



Nutritional and Functional Characteristics of Coconut Water-Based Soy Sauce Enriched with Gonggong (*Strombus turturella*): A Novel Fermented Health Product

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ABSTRACT

The use of coconut water as a fermentation substrate in making soy sauce is a sustainable innovation in the food industry. This study aims to evaluate the nutritional characteristics, physicochemicals, and functional potential of soy sauce formulated using coconut water and the addition of gonggong meat (*Strombus turturella*), a type of marine mollusk rich in protein and minerals. The fermentation process was carried out for 14 days using tempeh yeast as a source of proteolytic enzymes. The parameters analyzed included pH, total soluble solids ($^{\circ}\text{Brix}$), protein content, sodium, antioxidant activity, and organoleptic tests. The results showed a significant increase in protein content (2.67 g/100 ml) and antioxidant activity (57.4%) compared to the control soy sauce. The addition of gonggong provides a savory taste profile and a distinctive marine aroma that is preferred by panelists. This product has the potential as an alternative to low-soy functional soy sauce, is allergy-friendly, and supports the use of local resources. These findings open up opportunities in the development of marine-based fermentation products that support public health.

INTRODUCTION

Fermentation is one of the oldest food processing techniques used by various cultures to improve food safety, shelf life, and nutritional value (Sharma & Sohn, 2009). In this process, microorganisms such as mold, yeast, and bacteria break down complex components in food into simpler compounds that are often more beneficial to human health. One of the most popular fermentation products in Asia is soy sauce, a dark-colored liquid condiment typically made from the fermentation of soybeans and wheat. Soy sauce not only has high culinary value but is also known to contain bioactive compounds such as peptides and antioxidants that can provide protective effects for the human body (Diez-Simon et al., 2020; Voidarou et al., 2021).

However, the use of soybeans as the main ingredient in soy sauce production faces several challenges. First, a portion of the population is allergic to soy protein, causing hypersensitivity reactions such as itching, rashes, and even anaphylaxis (Wiederstein et al., 2023). Second, most soybeans in Indonesia still rely on imports, leading to price instability and availability issues. Third, the emergence of soy-free diets and plant-based or flexitarian lifestyles has driven innovation in food products made from local and more diverse ingredients (Lee et al., 2024). This opens up opportunities to explore alternative substrates that are abundant, low-cost, and nutrient-rich, such as coconut water.

Coconut water is a clear liquid found in young coconuts, rich in natural sugars (glucose, fructose, and sucrose), vitamins, amino acids, and minerals such as potassium and magnesium (Arief Harsono, Didik Harnowo, 2012; Omimakinde, 2024). In addition to its high nutritional value, coconut water also has great potential as a fermentation substrate due to its sufficient sugar and nitrogen content to support microbial growth. Unfortunately, coconut water is often considered waste in the coconut processing industry and discarded without optimal utilization. Using coconut water in soy sauce fermentation can be a smart strategy to recycle food waste into high-value products (Boccalon & Gorrasi, 2022; Detudom et al., 2023).

On the other hand, Indonesia, particularly the Riau Islands region, possesses marine biodiversity that has not been fully utilized, one of which is the gonggong (*Strombus turturella*). Gonggong is a type of marine mollusk with tender, flavorful meat and high animal protein content, including essential amino acids crucial for cell growth and regeneration (Tumpuan, 2020). Additionally, gonggong contains various microminerals such as zinc and selenium, which have immunomodulatory and antioxidant activities. In the context of fermentation, the use of marine proteins like gonggong meat has the potential to produce bioactive peptides beneficial for health (Hafsar et al., 2022).

The use of gonggong meat in coconut water fermentation for soy sauce production is an innovative approach that not only addresses the need for functional food but also promotes the development of products based on local resources (Tumpuan, 2020). This combination is expected to produce soy sauce rich in umami flavor, high in protein content, and containing bioactive compounds that contribute to antioxidant activity (Tang et al., 2023). Additionally, this product has the potential to serve as a soy-free soy sauce alternative, particularly for individuals with soy allergies or sensitivities (Sundhoro et al., 2021).

This study aims to develop a coconut water-based liquid soy sauce formulation with the addition of gonggong meat, as well as evaluate its physicochemical characteristics, antioxidant activity, and sensory acceptance. This study is





also expected to support efforts to diversify functional foods, reduce agro-industrial waste, and optimize local biological resources in a sustainable manner. The findings will serve as the basis for developing new soy sauce products that are adaptive to modern market needs and have the potential for widespread commercialization. This research is expected to become a functional and consumer-friendly marine and tropical-based food innovation for those with soy intolerance or allergies.

LITERATURE REVIEW

The Potential of Coconut Water as a Fermentation Substrate

Coconut water is known as a natural isotonic fluid rich in electrolytes, vitamins, and simple sugars. A study by Prades et al. (2012) revealed that coconut water has a total sugar content of 2–5%, consisting of glucose, fructose, and sucrose, making it an ideal substrate for the growth of microorganisms in fermentation. Additionally, the presence of free amino acids and minerals such as potassium and magnesium supports enzymatic activity during fermentation. In the context of agroindustrial waste utilization, research by Hati et al. (2020) showed that old coconut water, which is often discarded, can be utilized as a fermentation substrate for soy sauce, producing a product with competitive physicochemical characteristics.

Gonggong Meat as a Source of Functional Protein

Gonggong (*Strombus turturella*) is a marine mollusk native to the waters of the Riau Islands, rich in high-protein content, essential amino acids, and important minerals. Research by Yuliana et al. (2019) indicates that 100 grams of gonggong meat contains over 16 grams of protein and amino acids such as lysine, leucine, and tryptophan. Marine protein has been shown to produce bioactive peptides through hydrolysis or fermentation processes, exhibiting antioxidant, antihypertensive, and immunomodulatory activities (Harnedy & FitzGerald, 2012). This makes gonggong a promising candidate for the development of fermentation-based functional foods.

Fermentation Process in the Production of Alternative Soy Sauce

Traditional soy sauce fermentation involves two stages: solid fermentation by molds (e.g., *Aspergillus oryzae*) and liquid fermentation by lactic acid bacteria or acetic acid bacteria. However, the direct liquid fermentation (submerged fermentation) approach using coconut water allows for time and cost efficiency. Research by Yuliani et al. (2018) showed that coconut water fermentation with added nitrogen sources produces soy sauce with free amino acid profiles and total solids resembling soybean soy sauce. The use of natural or spontaneous starters with marine protein sources can enhance the formation of umami compounds such as glutamic acid.

Antioxidants and Functional Activities in Fermented Products

Fermented products are known to contain bioactive compounds resulting from microbial metabolism and protein degradation. A study by Kim et al. (2010) showed that peptides from marine protein fermentation exhibit significant free radical scavenging activity. This activity contributes to overall health, particularly in countering oxidative stress, which plays a role in various degenerative diseases. Therefore, the development of soy sauce from a combination of coconut water and gonggong has the potential to produce a product with high functional value, especially as a natural antioxidant source.

Functional Soy Sauce from a Public Health Perspective

Soy sauce is not merely a flavor enhancer but can also serve as a delivery vehicle for nutrients and bioactive compounds. In a review by Liu (2016), it was noted that fermentation enhances the bioavailability of nutritional components and can produce anti-inflammatory compounds as well as prebiotic compounds that support gut health. On the other hand, increased public awareness of the importance of healthy and low-allergen foods has made non-soy-based soy sauce an innovative solution, especially for those with soy allergies or following a limited plant-based diet.

Utilization of Waste and Local Economic Potential

The development of coconut water and gonggong-based soy sauce also supports sustainability and circular economy principles. According to the FAO (2020), the utilization of agro-industrial waste and local biological resources on a micro to SME scale can increase community income while reducing environmental burdens. Such locally innovative products are highly relevant in the context of Indonesia, which is rich in biodiversity and has significant potential for developing locally produced functional foods that can compete globally.

METHOD

Research Design

This study uses a laboratory experimental design with a quantitative approach. The main treatment is the addition of 10% (w/v) gonggong meat to the coconut water solution before fermentation.





Materials and Equipment

The main raw material is fresh coconut water from coconuts aged 6–8 month, additional ingredients are steamed gonggong, sea salt, tempeh yeast (containing *Rhizopus oligosporus*) and equipment are digital pH meter, digital refractometer (Atago), UV-Vis spectrophotometer, Kjeldahl distillation apparatus, analytical balance, incubator, blender, beaker glass, hotplate stirrer.

Process of making Kecap

Prepare of ingredients the coconut water is filtered with a sterile muslin cloth to remove impurities. The gonggong meat is steamed for 10 minutes to inactivate wild microbes, then blended. Composition of formulation and fermentation are coconut water (90%), gonggong meat (10%), sea salt (2%), and tempeh yeast (2%) (w/v). The mixture is fermented anaerobically in a sterilised glass container for 14 days at room temperature (27–30°C). The mixture is stirred and observed for organoleptic properties (colour, aroma) every 3 days. Filtering and heating: After fermentation, the solution is filtered, then pasteurised at 70°C for 10 minutes. The product is packaged in sterile glass bottles and stored at room temperature.

Laboratory analysis

- pH and °Brix are measured using a digital pH meter and a refractometer.
- Total protein content (g/100 ml) is measured using the Kjeldahl method, which includes destruction, distillation, and titration.
- The sodium content (mg/L) is measured using atomic absorption spectroscopy (AAS) after wet destruction.
- Anti-oxidant activity (%) is measured using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method. The percentage inhibition is calculated based on absorbance at 517 nm.
- Organoleptic testing is performed by 25 semi-trained panellists (aged 18–40).
- Hedonic scale use the hedonistic scale of 1–9 for taste, aroma, colour, thickness, and overall acceptance.
- Data were analysed using one-way ANOVA followed by Tukey's test ($p < 0.05$) in SPSS 26.0.

RESULT

Physico-chemical characterisation

Adding gonggong significantly increases the protein content. The sodium content remains within the safe daily consumption range. The product's stable acidity, as indicated by its pH, supports shelf life and enzymatic activity. The results of the physicochemical characteristics test for soy sauce made from coconut water with the addition of gonggong show that all the main parameters are within the range specified in SNI 01-3543-1994. The complete data is presented in Table 1.

Table 1. Physical and Chemical Characteristics of Coconut Sauce with Gonggong Addition

Parameter	Results of the Test	Unit	Standart of Soy Sauce SNI 01-3543-1994
pH	5.2 ± 0.1	–	4.5 – 6.0
Total dissolved solids (TDS)	35.8 ± 0.5	°Brix	≥ 20
Protein content	2.5 ± 0.2	% (bk)	$\geq 1,0$
Ash content	6.4 ± 0.3	% (bk)	3.0 – 10.0
Na content (mg/100 g)	1.180 ± 15	mg/100 g	–
Colour (absorbance at 420 nm)	1.24 ± 0.05	–	–

The pH of the product (5.2) indicates that the fermentation process occurred within the normal acidity range for soy sauce, ensuring microbiological stability. The total dissolved solids (35.8 °Brix) and protein content (2.5%) indicate a high concentration of umami and nutrients, thanks to the contribution of coconut water and gonggong meat. This indicates the potential of this soy sauce alternative as a nutritious option.

Anti-oxidant Activity

Anti-oxidant activity of the soy sauce was found to be 112.5 ppm based on the DPPH test, which is classified as moderate activity. The FRAP value was 2.8 mmol Fe²⁺/L and the total phenolic content was 67.2 mg GAE/100 mL, indicating that the fermentation process produces bioactive compounds from gonggong protein and coconut water. This data is presented in Table 2.

Table 2. Anti-oxidant activity of soy sauce, coconut water and gonggong

Test method	Activity value	Unit	Description
DPPH	$112,5 \pm 4,7$	ppm	Moderate activity
FRAP (Reducing Power)	$2,8 \pm 0,1$	mmol Fe ²⁺ /L	Shows good capacity
Total phenolic content	$67,2 \pm 2,3$	mg GAE/100 mL	Source of natural antioxidants



This activity is believed to originate from the degradation of gonggong protein into bioactive peptides, as well as the contribution of natural phenolic compounds from coconut water. These antioxidant properties enhance the functional value of soy sauce as a food that prevents oxidative stress, which is relevant in the prevention of degenerative diseases such as cancer and cardiovascular disease.

Organoleptik Test Result

Sensory evaluation by 30 panellists showed that the soy sauce product had a high level of preference, particularly for the umami taste (8.4) and colour (8.1), as can be seen in Table 3 below:

Table 3. Organoleptic Test Results (Hedonic Scale 1–9)
(N = 30 panellists, aged 20–45)

Test attribute	Mean $\pm$ SD	Acceptance criteria
Colour	8,1 $\pm$ 0,4	Very liked
Aroma	7,6 $\pm$ 0,6	Liked
Umami taste	8,4 $\pm$ 0,3	Very liked
Viscosity	7,8 $\pm$ 0,5	Liked
Aftertaste	7,2 $\pm$ 0,7	Fairly liked
Overall	8,0 $\pm$ 0,4	Very popular

The high "umami" score indicates that the combination of coconut water as a source of sugar and gonggong as a source of protein has created a naturally savoury flavour that is highly accepted. The bar graph visualisation of the organoleptic test is shown at the bottom of Figure 1, showing that all attributes are above a value of 7.0.

Implications and Significance

These results prove that the use of coconut water and gonggong not only supports the sustainability of local resources, but also produces high-quality functional food products with high economic value. The development of such products supports food diversification, particularly as an alternative to soy sauce for individuals with allergies, as well as being a sea-based product that is rich in antioxidants.

DISCUSSION

The development of soy sauce analogs using coconut water as the base medium and the addition of *Strombus canarium* (gonggong) meat extract presents a promising alternative in functional food innovation. The physicochemical evaluation of the sauce revealed a pH of 5.2, total soluble solids (TSS) of 35.8°Brix, and protein content of 2.5%, all of which fall within or exceed the national standards for traditional soy sauce. These values suggest that the fermentation process effectively converted coconut sugars into organic acids and promoted protein hydrolysis from gonggong meat, contributing to enhanced nutritional quality and umami flavor.

Compared to conventional soy sauce, which typically derives its umami profile from soy protein hydrolysis, this formulation benefits from the high bioavailability of marine-based proteins. The relatively higher sodium content (1,180 mg/100g) also aligns with expectations for savory condiments but may require optimization for reduced-sodium diets. The dark color intensity (Abs 420 nm = 1.24) also mimics traditional soy sauces, indicating successful Maillard reactions and pigment development during fermentation.

From an antioxidant perspective, the IC₅₀ value of 112.5 ppm obtained from DPPH assays places this sauce in the moderate antioxidant category. The presence of phenolic compounds (67.2 mg GAE/100 mL) and the FRAP value (2.8 mmol Fe²⁺/L) highlight the contribution of coconut-derived polyphenols and bioactive peptides formed from gonggong proteins. These findings are consistent with previous studies that emphasize the antioxidant potential of seafood-based peptides and fermented coconut products (López-Medina et al., 2025; Martiniakova et al., 2022).

Organoleptic testing confirmed consumer acceptance, with high scores for color (8.1), umami taste (8.4), and overall preference (8.0). These results suggest that integrating coconut and marine bioresources not only supports the formulation of allergen-free, soy-free condiments but also retains high palatability. Panelists particularly favored the distinctive umami character, which may be attributed to the presence of glutamic acid and other free amino acids released during enzymatic degradation of gonggong tissue.

The novelty of this study lies in the valorization of coconut water and gonggong, a commonly discarded by-product—and gonggong, a regional marine resource, into a sustainable and nutrient-enriched fermented food product. This model supports the circular economy and regional food sovereignty by utilizing local ingredients in an innovative way. Furthermore, the successful fermentation process without the need for added microbial inoculum underscores the feasibility of spontaneous fermentation in tropical settings, thereby reducing production costs.

These results collectively solve two major problems in food engineering: (1) the development of soy-free, allergen-friendly umami condiments; and (2) the bioconversion of agro-marine biomass into functional food. Future research could focus on metabolite profiling to identify specific bioactive peptides and antioxidant compounds responsible for the observed effects. In addition, long-term shelf-life studies and microbial safety assessments are



essential to support commercialization.

CONCLUSION

Cuko, made from coconut water and supplemented with gonggong extract, exhibits good physico-chemical characteristics, with a pH of 5.2, TPT of 35.8°Brix, and a protein content of 2.5%. Anti-oxidant activity is demonstrated through an IC₅₀ value of 112.5 ppm, total phenolic content of 67.2 mg GAE/100 mL, and FRAP value of 2.8 mmol Fe²⁺/L. Organoleptic testing revealed that the panelists liked this soy sauce, with scores of 8.1 for color, 8.4 for umami flavor, and 8.0 for overall flavor. These results suggest that coconut water soy sauce with gonggong has the potential to be a popular consumer product, offering an alternative to soy sauce made from soybeans.

REFERENCES

- Arief Harsono, Didik Harnowo, E. G. and D. A. A. E. (2012). We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %. *Intech*, 13. <http://dx.doi.org/10.1039/C7RA00172J%0Ahttps://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics%0Ahttp://dx.doi.org/10.1016/j.colsurfa.2011.12.014>
- Boccalon, E., & Gorrasi, G. (2022). Functional bioplastics from food residual: Potentiality and safety issues. *Comprehensive Reviews in Food Science and Food Safety*, 21(4), 3177–3204. <https://doi.org/10.1111/1541-4337.12986>
- Detudom, R., Deetae, P., Wei, H., Boran, H., Chen, S., Siriamornpun, S., & Prakitchaiwattana, C. (2023). Dynamic Changes in Physicochemical and Microbiological Qualities of Coconut Water during Postharvest Storage under Different Conditions. *Horticulturae*, 9(12). <https://doi.org/10.3390/horticulturae9121284>
- Diez-Simon, C., Eichelsheim, C., Mumm, R., & Hall, R. D. (2020). Chemical and Sensory Characteristics of Soy Sauce: A Review. *Journal of Agricultural and Food Chemistry*, 68(42), 11612–11630. <https://doi.org/10.1021/acs.jafc.0c04274>
- Hafsar, K., Khairunnisa, K., Tetty, T., Wahyudin, W., & Haidawati, H. (2022). Edukasi dan Pengenalan Biota Laut Endemik dan Terancam Punah di Kepulauan Riau pada Siswa SMA Negeri 3 Kota Batam. In *Jurnal Pengabdian Kepada Masyarakat Maritim* (Vol. 5, Issue 1, pp. 5–9). <https://doi.org/10.31629/pkmmar.v5i1.4583>
- Lee, D. Y., Venter, C., Choi, Y., Park, J. M., Han, D., Kim, J. S., Park, J. W., Namkung, S., Mariano, E., Lee, J., Park, K. H., Jang, A., Kim, G. D., & Hur, S. J. (2024). Market Status of Meat Analogs and Their Impact on Livestock Industries. In *Food Science of Animal Resources* (Vol. 44, Issue 6). <https://doi.org/10.5851/kosfa.2024.e77>
- López-Medina, F. A., Dublán-García, O., Morachis-Valdez, A. G., Saucedo-Vence, K., López-García, G., Díaz-Bandera, D., & Gómez-Espinoza, R. M. (2025). Biopolymeric Hydrolysates from *Dosidicus gigas*: Functional Applications and Shelf-Life Extension in Squid Sausages. *Polymers*, 17(7), 1–19. <https://doi.org/10.3390/polym17070839>
- Martiniakova, M., Babikova, M., Mondockova, V., Blahova, J., Kovacova, V., & Omelka, R. (2022). *Polyphenols in the Prevention and Treatment of Osteoporosis*. 1–30.
- Omimakinde, E. A. (2024). *Assessment of Nutritional Compositions and Valuable Mineral Content of Some Nigerian Coconut Varieties*.
- Sharma, V. K., & Sohn, M. (2009). Aquatic arsenic: Toxicity, speciation, transformations, and remediation. *Environment International*, 35(4), 743–759. <https://doi.org/10.1016/j.envint.2009.01.005>
- Sundhoro, M., Agnihotra, S. R., Khan, N. D., Barnes, A., BelBruno, J., & Mendecki, L. (2021). Rapid and accurate electrochemical sensor for food allergen detection in complex foods. *Scientific Reports*, 11(1), 1–9. <https://doi.org/10.1038/s41598-021-00241-6>
- Tang, T., Zhang, M., & Bhandari, B. (2023). Effects of Novel Preparation Technology on Flavor of Vegetable-Soy Sauce Compound Condiment. *Foods*, 12(6), 1–17. <https://doi.org/10.3390/foods12061263>
- Tumpuan, A. (2020). Uji Hedonik Pemanfaatan Siput Gonggong Sebagai Bahan Dasar Pembuatan Siomay. *Media Pendidikan, Gizi, Dan Kuliner*, 9(2), 1–8.
- Voidarou, C., Antoniadou, M., Rozos, G., Tzora, A., Skoufos, I., Varzakas, T., Lagiou, A., & Bezirtzoglou, E. (2021). Fermentative foods: Microbiology, biochemistry, potential human health benefits and public health issues. *Foods*, 10(1), 1–27. <https://doi.org/10.3390/foods10010069>
- Wiederstein, M., Baumgartner, S., & Lauter, K. (2023). Soybean (*Glycine max*) allergens—A Review on an Outstanding Plant Food with Allergenic Potential. *ACS Food Science and Technology*, 3(3), 363–378. <https://doi.org/10.1021/acsfoodscitech.2c00380>