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RESEARCH ARTICLE

Utilization of Shrimp Head Wastes into Powder Form as Raw Material for Value-Added Products

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ABSTRACT

Shrimp processing industries produce large amounts of wastes in the form of shrimp heads, shells, and tails, which are more or less 50% of the raw materials. Improper disposal of these nutrient-rich wastes can cause environmental problems if not duly managed. This study aims to utilize *Penaeus monodon* shrimp head wastes into powder form using a cabinet type drier and establish the processing yield and important product qualities. Two treatments of shrimp head powders were studied: shrimp head powder with carapace (SHPwc) and shrimp head powder without carapace (SHPwoc). The yields obtained were 26.72% for SHPwc while 20.42% for SHPwoc; both are considered to have significant value since both are produced from wastes. Both products have satisfactory water activity levels; however, the bulk density was high, and the solubility was lower than other published powdered seafood by-products. Both products have light orange or brown color: however, in both odor and flavor, SHPwoc had a higher mean general acceptability, with "like slightly-like moderately" results. SHPwoc was subjected to a shelf-life study with added salt and ascorbic acid preservatives. Monthly analyses revealed that the microbiological parameters are still within limits, and both moisture and pH values were acceptable after eight months of storage at ambient temperature (28-30°C). However, the peroxide value is acceptable until only the sixth month, which signifies the end of shelf-life based on theoretical sensory changes. The results of this study show the promising significance of utilizing shrimp processing wastes into seafood-based products.

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1. INTRODUCTION

Large quantities of shrimp wastes are generated every year by shrimp processing industries in the form of head and carapace (Sachindra et al. 2007; Prameela et al. 2010). These wastes comprise 48.5-56% by weight of shrimp raw material depending on the species (Islam et al. 2004; Sachindra et al. 2005). The underutilization of shrimp head wastes poses a problem for the processing plants, and improper disposal of these wastes without any attempt to use it, can contribute to environmental issues on a larger scale. In addition, Islam et al. (2004) mentioned that seafood wastes contain a large amount of organic matter, flesh particles, breading, soluble proteins, and carbohydrates; and that droppings from unloading shells and appendages may also settle into the water, increasing the waste load. These may excessively provide nutrients to the adjacent bodies of water which may potentially increase the biochemical oxygen demand and reduce the oxygen concentration in water. To date, however, there are no impact assessments or management of shrimp processing wastes recorded in the Philippines.

The Philippines produces about 24,000 tons of tiger shrimp (*Penaeus monodon*) and 30,000 tons of white shrimps (*Litopenaeus vannamei*) annually. Sixty percent (60%) are distributed in the domestic market, while the remaining forty percent (40%) are exported (DOST-PCAARRD 2015). Exported shrimps are processed according to the buyer's requirements and specifications. These are processed either as whole wherein shrimp is left with head and shell intact, headless when the head is removed with shell intact, and peeled wherein head and shell are removed, or in some cases veins are also removed (Tan 1984).

Although no reports were recorded on handling the head and carapace of the shrimps, these body parts are commonly discarded as wastes. According to processors, most shrimp processing plants can generate approximately one ton of shrimp head wastes per day.

These wastes are good sources of marine protein and oils. Major components of shrimp head are protein (54.4%), minerals (21.1%), lipid (11.9%), chitin (9.3%), and small amounts of valuable carotenoids (Trung and Phuong 2012). Heu et al. (2003) also studied the amount of components and nutritional content of shrimp by-products, including the specific fatty acids, amino acids, minerals, and phosphorus. These valuable compounds can add substantially to overall profitability after appropriate processing (Prameela et al. 2012).

Shrimp wastes reportedly contain nutritive protein extracts that are feasible for use in aquafeeds, livestock, and poultry diets (Mizani et al. 2005). Furthermore, innovations by Wyss Institute (2020) gave rise to the development of shrilk, a biodegradable plastic produced by combining chitosan from shrimp shells and a silk protein called fibroin.

Still, there are only a few published studies on the processing of shrimp wastes, such as into powder form, which can be used as the main ingredient in making shrimp flavoring agent; processing smoked or dried shrimp powder for bouillon cubes; and as an ingredient in making shrimp crackers (Teerasuntonwat and Raksakulthai 1995; Essuman 2005; Khan and Nowsad 2012). However, in Indonesia, shrimp heads and shells are processed into *petis-udang*, a shrimp paste used as a seasoning in various dishes (Hajeb and Jinap 2012).

This study aims to utilize shrimp head wastes into powder form using a cabinet type drier and establish the processing yield, product quality, and shelf stability. Utilizing shrimp head wastes into ready-to-use convenience products, in this case, a powder with high nutritional value is expected to generate high consumer demand. Thus, it will increase the economic potential of the shrimp in food industries (Jeyasanta et al. 2013) for uses such as shrimp flavor powder, shrimp-based soup, and other food formulations.

2. MATERIALS AND METHODS

2.1 Collection of raw materials

A total of 70 kg of fresh chilled, free from blackening tiger shrimp (*Penaeus monodon*) head (SH) wastes were obtained from the HJR Shrimp International Corporation processing plant in Meycauayan, Bulacan, Central Luzon. The shrimp heads were packed in high-density polyethylene (HDPE) container and transported to the National Fisheries Research and Development Institute (NFRDI) processing laboratory in Quezon City. The temperature of the shrimp heads was maintained at close to 0°C during transport. These were washed, drained, packed, and frozen (-18°C) before processing

2.2 Processing of shrimp head wastes into powder

The sample preparation was done at the NFRDI Processing Room, wherein the frozen SH were partially thawed before processing. Two treatments were prepared: SH with carapace (SHwc) and SH without carapace (SHwoc). Both treatments were grounded using the food grinder or silent cutter Foodmach® for 10 min at a temperature of <10°C. Next, these were cooked separately for an hour at 90°C + 2°C in stainless steel casserole and constantly stirred to produce shrimp paste. After cooking, the pastes were cooled to room temperature and packed in 10” x 15” polyethylene (PE) bags with 2 kg each. These were kept frozen (-18°C) prior to the succeeding steps.

The frozen shrimp pastes were brought to the Department of Science and Technology – Industrial Technology Development Institute (DOST-ITDI), Bicutan, Taguig City. The shrimp head pastes were thawed, then distributed evenly in drying trays. These were dried using a preheated (50°C) cabinet dryer with LPG gas as the fuel source for 12 h at 70°C. The pastes were checked and stirred every hour for uniform heat distribution. The cabinet dried samples were pulverized using a food processor, blender, then sieved using a wire mesh. The SH powder was packed in leak-proof jars and labeled. These were returned to the NFRDI for product analyses and stored at chilling temperature (4°C) until used. Analyses were done in triplicates, except for the processing yield, which was determined only once.

2.3 Determination of processing yield

The percentage yield in all processing stages was computed in relation to the total amount of SH used in processing. The formula used for the determination of processing yield is:

Equation 1: $$\%\ \text{Yield} = \frac{\text{final weight}}{\text{initial weight}} \times 100\%$$

2.4 Determination of product quality

2.4.1 Proximate composition

The proximate analysis of SH powder was conducted at the NFRDI laboratory based on AOAC (2005) procedures. On the other hand, the fresh shrimp head (FSH) samples were analyzed at the *Sentro sa Pagsusuri, Pagsasanay at Pangangasiwang Pang-Agham at Teknolohiya Corporation* (SentroTek) Laboratory based on the procedures of AOAC (2012). The analytes determined were Moisture, Crude Protein, Crude Fat, and Ash.

2.4.2 Water activity, solubility, bulk density, and color

The water activity, solubility, bulk density, and color were analyzed in the NFRDI laboratory. Determination of water activity was done using the water activity meter Novasina®.

For the solubility, 0.5 g SH powder (W1) was placed in a 100 ml glass beaker, added with 5 ml distilled water at 25°C. The SH powder was gently mixed using a spatula for 1 min or until no more fine particles were seen. The solution was then filtered through a Whatman filter paper No. 4 with pre-determined weight (W2). The filter paper was dried at 100°C for four hours in a hot air oven, cooled in a desiccator, and weighed again (W3). Solubility was calculated by the procedure of Al-Kahtani and Hassan (1990) as:

Equation 2: $$\%\ \text{Solubility} = \frac{100-\{[W3 - W2] \times 100\}}{W1}$$

The bulk density was determined by using a 5.0+0.1 g sample, gently filled into a dry 10 ml cylinder, and the cylinder was rapped gently three times. The volume of the powder was recorded according to the method of Chitomarat (2002). The bulk density was calculated as the following relationship:

Equation 3: $$\text{Bulk density} = \frac{\text{Weight of SH powder}}{\text{Volume of SH powder}}$$

The color was determined using the chroma meter CR-400 Konica-Minolta with color data software, spectra Magic NX Lite, CM-S100W. The values were reported as the average of individual values as L (Lightness), a (+a is red, -a is green), and b (+b is yellow, -b is blue).

2.4.3 Peroxide value

The peroxide values were analyzed using Iodometric Titration of AOAC Official Method 965.33.

2.4.4 Sensory evaluation

The sensory evaluation was conducted by dissolving the powder in 10% boiled water (w/v) and was served hot in a bowl to each of the seven trained panelists (Jeyasanta et al. 2013). The panelists were asked to evaluate the products' odor and flavor using a 5-point scale rating from 1 (least accepted) to 5 (most accepted), based on the sensory forms of Gatchalian and Brannan (2011). In addition, the prepared samples were also evaluated for the general acceptability using the 9-point Hedonic scaling test (9 – like extremely to 1 – dislike extremely).

2.4.5 Shelf-life evaluation

The shrimp head powder (SHP) determined to have better quality was subjected to shelf-life evaluation. The same processing protocol was followed, but with the addition of 1.5% salt per kg uncooked SH, during grinding. After cooking, 1 g of ascorbic acid was added for every 1 kg SHP. The SH powder packed in laminated PET/Foil/PE 119u (100 mm x 140 mm x 60 mm; SUP with zip pouches) and stored at ambient temperatures (28-30°C) was analyzed for spoilage indicators (microbiological load, moisture content, pH, and peroxide value) from the initial (0 month) to the seventh month, with the monthly withdrawal of samples. All shelf-life parameters were analyzed in the NFRDI Laboratory.

2.4.6 Microbiological Load

The SH powder was evaluated for Aerobic Plate Count (APC), presence of *Escherichia coli* and *Salmonella* sp., and yeasts and molds count using the procedures of the Bacteriological Analytical Manual (1998). Results were compared against the Department of Health – Food and Drug Administration (DOH-FDA) Circular No. 2013-010.

2.4.7 Moisture content, pH, and rancidity

The moisture content and pH of the SH powder were determined using gravimetric and potentiometric methods of AOAC International

(2005), respectively. Rancidity was determined by the analysis of peroxide value using Iodometric Titration of AOAC International (2005).

3. RESULTS

3.1 Processing yield

Table 1 presents the percentage yield in the different stages during processing. The yield obtained from FSH was 26.72% SHPwc and 20.42% SHPwoc. The biggest loss in the processing of SHPwc was recorded at the drying step with a loss of 38.51%, while the cleaning or washing step contributed to 39.98% loss, and another 31.02% loss was incurred during drying of SHPwoc.

Table 1. Percent yield of shrimp head during processing

Stage	Percentage Yield (%w/w)	
	SHPwc	SHPwoc
Raw	--	--
Cleaned/washed	81.82	60.02
Cooked	72.73	53.48
Dried	34.22	22.46
Powdered	26.72	20.42

only one (1) trial conducted

3.2 Product quality

3.2.1 Proximate Composition

The proximate composition of the SH powder is presented in Figure 1. A huge loss in moisture was observed from FSH to SHP products (~65-67% difference), whereas the rest of the components increased for both SHP products. The crude protein of shrimp head powders was 53.13+0.34% and 50.04+0.34% for SHPwc, and SHPwoc, respectively. Both crude fat and ash content were higher in SHPwoc, with values of 17.38+0.53% and 18.52+0.06%, respectively.

3.2.2 Water Activity, Solubility, Bulk density, and Color

The water activity values of both SHPwc and SHPwoc were 0.12 + 001 and 0.09 + 005, respectively (Table 2). Percentage solubility was found to be higher in SHPwoc (29.33 + 1.15) compared to SHPwc (20.67 + 4.16). Bulk density of SHPwc, however, was higher at 0.58 + 0.01g/ml. The CIE color values obtained for both SHP are presented in Figure 2. Both lightness and redness values were higher for SHPwc (L^* = 52.68 + 1.21; b^* = 14.65 + 0.88), while yellowness was higher in SHPwoc (a^* = 2.57 + 0.13).

3.2.3 Peroxide value

The peroxide value (PV) for shrimp head powder for both SHPwc and SHPwoc are 2.95 + 0.04 meq/kg and 2.89 + 0.84 meq/kg, respectively (Table 2).

3.2.4 Sensory evaluation

The shrimp odor and flavor of SH powder were readily perceivable from the prepared 10% solution (Table 3), with both products perceived as

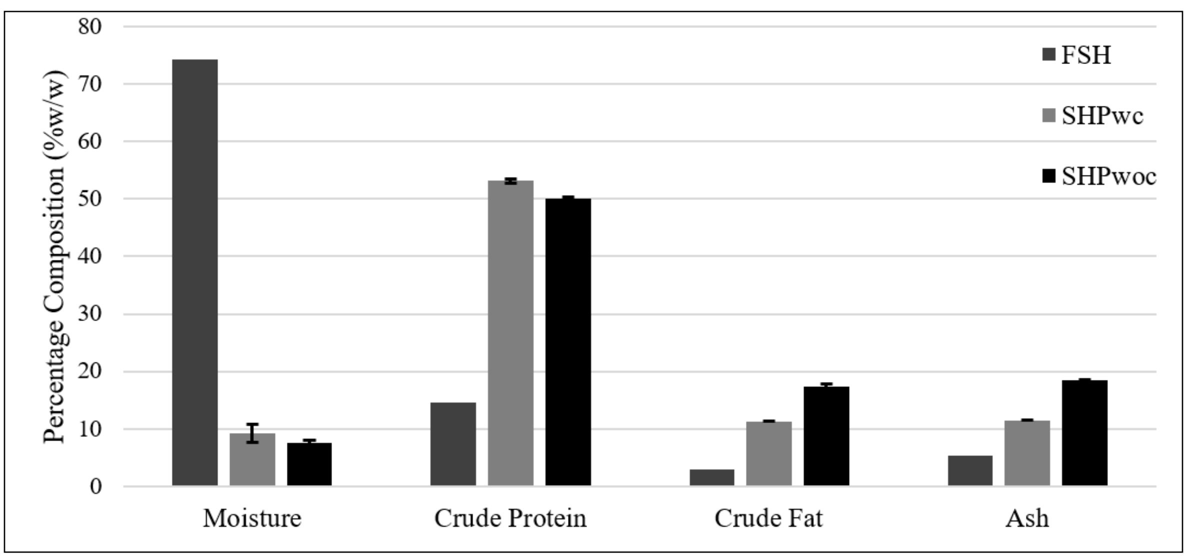

Figure 1. Proximate composition of fresh shrimp head and shrimp head powder

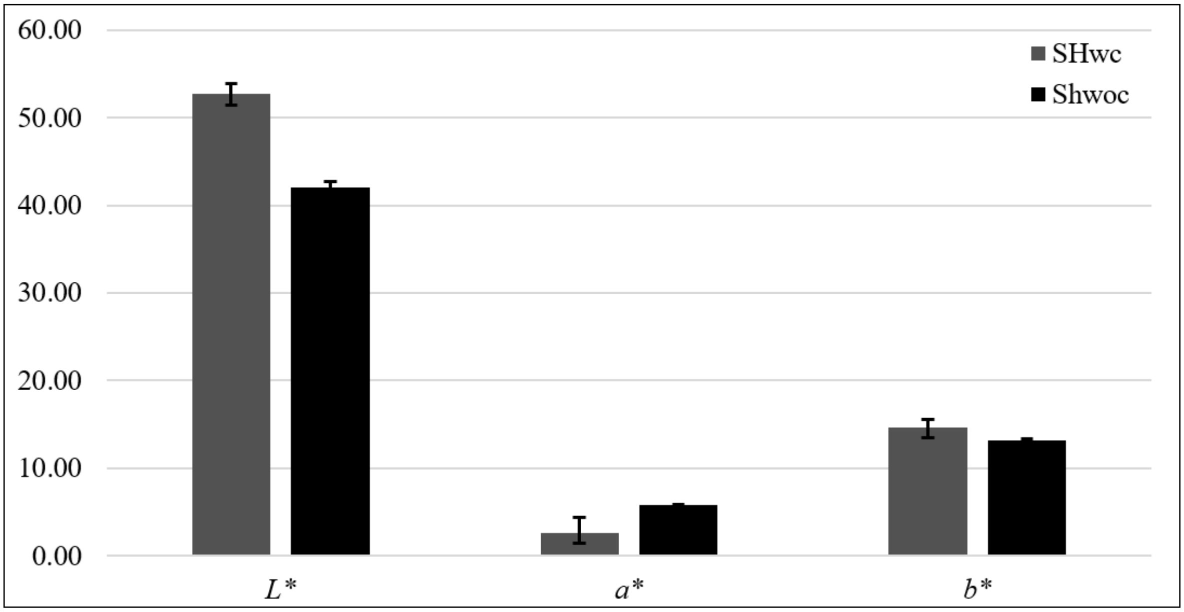

Figure 2. Shrimp Head Powder color values: L* (Lightness), a* (yellowness) and b* (redness)

Table 2. Physico-chemical and physical properties

Property/Parameter	Treatment	
	SHPwc	SHPwoc
Water Activity	0.12 + 0.001	0.09 + 0.005
Solubility (%)	20.67 + 4.16	29.33 + 1.15
Bulk Density (g/ml)	0.58 +0.01	0.55 + 0.12
Peroxide value (meq/kg)	2.95 + 0.04	2.89 + 0.84
Powdered	26.72	20.42

Table 3. Results of sensory evaluation for shrimp head powder

Characteristic	Treatment	
	SHPwc	SHPwoc
Odor *	3.13 + 0.45	3.37 + 0.06
Flavor *	2.53 + 0.86	2.97 + 0.95
General acceptability **	5.90 + 0.56	6.73 + 0.74

** 5-point Hedonic Scale:1 = No shrimp odor/flavor; 5 = Strong shrimp odor/flavor*
*** 9-point Hedonic Scale: 1 = Dislike extremely; 9 = Like extremely*

"just right shrimp odor" and "slight-just right shrimp flavor." Sensory evaluation of samples revealed that both SHP are generally acceptable, with SHPwc having an average rating of 5.90 + 0.56, equivalent to "like slightly" and SHPwoc with 6.73 + 0.74 "like slightly-like moderately."

3.2.5 Shelf-life evaluation

Monthly monitoring of the microbiological load of shrimp head powder without carapace (SHPwoc) showed that the product was deemed safe until the 7th month. The highest recorded APC and YMC were on the 6th month (325 CFU/g) and 4th month (20 CFU/g), respectively. *S. aureus*, *E. coli*, and *Salmonella* levels remained at <10CFU/g, <3MPN/g and Absent, respectively, from the beginning until the end of the shelf-life study. On the other hand, moisture content reached up to 11.38 + 0.22 on the 5th month, the lowest recorded on the onset of study with 5.42 + 0.54. The pH values ranged 7.7-8.3, with the lowest noted on the onset and the highest on the 2nd month. Peroxide value was recorded highest on the 7th month, with a value of 25.42 meq/kg.

4. DISCUSSION

4.1 Processing Yield

The removal of the carapace and other SH appendages from the cleaning or washing step caused a significant decrease in the weight of SHPwoc after the operation. Furthermore, 2 hrs of cooking in both treatments caused a loss of more than 30% due to the evaporation of moisture. Nevertheless, SHPwc has a yield of approximately 6% higher than SHPwoc. The yields obtained are about 5-11% higher than

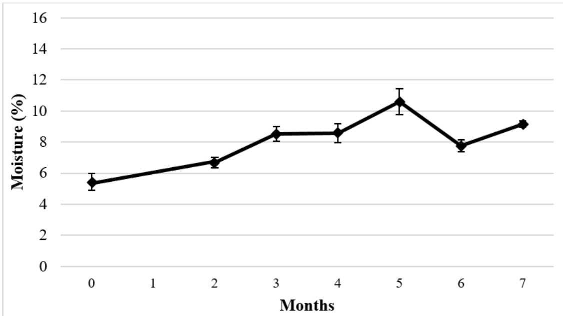

Figure 3. Monthly monitoring of moisture content (%) of SHPwoc

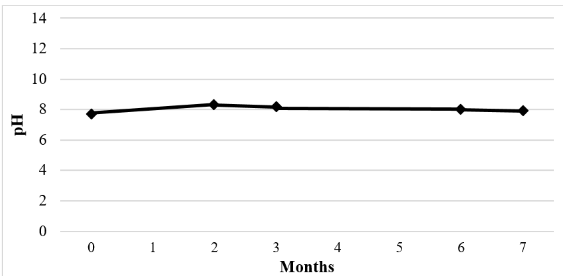

Figure 4. Monthly monitoring of pH of SHPwoc

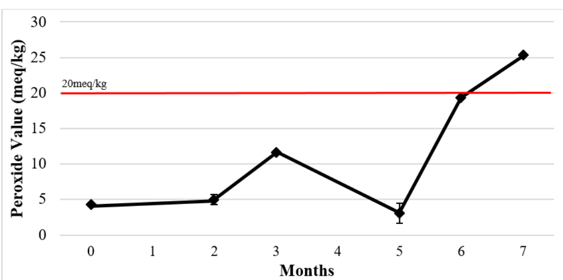

Figure 5. Monthly monitoring of peroxide value of SHPwoc

Fernandes et al.'s (2013) yield from using shrimp cephalothorax into flour and approximately 13-19% lower than the shrimp flavor powder yield by Suparmi et al. (2020) from shrimp wastes. Considering that the raw materials used were processing wastes, the percent yield obtained is still of significant economic and industrial value.

4.2 Product Quality

4.2.1 Proximate Composition

The values obtained for the proximate composition of fresh shrimp heads (FSH) agree with the findings of Fernandes et al. (2013) using *Penaeus monodon* and Teerasuntonwat et al. (1995) using *Litopennaeus vannamei*. With the reduction of water through drying, the other components in both SHP products were concentrated, explaining the increase in percentages of protein, fat, and ash components. The protein content of both SHPwc and SHPwoc is almost comparable to that of Fernandes et al.'s (2013) product; however, the fat content of both SHP products was higher than the sample mentioned above.

On the other hand, the ash content of SHPwoc is almost comparable with Fernandes et al.'s (2013) product. High ash content in shrimp head powder is accounted for by the high mineral content of shrimp by-products, mostly composed of calcium carbonate (Mahmoud et al. 2007; Heu et al. 2003).

4.2.2 Water activity, solubility, bulk density, and color

The microbiological quality of dried products is significantly affected by lowering water activity to less than 0.60, where no microbial proliferation is expected (Dilbaghi and Sharma 2007; ICMSF 2005; Montville et al. 2005). In this regard, the water activity values obtained imply that both shrimp head powders are microbiologically safe.

In terms of solubility in water, the developed shrimp head powders have a low solubility value compared with the tuna flavor powder by Kanpairo et al. (2012). This may be due to the presence of high amounts of insoluble ash or minerals in dried shrimp shells and wastes (Singh et al. 2018). Solubility is one of the most important physicochemical and functional properties of a powdered product as it determines whether a slurry or a solution will be produced (Jumah and Mujumdar 2006).

Another essential property of a product is bulk density, which indicates flow and compressibility. Thus, it determines the appropriate container size and concentration of food upon reconstitution of powder if prepared from a given volume (Micha 1983; Jumah and Mujumdar 2006). The bulk density values obtained for both SHP are relatively higher than that of Kanpairo et al.'s (2012) tuna flavor powder. The high bulk density of the SHP developed means that the particles tend to stick together or are compressed.

Color-wise, the product obtained CIE Lab values that fall in the red-yellow spectrum (Figure 2). No other quantified color values were found in the literature for similar products; however, the Lab values agree with the report of Essuman (2005) with quality standards of shrimp powder having a light orange or brown color.

4.2.3 Peroxide Value

The SH powder with high-fat content is susceptible to lipid oxidation, where peroxide value (PV) is a suitable parameter for measuring early oxidation or rancidity and quality deterioration over time (Wasowicz et al. 2004; Matthaus 2010). Rancidity is exhibited by off-flavors generally detectable at PVs exceeding 20 meq/kg (O'Keefe and Pike 2010), of which the values obtained for both SHP are far below.

4.2.4 Sensory Evaluation

SH powder's shrimp odor and flavor were readily perceivable from the prepared 10% solution, probably due to its high solubility. According to Suparmi et al. (2020), the highest non-essential amino acid found in their shrimp flavor powder is glutamic acid, which stimulates the mouth receptors for umami taste. These results show that both products are generally acceptable, but SHPwoc was noted to have higher acceptability.

4.3 Product Shelf Stability

Generally, all samples were deemed safe and of good quality; however, SHPwoc was chosen over SHPwc based on some parameters. On preparation, SHPwoc production was noted to consume less effort and time during grinding and sieving. Salt and ascorbic acid were both added to enhance the shelf-keeping stability of the products. Ascorbic acid is an antioxidant that acts as a stabilizer for fats and oils, which also removes oxygen, in turn inhibiting oxidative rancidity in foods (Gordon 2003), while salt partially dehydrates microbial cells by virtue of osmosis (Sancho-Madriz 2003).

4.3.1 Microbiological load

The product's microflora (Table 4) after seven months of storage shows that the product is still safe, based on the Philippine Food and Drug Administration (FDA)'s microbiological criteria for Frozen Cooked Crustaceans (FDA 2013). These criteria do establish limits for yeasts and molds; however, David (2014) of the same agency stated a limit of 50 cfu/g for yeasts and molds in non-sterile products, which the SH powder still falls safe under. In addition, monthly testing of the SH powder showed that the product is microbiologically safe after seven months of storage at ambient temperature (28-30°C), based on the criteria mentioned above.

4.3.2 Moisture content, pH, and rancidity

The product moisture has an increasing trend over time; however, it is still within the 25% moisture content for dried foods. This shows the effectiveness of the packaging material used in controlling moisture migration into the product. With the increasing trend, the water activity is also expected to increase over time. With the pH values relatively close to the optimum range for most bacteria of pH 6.5-7.5 (Dilbaghi and Sharma 2007), this observation may soon encourage more microbial proliferation.

The rancidity with peroxide value was observed to have an increasing trend over time. The longest storage with PV without theoretically affecting the sensory properties is after six months (19.32 meq/kg), eventually exceeding the limit after seven months (25.24 meq/kg). However, sensory evaluation was not performed to detect rancidity and correlate with the peroxide value. Therefore, the last month recommended for storage without theoretically having off-flavors is six months of storage. With this, the optimization of using preservatives, especially those of antioxidants to prevent the oxidation of fats, may be improved.

Les Pêcheries MarinardLtée Canada (2014) states a

Table 4. Monthly monitoring of microbiological load of SHPwoc

Reference Microorganism	Standard Guideline (DOH-FDA Circular No. 2013-010)*	Period of Storage (months)							
		0	1	2	3	4	5	6	7
APC (CFU/g)	$5x10^5$	<25	-	<25	100	220	-	325	200
Yeast and Molds (CFU/g)	-	<10	-	13	10	20	-	<10	<10
S. aureus (CFU/g)	10^2	<10	-	<10	<10	<10	-	<10	<10
E. coli (MPN/g)	11	<3	-	<3	<3	<3	-	<3	<3
Salmonella (per 25g)	Absent	A	-	A	A	A	-	A	A

(-) no data; (A) absent
**for Frozen Cooked Crustaceans; acceptable level of microorganism achievable under GMP*

15-month shelf-life for shrimp shell powder, whereas Zarehgashti et al. (2019) reported a 4-month shelf-life for soup powder using 4% dried shrimp, based on sensory analyses. With the trend mentioned above of peroxide value on the developed SH powder, the acceptable limit (20 meq/kg) for peroxide value is only up to the six months of storage.

5. CONCLUSION

With the world's increasing shrimp production and consumption, the number of wastes produced from processing companies is also expected to increase. Though without local records of waste management, improper disposal of nutrient-rich shrimp by-processing by-products may negatively impact the environment by enriching the nearby waters, eventually leading to oxygen depletion and overloading of nutrients. From this study, the powders developed from *Penaeus monodon* head wastes, both with and without carapace, are of high nutritional value, have acceptable physico-chemical, microbiological, and sensory qualities, thus showing promising qualities for further development. Further exploring the shelf-life of shrimp head powder without carapace can reach up to six months of storage. This data may help further utilize shrimp head powder into a more elaborate shrimp-based food product and suggest an alternative way of minimizing seafood wastes through processing.

With the potential of using shrimp head wastes into powder form, it is recommended that the use of shrimp head powder in the development of seafood products be explored, such as in seafood broths or soups, shrimp flavor seasoning, and the likes. In addition, the effectivity of the preservatives added should also be further studied to optimize the application and improve the product's shelf-life. Furthermore, it is recommended that shelf-life stability on shrimp head powder with carapace be conducted for a complete picture of the study.

AUTHOR CONTRIBUTIONS

Bassig RA: Writing-Review, Validation, Formal Analysis. **Obinque AV:** Conceptualization, Methodology, Validation, Formal Analysis, Data Curation, Investigation. **Nebres VT:** Methodology, Data Curation, Validation. **Delos Santos VH:** Methodology, Data Curation, Validation, Investigation. **Peralta DM:** Methodology, Formal analysis, Investigation. **Madrid AJJ:** Writing—Original Draft, Formal Analysis, Visualization

CONFLICTS OF INTEREST

We have no conflict of interest to declare.

ETHICS STATEMENT

No animal or human studies were carried out by the authors.

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