

Enhancing Chinese Steam Bun Characteristics with *Chlorella vulgaris*-Enriched Coconut Oil

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Abstract Chinese steam buns (CSB) are traditional steamed buns with nutritional limitations due to primarily consisting of carbohydrates. We explored the potential of *Chlorella vulgaris*, rich in essential nutrients and bioactive compounds, as functional ingredients for CSB. However, *C. vulgaris* has an intensely fishy aroma; therefore, we extracted bioactive compounds of *C. vulgaris* with coconut oils and applied them in CSB. Our study investigated the effect of chlorella-enriched coconut oil (CECO) on CSB characteristics with varying concentrations (0%, 2.5%, 3.5%, 4.5%, and 5.5%). CECO has 46.83% antioxidant activity, 9.81 µmol/g of carotenoids, and 22.32 mg/g of chlorophylls. The 5.5% concentration of CECO in CSB was found to have high quantities of carotenoids (2.36 µmol/g) and chlorophylls (10.45 mg/g), as well as impressive antioxidant activity (85.50%). At this concentration, the physical attributes include a pleasing chewy texture, distinct scent, unusual sweet flavor, and light green appearance. According to our research, CSB bread may out to be an inexpensive and functional foods.

Keywords: *Chlorella vulgaris*, Functional food, Green extraction, CSB bread, Pigments

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1. Introduction

Chinese steamed bun (CSB), or "mantou," is a traditional staple food made from wheat flour in North China. CSB has a vital role in the Chinese people's diet [1]. The main ingredients of CSB consist of wheat flour, water, and yeast processed by steam cooking [2]. The high carbohydrate level in CSB, which is not accompanied by excess ingredients such as active compounds of flavonoids, chlorophyll, carotenoids, and high protein levels, can be this product's most significant deficiency factor [3]. As consumer demand for healthy food increases, innovative food products are needed. As part of essential diets in China, CSB is suitable for nutrient-rich carrier products [4]. Therefore, most studies have incorporated functional ingredients into CSB, such as soy milk [4], high protein dairy [5], sweet potato [6], to increase the nutrition value of CSB.

Chlorella sp. is a tiny, single-celled green microalgae with high nutritional value and is often used as a supplement [7]. It is high in protein, carbohydrates,

unsaturated fatty acids, vitamins, enzymes chlorophyll (chl) a, chl b, and carotenoids (cars) [8]. European Novel Food Regulations have approved *Chlorella* sp and the FDA (Food Drug Administration) in the USA and has been used in several countries (USFDA, 2012) [9,10]. *Chlorella vulgaris* has been incorporated into food as powder/dried biomass [11,12]. Incorporating biomass *C. vulgaris* into food products will improve nutritional and bioactive compounds; however, it produces a pungent smell. The pungent smell produced from microalgae biomass can be reduced by extraction of microalgae.

Incorporating *C. vulgaris* extract in CSB is expected to be one of the solutions and produce healthy food with high nutritional value for snacks. The CSB product was fortified with *C. vulgaris* oil extract (CECO). It is hoped that it will benefit health and meet the community's nutritional needs, especially for the lower middle class who find it difficult to reach food prices, which are quite expensive, and the problem of malnutrition in the community can be overcome. Therefore, this study aims to improve the nutritional characteristics of CSB with CECO. Furthermore, this research will determine the consumer preference and antioxidant activity of the CECO enriched CSB.

2. Material and Methods

2.1. Materials

Chlorella powder (purity 100%) was purchased from Daesang Corp., South Korea. Coconut oil, wheat starch, wheat flour, powdered sugar, baking powder, and yeast were obtained from the local market in Semarang City, Indonesia.

2.2. Preparation of *Chlorella Vulgaris*-Enriched Coconut Oil (CECO)

CECO was prepared according to Susanto et al. 2024 with slight modifications. *Chlorella vulgaris* powder was immersed in coconut oil (1:3). The mixture was sonicated for 20 minutes to break the *C. vulgaris* cell wall. Then, the mixture was extracted under dim light for 24 hours at room temperature. The extract was filtered to obtain CECO. All extraction processes were conducted in dark light to maintain bioactive compounds.

2.3. CSB Preparation

CSB was prepared according to [13] with modifications. The ingredients presented in Table 1 were mixed based on the treatment. After mixing, the different concentrations of CECO were added and fermented for 50 minutes at room temperature. After fermentation, the dough was flattened to reduce the thickness to 2-3 mm. The flattened dough was then rolled and molded to form CSB with 36 x 22 x 34 mm diameter. The CSB was then steamed for 10 minutes at 90 - 95°C.

Table 1. Formulation of Making Chinese Steamed Buns (Mantou) with COCE

Ingredients	Research Treatment				
	Control	COCE 2.5%	COCE 3.5%	COCE 4.5%	COCE 5.5%
Coconut Oil / COCE (%)	4.5	2.5	3.5	4.5	5.5
Flour (%)	51	51	51	51	51
Wheat Starch Flour(%)	6.5	6.5	6.5	6.5	6.5
Fine granulated sugar (%)	10.5	10.5	10.5	10.5	10.5
Baking powder (%)	0.9	0.9	0.9	0.9	0.9
Water (%)	25.5	27.5	26.5	25.5	24.5
Instant yeast (%)	1.1	1.1	1.1	1.1	1.1
Total (%)	100	100	100	100	100

Information :

Coconut oil : Pure coconut oil (Control)

COCE : Coconut oil enriched with *Chlorella* sp.

2.4. Proximate Analysis

The proximate analysis was performed for CSB added with 0%, 2.5%, 3.5%, 4.5%, and 5.5% CECO. Each sample was first homogenized before performing analysis using methods from AOAC 2005. The moisture content was determined using the oven drying method at 105°C overnight (AOAC 984.20). The crude fat content was determined using the Soxhlet method (AOAC 922.06). Meanwhile, the crude protein was determined using the Kjeldahl method and calculated using the conversion factor 6.25 (N x 6.25) (AOAC 981.10). The ash content

was determined using a muffle furnace at a temperature of 600°C for 4 hours until there was no presence of black (AOAC 923.03). The total carbohydrates were obtained using a different method.

2.5. Texture Profile Texture

The specific volume of treated buns was determined. Images of the sliced breads were captured using Nexygen software. Texture analysis of treated CSB was performed by using the *Texture Analyzer* model TATX plus (Stable Micro Systems) according to [14] equipped with 30 Kg load cell and the TA-TX plus Cylindrical probe (12.7 mm diameter AOAC standard precise acrylic 50 mm length, 30% target deformation, 6 mm s⁻¹ test, and post-test speed. The texture profile analysis (TPA) of CSB was determined according to the methods of [14] with slight modification. The whole treated and untreated CSB (4 x 1 x 1 cm³) were assayed using a TA-TX with Nexygen software and used probe (cylinder 12.7 mm diameter). The test conditions were set at a pre-test speed of 2 Mm/s, a test speed of 2 Mm/s, and a post-test speed of 2 Mm/s. Hardness, adhesiveness, cohesiveness, gumminess, springiness, and chewiness were calculated.

2.6. Pigments

Determination of total chls and cars in CECO and CSB was performed based on the spectro UV-Vis method previously described by [15] with minor modification. The methanolic extract of CECO and the powdered, freeze-dried CSB were used to calculate the total pigment content of both samples. Total pigments were extracted from CECO and CSB with methanol 1:2 (w/v) and vortexed for 3 minutes. The mixtures were centrifuged at 4000 x g for 15 minutes.

The total chlorophylls and carotenoids amounts were determined spectrophotometrically using a UV-Vis mini-Spectrophotometer (Shimadzu, Japan). The light absorbance was measured at 646 and 663 nm (chlorophylls) and 470 nm (carotenoids). The content of pigments was calculated using Equations 1 and 2.

$$\text{Total Chlorophylls (mg / g)} = (12.21 \times A_{663}) - (2.81 \times A_{646}) \quad (1)$$

$$\text{Total Carotenoids (}\mu\text{g / g)} = \mu \frac{(1000.A_{470}) - (3,27.Ca) - (104.Cb)}{229} \quad (2)$$

where A_{470} , A_{663} , and A_{646} are the absorbance of the sample at 470 nm, 663 nm, and 646 nm, respectively.

Finally, the total chlorophyll contents were calculated as mg/g dried sample, while total carotenoids were calculated as $\mu\text{g/g}$ dried sample.

2.7. Antioxidant Activity

The antioxidant activity was evaluated by DPPH radical scavenging activity assay according to [16] with some modifications. The CECO and each treatment's freeze dried CSB samples were prepared for 0.5 mg/mL⁻¹ in methanol. The samples (1 mL) were mixed with 2 mL of

diluted stock DPPH solution (50 in μM in methanol). The samples were incubated at room temperature for 60 minutes. The absorbance was measured with a UV-Vis spectrophotometer 410 at a wavelength of 517 nm. DPPH RSA (radical scavenging activity) is expressed as the percentage of DPPH inhibition according to the formula. Antioxidant capacity (% inhibition) to inhibit free radicals is determined according to the following Equation 3.

$$\% \text{ Inhibition} = X100\% \quad (3)$$

2.8. Color

About 5 mL of CECO were analyzed for color analysis. While, 5 g of freeze dried CSB were ground from color parameters according to [17] by using Colorimeter Konica Minolta CR-400 was used to measure the color of untreated and treated CSB bread. According to the CIELAB (L^* , a^* , b^*) system, the values of L^* , a^* , and b^* indicate the lightness-darkness (L^*), redness-greenness (a^*), and yellowness-blueness (b^*) of CSB, respectively. The white index (WI) is calculated according to the Equation 4.

$$WI = 100 - \left((100 - L^*)^2 + a^{*2} + b^{*2} \right)^{1/2} \quad (4)$$

2.9. Scanning Electron Microscopy

SEM examined the microstructure of treated and untreated CSB. Prior to SEM, CSB samples were dehydrated in a freeze dryer (24 hours). Samples were fixed, coated with carbon and gold glue or metal in a vacuum-producing microwave plasma device (magnetron sputtering device) equipped with a vacuum pump and examined using a scanning electron microscope in high voltage 20 kV, and then work distance of 10 Mm (JEOL JCM 7000, Osaka, Japan).

2.10. Sensory Test

A panel of sensory analysts consisting of thirty panelists aged between 20 and 50 was used for sensory evaluation. CSB was prepared as described above. CSB was cooled to room temperature and then provided for sensory evaluation. The scoresheet followed Indonesian National Standard (INS) No. 01-2346-2006. The appearance, texture, taste, aroma, and overall acceptance were evaluated using a 9-point hedonic scale (1 extremely dislike and 9 extremely like). The sensory analysis was carried out by 30 trained panelists from the Faculty of Fisheries and Marine Science, Universitas Diponegoro.

2.11. Statistical Analysis

All data are reported as means of $\pm$ standard error over three replications. Statistical analyses were conducted using the SPSS Application. The difference between samples was determined using one-way ANOVA and Tukey's test at a significance level of $p < 0.05$. The OriginLab was analysed using OriginPro 2023b (USA).

3. Result and Discussion

3.1. CECO Characteristic

Before being added to CSB, CECO carries out a characteristic analysis to determine its quality. CECO carried out characteristic tests as in Table 2. The pigments at CECO has a very high chlorophyll ($22.31 \pm 0.17 \text{ mg/g}$) and carotenoids content ($9.81 \pm 0.67 \mu\text{mol/g}$). The high value of chlorophyll and carotenoid pigments shows that CECO can be used as functional ingredients. Furthermore, the antioxidant activity of CECO was 46.83%. Color testing using a CR-410 Chroma meter was used to analyze brightness (L^*), reddish (a^*), and yellowish (b^*). The CECO's brightness value (L^*) is 26.74 ± 0.71 , indicating a high level of darkness (dark green). The redness rating (a^*) of 1.97 ± 0.11 indicates that no red hue was detected. Meanwhile, the yellowness value (b^*) was 13.07 ± 0.64 . According to Durmaz et al. (2020) samples that have negative values. shows an increase in green color.

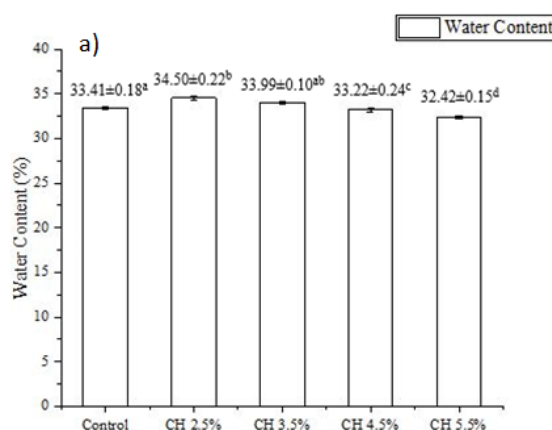
Table 2. Characteristics *Chlorella vulgaris* Enriched Coconut Oil (CECO) Extract

Parameter Analyze	
Chlorophyll (mg/g)	$22,31 \pm 0.17$
Carotenoids ($\mu\text{g/g}$)	$9,81 \pm 0.67$
Antioxidant (%)	$46,83 \pm 0.51$
Lightness (L^*)	$26,74 \pm 0.71$
Redness (a^*)	$1,97 \pm 0.11$
Yellowness (b^*)	$13,07 \pm 0.64$

3.2. CSB Characteristic

3.2.1. Proximate

The proximate composition of the CSB with CECO is presented in Figure 1. The higher concentration of CECO in CSB significantly increases fat and carbohydrate content. However, it reduced the moisture and ash content in CSB. The increasing concentration of CECO in CSB resulted in a low ash level. This might be attributed to the addition of oils, which decrease the moisture and ash level of the dough during processing. The added oil might have replaced more moisture during steaming. The 2.5% CECO showed the highest content of moisture and ash.



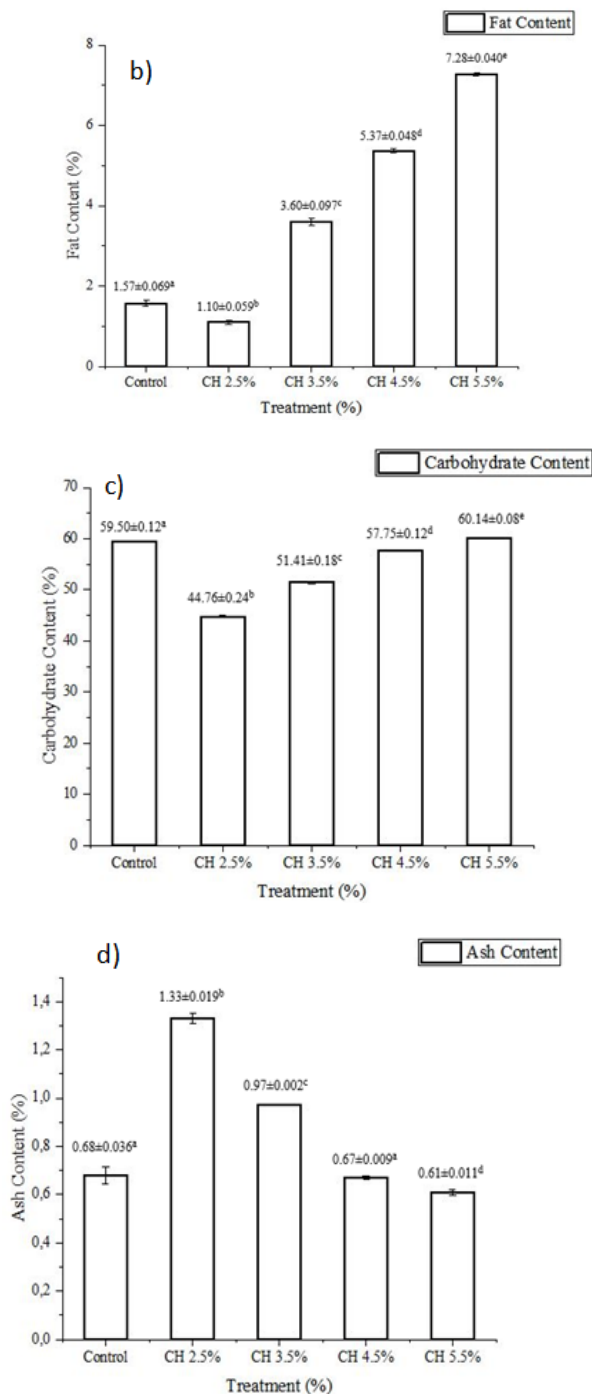


Figure 1. Proximate analysis of (a) Water content; (b) Ash content; (c) Carbohydrate content; (d) Fat level. Data are the mean of three replicates $\pm$ standard deviation. Data followed by different lowercase letters indicate a significant difference ($p < 0.05$)

Lipid content significantly increased ($p < 0.05$) about 6.18% in 5.5% CECO CSB. This could be due to the increasing concentration of CECO substitution. In addition, the CECO contains lipids from coconut oil and is obtained from *Chlorella* sp. Furthermore, carbohydrate content in CSB significantly increased ($p < 0.05$) from 44.7% in control to 60.14% in 5.5% of CECO. The high levels of carbohydrates in CSB bread are a source of energy for the body. The World Health Organization (WHO) recommends consuming as much as 20-30% of total energy needs, which is considered good for health.

3.2.2. Total pigments

Chinese steam buns (CSB) are white; after adding CECO, the colour will be more greenish. *Chlorella* contains natural lipid soluble pigments, chlorophyll, and carotenoids [18]. Figure 2a shows the total chlorophyll and carotenoid content in CSB after adding different concentrations of CECO.

The data from one-way ANOVA exhibited that the addition of CECO significantly affected the chlorophyll and carotenoid content of CSB. The total value of chlorophyll ranged from 1.42 to 10.45 $\text{mg}\cdot\text{g}^{-1}$, while carotenoid content ranged from 0.52 to 2.36 $\mu\text{mol}\cdot\text{g}^{-1}$. The control of CSB contains low amounts of chlorophyll from the ingredients. According to [19], *Chlorella* sp. is known industrially as one of the Chlorophyceae groups, with the dominant chlorophyll-a pigment. In addition, it contains the pigment chlorophyll-b, carotene, and xanthophyll in the form of lutein. CSB bread, with the addition of CECO 5.5%, had the highest total carotenoids of 2.36 $\mu\text{mol}\cdot\text{g}^{-1}$, while the control CSB bread was 0.52 $\mu\text{mol}\cdot\text{g}^{-1}$. This indicated that the total carotenoids increased with the addition of higher CECO.

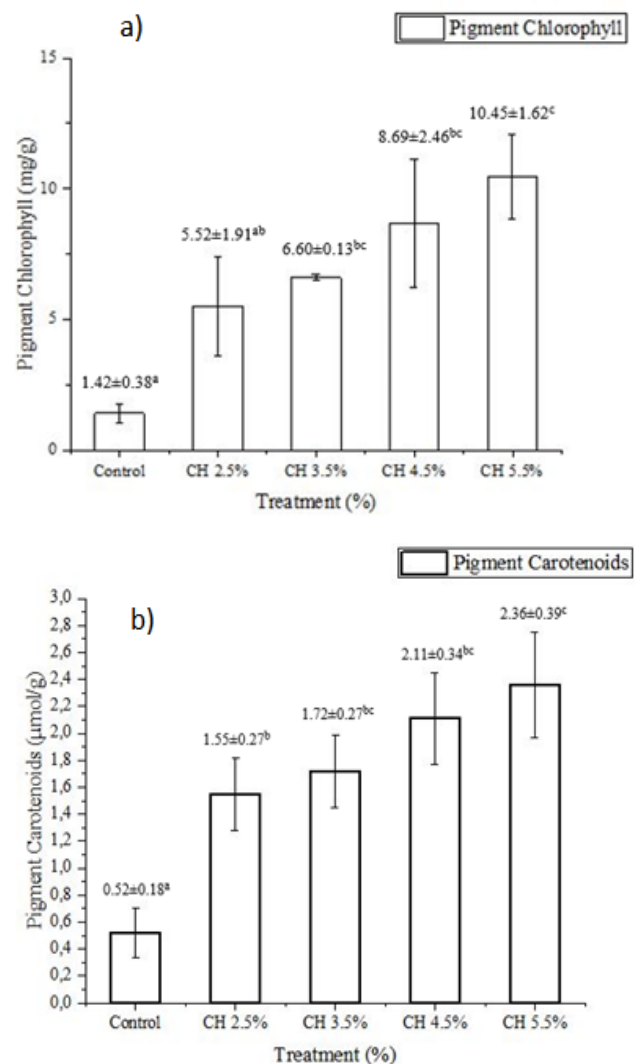


Figure 2. Effect of COCE addition on the (a) total chlorophyll and (b) total carotenoids content of Mantou bread. Data followed by different lowercase letters indicate a significant difference ($p < 0.05$)

3.2.3. Antioxidant Activity

The antioxidant activity of untreated and treated CSB bread samples was determined using DPPH free radical scavenging activity assays. Among the CSB samples with the addition of CECO, 5.5% showed the highest radical scavenging activity, 84.49%, much better than other concentrations (Figure 2b). The 0% of CECO exhibited high antioxidant activity, about 63.11, probably due to the presence of antioxidant compounds in commercial coconut oils. Our results showed that adding CECO could increase bread's antioxidant activity. According to [20], *Chlorella* sp. was reported to have beneficial effects on growth, antioxidant activity, immunity, and tissue rebuilding.

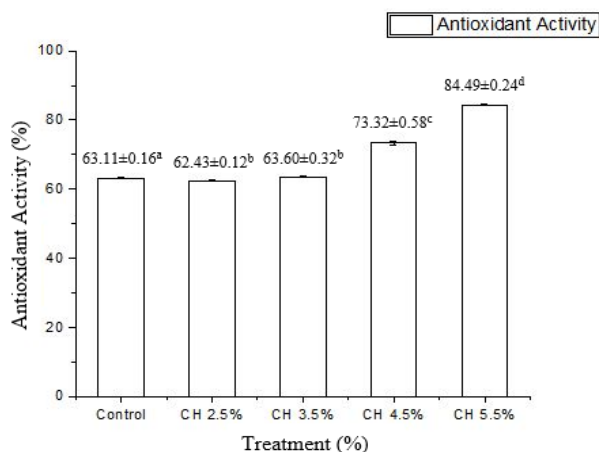


Figure 3. Antioxidant activity of untreated and treated Mantou after addition of COCE with different concentration. Data followed by different lowercase letters indicate a significant difference ($p < 0.05$)

3.2.4. Color Degrees

Table 3 shows that CECO significantly ($p < 0.05$) altered color compared to the control group. The color analysis performed on the samples (Table 3) revealed that the presence of CECO had a substantial effect on the CSB color. The treated CSB darkened (decreased L^* index), reddened (decreased a^* index), and yellowed (increased b^* index). The control had much greater lightness (L^*) values, suggesting a lighter color and less natural pigment content; however, CSB with 5.5% CECO had significantly lower lightness, indicating a darker hue and a higher natural pigment content with CECO addition. The redness (a^*) value differed significantly between untreated and treated CSB. Untreated CSB had the highest redness value (-1.71), indicating a higher level of redness without treatment, where the other parameter of Lab color is yellowness (b^*). The yellowness parameter shows from yellow (+60) to blue (-60), according to CIELAB [21]. The addition of CECO showed significant ($p < 0.05$) on the b^* value. The yellow color (+ b^*) is obtained from microalgae pigments such as carotenoids, which remain

stable after extrusion [22].

Mean values with different superscripts significantly ($P < 0.05$) in rows for each L^* (lightness); a^* (redness); and b^* (yellowness) values between control, CHSD, OD, and FD bread samples

Based on research by [23] shows a greenish color on the bread, which is intensive with the amount of *Chlorella vulgaris*. The degree a^* on the CSB bread showed that the intensity of the red color was not detected in the product. According to [24], decreasing a^* and b^* is more significant, meaning the color is greener. This color variation is attributed to the presence of pigments such as chlorophyll due to the higher concentrations of CECO [23]. The microalgae extracts' concentration function reduced fresh bread's surface red color (a^*) [25].

Table 3. Colorimeter Test on Chinese Steamed Buns (Mantou) with COCE

Sample	L^*	a^*	b^*
Control	81.76±0.21 ^a	-1.71±0.01 ^a	19.64±0.19 ^a
CH 2.5%	78.11±0.14 ^b	-3.69±0.15 ^b	23.10±0.82 ^a
CH 3.5%	77.38±0.55 ^b	-2.45±0.13 ^c	20.15±0.31 ^b
CH 4.5%	77.69±0.39 ^b	-4.92±0.20 ^d	26.51±0.35 ^c
CH 5.5%	75.58±0.09 ^c	-5.47±0.16 ^e	27.14±0.40 ^c

3.2.5. Texture Profile and Volume of CSB

Table 4 shows the profile analysis curve for control and CSB with CECO. The CSB's hardness, gumminess, chewiness, and cohesiveness reduced with the addition of CECO, but adhesiveness decreased (Table 4). It was found that adding CECO reduced the hardness, gumminess, chewiness, and cohesiveness of CSB. As a result, the concentration of microalgae suspension has a minor impact on textural qualities. The microalgae cell walls disintegrate after treatment, and polysaccharides and proteins dissolve and form aggregates [26].

The higher the gumminess, the greater the force required to change the product's structure, so that when eaten, the product is increasingly difficult to separate [27]. Wheat gluten in wheat flour is essential for good dough composition, forming an elastic-cohesive mass in the final product. End-product quality attributes of soft wheat products are mainly defined by the gluten properties of the flours [28]. The gluten quality, primarily genetically controlled, significantly impacts the dough's viscoelastic properties [29]. Strengthened by [30], the protein found in wheat flour can make the networks that bind them more compact.

Table 4 shows that as the concentration of CECO increased, the hardness and chewiness of CSB steadily decreased, with no significant change in chewiness. Furthermore, the cohesiveness of CSB with a CECO concentration increased and reduced, indicating a maximum limit in oil concentration. In general, adding CECO to the texture of CSB made more CSB easier to ingest, particularly as the CECO increased concentrations.

Table 4. Texture Profile Analyzer of Chinese Steamed Buns (Mantou) with COCE

Sample	Hardness	gumminess	Adhesiveness	Chewiness	Cohesiveness
Control	1.22±0.096 ^{ab}	0.571±0.03 ^{bc}	0.104±0.0047 ^{bc}	5.84±1.00 ^a	0.399±0.06 ^{ab}
CH 2.5%	1.51±0.184 ^{bc}	0.573±0.07 ^{bc}	0.068±0.0137 ^a	5.85±1.23 ^a	0.401±0.07 ^b
CH 3.5%	1.72±0.034 ^c	0.625±0.02 ^c	0.098±0.0000 ^b	6.06±0.09 ^a	0.439±0.09 ^c
CH 4.5%	1.19±0.105 ^{ab}	0.427±0.02 ^a	0.106±0.0063 ^{bc}	5.57±0.25 ^a	0.406±0.06 ^b
CH 5.5%	1.10±0.208 ^a	0.508±0.04 ^{ab}	0.117±0.0027 ^c	5.25±0.74 ^a	0.382±0.02 ^a

The different uppercase letters indicate significant differences ($p < 0.05$), while the same uppercase indicate no significant difference ($p < 0.05$)

3.2.6. Microstructure of CSB

Scanning Electron Microscope (SEM) is a method for viewing microscopic structures related to the rheology, topology, morphology, and composition of the CSB. The microstructure of CSB with different CECO concentrations was observed by SEM (Table 5). Starch granules were embedded in the gluten network, and the holes were irregular and not uniform. This phenomenon was in accordance with [31], a control bread sample without any additions, has less uniform and irregular pore sizes. However, the control bread dough exhibited a continuous and complete gluten network, and the starch grains were tightly embedded in the gluten film. Dough on bread derived from wheat flour forms a complex network

where gluten forms a continuous three-dimensional network filled with starch granules [32].

According to Table 5, the volume and density of bread cells reduced as CECO concentrations increased. The structural properties of white bread and modified bread with the addition of CECO will differ in microstructure.

Microstructure results on CSB bread with the addition of demonstrate that the more compact the structure, the smaller and more homogeneous the bread tissue compared to the control. This will have an impact on the cell area of bread slices as well as loaf volume. The crumb area in bread in 2D reduced as the CECO level increased. The steaming procedure affects the integration of CECO, reducing bread expansion and loaf volume.

Table 5. Scanning Electron Microscope (SEM) of Chinese Steamed Buns (Mantou) with COCE

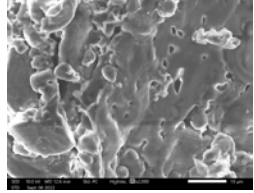
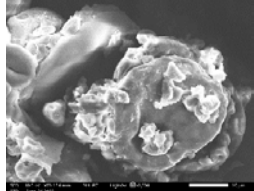
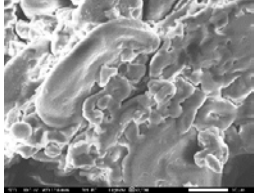
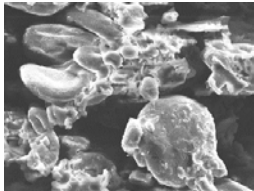
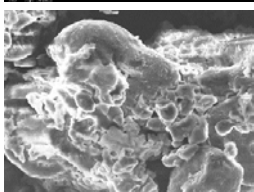
Sample	Chinese Steam Buns (Mantou)	Slice of Chinese Steam Buns (Mantou)	Scanning Electron Microscope (SEM) 2000X
Control			
CH 2.5%			
CH 3.5%			
CH 4.5%			
CH 5.5%			

Table 6. Hedonic Score of Chinese Steamed Buns (Mantou) with COCE

Sample	Specification				
	appearance	Aroma	Flavor	Texture	Overall acceptability
Control	7.06±0.92 ^a	6.96±1.11 ^a	7.00±1.15 ^a	6.76±1.02 ^a	6.94±1.05 ^a
2.5%	7.26±0.89 ^a	6.80±0.94 ^a	6.93±1.31 ^a	6.66±1.04 ^a	6.91±1.04 ^a
3.5%	7.36±0.75 ^{ab}	6.93±1.12 ^a	7.03±0.94 ^a	6.96±1.19 ^{ab}	7.07±1.00 ^a
4.5%	7.46±0.95 ^b	6.93±1.26 ^a	7.20±0.90 ^a	7.00±1.46 ^b	7.14±1.14 ^b
5.5%	7.93±0.99 ^c	7.03±1.37 ^a	7.56±0.95 ^a	7.60±1.28 ^c	7.53±1.14 ^c

3.2.7. Consumer Preference

Different CECO substitutions had a substantial effect on CSB quality as determined by instrument analysis. Table 6 shows consumers' sensory assessments of CSB with the addition of CECO. CSB supplemented with 2.5% CECO received considerably worse sensory scores for appearance, scent, flavor, texture, and overall control. The addition of CECO resulted in the highest customer preference score and a significant difference ($p < 0.05$) from the control CSB. Overall, the score was 3.5%. As a result, we indicate that enriched CSB can be produced for pigment ingestion while maintaining consumer sensory appeal.

The color pigments chlorophyll and carotenoids give CSB bread products a bright green color. The results of research conducted by [33] stated that the increase in color in bread and dough depends on the presence of pigments in the microalgae biomass. CECO applied to bread is regarded as a beneficial form since it can improve the appearance of the bread, which is typically more colorful.

The aroma of CSB bread, which contains both gluten and CECO, efficiently hides the slightly strong odor of CECO. As a result, applying CECO had no significant effect on the bread's scent ($p > 0.05$). Incorporating microalgae into food usually results in an unpleasant fragrance, which makes consumer acceptance difficult. This is consistent with the findings of [34], who revealed that microalgae contain volatile chemicals responsible for these disagreeable odors.

CSB bread with a CECO concentration of 5.5% has a softer, compact, and chewy texture. The addition of CECO to the final CSB bread product has an effect on its texture. Aside from that, the increase in texture preference is most likely the result of the addition of *C. vulgaris*-derived protein. According to [35], microalgae can affect nutritional, functional, sensory, and technological properties (color, texture, and stability of water activity) throughout the product's shelf life. Because it has a positive impact, the utilization of microalgae *Chlorella* sp. in food is an important innovation. Research conducted by [36] shows the positive attitude of respondents with several scales towards food (bread) enriched with microalgae.

4. Conclusion

The CECO has a high pigment content and mild antioxidant activity. The addition of CECO to CSB bread enhanced the bread's chemical, physical, and sensory qualities. Adding 5.5% CECO to CSB bread may boost its nutritional value and bioactive component content. The study's findings revealed a moisture content of 32.42%, ash content of 0.62%, carbohydrate content of 60.14%, fat

content of 7.28%, SFA of 91.52%, PUFA of 8.47%, chlorophyll of 10.45%, carotenoids of 2.36%, and antioxidants of 84.50%. A hardness value of 1.104 k.gf and a scanning electron microscope revealed a matrix microstructure with stable density, a more uniform network, and a good compaction level. The hedonic value was 7.53±1.14. As a result, enriched CSB bread products may provide a solution to societal hunger challenges while also enhancing general bodily health. Then, further studies are expected to provide unique approaches targeted at increasing the shelf life of CSB, allowing for more convenient eating of CSB bread.

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Conflict of Interests

The authors have declared no conflicts of interest for this article

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