAT 2023 software included must have, nice to have, does not influence, does not harm, and must not have. However, only the categories of must-have, nice-to-have, and must-not-have are analyzed because they are more influential for product development (Hunaefi & Marusiva, 2021). “Must-have” is a category of attributes that must be owned by

a product. There are criteria to show that an attribute belongs to the “must-have” group, namely that the attribute is desired in the ideal product (Adawiyah & Yasa, 2017). The “must-have” category refers to basic attributes that consumers perceive as essential and non-negotiable in an ideal product, where the absence of these attributes causes significant dissatisfaction, although their presence is generally considered a standard expectation rather than a source of increased satisfaction. Recent studies have further emphasized that must-have attributes play a critical role in shaping customer perceptions, service quality, and product competitiveness in both digital and consumer-based industries (Peneder *et al.*, 2025).

The penalty analysis presented in Figure 4 illustrates the relationship between the frequency of the selected attributes and their impact on the liking scores given by the panelists. The X-axis represents the percentage of panelists who selected each attribute, whereas the Y-axis shows the mean drop, which indicates the average change in liking scores when an attribute is present in a sample. Positive mean drops suggest that the presence of an attribute increases

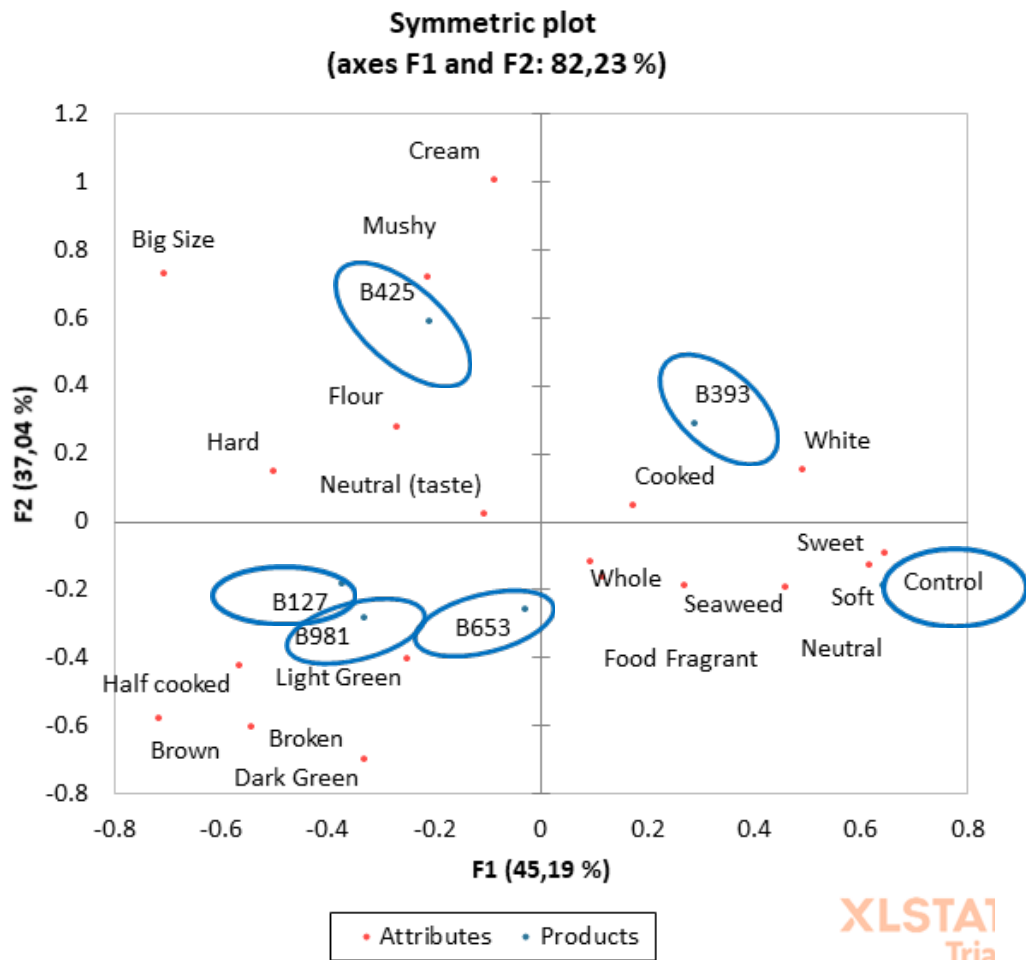


Figure 2 Sensory profile representation of seaweed analog rice; B425: commercial analog rice; B393: seaweed analog rice (rice flour, *E. cottonii* seaweed, 20% of rice flour); B127: Seaweed analog rice (rice flour, *E. cottonii* seaweed 13.2% and *Ulva* sp. 6.8% of rice flour); B981: Seaweed analog rice (rice flour, *E. cottonii* seaweed 6.8% and *Ulva* sp. 13.2% of rice flour); B653: Seaweed analog rice (rice flour, *Ulva* sp. seaweed, 20% of rice flour).

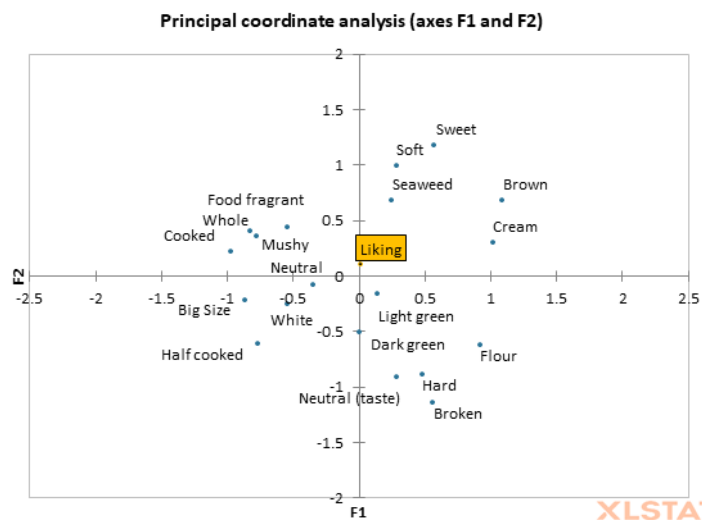


Figure 3 Attribute and favorability correlation map

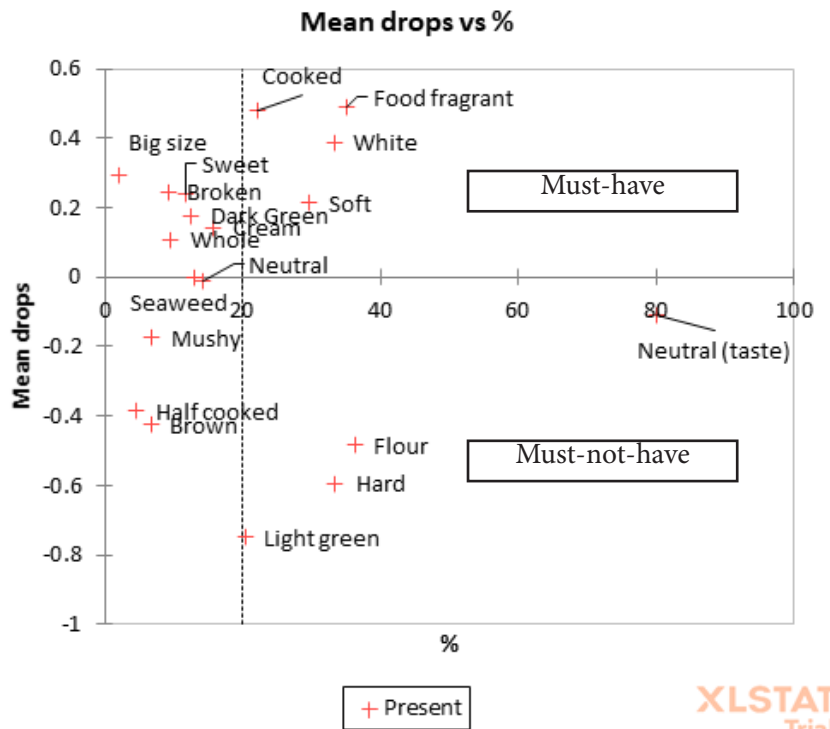


Figure 4 Must-have and must-not-have attribute analysis graph

liking, whereas negative mean drops indicate a decrease in liking. Attributes located in the must-have quadrant appear frequently and contribute positively to the liking score. In the figure, attributes such as white, soft, cooked, and food fragrance fall into this category. These attributes are important because they strongly enhance consumer acceptance of the product. For example, white color and a properly cooked texture are characteristics commonly expected in rice products, reinforcing perceptions of quality and readiness for consumption. Soft texture and pleasant food aroma also contribute to a more favorable eating experience, making these attributes essential for an ideal analog rice profile.

In contrast, the “must not have” quadrant contains attributes with high frequency but negative mean drops, indicating that they lower consumer preference. Attributes such as flour, hard, and light green were positioned in this quadrant. Floury aroma and hard texture are associated with inferior quality, suggesting incomplete cooking or an unsuitable formulation. Similarly, a light green color negatively affects acceptance because it

appears unnatural for rice products and may indicate an uneven color distribution in the formulation. Several other attributes appear on the left side of the plot, such as brown, half-cooked, dark green, broken, and large size, which show lower frequencies and therefore exert a smaller impact on overall liking. However, some of these attributes, particularly brown color, half-cooked texture, and dark green appearance, still tend to reduce liking when present and should be considered in future formulation improvements. Based on the liking, B653 (rice flour, *Ulva* sp. seaweed, 20% rice flour) was selected as the superior product with high acceptability and positive attributes.

Chemical Characteristic of Seaweed Analog Rice

The quality of seaweed-based analog rice is reflected in its chemical characteristics. Table 5 presents the chemical characteristics of the analog rice containing 20% *E. cottonii*. These characteristics are important for evaluating the nutritional composition and functional properties of products. In addition, the chemical profile may indicate the potential

Tabel 5 Characteristics of analog rice containing 20% *E. cottonii*

Parameter	Result
Total energy (kcal/100 g)	339.24±0.05
Energy from fat (kcal/100 g)	0.00±0.00
Water content (%)	14.70±0.01
Ash content (%)	0.49±0.05
Fat content (%)	0.00±0.07
Protein content (%)	8.27±0.01
Carbohydrate (by difference)	78.54±0.10
Total dietary fiber (%)	11.87±0.04

of seaweed incorporation to improve the quality and health benefits of rice analogs.

The seaweed-based analog rice containing 20% *E. cottonii* exhibited chemical characteristics that reflected a high-fiber functional food profile with moderate energy content. The total energy was 339.24±0.05 kcal/100 g, with an energy contribution from fat of 0.00±0.00 kcal/100 g, consistent with its very low-fat content of 0.00±0.07%. The moisture content was 14.70±0.01%, while the ash content reached 0.49±0.05%, indicating relatively stable product characteristics and the mineral contribution of the seaweed. The protein content was relatively high at 8.27±0.01%, suggesting that the incorporation of *E. cottonii* enhanced the nutritional value of the rice analog. In addition, the carbohydrate content reached 78.54±0.10%, representing the main component of the product. Research conducted by Salsabila *et al.* (2025) reported that the fiber and fat contents of *Gracilaria* sp. analog rice were 7.35% and 4.17%, respectively. The most notable characteristic was the total dietary fiber content of 11.87±0.04%, which was substantially higher than that of analog rice *Gracilaria* sp. 6.09–10.77 % (Purwaningsih, 2022) and may provide potential functional benefits, such as improved digestive health and reduced glycemic response.

CONCLUSION

In conclusion, the check-all-that-apply (CATA) method combined with Cochran's Q test, correspondence analysis (CA), PCoA, and penalty analysis successfully identified the

sensory attributes and preference profiles of analog rice made from *E. cottonii* and *Ulva* sp. The results showed that formulation B393 (20% *E. cottonii*) was closest to the ideal profile, characterized by a white color, cooked and soft texture, neutral to fresh seaweed aroma, and intact grain shape. Penalty analysis identified soft texture, white/cream color, and pleasant food aroma as “must-have” attributes, while floury aroma and hard texture as “must-not-have” attributes. Thus, the CATA method is effective for sensory mapping of seaweed analog rice, and B393 is recommended as the optimal formulation for product development.

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