SEHATMAS (Jurnal Ilmiah Kesehatan Masyarakat)
https://journal.literasisains.id/index.php/SEHATMAS
e-ISSN 2809-9702 | p-ISSN 2810-0492
Vol. 5 No. 2 (April 2026) 286-298
DOI: 10.55123/sehatmas.v5i2.7874
Submitted: 13-02-2026 | Accepted: 07-03-2026 | Published: 15-04-2026

Addressing Adolescent Constipation Through Functional Snack Innovation: Narrative Review on *Eucheuma Cottonii* and *Pleurotus Ostreatus*

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Abstract

Constipation is a common digestive disorder characterized by infrequent bowel movements, hard stools, and straining, and is particularly prevalent among adolescents due to low dietary fiber intake. Addressing this issue requires innovative approaches to improve fiber consumption through foods that are both familiar and acceptable to this age group. This narrative review explores the potential use of Eucheuma cottonii (seaweed) and Pleurotus ostreatus (white oyster mushroom) as high-fiber functional ingredients in adolescent-targeted food products. Evidence from recent studies indicates that both ingredients are rich in dietary fiber and can contribute to improved digestive health. When moderately substituted into popular food formulations such as dimsum mentai, they can enhance nutritional value while maintaining acceptable sensory characteristics. This review aims to explore the potential of these two ingredients by discussing their nutritional composition, functional roles, and sensory effects, highlighting their promise in the development of fiber-enriched snacks for constipation prevention and management in adolescents. These strategies are expected to support healthier dietary patterns and improve overall gastrointestinal well-being in this population.

Keywords: *Adolescents, Constipation, Dietary Fiber, Eucheuma Cottonii, Functional Food, Pleurotus Ostreatus.*

INTRODUCTION

Constipation is a digestive disorder characterized by infrequent bowel movements (less than three times per week), hard stools, pain during defecation, and a sensation of incomplete defecation (Rao *et al*., 2022). According to the 2023 Indonesian National Consensus on Constipation Management, constipation is classified into two types: primary (functional) constipation, which is not related to structural or inflammatory diseases, and secondary constipation, which is caused by specific medical conditions. Globally, constipation is relatively common, with a prevalence ranging from 12% to 17% in the adult population and increasing significantly in older adults. Although data on adolescent constipation is limited, several studies in Indonesia have reported high prevalence rates among teenagers: 18.9% in Palembang, 61% in Lombok, 68.5% in Semarang, and 75.3% in Jakarta (Kesuma *et al*., 2021; Rizal *et al*., 2024; Claudina *et al*., 2018; Thea *et al*., 2020). These figures far exceed the 15–20% threshold typically considered indicative of a significant public health concern (Dharmatika *et al*., 2019).

Several risk factors contribute to adolescent constipation, with low dietary fiber intake consistently identified as a major contributor (Claudina *et al*., 2018; Fikroh, 2017). Dietary fiber plays a key role in maintaining digestive health by increasing stool bulk, promoting intestinal motility, and supporting gut microbiota balance (Haliza *et al*., 2017; Bardosono *et al*., 2020). Fiber is generally classified into soluble and insoluble types, both of which help soften stool by absorbing water and stimulate bowel movements. However, adolescents often follow unbalanced diets, with limited fiber intake and high consumption of processed foods. Data from the Global School-based Student Health Survey (GSHS) and national reports indicate that the majority of adolescents do not meet the recommended intake of fruits and vegetables (WHO, 2014; Salwa *et al*., 2021).

At the national level, increasing fiber intake is aligned with public health programs such as Gerakan Masyarakat Hidup Sehat (GERMAS), which promotes healthy lifestyle behaviors including increased consumption of fruits and vegetables, as well as the Balanced Nutrition Guidelines (Pedoman Gizi Seimbang), which recommend adequate daily fiber intake as part of a balanced diet (Kementerian Kesehatan RI, 2017; Kementerian Kesehatan RI, 2020). However, conventional nutrition education alone is often insufficient to change adolescents eating behavior. Adolescents tend to prioritize taste, convenience, price, and peer influence over nutritional considerations, making them more likely to consume fast food and snacks rather than balanced meals (Vaitkeviciute *et al*., 2015; Daly *et al.,* 2022). Therefore, innovative and practical approaches are needed to translate these policy recommendations into forms that are more acceptable and appealing to adolescents.

One such approach is the development of healthier snack alternatives, considering that snacking behavior is highly prevalent among adolescents and contributes significantly to their daily energy intake. Evidence suggests that snacks can contribute up to 30% or more of total daily energy intake among adolescents, and these snacks are often low in fiber and high in fat, sugar, and salt (Hass *et al*., 2016; Larson *et al*., 2016). Moreover, adolescents are more likely to accept dietary interventions when they are incorporated into familiar and palatable foods rather than delivered through conventional counseling alone (Lanham & van der Pols, 2025). These days, one popular snack among adolescents is dimsum mentai, which is generally low in fiber and high in calories. Therefore, modifying commonly consumed snack products into healthier versions presents a strategic opportunity to improve dietary quality without drastically changing eating habits.

The substitution of conventional dimsum mentai ingredients with high-fiber food sources such as *Eucheuma cottonii* (seaweed) and *Pleurotus ostreatus* (white oyster mushroom) represents a promising and innovative approach to improving adolescents daily fiber intake, particularly among those who are experiencing constipation. *Eucheuma cottonii* is a rich source of soluble fiber, such as carrageenan, which has the ability to absorb water and form a gel-like mass (Desiana & Hendrawati, 2015). This property can help increase stool bulk and softness, as well as accelerate intestinal transit time (Budaraga, 2024). Meanwhile, *Pleurotus ostreatus* contains insoluble fibers such as chitin and hemicellulose, which play a role in stimulating peristaltic movements and promoting regular bowel movements (Putri *et al*., 2023; Suswanto & Hernowo, 2024). Another advantage of white oyster mushrooms is their soft texture and neutral taste, which make them suitable for use in various processed foods, including dimsum, without compromising sensory acceptability. By incorporating these two ingredients into a snack product that is popular among adolescents, such as dimsum mentai. This functional food alternative is designed to be acceptable to adolescents in terms of taste and appearance, while also serving as a practical dietary solution for constipation prevention through improved fiber intake.

Considering the importance of increasing fiber intake among adolescents and the need for healthy snack alternatives that remain appealing in both taste and appearance, it is essential to conduct a scientific review on the potential substitution of ingredients in dimsum mentai using *Eucheuma cottonii* (seaweed) and *Pleurotus ostreatus* (oyster mushroom). This narrative review aims to examine scientific evidence regarding the effectiveness and benefits of fiber derived from these two ingredients, including their nutritional content, health-promoting properties, and organoleptic potential in the final product. This review is expected to serve as a foundation for developing functional food innovations that not only promote digestive health but are also acceptable and appealing to adolescents as part of constipation prevention and management efforts.

METHOD

This study is a narrative review aimed at summarizing and analyzing the literature related to the potential substitution of *Eucheuma cottonii* (seaweed) and *Pleurotus ostreatus* (white oyster mushroom) in snack formulation as an effort to increase fiber intake among adolescents experiencing constipation. The literature search was conducted systematically using several credible academic databases, including Google Scholar, ScienceDirect, and Web of Science. Article searches employed combinations of keywords with Boolean operators (AND/OR) to broaden and refine relevant search results. The keywords used included: “Eucheuma cottonii” OR “seaweed”, “Pleurotus ostreatus” OR “oyster mushroom”, “formulation” OR “substitution”, “fiber”, “organoleptic” OR “sensory quality”. An initial screening of article titles and abstracts was performed to determine their relevance to the objectives of this review.

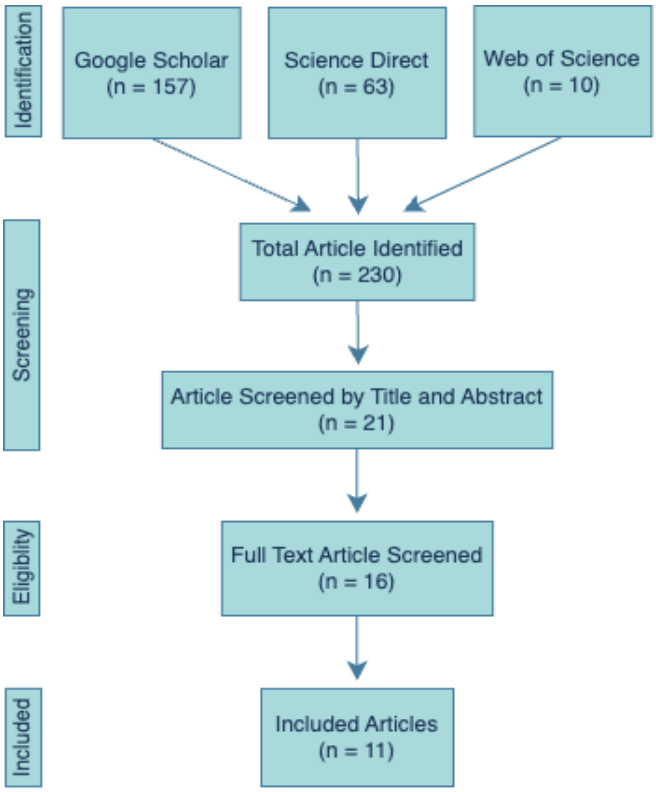

Figure 1. Literature Selection Process

The inclusion criteria for this review consisted of scientific articles written in English or Indonesian, published within the last ten years (2015–2025), and comprising either primary studies or relevant review articles. The selected literature focused on the

following areas: (a) the health benefits of dietary fiber from *Eucheuma cottonii* and *Pleurotus ostreatus*, (b) the application of these two ingredients in the development of food or snack products, (c) organoleptic assessment and/or consumer acceptance of fiber-based food products.

To strengthen the relevance of this review to dimsum mentai development, the selected studies represented a wide range of processed food and protein-based products, including sausages, dimsum, meatballs, nuggets, and biscuits. This variation was considered important to provide a comprehensive understanding of how *Eucheuma cottonii* and *Pleurotus ostreatus* influence sensory characteristics, texture, and overall acceptability across different food matrices. The findings from these diverse product formulations were then critically synthesized to identify common patterns in texture modification, flavor acceptance, and fiber enrichment potential, which can be conceptually adapted to dimsum mentai as a similar processed snack product with a composite structure (protein base and coating).

In addition, the methodological quality of the included studies was assessed descriptively to enhance the credibility of the review process. Particular attention was given to the design of organoleptic or sensory evaluation, including the type of panelists used (trained panelists versus untrained consumer panels), sample size, and evaluation methods (such as hedonic scale testing). However, not all included studies reported complete information regarding sensory evaluation procedures, and some were categorized as not reported (NR). Also, one study did not include sensory evaluation and focused solely on physicochemical analysis. These variations in reporting were taken into consideration during the data synthesis process. Most studies employed consumer-based sensory evaluation using untrained panelists, which is relevant for assessing general product acceptability, while limited information was available regarding the use of trained panelists. By incorporating these methodological considerations, this review aims to ensure a more transparent and balanced evaluation of the included literature.

Articles that did not meet the inclusion criteria were excluded from the analysis. The exclusion criteria included articles that were not available in full-text, experimental studies on animals without direct relevance to human health, opinion pieces, editorials, or popular narratives lacking a scientific evidence base, as well as literature not directly related to the topics of functional foods, dietary fiber, or constipation. The selected time frame (2015–2025) was applied to ensure that the evidence reviewed reflects current developments in nutrition, functional food innovation, and public health, particularly in relation to adolescent populations.

RESULT

The increasing demand for functional foods has prompted researchers to explore natural ingredients with proven nutritional and physiological benefits. Among these, *Eucheuma cottonii* (a type of seaweed, that is rich in soluble fiber and bioactive compounds) and *Pleurotus ostreatus* (oyster mushroom, known for its high insoluble fiber and antioxidant content) have gained attention for their potential in food formulation. Numerous studies have evaluated the incorporation of these ingredients into various food products, with the aim of improving dietary fiber content, enhancing functional value, and addressing specific health concerns, including constipation. Building on these efforts, the present analysis adopts a comparative formulation approach to examine how substituting conventional ingredients with *E. cottonii* and/or *P. ostreatus* influences the nutritional composition, physicochemical characteristics, and sensory properties of the final products. The summary of the findings from the reviewed literature is presented in Table 1.

Table 1. The Use of *Eucheuma cottonii* and *Pleurotus ostreatus* in Food Formulations

Publication Author(s) Year	Sensory Test Population (Number)	Substituted Ingredient(s)	Formulation Code and Composition	Target	Outcomes
Rohmawati *et al*., 2019	Organoleptic Panelists (n= NR)	*P. ostreatus* : Tempeh +carrageenan (*E. cottonii)*	F1 = (50:100) +4/6/8g F2 = (75:75) +4/6/8g F3 = (100:50) +4/6/8g	Sausages	- The more mushrooms and carrageenan will increase the fiber content - Darkest color found in sausages with more tempeh (100g) and highest addition of carrageenan (8g) - The formulation of more tempeh and a lot of carrageenan, will tend to make the sausage dense - Formulations containing excessive amounts of mushroom or tempeh are likely to be less preferred due to their strong odor - The most preferred sausage is F2 +6g carrageenan
Widati *et al*., 2020	NR	%NaCl : %*E. cottonii*	F1 = (2/2.5/3/3.5) : 2.5 F2 = (2/2.5/3/3.5) : 5 F3 = (2/2.5/3/3.5) : 7.5	Beef-salt soluble proteins	- Higher addition of *E. cottonii* flour results in higher gel strength - The addition of *E. cottonii* flour decrease the lightness color of gel protein - The addition of *E. cottonii* flour significantly decreased the water content of the gel protein but increased the protein content - *E. cottonii* flour showed the potential to be used as binding/filling agent for restructured meat products
Sihite *et al*., 2023	Organoleptic Panelists (n= 30)	+*E. cottonii* (flour)	F1 = 25% F2 = 45% F3 = 55%	Dimsum	- The higher addition of *E. cottonii*, the greater the fiber content and the darker the color of the product - As the amount of *E. cottonii* increased, the texture of the dimsum became more fibrous, with detectable sticky particles of seaweed flour - The fortification of dimsum with *E. cottonii* is highly recommended as a high-fiber food that supports digestive health and overall well-being
Ramadhani *et al*., 2024	Organoleptik Panelists (n= 35)	*P. ostreatus* : *E. cottonii*	F1 = 75:150 F2 = 100:125 F3 = 150:100	Burgo	- The higher addition of *P. ostreatus* and *E. cottonii*, the greater the fiber content is; however, it also intensified the off-flavor (earthy aroma) of the burgo - Increasing the proportion of *P. ostreatus* improved the texture of the burgo, making it more chewy and tender - A higher composition of *E. cottonii* resulted in a slightly bitter aftertaste in the burgo - Overall, the most preferred formulation was F2
Ukhty *et al*., 2025	Organoleptic Panelists (n= 30)	%Toro tuna : %*E. cottonii* (flour)	F1 = 94:6 F2 = 88:12 F3 = 82:18 F4 = 76:24	Porridge	- The darker color observed in the formulations was attributed to the higher *E. cottonii* content - F2 was more acceptable by the panelist as the ratio is similarly proportional - The higher the formula will affects the odor (fishy)
Meiliany, 2024	Organoleptic Panelists (n= 60)	%Chicken meat : %*P. ostreatus*	P1 = 100:0 P2 = 90:10 P3 = 80:20 P4 = 70:30	Meatball	- P4 formula with 30% *P. ostreatus*, yielded the highest moisture content compared to other formulas - The addition of *P. ostreatus* making

Publication Author(s) Year	Sensory Test Population (Number)	Substituted Ingredient(s)	Formulation Code and Composition	Target	Outcomes
					chicken meatballs color yellowish-white - The addition of *P. ostreatus* will increase the (unpleasant) aroma that is not suitable for meatballs - The addition of *P. ostreatus* greatly influences the level of liking for the taste of meatballs (tastier) - The water content increased along with the addition of *P. ostreatus* making it wet and mushy texture
Vatria *et al*., 2023	Organoleptic Panelist (n= NR)	%Parrot fish : %carrageenan (*E. cottonii*)	A1 = 99:1 A2 = 97:3 A3 = 95:5 A4 = 93:7	Dimsum	- The highest water-holding capacity and gel formation were observed in dimsum A4, which had the highest level of *E. cottonii* - Increasing the amount of *E. cottonii* led to a firmer texture and decreased palatability - The more *E. cottonii* was added, the duller the color of the dimsum became
Handayani *et al*., 2016	Organoleptic Panelists (n= 20)	%*P. Ostreatus* : %Tapioca flour	F1 = 50:50 F2 = 65:35 F3 = 80:20	Meatball	- Higher proportions of *P. ostreatus* resulted in increased protein and moisture content in the meatball - The most preferred flavor by panelists was F2 - As more *P. ostreatus* was added, the color of the meatballs became brighter and more uniform - The greater the amount of *P. ostreatus* used, the higher the elasticity and chewiness of the meatball
Muhammad *et al*., 2024	Organoleptic Panelists (n= 30)	*E. cottonii* (flour) : Wheat flour	F1 = 6:194 F2 = 12:188 F3 = 18:182	Biscuit	- Fiber content increased along with the addition of *E. cottonii* - The more *E. cottonii* added, the darker the biscuits became - F2 was the most preferred biscuit formulation by panelists
Kesuma *et al*., 2015	Organoleptic Panelists (n= 25)	%*E. cottonii* (flour) : %*P. ostreatus* (flour)	F1 = 50:25 F2 = 45:40 F3 = 30:35	Biscuit	- Biscuit F3 had the best overall acceptability, characterized by a dark color, crispy texture, and pleasant taste - As *E. cottonii* increased, the texture of the biscuits became harder - The highest fiber content was found in biscuit F1, which contained the largest proportion of *E. cottonii*
Candra *et al*., 2020	Organoleptic Panelists (n= 25)	100g Snakehead fish + %*E. cottonii* (flour)	F0 = 0 F1 = 5 F2 = 10 F3 = 15 F4 = 20 F5 = 25 F6 = 50 F7 = 75	Nuggets	- The higher substitution of *E. cottonii*, the lower the acceptability scores for color, aroma, taste, and texture of the nuggets - The addition of *E. cottonii* darkened the nugget color and made the texture firmer - The 15% *E. cottonii* substitution was the highest acceptable level preferred by panelists

DISCUSSION

Constipation is a disorder of the digestive system, not classified as a disease per se, but rather a collection of symptoms that reflect disturbances in the defecation process. According to the American Gastroenterological Association, a person is considered constipated when experiencing symptoms such as difficulty passing stool, infrequent bowel movements (fewer than three times per week), excessive straining, a sensation of

incomplete evacuation, and hard, dry, or pellet-like stools (Rao *et al*., 2022). Although it is not a disease, constipation can significantly affect comfort, quality of life, and overall digestive health, especially when it persists over time (Kotarumalos & Herwawan, 2021). According to the National Consensus on the Management of Constipation in Indonesia, functional constipation is more common globally than structural constipation, with a prevalence ranging from 1% to 30%. Although no universal cutoff has been established, a prevalence rate exceeding 15–20% within a population is considered high and require special attention in the context of public health (Makmun *et al*., 2019; Dharmatika *et al*., 2019). The high prevalence of functional constipation suggests the presence of several contributing factors that increase the risk of constipation.

The World Journal of Gastroenterology notes several factors associated with constipation, including demographic characteristics (age, gender, income, education, employment status, and geographic region), lifestyle and behavioral factors (physical activity, smoking, and intake of fiber, fluids, alcohol, and coffee), as well as health-related factors (medical conditions and medications) (Werth & Christopher, 2021). Among these, low fiber intake has been consistently linked to constipation. Several studies revealed that adolescents with low dietary fiber intake are more likely to experience functional constipation than those who consume adequate amounts (Claudina *et al*., 2018; Fikroh, 2021; Dwinoviya, 2020). If constipation in adolescents is left untreated, it can lead to serious long-term consequences, including significantly reduced health-related quality of life. This is because anorectal dysfunction may increase the risk of developing psychological issues such as depression and anxiety (Brochard *et al*., 2019). Adolescents are particularly vulnerable to constipation due to poor eating habits and low awareness of dietary fiber intake. During this developmental stage, lifestyle changes, increased consumption of processed foods, irregular eating patterns, and academic or social stressors may contribute to inadequate fiber intake (Yamada *et al*., 2021). As a result, identifying effective strategies to increase fiber intake (particularly through acceptable and appealing functional snacks) is essential for improving bowel health in this age group. Addressing adolescent constipation through nutritional interventions such as fiber-enriched snack formulations may offer a practical and preventive approach to a widespread yet often overlooked digestive issue.

Beyond fiber intake, emerging evidence highlights the role of bioactive compounds from functional food ingredients in modulating gut microbiota, which plays a crucial role in gastrointestinal health. *Eucheuma cottonii* contains carrageenan, a sulfated polysaccharide that functions as soluble fiber and may act as a prebiotic by promoting the growth of beneficial gut bacteria such as Bifidobacterium and Lactobacillus (Deniz *et al.*, 2025; Zang *et al.*, 2023; Singh *et al.*, 2022). Meanwhile, *Pleurotus ostreatus* is rich in β-glucans, phenolic compounds, and antioxidants that contribute to anti-inflammatory effects and microbial balance in the gut (Törős *et al.*, 2023; Lesa *et al.*, 2022). These bioactive components may work synergistically with dietary fiber to improve intestinal transit and stool consistency, while also supporting overall gut microbiota composition, which is increasingly recognized as a key factor in the prevention and management of constipation.

The incorporation of fiber-rich ingredients such as *Eucheuma cottonii* and *Pleurotus ostreatus* in food products has demonstrated notable impacts on sensory attributes, particularly texture, color, and taste. While these functional ingredients contribute significantly to the nutritional profile, such as enhancing fiber, protein, and moisture content, they also alter the organoleptic qualities that directly influence consumer acceptance. In general, the substitution of *E. cottonii* tends to darken product color and create a firmer or more fibrous texture, whereas *P. ostreatus* can produce a

lighter, chewier, or more tender consistency, depending on its proportion in the formulation. Several studies from the reviewed literature assessed consumer acceptance of products enriched with these ingredients like meatballs, nuggets, dimsum, biscuits, and porridge underwent sensory testing to evaluate preferences for taste, texture, aroma, and appearance. The results consistently showed that moderate levels of substitution, such as 15–20% *E. cottonii* or 20–30% *P. ostreatus*, struck the best balance between functional benefits and organoleptic appeal. At higher substitution levels, however, unfavorable characteristics were often noted, including strong or unfamiliar odors (e.g., the earthy or "langu" smell of mushrooms or the bitter aftertaste from seaweed) (Ramadhani *et al*., 2024), as well as excessive hardness or stickiness in texture (Sihite *et al*., 2023).

One common challenge in formulating fiber-enriched foods is maintaining desirable sensory quality while integrating a sufficient amount of functional ingredients to provide health benefits. At excessive levels, the distinct aromas and textures of seaweed and mushrooms can dominate and negatively impact consumer perception. To address this, various processing and formulation strategies have been proposed, such as balancing the ratio of functional ingredients, using masking agents to neutralize off-flavors, optimizing moisture retention, and combining with familiar base ingredients to enhance palatability (Salta & Du, 2024). Notably, *E. cottonii* also shows promise beyond its nutritional value. In studies involving meat-based products such as sausages and nuggets, it served effectively as a gelling or binding agent, improving water-holding capacity and product structure (Rohmawati *et al*., 2019; Widati *et al*., 2020; Candra *et al*., 2020). This functional property can be harnessed to enhance the physical characteristics of restructured or plant-based food items while contributing to fiber enrichment. Overall, with careful formulation and process control, both *E. cottonii* and *P. ostreatus* offer substantial potential to support the development of nutritious, fiber-rich foods without compromising sensory quality.

Despite these promising functional and sensory properties, food safety considerations remain an important aspect in the development of such products. Seaweed such as *Eucheuma cottonii* has the potential to accumulate heavy metals, including arsenic, lead, and cadmium, depending on environmental conditions and cultivation practices (Afiah *et* al., 2019). Therefore, proper sourcing, quality control, and adherence to food safety standards are essential to ensure safe consumption. Similarly, *Pleurotus ostreatus* requires hygienic cultivation and handling processes to prevent microbial contamination, as mushrooms are highly perishable and sensitive to environmental conditions (Schill *et al*., 2021). Ensuring compliance with good agricultural practices and proper post-harvest handling is crucial, particularly when these ingredients are used in food products targeted at adolescents.

Dimsum mentai is a popular and adaptable snack among adolescents, making it an ideal vehicle for functional food innovation. Incorporating *Eucheuma cottonii* and *Pleurotus ostreatus* into its formulation offers the potential to enhance nutritional value, particularly by increasing dietary fiber, which is often lacking in adolescent diets. *E. cottonii* contributes soluble fiber and essential minerals (Rizkaprilisa, 2023), while *P. ostreatus* provides insoluble fiber, plant-based protein, and antioxidants beneficial for digestion and general health (Nafisah *et al*., 2024). From a sensory standpoint, moderate substitution levels (e.g., up to 20–30%) of these ingredients have been shown in previous studies to maintain or even improve product acceptability. *P. ostreatus* enhances texture and flavor, while *E. cottonii* acts as a binding agent and boosts fiber without severely affecting taste if both are given in sufficiently proportional amounts. Therefore, dimsum mentai enriched with these ingredients has strong potential as a functional snack for adolescents with constipation.

From a public health perspective, the development of fiber-enriched dimsum mentai using *Eucheuma cottonii* and *Pleurotus ostreatus* offers practical opportunities for real-world implementation. This product can be integrated into school canteens or adolescent nutrition programs as part of strategies to improve dietary habits and increase fiber intake. School-based food interventions have been shown to be effective in influencing adolescents' food choices when healthy options are accessible and appealing (Chaudhary *et al.*, 2020; Rose *et al.*, 2021). In addition, collaboration with local food vendors and small-scale food industries could support the production and distribution of such functional snacks at an affordable cost. Educational initiatives can further reinforce this approach by promoting awareness of digestive health and the importance of fiber consumption. By combining product innovation with behavioral and environmental strategies, this approach has the potential to contribute to reducing the prevalence of constipation among adolescents at the population level.

CONCLUSION

This narrative review demonstrates that the utilization of *Eucheuma cottonii* and *Pleurotus ostreatus* as functional food ingredients that has strong potential to improve dietary fiber intake and support digestive health among adolescents, particularly in the prevention and management of constipation. The combined presence of soluble and insoluble fiber, along with bioactive compounds such as carrageenan and β-glucans, contributes not only to improved bowel function but also to the modulation of gut microbiota, which plays a crucial role in gastrointestinal health. The findings further indicate that appropriate substitution levels are essential to maintain a balance between nutritional enhancement and sensory acceptability, as excessive amounts may lead to undesirable changes in aroma, taste, or texture of the product. The development of fiber-enriched products such as dimsum mentai represents a practical and acceptable strategy to increase fiber intake among adolescents without requiring major changes in eating habits. Therefore, it is recommended that such functional food innovations be further developed and integrated into school-based nutrition programs and community food environments, while ensuring food safety standards and product quality. Future research is also needed to evaluate long-term health outcomes and consumer acceptance in real-life settings, particularly among adolescent populations.

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