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Research Article

The Potential Applications of Shrimp Wastes: Developing Value-added Products to Enhance Their Nutritional Profiles and Flavour

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Abstract

This study investigates the development of value-added food products from shrimp (*Metapenaeus monoceros*) waste (SW) with the aim of enhancing nutritional value, sensory quality, and sustainability. Shrimp waste was sun-dried and ground into shrimp waste powder (SWP), which was incorporated into four products: chips, soup powder, samosa wrapper, and wonton wrapper. Chips were prepared by combining sago powder and SWP with water, followed by cooking, drying, and frying. Soup powder was produced by mixing SWP with flour and selected ingredients, while samosa and wonton wrappers were prepared using SWP, flour, water, and salt. Proximate composition was determined using standard analytical methods: protein by the Dumas method, fat by rapid fat extraction, moisture by a Shimadzu moisture analyzer, ash by muffle furnace, and carbohydrate by difference. On a dry basis, SWP chips contained 8.75% protein, 0.50% fat, 67.75% carbohydrate, 10.18% moisture, and 12.85% ash. SWP soup powder showed higher protein content (19.50%) with 0.67% fat, 66.22% carbohydrate, 8.84% moisture, and 4.77% ash. Both SWP samosa and wonton wrappers contained 14.84% protein, 0.90% fat, 57.49% carbohydrate, 10.45% moisture, and 16.32% ash. Sensory assessment by 70 panelists indicated excellent acceptability, highlighting superior crunchiness and flavor in chips, desirable flavor in soup, and high-quality attributes in samosa and wonton wrappers. Microbial analysis revealed safe microbial loads, with shelf lives of approximately six months for chips, four months for soup powder at ambient conditions, and 45 days for wrappers at −40°C. Production costs were lower than commercially available alternatives. Overall, this study demonstrates the potential of shrimp waste valorization for sustainable food innovation and improved waste management.

Keywords

Value-added Products, Shrimp Waste, Chemical Analysis, Sensory Assessment, Microbial Load Analysis, Cost Assessment

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1. Introduction

In the diverse and dynamic world of food processing and culinary arts, countless components are utilized to create an array of value-added products (VAP) that cater to various tastes, nutritional needs, and market demands; among these, shrimp stands out as the most valuable component for the preparation of high quality, VAP, prized for its delicate flavor, nutritional benefits, and versatility in numerous gourmet and convenience food applications. VAP refers to commodities that have transformed the production process, resulting in an increase in their overall value. This enhancement can take various forms, such as the incorporation of new features, improved quality, innovative design, or additional services that augment the product's appeal and functionality, there by meeting specific consumer demands. Value addition, product diversification, utilization, and efficient management of seafood waste will generate more profits [3].

According to several studies, these seafood waste materials have significant protein concentration that could be used to prepare value-added goods [22]. Shrimp waste contains valuable compounds such as bioactive compounds such as proteins, peptides [23], polysaccharides (chitin and its derivative chitosan) [31], pigments (mostly carotenoids) [36], enzymes [34], lipids [35], minerals (especially calcium, potassium, sodium, and zinc) [9], and vitamins [26], making it a potential resource for creating VAP.

Consequently, SW represents a promising substrate for the development of value-added products. Potential applications include the extraction of astaxanthin, the production of organic fertilizers, and the formulation of animal feed. SW is also used for the preparation of cosmetics and skin care products. Astaxanthin helps prevent lipid peroxidation, which in turn keeps skin hydrated and reduces roughness, a precursor to wrinkle formation, as well as age spots and atopic dermatitis [39]. This property effectively blocks UVB rays [33]. Shrimp shell peptide hydrolysates inhibit the proliferation of human cancer cells [19]. Besides the processing of shrimp waste into powder form, it can be used as the main ingredient in making shrimp flavouring agent, shrimp crackers, soup bases, dips, chowders, or sauces, processing smoked or dried shrimp powder as an ingredient [38]. In Indonesia, shrimp heads and shells are processed into shrimp paste products, which are used to make petis-udang and otak-udang, seasoned shrimp pastes that are incorporated into various cuisines [10], besides that using shrimp waste to create value-added products will contribute to reducing environmental pollution and preserving the industry’s economic viability[37]. The shrimp by-products are rich in both micronutrients and bioactive components, which are highly beneficial for the human body and present new opportunities for the food and nutraceutical sectors to develop innovative products through fortification and enrichment. This could further alleviate food insecurity issues worldwide [24].

According to FAO, among all crustaceans and fish products, shrimps are the most commercially significant and internationally traded item. Shrimp and prawn are the second most exported species. In 2020, the combined supply of shrimp from fisheries and aquaculture reached approximately 10 million metrictonnes (wet weight), resulting in roughly 3.5-6.5 million metrictonnes of shrimp solid processing waste [7, 8]. According to a survey of the global farmed shrimp industry, the global shrimp production in 2023 is forecasted to be around 5.6 million metric tons. Additionally, IMARC (International Market Analysis Research and Consulting) reported that the value of shrimp was recorded at $62.8billion in 2021 [1]. The shrimp processing industry produces around 3.8 million tons of waste worldwide annually, constituting approximately 50 to 60% of the catch volume, taking into account that, in the case of shrimps, the head and tail portions may collectively represent 45 to 60% of the total weight. A limited amount of shrimp waste is employed as animal feed and incorporated into aquaculture feed formulations [28].

A few years ago, across the shrimp processing industry in Bangladesh, approximately 30,000 tons of shrimp wastes were discarded annually [29]. Nowadays, around 43,320.88 tons of sea food waste is produced per year, worth USD 13.73 to USD 44.09 million. Shrimp and fish waste are produced at the highest rates of 23,190.24 and 17,605.71 tons per year, respectively [15]. This waste also generates from fishing boats or shrimp processing plants during the shrimp fishing season, and the shrimp heads alone contribute around 35%-45% of the total shrimp production [16]. Most of it ends up being disposed of, and disposing of this waste is not only unprofitable but it can also represent an environmental problem if not correctly handled [40].

Currently, the primary disposal method for shrimp processing waste involves land filling and ocean dumping, causing alterations to soils, water, and marine ecosystems. Moreover, this approach may lead to the release of unpleasant amine gases during the fermentation of shrimp waste, rendering nearby areas inhospitable. This poses a substantial environmental challenge, contributing to pollution and potentially endangering the ecological environment. Additionally, the washing and cooking processes of shrimp contribute to waste water pollution, generating approximately 1L of waste water per Kg of cooked shrimp [5]. Only a small fraction of global shrimp processing waste is further processed for other industries, whereas most is disposed of inland fills due to its perishable nature. The disposal of shrimp processing waste is not only a loss of valuable nutrients. However, it is also associated with adverse environmental impacts, including water pollution, habitat degradation, and greenhouse gas emissions [18]. The more efficient utilization of shrimp processing waste can enhance the sustainable and economic viability of shrimp processing industries, while simultaneously contributing to the concept of a circular economy [6].

In Bangladesh, the management of SW poses a significant challenge. Instead of being processed or repurposed, a significant portion of this waste is often discarded in municipal landfills or dumping sites. Alternatively, some of the discarded shrimp waste is sold to individuals, either in its raw form or as a dried product. However, for many countries, including Bangladesh, information on the amount of seafood waste produced and the present management status is still lacking [17]. In this study, we aim to transform SW into nutritious and delicious edible products for a sustainable solution to SW management and also contribute to food security, economic resilience, and environmental sustainability in Bangladesh's seafood industry. By focusing on this ambitious goal, we will pursue the following objectives: (i) Development of new food products, (ii) Develop the nutritional profile of the VAP, (iii) Examine the way of additional revenue streams for seafood processors, (iv) Observe waste reduction to decrease environmental pollution, and (v) Conduct a study to explore opportunities for market expansion.

2. Materials and Methods

The SW (*Metapenaeus monoceros*) were sourced from the fishing communities of coastal areas in Bangladesh (Figure 1). The subsequent experiments were conducted at the Marine Fisheries Academy in Chattogram, Bangladesh, and the Bangladesh Council of Scientific and Industrial Research in Dhaka, Bangladesh. To develop value-added products, including SWP chips, SWP soup, SWP samosa wrapper, and SWP wonton wrapper, the manufacturing process outlined below was employed.

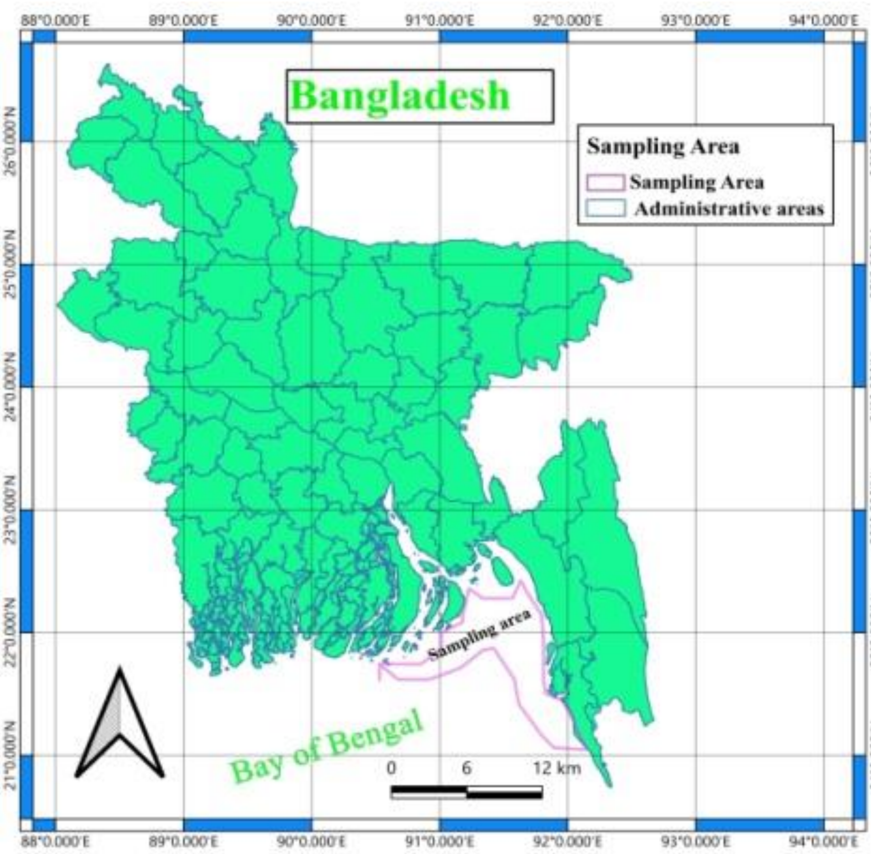

Figure 1. *Sampling Area.*

2.1. Preparation of SWP

The collected SW (Figure 2a), specifically the heads and tails, were subjected to multiple washes using fresh water to remove any residual contaminants. The heads were meticulously cleaned by extracting the meat and thoroughly rinsing the remaining material. After the cleaning process, the SW (Figure 2b) was distributed on a drying tray (Figure 2c). The tray was then positioned under direct sunlight to facilitate the drying process, which typically spans several days, contingent on ambient weather conditions. Once the SW were fully desiccated and had achieved a brittle consistency (Figure 2d), they were processed into a fine powder utilizing a high-speed blender (Figure 2e). For a finer texture, sift the ground powder through a fine mesh sieve and get a fine SWP (Figure 2f). Then, store the SWP in an airtight container and keep it refrigerated at 4 ℃ [21].

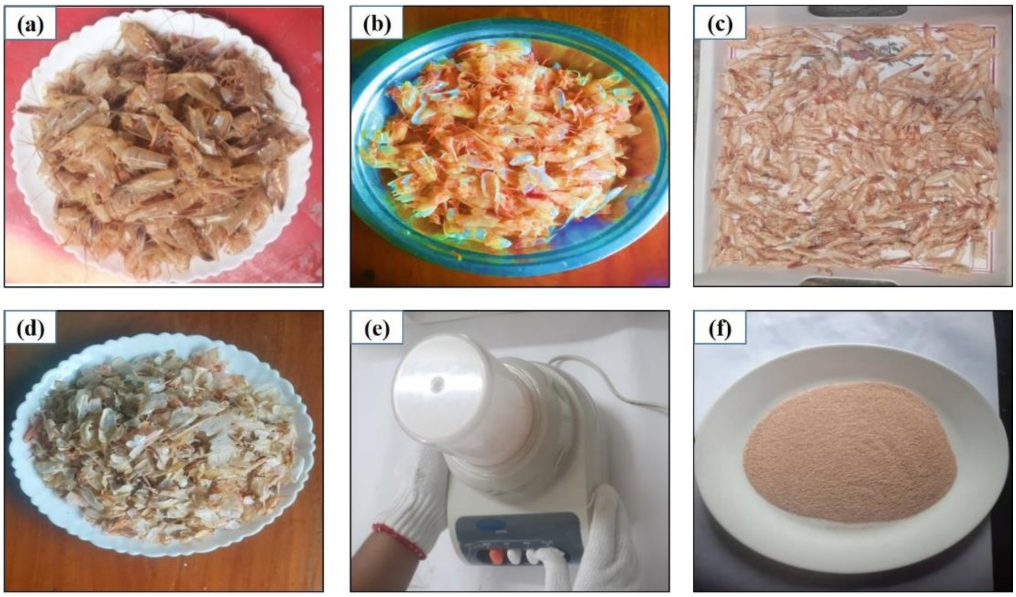

***Figure 2**. (a) SW, (b) Cleaned SW, (c) Ready to dry SW, (d) Dried SW, (e) Grinding SW, (f) SWP.*

2.2. Preparation of SWP Chips

The ingredients and amounts used to prepare SWP chips are listed in Table 1.

***Table 1**. The ingredients and their amounts are used to prepare SWP chips.*

Ingredients	Amounts
Sago powder	4.94 gm
SWP	1.40 gm
Water	79.05ml
Citric acid	0.09 ml
Oil	13.83 ml
Spices (red chili, garlic, ginger, bit salt, coriander)	0.69 gm
Salt	According to taste

For the preparation of SWP chips at first, combine sago powder and water in a pan and mix thoroughly. Cook the mixture in a gas oven at medium temperature, stirring continuously. After five minutes, add citric acid. Continue cooking for 10–12 minutes or until the mixture has thickened. Add SWP and salt, and mix continuously until smooth. After cooking, let the mixture cool slightly. Take spoonfuls and place them on a polythene-wrapped tray, repeating until all the mixture is used. Place the tray under sunlight (Figure 3a) until the SWP chips dry completely (Figure 3b). Fry the dried SWP chips in oil until they turns lightly yellow. Add spices and store the chips in airtight polythene bags at room temperature (Figure 3c).

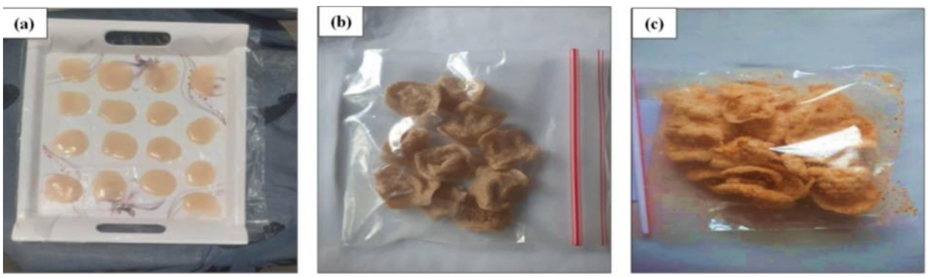

***Figure 3**. (a) SWP chips dried in the sun, (b) Dried SWP chips (c) Fried SWP chips.*

2.3. Preparation of SWP Soup Powder

The ingredients and amounts used to prepare SWP soup powder are listed in Table 2.

Table 2. The ingredients and their amounts are used to prepare SWP soup powder.

Ingredients	Amounts (%)
Flour	40
SWP	16
Corn flour	8
Dried granular carrot	8
Sugar	8
Garlic powder	4
Red chilli flakes	4
White pepper powder	2
Onion powder	2
Coriander powder	2
Salt	According to taste

For the preparation of SWP soup powder at first carefully combine all the specified ingredients listed in Table 2. Following the thorough mixing process, and then the SWP soup powder is stored in an air tight polyethylene bag (Figure 4a) at ambient temperature. Each bag should contain 25 grams of the SWP soup powder.

2.4. Cooking Procedure of SWP Soup

The ingredients and their amounts used to prepare the SWP soup are listed in Table 3.

Table 3. The ingredients and their amounts are used to prepare SWP soup.

Ingredients	Amounts
Semi-ready-to-eat SWP soup powder	25gm
Water	300ml
Egg	1/4
Salt, tomato sauce, and coriander or basil leaf flakes	According to taste

For cooking the SWP soup first of all, mix 25g of SWP soup powder with 300ml of water. A pan was placed in the oven with oil. The mixture was added to the warm oil. After 10-12 minutes, ¼ of the egg was added. A few minutes later, salt, tomato sauce and coriander or basil leaf flakes were added, and then completed the cooking of SWP soup (Figure 4b).

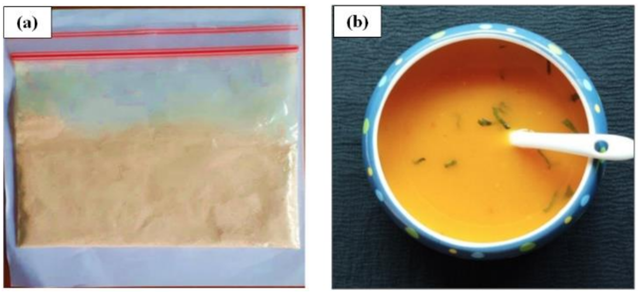

Figure 4. (a) SWP soup powder in an airtight polyethylene bag, (b) Cooked SWP soup.

2.5. Preparation of SWP Samosa Wrapper and SWP Wonton Wrapper

The ingredients and their amounts used to prepare the SWP samosa wrapper and the SWP wonton wrapper are listed in Table 4.

Table 4. The ingredients and their amounts are used to prepare the SWP samosa wrapper and the SWP wonton wrapper.

Ingredients	Amounts (%)
Flour	46
SWP	17
Water	37 or according to requirement
Salt	According to taste

The procedure is identical for the preparation of SWP samosa wrapper and SWP wonton wrapper, but their shapes are different. First, take flour, SWP, and salt in a bowl and mix thoroughly. Gradually add water to make smooth and pliable dough. Cover the dough and let it rest for a few minutes. Then cut the dough into even pieces and make them into round balls. Roll the ball with a rolling pin and flatten it into a thin sheet. Bake the sheet at a low temperature for 30-40 seconds, and then cut it to the desired size to produce SWP samosa wrapper (Figure 5a) and SWP wonton wrapper (Figure 5b).

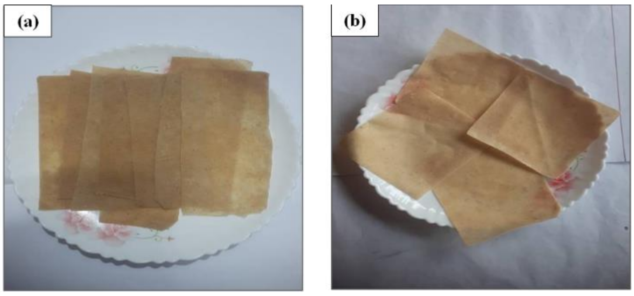

Figure 5. (a) SWP samosa wrapper, (b) SWP wonton wrapper.

2.6. Preparation of SWP Samosa and SWP Wonton

The ingredients and their amounts used to prepare SWP samosa and SWP wonton are listed in Table 5.

Table 5. The ingredients and their amounts used to prepare SWP samosa and SWP wonton.

Ingredients	Amounts
SWP samosa wrapper and SWP wonton wrapper	4 pieces of each
Oil	150 gm (Approximately)
Vegetables (potatoes, carrots, onions)	120 gm (Approximately)
Chopped chicken	50 gm (Approximately)
Egg	1piece
Water	200 ml (Approximately)
Spices and Salt	According to taste

2.6.1. SWP Samosa

First of all to prepare the filling heating some oil in a pan and saut ɑ́ng the chopped potatoes, carrots, and onions until they become soft. Then add the spices and continue cooking for a few more minutes until they become aromatic. This will ensure that the filling is flavorful and well cooked. Form cones with a SWP samosa wrapper and fill them with a vegetable filling. Brush the edges of the cones with water to seal the SWP samosa. After that, fry them in hot oil until they had become golden brown and crispy (Figure 6a).

2.6.2. SWP Wonton

In this same process, wonton was prepared, but it can be used with different fillings, such as fried chicken, chopped or mixed vegetables with eggs, to cater to a variety of tastes. Fold the SWP wonton wrapper to form the shape of SWP wonton and add the filling. After preparing all the SWP wontons, drop them in to hot oil and fry them until they become golden brown and crispy (Figure 6b).

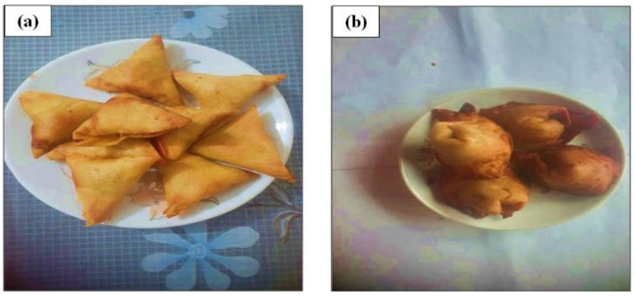

Figure 6. (a) Fried SWP samosa, (b) Fried SWP wonton.

2.7. Assessment of Proximate Composition of Products

The proximate composition, including protein, fat, carbohydrates, moisture, and ash, of SWP, SWP chips, SWP soup powder, SWP samosa wrapper, and SWP wonton wrapper was analyzed. The analyses were conducted at the Bangladesh Council of Scientific and Industrial Research in Dhaka, Bangladesh.

2.7.1. Determination of Protein

The Dumas Protein Analysis method was used to determine the protein. First, weigh the sample directly in tin foil for solid and semi-solid samples, and absorb the liquid sample in superabsorbent powder. Put the sample in the auto-sampler. Prepare sequence for checkup, calibration, and sample run. Calculate the result using the calibration curve.

2.7.2. Determination of Fat

The Rapid Fat Extractor method is used for determining the amount of fat. Initially, approximately 5g of the well-mixed test sample is placed in an extraction thimble. Place the thimble in the extraction beaker and add about 70 ml of solvent. Move the extractor lid up, place the beaker inside the machine, and then lower the lid. Run the extraction cycle as required. Collect the recovered solvent and turnoff the extractor and the chiller after a while. Weigh the extraction beaker (with the extracted fat) after it has reached room temperature. Calculate the fat percentage compared to the empty weight.

2.7.3. Determination of Moisture Content

The moisture content was determined using a Shimadzu Moisture Analyzer (Model Moc63u, Japan).

2.7.4. Determination of Ash

For the determination of ash, the principle of ashing is to burn off the organic matter and to determine the in organic matter that remains. Heating is carried out in two stages, firstly to remove the water present and to char the sample thoroughly, and finally, ashing at 550 ℃ in a muffle furnace [27]. The calculation method is given below:

$$\text{Ash content (\%)}=\frac{\boldsymbol{wt\ of\ ash}}{\boldsymbol{wt\ of\ sample}}\frac{\text{Weight of ash}}{\text{Weight of sample}}\times 100$$

2.7.5. Determination of Carbohydrate

In this study, carbohydrates were calculated using a specific method. This method subtracts 100 from the sum of total protein, fat, ash, and moisture.

$$\text{Carbohydrate (\%)}=100-(\text{Protein \%}+\text{Fat \%}+\text{Ash \%}+\text{Moisture \%})$$

2.8. Sensory Assessment of Products

Around 40 cadets and 10 instructors from the Marine Fisheries Academy, Bangladesh, as well as 20 other individuals, have been provided with a sensory assessment of the products. They meticulously sampled every product, providing detailed comment sand assigning scores of up to 10 marks to each. All comments and scores evaluated the quality of products.

2.9. Cost Assessment of Products

The cost of SWP chips, SWP soup, SWP samosa, and SWP wonton is determined by using the regular market price of the materials used to make them.

2.10. Microbiological Load Analysis, Quality Control and Sensory Evaluation

The SWP chips, SWP soup powder, SWP samosa, and SWP wonton wrapper were stored in a refrigerator at 4 ℃ and also at room temperature (28-30 ℃) to deter mine the shelf life of the products. For the determination of microbiological loads, the Total Aerobic Bacterial Count (CFU/ml) and Total Yeast and Mold Count (CFU/ml) were determined using the spread plate method.

Rigorous quality control measures were implemented throughout the study to ensure data reliability and reproducibility [14]. Standardized protocols were established for shrimp waste processing, including triple-washing with potable water and controlled sun-drying to achieve consistent moisture content (≤8%). Particle size uniformity in shrimp waste powder was verified through 150-µm mesh sieving (USP<786>). All proximate analyses were conducted in accordance with AOAC International guidelines, and instrument calibration was verified using certified reference materials. Product formulations maintained strict ingredient ratios, with process parameters (e.g., frying temperature at 180 ℃±5 ℃) continuously monitored using calibrated equipment.

Sensory evaluation was conducted using trained panelists (n=70) with randomized, blinded samples to minimize bias [12]. Microbiological safety was assessed according to ISO4833-1, 2013 standards [13]. All measurements were performed in triplicate ($p<0.05$), with data cross-verified by independent analysts to ensure accuracy. Detailed documentation of procedures, batch records, and analytical results was maintained to ensure complete traceability, in accordance with the principles of Good Laboratory Practice [30].

3. Results

To date, there has been no initiative to formulate or develop edible products or other value-added derivatives utilizing SW in Bangladesh. Considering the facts, the research work successfully developed a SWP from underutilized shrimp heads and shells. Furthermore, this innovative SWP has been incorporated into a variety of food products, including chips, soup powder, samosa, and wonton, highlighting its versatility and potential for reducing food waste. In the current study, chemical analysis was also performed to assess the proximate compositions of SWP, SWP chips, SWP soup powder, SWP samosa wrapper, and SWP wonton wrapper on a dry weight basis, thereby determining their nutritional value. The proximate composition of commercially available sago powder, flour and soup powder was also analyzed and compared with the SWP and SWP chips, SWP samosa wrapper and SWP wonton wrapper, and SWP soup powder on a dry weight basis respectively (Figures 7-9).

3.1. Chemical Analysis to Calculate Proximate Composition (on a Dry Weight Basis)

The results of the chemical analysis are presented in Tables 6-8 and illustrated with bar and column charts in Figures 7-9.

Table 6. Proximate composition of sago powder, SWP, and SWP chips.

Proximate composition	Sago powder(%)	SWP(%)	SWP chips (%)(basic ingredients are SWP and sago powder)
Protein	3.83	21.84	8.75
Fat	0.65	0.57	0.50

Proximate composition	Sago powder(%)	SWP(%)	SWP chips (%)(basic ingredients are SWP and sago powder)
Carbohydrate	82.67	13.84	67.75
Moisture	12.65	7.55	10.18
Ash	0.20	56.20	12.85

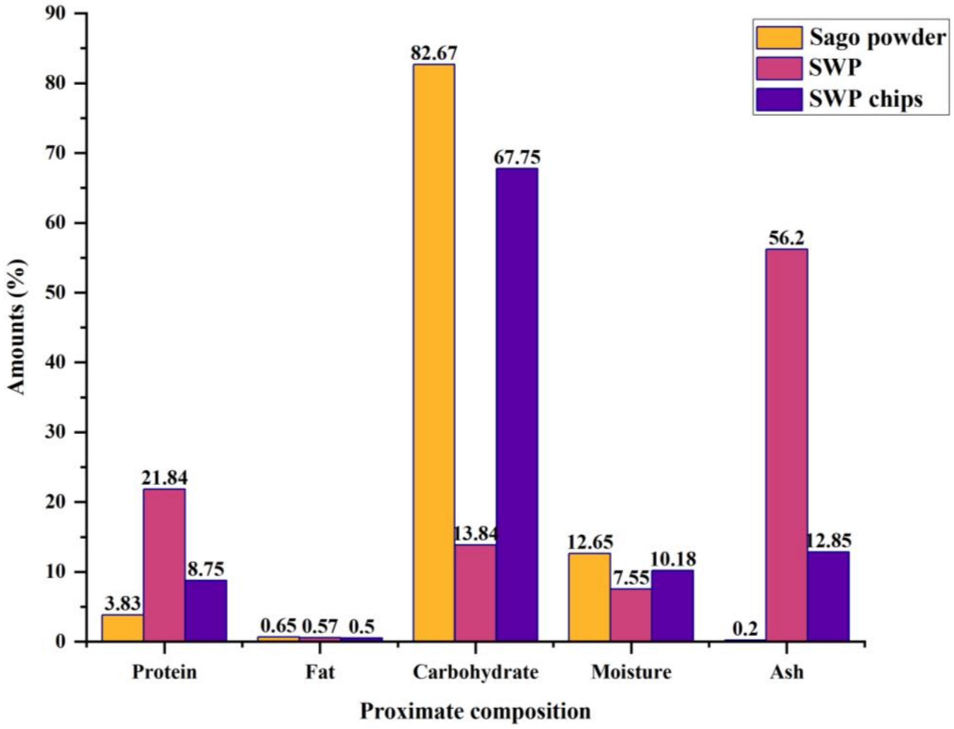

Figure 7. *Proximate composition of sago powder, SWP and SWP chips.*

Table 7. *Proximate composition of SWP soup powder and commercially available soup powder.*

Proximate composition	SWP soup powder (%)	Commercially available soup powder (%)
Protein	19.50	7.10
Fat	0.67	3
Carbohydrate	66.22	73.09
Moisture	8.84	4.82
Ash	4.77	11.99

Table 8. *Proximate composition of SWP samosa wrapper and SWP wonton wrapper, as well as commercially available flour.*

Proximate composition	SWP samosa wrapper and SWP wonton wrapper (%)	Commercially available flour (%)
Protein	14.84	10.87
Fat	0.90	1.38
Carbohydrate	57.49	75.43
Moisture	10.45	11.52

Proximate composition	SWP samosa wrapper and SWP wonton wrapper (%)	Commercially available flour (%)
Ash	16.32	0.80

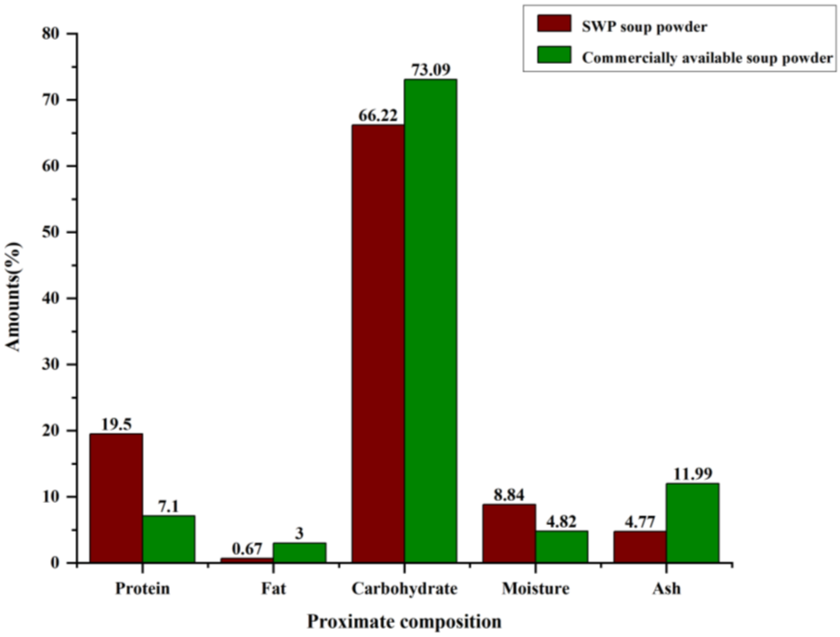

Figure 8. *Proximate composition of SWP soup powder and commercially available soup powder.*

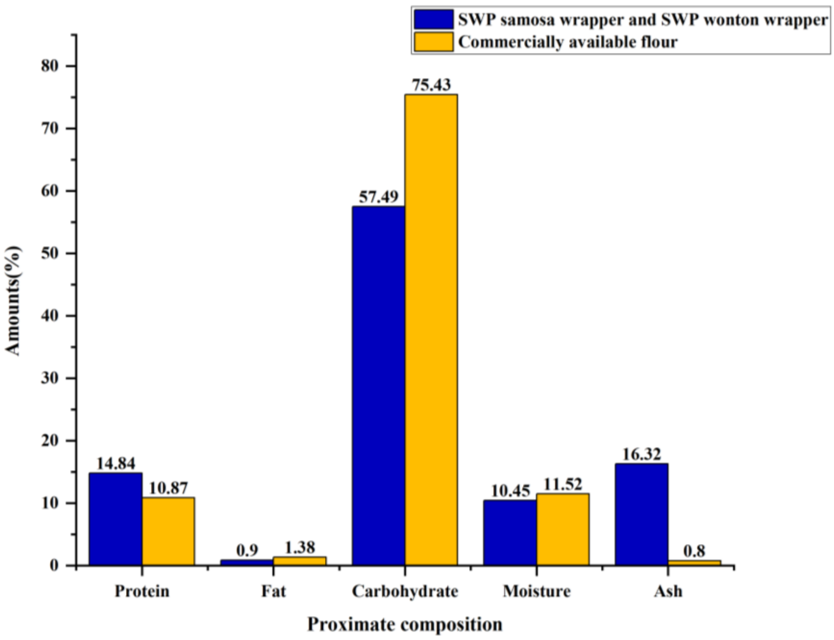

Figure 9. *Proximate composition of SWP samosa wrapper, SWP wonton wrapper, and commercially available flour.*

3.2. Sensory Assessment

In this study, 70 assessors assigned marks out of 10 to evaluate the product's quality. The results of the sensory assessments of SWP chips, SWP soup, SWP samosa, and SWP wonton are presented in Table 9 and illustrated with a bar chart in Figure 10.

Table 9. The sensory assessment results for SWP chips, SWP soup, SWP samosa, and SWP wonton (scored on a 10-point scale).

Quality of the products	Products					
	SWP chips		SWPsoup		SWP samosa and SWP wonton	
	Average score	Overall quality	Average score	Overall quality	Average score	Overall quality
Color	9	Excellent	10	Excellent	9	Excellent
Crispiness	9	Excellent	-	-	8.7	Very good
Aroma	8	Good	7.8	Good	7	Good
Taste	8.7	Very good	7.8	Good	8	Good
Appearance	8.5	Very good	8.2	Very good	8.2	Very good

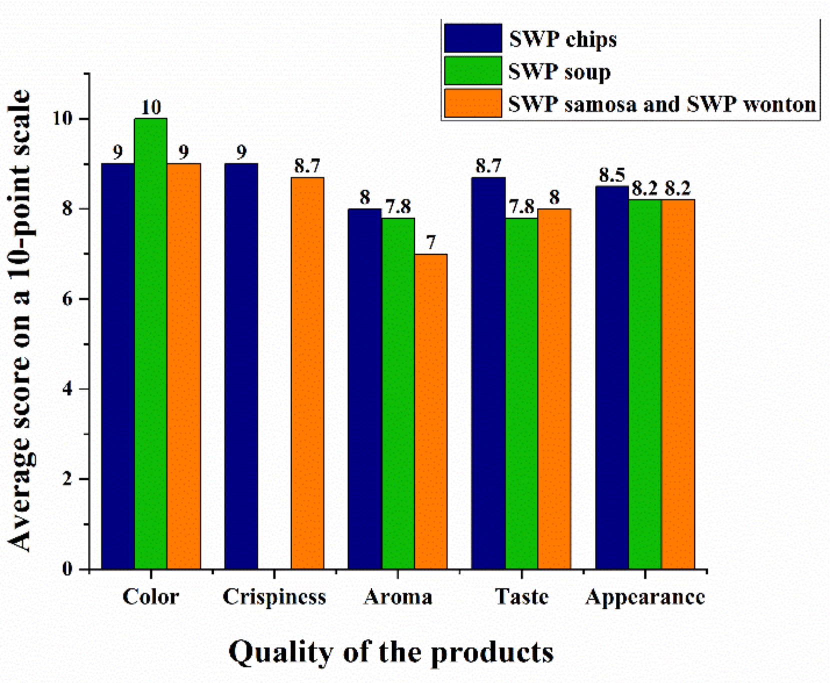

Figure 10. Sensory assessments of SWP chips, SWP soup, SWP samosa and SWP wonton.

3.3. Microbial Load Analysis and Determination of Shelflife

Microbial load analysis and shelflife determination results are presented in Tables 10-11.

Table 10. Microbial load in dried raw SWP chips and SWP soup powder and their shelflife.

Products	Results		Shelflife(months)
	Total Aerobic Bacterial Count, CFU/ml	Total Yeast and Molds Count, CFU/ml	
Dried raw SWP chips	4×10^3	Absent	±6
Raw SWP soup powder	6×10^3	Absent	±4

Table 11. Microbial load of SWP samosa wrapper and SWP wonton wrapper and their shelflife.

Products	Preservation temperature (℃)	Preservationperiod (days)	Results	Shelflife(days)
SWP samosa wrapper and SWP wonton wrapper	28-30	3	Growth of yeast and molds	±2
	- 40	46	Growth of yeast and molds	±45

3.4. Cost Assessment

The cost assessment results are presented below in Tables 12-14.

Table 12. Cost assessment of SWP chips.

Product	Net weight	Ingredients	Price (BDT)
SWP chips	Around 35 grams	Sago	3.75
		Salt	0.045
		Citric acid	1.125
		Spices	3.88
		Oil	11.2
		SWP	0
Total expenditure			20

Table 13. Cost assessment of SWP soup powder.

Product	Net weight	Ingredients	Price(BDT)
SWP soup powder	Around 25 grams	Flour	0.9
		Corn flour	1.5
		Dried granular carrot	0.52
		Salt	0.08
		Spices	4.5
		Sugar	0.50
		SWP	0
Total expenditure			8

Table 14. Cost assessment of SWP samosa wrapper and SWP wonton wrapper.

Product	Amount	Ingredients	Price(BDT)
SWP samosa wrapper and SWP wonton wrapper	4 pieces of each	Flour	1.75
		Salt	0.050
		SWP	0
Total expenditure			1.8

4. Discussion

In this study, various VAP such as chips, soup, samosa, and wonton have been produced using SWP. By incorporating SWP into the seafood products, their nutritional content has been enhanced, consequently increasing their market value.

4.1. Proximate Composition of Sago Powder, SWP, and SWP Chips

This study conducted a comparative analysis of the proximate composition of sago powder in relation to SWP chips and SWP, as sago powder serves as a fundamental component in the production of certain commercially available chip varieties. After making chips with sago powder and SWP, the quality has improved significantly compared to chips made with sago powder alone. The proximate composition of sago powder, SWP, and SWP chips exhibited distinct dissimilarity across the analyzed parameters (Table 6). Sago powder demonstrated a high carbohydrate content (82.67%), with comparatively low levels of protein (3.83%), fat (0.65%), moisture (12.65%), and ash (0.2%), indicating its primary function as a carbohydrate-rich energy source. On the other hand, SWP showed significantly elevated protein (21.84%) and ash content (56.2%), while exhibiting lower carbohydrate (13.84%) and moisture (7.55%) levels, suggesting potential applications as a protein-and mineral-enriched supplement. SWP chips showed intermediate characteristics, with moderate carbohydrate (67.75%) and protein (8.75%) contents, along with relatively lowfat (0.5%), moisture (10.18%), and ash (12.85%) levels. These analyses indicate that, in terms of nutritional composition, SWP and SWP chips exhibited significantly greater nutritional value when compared to sago powder. These compositional differences highlight the diverse nutritional and functional properties of the SWP chips, potentially informing their utilization in VAP production and industrial applications that cater to specific nutritional requirements. Protein may have a significant role in maintaining weight loss, reducing the rate of muscle loss that comes with ageing and maintaining body weight satiety [25]. Fats serve as a concentrated energy source and also necessary for the absorption of fat soluble vitamins. Dietary carbohydrates are main source of energy [4]. Carbohydrate play an important role and also take a role in the metabolism of triglycerides and cholesterol, assist regulate blood sugar and insulin, and aid in fermentation [11]. Ash indicates the concentration of minerals. The minerals like calcium and phosphorus are crucial for maintain strong bones and teeth. Typically, exoskeletons consist of approximately 20–40% proteins, 30–60% minerals (predominantly calcium carbonate), 20–30% polysaccharides, and 0–14% other compounds such as pigments (e.g., astaxanthin) and lipids (muscle residues and carotenoids) [20]. The presence of 10-40% protein, 15-46% chitin, 30-60% minerals, and 10-40% lipids was found in the biochemical content of shrimp waste [2].

4.2. Proximate Composition of SWP Soup Powder and Commercially Available Soup Powder

The proximate composition of SWP soup powder and commercially available soup powder exhibited distinct differences across all analyzed parameters (Table 7). SWP soup powder demonstrated a significantly higher protein content (19.5%) compared to the commercially available soup powder (7.1%), indicating its potential as a superior protein source. Fat content was lower in SWP soup powder (0.67%) than in the commercial counterpart (3%), suggesting a potentially healthier profile for consumers seeking low-fat options. Carbohydrate content was higher in the commercially available soup powder (73.09%) compared to SWP soup powder (66.22%), reflecting a greater energy contribution from carbohydrates in the commercial product. Moisture content was also higher in SWP soup powder (8.84%) than in the commercial variant (4.82%), which may influence shelflife and storage stability. Conversely, ash content was lower in SWP soup powder (4.77%) compared to the commercially available soup powder (11.99%), suggesting differences in mineral content or added fortification. Overall, SWP soup powder offers a nutritionally advantageous profile, characterized by higher protein and lower fat and ash contents, which may make it a favorable alternative for health-conscious consumers or those with specialized dietary needs.

4.3. Proximate Composition of SWP Samosa Wrapper, SWP Wonton Wrapper and Commercially Available Flour

A comparison of the proximate composition between the SWP samosa wrapper and the SWP wonton wrapper, and the commercially available flour reveals notable nutritional differences (Table 8). The SWP samosa wrapper and SWP wonton wrapper exhibited a higher protein content (14.84%) compared to the commercially available flour (10.87%), suggesting enhanced nutritional value in terms of protein enrichment, which may contribute to better structural and functional properties in the final product. The fat content was slightly lower in SWP samosa wrapper and SWP wonton wrapper (0.9%) compared to commercially available flour (1.38%), which may result in a marginally lower caloric contribution from fats in the wrapper. The carbohydrate content was substantially lower in the SWP samosa wrapper and SWP wonton wrapper (57.49%) compared to the commercially available flour (75.43%), indicating a possible replacement of carbohydrates with protein and mineral components during the formulation process. The moisture content was relatively similar between the two samples, with commercially available flour showing slightly higher moisture (11.52%) compared to the SWP samosa wrapper and SWP wonton wrapper (10.45%). Interestingly, the ash content was significantly higher in the SWP samosa wrapper and SWP wonton wrapper (16.32%) compared to the commercially available flour (0.8%), suggesting a greater mineral content, which may arise from the inclusion of additional ingredients or fortification processes during preparation. Overall, the SWP samosa wrapper and SWP wonton wrapper exhibit a nutritionally enhanced profile, characterized by higher protein and mineral content, as well as lower carbohydrate levels, compared to conventional flour. These characteristics may contribute to improved nutritional quality and functional properties in the final wrapped food products.

4.4. Sensory Assessment of SWP Chips, SWP Soup, SWP Samosa, and SWP Wonton

The sensory evaluation of the three products, SWP chips, SWP soup, and SWP samosa and SWP wonton, was assessed based on five quality attributes: color, crispiness, aroma, taste, and appearance. The products were scored on an average scale, providing insights into consumer acceptance and overall product quality (Table 9). For color, SWP soup received the highest score (10), indicating excellent visual appeal. In contrast, both SWP chips and samosa and wonton received slightly lower but still high scores of 9, suggesting all products had acceptable and appealing coloration. Interms of crispiness, only SWP chips were evaluated (9), as crispiness is not a relevant attribute for SWP soup, SWP samosa, or SWP wonton. The high score reflects desirable textural properties for the chip product. For aroma, SWP chips (9) and SWP soup (8.7) received favorable ratings. At the same time, SWP samosa and SWP wonton scored slightly lower (7), suggesting that aroma maybe less pronounced or appealing in the wrapper compared to the other products. Taste scores showed that SWP chips led with 8.7 followed by SWP soup (7.8) and SWP samosa and SWP wonton (both at 8). This indicates that while all products were generally acceptable in taste, SWP chips had a slight advantage in flavor preference. Finally, for appearance, all products received relatively close scores: SWP chips (8.5), SWP soup (8.2), and SWP samosa and SWP wonton (8.2). This suggests that, despite minor variations, all products were visually satisfactory to the panelists. Overall, SWP chips consistently scored high across most attributes, particularly in crispiness, aroma, and taste, indicating superior sensory quality. SWP soup excelled in color and performed well in other categories. At the same time, SWP samosa and SWP wonton showed satisfactory results, albeit with slightly lower scores in aroma and taste compared to the other products. These findings highlight the consumer acceptability of SW-based products and their potential for further product development.

4.5. Microbial Load Analysis

The microbial growth in dried SWP chips is 4×10^3 after 5 months (Table 10), when stored at room temperature, and shows no growth of yeast and molds. The SWP chips have proven to remain fresh and easily consumable even after being stored at room temperature for more than 5 months. This suggests that the shelflife of the SWP chips is up to ±6months.

The microbial analysis of SWP soup powder indicates that microbial growth is 6×10^3 after 3 months of storage at room temperature, which denotes poor bacterial growth. After 3 or 4 months of storage at room temperature (28-30 ℃), this SWP soup powder has remained fresh. As a result, the shelflife of SWP soup powder is up to ±4months.

To determine the microbial load of SWP samosa and SWP wonton wrapper, microbiological analysis was conducted in this study (Table 11). Through this analysis, the wrapper remains fresh for up to 30 days when stored in a refrigerator at-40 ℃. On the other hand, when this wrapper was kept at room temperature, many types of yeast and molds were seen after 2days, which are inedible for human. Overall, the analysis suggests that the wrapper has a shelflife of up to1 month and remains edible even after being stored for 30 days at a temperature of -40 ℃.

Some of the problems created by seafood waste include water pollution, fouled beaches, insect/rodent infestations, and obnoxious odors [15]. One of the key concerns associated with shrimp waste water is its high organic content, which can lead to oxygen depletion in water bodies if released untreated. This oxygen depletion can harm aquatic life and disrupt ecosystems [32]. Sea food waste generates visual environmental pollution, which is often accompanied by air pollution. The incorporation of SWP in chips, SWP soup powder, SWP samosa wrapper, and SWP wonton wrapper has led to an overall enhancement of a microbial load-free profile. This makes them a convenient and long-lasting snack option and safe for human consumption. It can also protect the environment from pollution.

4.6. Cost Assessment of SWP Chips, SWP Soup, SWP Samosa Wrapper, and SWP Wonton Wrapper

In evaluating the production costs of SWP chips (Table 12), it was determined that approximately 20 BDT was utilized to manufacture 35 grams of the SWP chips. In contrast, commercially available chips, weighing 15grams, are priced at 15 or 20 BDT, indicating a higher market price than that of the SWP chips. This cost analysis highlights that the expense of producing SWP chips is lower compared to market alternatives. The production cost for 25 grams of the SWP soup powder is approximately 8 BDT (Table 13). In contrast, similar quantities of soup powder are currently retailed in the market at prices ranging from 40 to 50 BDT, indicating a substantial markup compared to the cost identified in this study. The production cost for four pieces of SWP samosa wrapper and SWP wonton wrapper is 1.8 BDT (Table 14), translating to a unit cost of 0.45 BDT per piece. This cost efficiency is notably lower than that of traditional commercially available alternatives.

Consequently, this study presents an opportunity for individuals from different economic backgrounds to produce affordable crunchy SWP chips, SWP soup powder, SWP samosa wrapper, and SWP wonton wrapper. Lower production costs make these products more affordable, allowing consumers to prepare them and potentially generate income streams through marketing efforts.

4.7. Key Findings

By converting SW into edible, marketable products, the present study addresses several key findings:

1) *Innovation:* Promotes culinary innovation and development of new food products.
2) *Nutritional value:* Can develop the nutritional profile of the VAP.
3) *Economic benefits:* Can create additional revenue streams for seafood processors.
4) *Waste reduction:* Significantly helps to reduce environmental pollution.
5) *Marketing:* Be capable of expanding market opportunities.

5. Conclusion

The present study focused on the development and evaluation of VAP, including chips, soup, samosa wrapper, and wonton wrapper derived from SWP, a by-product of seafood processing. The proximate composition analyses revealed that SW-derived products typically exhibit higher protein content and more favorable macronutrient profiles compared to commercially available counterparts. Specifically, SW-based products, such as SWP chips and SWP soup powder, exhibited significantly higher protein and mineral contents, along with reduced fat levels, suggesting improved nutritional benefits. Sensory evaluation further confirmed the consumer acceptability of these products. SWP chips consistently scored the highest across multiple sensory parameters, including color, crispiness, aroma, and taste, indicating superior organoleptic properties. The SWP soup exhibited excellent color, an acceptable aroma, and a pleasant taste. At the same time, SWP samosa and SWP wonton were rated favorably in most categories, though they exhibited slightly lower scores in aroma and taste compared to SWP chips. The elevated nutritional value, combined with good sensory characteristics and acceptable shelf life, demonstrates the potential of SW as a sustainable raw material for food product development. Furthermore, the low production costs associated with utilizing seafood processing by-products contribute to economic viability. This approach not only supports the efficient utilization of industrial waste streams but also aligns with the principles of the circular economy, offering both environmental and financial benefits. Overall, the transformation of SW into high-value food products represents a sustainable solution to waste management, while expanding the range of nutritious and marketable food products available to consumers.

Abbreviations

AOAC	Association of Official Analytical Chemists
BDT	Bangladeshi Taka
CFU	Colony-Forming Unit
SW	Shrimp Waste
SWP	Shrimp Waste Powder
VAP	Value -added Products

Author Contributions

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Data AvailabilityStatement

Data will be made available on request.

Conflicts of Interest

The authors affirm that this research was conducted independently, without any commercial or financial ties that could be perceived as a potential conflicts of interest.

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