

REVALORISING FOOD PROCESSING WASTE: CONSUMER PERCEPTION OF SEAFOOD- AND VEGETABLE-ENRICHED NOODLES

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Abstract

This study examines the sensory acceptability of noodles enriched with shrimp shell powder, fish bone powder, and mustard stalk extract as part of a sustainable food waste valorization strategy. By assessing color, taste, aroma, and texture across different substitution levels, the research highlights the trade-offs between enhanced nutritional profiles and consumer acceptance. Results indicate that while lower inclusion levels maintain desirable sensory qualities, higher levels can lead to less appealing color, more pungent fishy odors, and bitter or mineral-like tastes that may limit market success. These findings underscore the need for careful formulation and advanced processing to strike a balance between functionality and palatability. The outcomes offer practical insights for food producers seeking to develop functional foods that align with the principles of a circular economy. Furthermore, this study contributes to ongoing discussions about the revalorization of seafood and agricultural by-products, especially in regions with high seafood consumption and waste generation. Future research should focus on optimizing ingredient treatment, exploring taste-masking strategies, and engaging consumers through education to increase the acceptance of novel, sustainable ingredients in staple foods.

Keywords: *food waste valorization, functional noodles, mustard stalk extract, seafood by-products, sensory evaluation.*

INTRODUCTION

In recent years, there has been increasing global attention toward sustainable food production, particularly in revalorizing food processing by-products and agricultural waste (Spaggiari et al., 2020). Seafood processing generates substantial amounts of waste, including shrimp shells and fish bones, which, if untreated, can cause environmental pollution but are rich in valuable nutrients such as protein, minerals, and chitin (Bhatt et al., 2017; Shahidi & Ambigaipalan, 2015a). Concurrently, vegetable by-products such as mustard stalks remain underutilized, despite being potential sources of dietary fiber and bioactive compounds (Ahmad et al., 2021). Noodles are among the most widely consumed staple foods in Asia, making them a strategic vehicle for developing functional foods. Several studies have demonstrated that incorporating alternative ingredients, such as fish bone powder or vegetable fiber, can enhance nutritional value but may also impact sensory attributes, including color, taste, aroma, and texture (Elleuch et al., 2011; Sinthusamran et al., 2019). This duality raises critical questions about consumer acceptance. Therefore, the development of noodles enriched with seafood waste (shrimp shells and fish bones) and mustard stalk extract presents a promising yet complex challenge: how to combine sustainability, nutrition, and palatability in a single product. Understanding consumer sensory acceptance is vital to ensuring that such functional products can succeed in the market. Despite the acknowledged potential of seafood and vegetable waste valorisation, few studies have specifically investigated the combined use of shrimp shells, fish bones, and mustard stalk extract as functional ingredients in noodle products. Moreover, there remains limited evidence on how varying substitution levels affect consumer hedonic perceptions in developing countries, such as Indonesia, where noodles are a daily staple. Previous research has primarily focused on nutritional improvement, but has given less attention to the trade-off between nutritional enhancement and sensory acceptability (Kera et al., 2023; Pathare et al., 2013). This gap highlights the need to investigate optimal formulation levels that strike a balance between dietary benefits and consumer preferences. Given the global push toward sustainable food systems and circular bioeconomy, research that bridges the nutritional and sensory aspects of upcycled food products is urgently needed. Indonesia, with its abundant seafood

resources and diverse agriculture, stands to benefit significantly from practical valorisation models that convert waste into value-added, functional foods. Insights from this study could inform not only product development but also strategies for consumer education, aiming to improve the acceptance of novel ingredients derived from food waste.

LITERATURE REVIEW

The increasing concern regarding food waste and its environmental repercussions has catalysed a worldwide transition towards circular food systems and the valorisation of by-products into value-added ingredients (Nawaz et al., 2020). Waste from seafood processing, particularly shrimp shells and fish bones, has garnered attention due to its substantial content of protein, calcium, chitin, and other bioactive compounds (Shahidi & Ambigaipalan, 2015a). (Shahidi et al., 2019) emphasize that crustacean by-products can be converted into functional ingredients; however, their integration into mainstream food products remains somewhat limited due to sensory issues such as undesirable flavors or odors. Studies focusing on incorporating seafood waste into staple foods, such as noodles, demonstrate its nutritional potential. For example, it was found that adding fish bone powder to noodles significantly increased calcium levels, but also altered the texture and taste. Similarly, (Zhu et al., 2023) researchers reported that while seafood waste can enrich noodle nutritionally, it often imparts a fishy aroma that may reduce consumer acceptance, indicating a need for improved processing techniques or flavor masking strategies.

In parallel, the valorization of vegetable by-products, such as mustard stalks, aligns with the demand for dietary fiber enrichment and the use of local agricultural residues (Ahmad et al., 2021). Mustard greens, like other cruciferous vegetables, are known for their glucosinolates, which provide health benefits but can also impart a bitter taste to food. Emphasize that while adding fiber-rich agro-waste improves nutritional profiles, it can negatively affect the texture and appearance of wheat-based products due to disruptions in the gluten matrix. Consumer sensory perception remains a critical factor in the success of functional foods. (Pathare et al., 2013) note that color is among the first quality cues influencing purchasing decisions, and any undesirable changes may discourage repeat purchases. The balance between nutrition enhancement and sensory quality is therefore a recurring theme. (Abirami et al., 2020) discuss how the Maillard reaction during processing can darken shrimp waste-derived products, influencing visual appeal. Likewise, it (Liu et al., 2024) is emphasized that off-flavors associated with seafood by-products must be addressed through innovative processing methods, such as enzymatic treatments or encapsulation, to maintain consumer acceptability.

While previous studies provide valuable insights into individual uses of seafood or vegetable waste in food products, there remains limited evidence on combining both in a single formulation. (Mashau et al., 2025) emphasize that an integrated approach can optimize nutritional benefits, but it requires careful formulation to prevent adverse sensory outcomes. This intersection of sustainability, nutrition, and sensory science is increasingly recognized as a key research priority, enabling practical innovations that convert waste into food. Collectively, the literature suggests a clear need for systematic sensory evaluation of novel products that combine multiple by-products, along with advanced processing and consumer education, to ensure market acceptance (Spaggiari et al., 2020). The present study contributes to filling this gap by evaluating the impact of different levels of seafood waste and mustard stalk extract on the hedonic attributes of noodles, providing practical insights for future product development and commercialization.

METHOD

The hedonic evaluation of the noodle samples employed a 5-point scale, ranging from 1 ("strongly dislike") to 5 ("strongly like"), across four sensory attributes: color, taste, aroma, and texture (Stone et al., 2021). Thirty untrained panelists participated in the sensory assessment.

RESULTS AND DISCUSSION

Table 1. Hedonic test measurement

Numeric scale	Color	Taste	Aroma	Texture
5	Strongly like	Strongly like	Strongly like	Strongly like
4	Like	Like	Like	Like
3	Moderately like	Moderately like	Moderately like	Moderately like
2	Dislike	Dislike	Dislike	Dislike
1	Strongly dislike	Strongly dislike	Strongly dislike	Strongly dislike

Sensory evaluation

The appearance of noodles is one of the most immediate cues that shapes how consumers judge their overall quality. In this study, it became clear that enriching noodles with seafood by-products and mustard stalks noticeably altered their visual appeal. At lower substitution levels, the product retained a lighter, more uniform colour that most panellists linked with freshness and good quality, supporting the view that consumers often rely on visual cues to form expectations about taste and acceptability (Pathare et al., 2013). However, as the proportion of shrimp shells, fish bone powder, and mustard stalk extract increased, the noodles tended to develop a darker, more muted tone that some panelists perceived as less attractive. This color shift can be attributed to a change in color that occurs during processing. Chlorophyll and other natural green pigments present in mustard stalks are sensitive to heat and pH changes, which can cause them to degrade and shift from vibrant green to an olive or brownish hue (Wahyuni et al., 2023).

Additionally, the presence of protein-rich seafood ingredients encourages Maillard reactions during processing. The reaction between amino acids and reducing sugars produces melanoidins that deepen the color but can also lead to undesirable darkening if not well controlled (Abirami et al., 2020; Kathuria et al., 2023; Murata, 2021). While a slight browning effect can signal certain desirable flavour notes, excessive darkening may reduce consumer appeal, as colour is a strong driver of perceived freshness and quality. Given these challenges, practical strategies to stabilise or protect pigments have become increasingly relevant. Research has pointed to the potential use of natural stabilisers like rosemary extract or the application of microencapsulation techniques to shield sensitive pigments from processing stress (Otálora et al., 2023). Integrating these methods into noodle development could help maintain a more attractive appearance while still delivering the nutritional benefits of incorporating seafood and vegetable-based ingredients.

Taste plays a pivotal role in shaping whether a novel functional food will be welcomed by consumers or rejected after the first try. In this study, a clear downward trend in taste preference emerged as the inclusion of shrimp shell powder, fish bone powder, and mustard stalk extract increased. When only a small proportion was added, the noodles retained a mild, balanced savouriness that many panelists found pleasant and approachable. This balance likely stems from subtle umami notes contributed by seafood proteins, which can enrich flavor without overpowering it when maintained at moderate levels (Abotsi et al., 2024). However, at higher substitution levels, the intensified seafood flavour profile began to push the boundaries of acceptability. Panellists commonly noted a more pungent marine taste, accompanied by hints of bitterness and a lingering mineral saltiness, which disrupted the overall flavour harmony. This is consistent with studies highlighting that excessive inclusion of seafood by-products can introduce challenging taste attributes if the formulation is not carefully refined (Ramakrishnan et al., 2023).

One underlying reason is the significant increase in ash content resulting from the addition of more shell and bone material. Elevated ash levels result in higher concentrations of minerals, such as calcium and phosphorus, which can impart a slightly chalky or mineral-like taste that some consumers find unpleasant when too prominent (Mashau et al., 2025). Moreover, the presence of chitosan in shrimp shells, while valuable for its functional properties, is also linked with a subtle bitter aftertaste. Meanwhile, glucosinolates naturally present in mustard stalks can break down into pungent, bitter compounds during cooking or storage, further contributing to flavour challenges (Kapusta-Duch et al., 2016). Taken together, these factors demonstrate that taste is highly sensitive to small shifts in formulation. Achieving the right balance calls for more than simply adjusting raw material ratios. It may involve integrating

culinary strategies, such as adding natural herbs and spices, or employing advanced taste-masking technologies to soften bitterness and enhance savoury notes without compromising nutritional value (Luckow et al., 2006). Doing so would help maintain the product's unique functional appeal while improving repeat purchase intent, a crucial aspect of market success for seafood-enriched noodles. Aroma is equally important because it sets up consumer expectations even before the first bite. In this research, panellists' aroma scores declined more sharply than for any other sensory attribute, revealing just how challenging it can be to manage odour when working with seafood-based ingredients. At lower inclusion levels, the noodles' mild seafood scent was generally acceptable and even contributed to an authentic character. However, as more shrimp shells and fish bone powder were added, the intensified fishy odour became a deterrent for many. This is hardly surprising since seafood products are prone to the generation of volatile amines and other odorous compounds during processing, especially when protein and fat break down under heat and moisture (Liu et al., 2024). Compounds like trimethylamine oxide (TMAO) are notorious for producing that characteristic fishy smell when reduced to trimethylamine. Such aromas, while natural to seafood, can easily overwhelm the delicate sensory balance of a noodle dish if not adequately controlled. Several promising techniques could address this issue in future development. One approach is the use of natural aromatic herbs and spices, which can help mask or neutralise undesirable odours without the need for artificial additives (Luckow et al., 2006). Another is optimising drying and storage conditions to limit microbial activity and enzymatic breakdown that produce volatile amines (Shahidi & Ambigaipalan, 2015b). Additionally, innovative deodorization methods or the incorporation of natural odor absorbents have been explored in recent research, yielding encouraging results. These strategies provide practical approaches to maintain nutritional benefits while enhancing the aroma profile, thereby strengthening consumer acceptance.

CONCLUSION

Considering the sensory challenges identified in this study, it is highly recommended that future product development efforts focus on optimizing ingredient ratios to achieve a balance between nutritional value and sensory quality. The application of innovative processing techniques, such as fine particle milling, enzymatic treatments, or microencapsulation, may be employed to mitigate undesirable flavors and ensure pigment stability. Additionally, the incorporation of natural flavor-masking herbs or aromatic spices should be explored to enhance the taste and aroma, thereby ensuring that the nutritional advantages of shrimp shells, fish bones, and mustard stalks are not compromised due to consumer acceptance. The practical implications of this research extend to local food producers and policymakers in regions such as Indonesia, where seafood waste and vegetable by-products are plentiful yet underutilised. By demonstrating how these by-products can be revalorised into functional foods through meticulous sensory optimization, this study underpins wider initiatives to develop circular bioeconomies and sustainable food systems. Additionally, it highlights the importance of consumer education and transparent labeling in fostering public trust and increasing the willingness to adopt foods made with upcycled ingredients. Ultimately, future research would benefit from expanding the scope of sensory evaluation to encompass diverse consumer groups and authentic market environments. Additionally, assessments of long-term storage stability, cost-benefit analysis, and scalability are essential to ascertain commercial viability. Collaboration among food scientists, culinary experts, and the local seafood industry may expedite the development of innovative and attractive products that transform food waste into substantial nutritional value, thereby supporting both environmental sustainability and food security.

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