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RESEARCH ARTICLE

Nutritional and Sensory Profiling of Circular Food Product Innovation Through Lush Bites: Utilizing Marine-Agricultural Waste for Sustainable Consumption

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ABSTRACT
The growing issue which is food waste that responsible for an estimated 7,29% of Indonesia's greenhouse gas emissions in Indonesia over the past 20 years, demands urgent action. This food waste can be repurposed into a sustainable food innovation that meets the demand for business models integrating circular blue-green economy principles. This study presents Lush Bites, a nutritional food product developed by valorizing shrimp waste and onggok, two underutilized nutrient-rich by-products commonly discarded in Indonesia. The formulation process involved detoxification and drying techniques to ensure safety and nutritional retention. Nutritional values were estimated using reliable secondary data from Scopus-indexed publications, highlighting significant contributions of starch (72,43%) and astaxanthin (up to 160.06 µg/g). Sensory evaluation was conducted on 35 informed panelists with backgrounds in food science, showing a favourable acceptance, especially in taste and overall attributes (mean >4.0 on a 5-point scale). Lush Bites aligns with green and blue economy goals by turning food waste into a value-added product with a lowcost production, supporting SDGs 2, 12, and 13. This research bridges theoretical findings from food waste valorization with practical application, demonstrating a profitable pathway for eco-friendly food production.

KEYWORDS: *Circular economy, Shrimp waste, Cassava peel, Nutritional food, Sensory evaluation, Food waste utilization*

Introduction

According to the United Environment Programme (UNEP) in 2021, Indonesia ranked fourth as the world's largest producer of food waste with 20.93 million tons per year. Food waste results from the dominance of fruit, vegetable, and fish waste as food that is easily damaged and decomposed. It is ironic that the food we eat can contribute to complex problems in many aspects, such as economic, social, and environmental. Over the past 20 years, Food Loss and Waste (FLW) in Indonesia is estimated to be equivalent to 7.29% of the average greenhouse gas emissions over the same time span (Dou *et al.*, 2016). Carbon emissions produced into the environment can cause global warming (Sampepajung *et al.*, 2023).

The high number of FLW in Indonesia can be caused by unwise human factors in managing food waste, but Indonesia's geographical location which is a maritime and agricultural country affects the food waste produced. Production from agricultural and marine commodities generally deteriorates rapidly and decays (Mushollaeni *et al.*, 2023). These commodities have not been utilized optimally because some marine commodities contain allergenic compounds.

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An example of a marine commodity that has not been utilized to the maximum is shrimp. Shrimp is classified as the main commodity of fishery products, whose production will reach 941,646 tons in 2023 (BPS, 2025). This amount is in line with the amount of shrimp processing waste, which is around 30%-75% of the weight of shrimp (Saman and Lapamona, 2024). Shrimp waste consisting of heads, skins, and legs with a production rate of 141,040 tons/year ends up in landfills (Massi *et al.*, 2023). Shrimp waste that still contains these nutritional components eventually contributes to the carbon footprint on earth. If further researched, the nutritional component of shrimp waste, especially on the head, contains 21% protein, 0.93% fat, and 2.64% ash so that it has the potential to be used as a functional food (Prakoso *et al.*, 2023). In addition, the antioxidant content of astaxanthin in shrimp head extract is 4.02 mg/g which can act as an antioxidant with an effectiveness of 500 times better than vitamin E oxidants in fighting free radicals (Rahmalia *et al.*, 2024; Pailing *et al.*, 2018).

In addition to waste from marine commodities, agricultural waste, especially agroindustrial waste from processed agricultural products, contributes to the high level of food waste. One example of this agro-industrial waste is onggok. Onggok is a solid by-product (dregs) from tapioca flour processing whose utilization has not been maximized. According to Nugroho (2016), each ton of cassava can produce 250 kg of tapioca and 114 kg of cocoa as a by-product. By product from agro-industrial will again end up being dumped and become waste that contributes to carbon emissions. Therefore, the by-products of the tapioca teoung industry can be used with nutritional content considerations. Widiyatun *et al.*, (2024) stated that onggok contains carbohydrateates (63-68%), water (20%) and in dry conditions contains 4.26% crude fiber, 2.80% crude protein, 1.18% ash, 0.76% crude fat. Onggok flour also contains a moisture content of 8.84%, ash content of 0.71%, starch content of 72.43%, and crude fiber of 6.77% (Farisy *et al.*, 2024).

This abundant amount of shrimp waste and tapioca flour by-products has the potential to be developed into functional food due to its high nutritional content. In addition to basic nutritional needs, the antioxidant content of astaxanthin and fiber offers health benefits. The use of these two wastes as functional food has not been maximized because there is a content of tropomyosine allergen compounds in shrimp compounds and cyanide acid (HCN) in shrimp (Su *et al.*, 2024; Hidayat *et al.*, 2021). However, both materials can be reused with proper treatment so that waste optimization in overcoming environmental problems is ultimately in line with the principles of the blue economy and green economy (Firmansyah, 2022). Thus, the use of shrimp and shrimp waste not only plays a role in Sustainable Development Goals (SDGs) number 2, 12, and 13, but also supports economic growth and the development of functional food from waste.

Material and Method

Product Preparation

This study was begun with the manufacture of shrimp waste flour. Shrimp waste was pre-treated by washing the head, skin, and tail to remove dirt and soaking with lemon juice for about 30 minutes to remove the fishy smell (Patadjai *et al.*, 2024). After that, the shrimp waste was fermented to remove allergen compounds by adding salt (15%), water (50%), and cooked shrimp paste starter (15%) to the shrimp waste mixture that had been coarsely ground (Amalia, 2024). This mixture was then tightly closed and left at room temperature for 1-2 days. Fermented shrimp waste then was drained and blanched to remove fishy taste. After that, the shrimp waste was dried in an oven (150ºC; 30 minutes) then ground and sifted with sieve.

In a separate process, onggok flour was prepared. Onggok flour was soaked in iodized brine for 16 hours before it washed again to reduce the HCN content (White *et al.*, 2022). After soaking, onggok flour was separated from the salt solution so it could be carried on

to the drying step in the oven (100ºC) until completely dried. The onggok flour then was mashed using a flour blender and then sifted so that the fine and coarse grains could be separated.

Next, to get into the stage of making Lush Bites where onggok flour, shrimp waste flour, and milk powder were mixed in a ratio of 2:1:4. Melted butter (5 tbsp) was poured to help bring the dough together well. Lastly, the dough was pressed into a small box shape with a size of approximately 2x1x1 cm as the last step.

Nutritional Value Analysis

The nutritional content of both wastes was obtained from secondary data obtained from Scopus-indexed publications. Then, estimated nutritional value of a product with total weight of 250g was analyzed on NutriSurvey application.

Panelist Selection

35 informed panelists were required to complete questionnaire via Google Form. Prospective panelists were recruited from around CitraLand Surabaya with background Food Technology Student or Food Technologist. These panelists were represented general consumer preferences and serves as a suitable population for hedonic testing in this context and for this product (Lim., 2011). The sensory evaluation was carried out by the panelists filling in several questions including color, aroma, texture, taste, overalls, and age of the respondents on the google form that had been prepared.

Preparation of Edible Origami Paper from Purple Cabbage

The sensory evaluation procedure using the 5-point hedonic scale referred to Sugumar & Guha (2022) where untrained panelists were asked to rate their level of preference on five-point scale (1= strongly dislike, 2= dislike, 3= neutral, 4= like, and 5 = strongly like). Panelists were encouraged to neutralize their taste buds with mineral water before and after testing the product. This method was chosen because its capability to measuring consumer preferences in sensory evaluation straightforward, and helping researchers to understand how much people like or dislike specific food attributes.

Cost Analysis and Sustainable Production Approach

To evaluate the economic feasibility and sustainability of Lush Bites, a cost analysis was conducted alongside the development of the product. The production process was intentionally designed to align with circular economy principles by utilizing waste, specifically shrimp waste and onggok as primary ingredients. The cost components analyzed included raw materials, labor, energy and packaging. All processes were carried out using existing small-scale equipment. The total production cost per unit was calculated based on the total input for one production batch divided by the number of units produced. An estimate of cost- efficiency was provided in this analysis to assess the potential scalability of the product under a blue green economy framework.

Data Analysis

The results of sensory evaluation obtained from the panelists were analyzed using descriptive analysis by calculating the mean and standard deviations of attributes (color, aroma, texture, taste, overall, age) to determine consumer preferences, ingredient evaluation, determination of sensory parameters, quality assessment, and product development.

Results and Discussion

Product Development (Lush Bites) and Sensory Evaluation Results

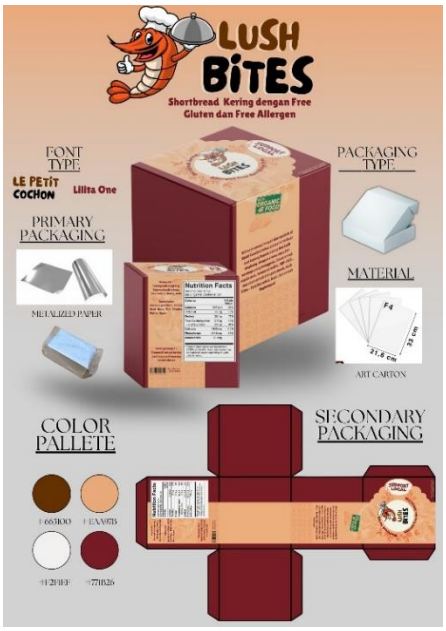

Figure 1. Moodboard prototype of the product.

Figure 1 illustrates the mood board for the packaging design used in this product. The packaging presents Lush Bites as a by-product derived from shrimp waste and tapioca by-product. Not only recycling food waste in Indonesia, but also expected to be able to offer nutritious snacks suitable for any ages. More specifically, Lush Bites are in the form of dry, crumbly shortbread that melts in the mouth, leaving a powdery texture once dissolved. This product is small in size, comparable to gummy candy, but contains rich nutritional value. Therefore, Lush Bites presents a dominant milk and butter aroma with gluten-free ingredients, complemented by the savoury taste of shrimp head flour. This balanced flavour makes this product suitable as a light snack to satisfy hunger for a wide segment of consumers. However, this study was not to evaluate and validate the number of allergic compounds, heavy metal contamination and final HCN content that the product had. Future work needs to be done for this. In addition, the final product received high acceptance in the market with sensory evaluation analysis using a 5-point hedonic scale to assess consumer preferences. The results of this analysis are presented in Figure 2.

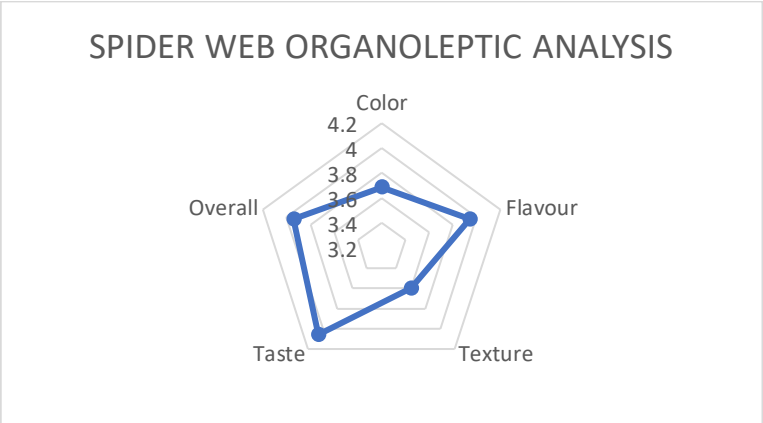

Figure 2. Spider web graph of sensory evaluation analysis.

Based on Figure 2, it can be seen that the taste attribute has the highest average of 4.1 so it can be said that the panelists liked this aspect the most. Followed by the flavour aspect with the number 3.9 considering that this product does not have a fishy smell typical of shrimp but has a typical smell of milk. This finding is supported by Kocyigit *et al.*, (2024) stated that the milk flavour in a new food product will be more acceptable for the public. On the other hand, the texture aspect has the lowest average of 3.6 which then need a special concern to be developed. However, an overall average aspect close to 4.0 indicates that the product can be well received by the panelists on the condition that there is an improvement in texture attributes.

Nutritional Content

Based on the ingredients used with nutritional content, Lush Bites contains an array of complex nutritional profile. Bernard and Bolatito (2016) reported that shrimp, particularly species such as Penaeus notialis and Penaeus monodon, contain approximately 9.21% protein, 4.67% fat, and 3.53% minerals, with high levels of calcium and zinc. In addition, Kaya *et al.* (2025) stated that shrimp, especially in the shell, possess notable antioxidant properties, with astaxanthin levels of 336.4 µg/g and total phenolic content (TPC) ranging from 4.7 to 10.4 mg gallic acid equivalents (GAE)/g dry weight. Shrimp shells also contain carotenoids such as β-carotene and astaxanthin, further enhancing their antioxidant potential. Onggok (cassava by-product), on the other hand, contains 8.84% moisture, 0.71% ash, 72.43% starch, and 6.77% crude fiber (Farisy *et al.*, 2024). Additional ingredients such as milk powder and melted butter contribute further protein and fat content to the formulation.

These attribute combinations create Lush Bites nutritious despite of the small size. Estimation of nutritional composition per box (250 g; 20 pieces) analyzed by NutriSurvey application is showed in the Table 1.

Table 1. Estimated nutritional value (per 250 g)

Nutritional value	Amount (250 g)
Energy	56,7 kcal
Water	0,5 g
Protein (11%)	1,5 g
Fat (58%)	3,7 g
Carbohydrate. (31%)	4,4 g
Dietary fiber (72.43%)	5,1 g
PUFA	0,1 g
Cholesterol	10,8 mg
Vit. A (carotene)	39,7 µg
Vit. E (eq.)	0,2 mg
Tot. Fol.acid	2,1 µg
Vit. C	1,5 mg
Sodium	15,2 mg
Potassium	45,6 mg
Calcium	31,7 mg
Magnesium	4,0 mg
Phosphorus	28,6 mg
Iron	0,3 mg
Zinc	0,2 mg

Cost Efficiency and Sustainability Potential

A detailed breakdown of the cost structure, as shown in Table 2, demonstrates a strategic allocation of resources that supports both cost efficiency and sustainability in the production of Lush Bites. The total production cost is Rp1.882.900 to make a total of 22 boxes final product with encompassing all expenses across consumables, services, transportation, and utilities.

Table 2. Cost justification

Variable				
No	Production Type	Unit Price (Rp)	Volume	Total (Rp)
1	Mask	Rp15.000	1 box	Rp15.000
2	Gloves	Rp5.000	1 box	Rp5.000
3	Gas 3 kg	Rp20.000	2 unit	Rp40.000
4	Primary Packaging	Rp210	440 pcs	Rp92.400
5	Secondary Packaging	Rp5.000	22 pcs	Rp110.000
6	Onggok	Rp10.000	1 kg	Rp10.000
7	Milk powder	Rp15.000	2 kg	Rp30.000
8	Shrimp waste	Rp5.000	0,5 kg	Rp2.500
9	Shrimp paste	Rp10.000	1 pack	Rp10.000
10	Water	Rp50.000	1	Rp50.000
11	Salt	Rp13.000	1 pack	Rp13.000
12	Grinder services	Rp5.000	2	Rp10.000
13	Gasoline	Rp60.000	1	Rp60.000
14	Labor cost	Rp150.000	1	Rp150.000
15	Electricity	Rp120.000	1	Rp120.000
			Subtotal	Rp717.900
Fixed				
No	Production Type	Unit Price (Rp)	Volume	Total (Rp)
1	Logo design services	Rp25.000	1	Rp25.000
2	Packaging design services	Rp50.000	1	Rp50.000
3	Spoon	Rp10.000	3 pcs	Rp30.000
4	Oven	Rp900.000	1 unit	Rp900.000
5	Scales	Rp40.000	2 unit	Rp80.000
6	Shiever (mesh80)	Rp40.000	2 unit	Rp80.000
			Subtotal	Rp1.165.000
Total Cost				
No	Components	Cost (Rp)	Volume	Total (Rp)
1	Variable Cost	Rp717.900	1	Rp717.900
2	Fixed Cost	Rp1.165.000	1	Rp1.165.000
			Subtotal	Rp1.882.900

The cost structure of Lush Bites shows a potential business model by utilizing food waste derivates and affordable services. Lush Bites as a new product has a future prospect to be a scalable and sustainable blue green economy framework.

Conclusion

The use of shrimp waste and onggok as a food raw material shows high potential both in terms of nutrient content and bioactive compounds contained. These combinations possess high protein, astaxanthin and dietary fiber produce functional. Furthermore, the use of waste is in line with SDGs number 12, waste reduction, and the realization of new economic opportunities through sustainable food products. However, this product produces potential future work, to ensure and validate the content of HCN, heavy metal risk and allergenic compounds in the final product since the raw materials contain those compounds even though they have been pre-treated.

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Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Conceptualization, Nafisah Zainuba Hasan; methodology, Nafisah Zainuba Hasan and Adisa Naila Lubna; writing original draft preparation, Nafisah Zainuba Hasan and Adisa Naila Lubna; writing, review and editing, Adisa Naila Lubna and Nafisah Zainuba Hasan; visualization, Nafisah Zainuba Hasan; data curation, Adisa Naila Lubna; supervision, Nafisah Zainuba Hasan. All authors agreed to the final version of this manuscript.

Ethical Statement

Hereby, the author declares that the author is committed to adhering to the ethical principles of applicable scientific publications, such as avoiding plagiarism, ensuring data transparency, and providing informed consent to participants.

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