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Effect of wash cycle on physical and chemical properties of rehydrated jellyfish by-products and jellyfish protein powder

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ABSTRACT

Production of salted jellyfish for export generates many minced or broken pieces as by-products, which have been sold as feed at a low price. From an economic perspective, changing the jellyfish by-products to a valued powder is needed. The washing of the salted by-products is a preparative step that has been changed from general washing to a mechanical washing machine for cost benefits. Little research on reducing salts and changes in mechanical washed jellyfish has been reported to date. Thus, this research aimed to determine the wash cycle's effect using the washing machine on loss and washed jellyfish by-products qualities. Results showed that the reduction of the salt content was from 14.28±0.03% to 3.08±0.11%, 1.10±0.11%, and 0.85±0.07%, and the washing losses were 27.39±0.94%, 38.92±0.93%, and 42.18±0.85% after performing the first, second, and third wash cycle, respectively. Results also showed that the increased wash cycle decreased the volatile compounds of hexanal, heptanal, octanal, nonanal, and 2,2-dimethyl-propanoic acid indicated as unsatisfied fishy grassy, fatty, green, ether, and pineapple odors, respectively**.** The quality of jellyfish powder selected from the second wash cycle had the protein, fat, moisture, and ash content of 76.41±0.14%, 1.35±0.00%, 7.69±0.00%, and 15.76±0.13% with brown color and minimal fishy odor.

Keywords: salted jellyfish by-products; wash cycle; jellyfish protein powder; jellyfish washing machine

1. INTRODUCTION

Jellyfish fisheries have a potential economic impact on local fishermen, processors, and exporters. Recently, jellyfish fisheries estimated value could exceed 100 million US dollars worldwide (Brotz et al., 2017). Thailand is one of the salted jellyfish processors and exports to many countries in the world (Omori and Nakano, 2001). The most popular edible jellyfish species in Thailand and used in this study is the "white type" (*Lobonema smithii*) (Omori and Nakano, 2001, Wongsa-ngasri et al., 2008), known in Thai as "Lodchong" that the beautiful tiny bright swollen strings attached to the roof of the umbrella. This preservation process has usually performed at the location of catching. Before salting, briefly, the whole jellyfish body is separated into the umbrella part (the top) and oral arms part (the legs), the gonad is removed, and the remaining viscous material is also cleaned (Huang, 1988, Hsieh et al., 2001; Wongsa-ngasri et al., 2008). Three salting chemicals are used in the multi-stage salting, including sodium chloride (NaCl), alum (potassium aluminium sulfate ($KAl(SO_4)_2$), and sodium bicarbonate ($NaHCO_3$). The sodium chloride function is to dehydrate, reduce water activity, and inhibit microbial spoilage. Alum reduces pH and prevents microbial growth (Hsieh et al., 2001). Sodium bicarbonate aids in producing a crunchy texture and facilitating the dehydration process. However, the salting process varies among jellyfish processors. Sodium bicarbonate does not allow for Chinese and European-style salting processes (Hsieh et al., 2001; Pedersen et al., 2017). In general, the length of preservation time at room temperature can be extended from 2 weeks to 6 weeks through a labor-intensive process (Hsieh et al., 2001; Wongsa-ngasri et al., 2008; Brotz et al., 2017). The slow salting preservation changes the jelly-type texture to a rigid, elastic, thin sheet of umbrella and shrunken irregular shape of the oral arm. The salted jellyfish will have distinctive and unique crunchy characteristics with a rubber-like texture (Hsieh and Rudloe, 1994; Pedersen and Vilgis, 2019). The salted jellyfish has been known for Asian cooking menus and mostly served in the restaurant.

Jellyfish food is considered low fat and cholesterol but has a collagen protein (Hsieh et al., 2001). For this reason, jellyfish dishes are served not only in Asian countries, including Singapore, Philippines, Japan, China, Taiwan, Hong Kong, South Korea, Indonesia, Vietnam, Myanmar, and Thailand but also becoming more familiar in European countries (Hsieh and Rudloe, 1994; Pedersen et al., 2017; Brotz et al., 2017). Before export, salted jellyfish manufacturing steps, using mostly the umbrella part, are grading the size, cleaning, trimming, and packing. Many salted jellyfish by-products are generated at the various processing steps, with irregularly shaped and broken pieces sold as feed meals at a low price of approximately 1 Baht per kg. Thus, turning this low-price product with the remaining protein into a valued product is needed from an economic perspective. Due to high salt levels in the salted jellyfish and by-products, washing is an essential preparative step for salt reduction. However, no requirement of minimum salt content in desalted product has been established. Before cooking, the conventional and practical wash step has been done by washing salted jellyfish several times and soaking overnight (Hsieh et al., 2001, Thumthanaruk and Lueyot, 2014; Kromfang et al., 2015). The physical characteristic of the washed product obtained from the conventional method appears the rehydrated texture with lowering salt content. The reduction of salt in the product changes its color and texture to be more appealing but reduces the shelf life of desalted jellyfish. The drawback of this method is time-consuming and labor-intensive. As a result, alternative cleaning has developed a jellyfish washing machine for manufacturing perspective and set up into the washing step. However, only a few data have been available on the quality of washed jellyfish affected by the washing cycle (Charoenchokpanich et al., 2020). Therefore, this research aimed to investigate the wash cycle effect on salt reduction and changes in washed jellyfish by-products qualities. Then, after subjected to drying at 60°C for 24 h, the qualities of dried jellyfish protein were compared.

2. MATERIALS AND METHODS

2.1 Materials

Salted jellyfish by-products referred to the jellyfish (*Lobonema smithii*) preserved with salt, alum, and sodium bicarbonate with irregular shape or broken pieces obtained from Chockdee Sea Products Co., Ltd., Samut Songkhram, Thailand. The by-products were stored in plastic drums and kept at room temperature until used.

2.2 Preparation of washed jellyfish by-products using washing machine

Each 10-kg sample of by-products was washed with tap water at a ratio of 1:40 (w/v) with mechanically assisted washing. Chockdee Sea Products Co., Ltd. developed and used the jellyfish washing machine for eliminating salt. The washing machine is a cylindrical tank with a diameter of 80 cm and a height of 100 cm. Inside the cylindrical tank, a rotating impeller circulates the sample at 100 rpm (Charoenchokpanich et al., 2020). The number of wash cycles was set at 1, 2, and 3 cycles and ran for 15 min per cycle. The washed water was drained for every washing cycle, and the new water was poured into the machine. The washing step was done in triplicate. After the washing steps, the samples were transferred to the plastic basket, drained for 5 min, and then weighed. The washed by-product samples were packed in sealed polyethylene (PE) bags, transported to the Department of Agro-Industrial, Food, and Environmental Technology, King Mongkut's University of Technology North Bangkok, Thailand, and kept at 10°C until analysis.

2.3 Preparation of dried jellyfish protein powder

After the washing step, each sample of desalted jellyfish by-products was dried in a tray drying (Binder, USA) at 60°C for 24 h (Rodsuwan et al., 2016). The dried samples were then ground into fine particles and filtered through a sieve of size 100 mesh. The samples were packed in sealed PE bags and kept at room temperature until analysis.

2.4 Analysis

2.4.1 Salt content (NaCl)

The salt content of the salted jellyfish by-products and washed samples was measured using the modified titration method (AOAC, 2000). The sample (1 g) was mixed with 25 mL of 0.1 N silver nitrate ($AgNO_3$) and 10 mL of 68% nitric acid (HNO_3). After that, the mixed sample was boiled for 10 min. Then, distilled water (50 mL) and 5% ferric alum indicator (5 mL) was added to the sample, which was then titrated with 0.1 N potassium thiocyanate (KSCN) standard solution until the solution became orange. The percentage of salt was calculated by equation (1):

$$Salt\ (\%) = \frac{(V_1 \times N_1) - (V_2 \times N_2)}{M} \times 100, \quad (1)$$

where V_1 = volume of $AgNO_3$ (mL), V_2 = volume of KSCN (mL), N_1 = concentration of $AgNO_3$ (N), N_2 = concentration of KSCN (N), and M = weight of sample (g).

2.4.2 pH and total soluble solids

For pH measurement, 5 g of the sample was blended with 45 mL of distilled water for 3 min. Then, the filtrate's pH value was measured using a pH meter (pH 700, Eutech, Singapore), and the total soluble solids were measured using a salinity refractometer (Master-S28M, Atago®, Japan).

2.4.3 Washing loss

The washing loss was calculated from the initial weight of the jellyfish by-products and the resulting weight after washing followed equation (2):

$$Washing\ loss\ (\%) = 1 - \frac{M_1 - M_2}{M_1} \times 100, \quad (2)$$

where M_1 = weight of salted jellyfish by-products before the washing process (10 kg) and M_2 = weight of salted jellyfish by-products after the washing process (kg).

2.4.4 Texture

The sample was cut into pieces of 2× 2 cm and was analyzed by a Texture Analyzer (TA-XT2i, Stable Micro Systems, UK) with an HDP/BS* blade set. The pre-test and post-test speeds were set at 2.0 mm/s (Wongsa-ngasri et al., 2008).

2.4.5 Color

The color of salted jellyfish, desalted jellyfish, and dried desalted jellyfish powder was measured using a colorimeter (ColorQUEST 45/0, HunterLab, USA) equipped with D65, a light source. For the salted and desalted jellyfish, the sample of 20 g was filled in the glass receptacle and measured three times by rotating at different angles. For the dried sample, a sample of 10 g was used and performed as described above. The results of the CIELAB color parameters were displayed as L^* (lightness 0-100), a^* (+redness, –greenness), b^* (+yellowness, -blueness), and the color difference (ΔE) calculated by equation (3):

$$Total\ color\ difference\ (\Delta E) = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2}, \quad (3)$$

where the values of L_0^*, a_0^*, and b_0^* were lightness, redness, and yellowness of salted jellyfish by-products before the washing process (wet and dried sample).

2.4.6 Determination of volatile compound by gas chromatography-mass spectrophotometry (GC-MS)

Analysis of the volatile compound of all jellyfish by-products was performed by a combination of dynamic headspace method and thermal desorption-gas chromatography-mass spectrometry (DH-TD-GC/MS) (Figure 1) (Kuraya et al., 2018). For this method, 0.2 g of the jellyfish by-products was septum-sealed in a 27-mL gas-tight vial. After introducing air through the activated carbon trap into the vial, the volatile compounds were aspirated by a minipump and adsorbed to Tenax TA (60/80 mesh, 130 mg) for 10 min at 60°C. Chemical analysis was performed using a GC/MS (QP-2010 Plus; Shimadzu Co., Kyoto, Japan) equipped with a TD-20 thermal desorption system (Shimadzu, Japan). Quantitative determinations of volatile components were made based on peak area measurements. GC/MS analyses were performed using a DB-WAX column of 60-m length, 0.32-mm ID, and 0.5-μm thickness (Agilent Technologies, Inc., Santa Clara, CA, USA). The GC oven temperature program was as follows: 40°C held for 3 min, increased by 3°C/min to 130°C, increased by 5°C/min to 240°C, and held for 5 min. The GC was interfaced with the injector and ionization source temperatures, maintained at 240°C. The mass range scanned was 20-400 amu. The GC/MS system and data peak processing were controlled using Shimadzu's GC/MS solution software, version 4.2. The volatile components were identified by comparing their retention indices and mass fragmentation patterns with MS libraries (NIST05 and FFNSC Library ver. 1.2; Shimadzu Co., Kyoto, Japan). The volatile components were identified based on their linear retention indices (RIs) and by comparison of their mass spectra with the MS data of reference compounds. The linear RIs were determined for all constituents using a homologous series of n-alkanes (C8-C24), injected under the same chromatographic conditions as the samples.

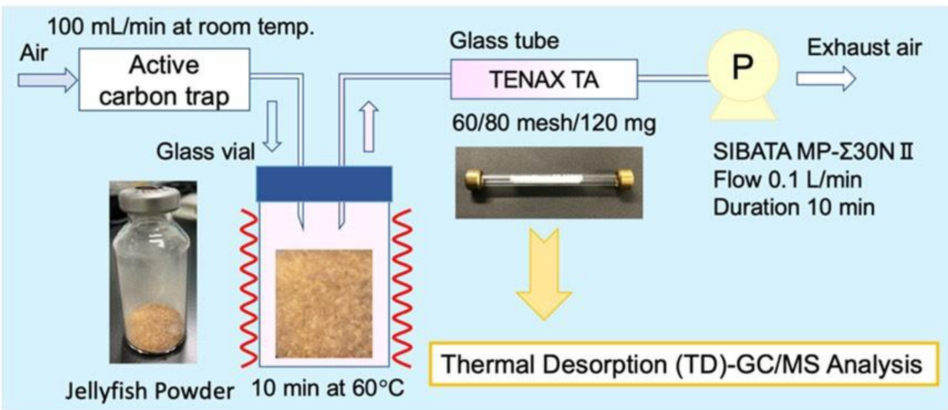

Figure 1. Analysis of the volatile compound of all jellyfish by-products

2.4.7 Chemical compositions

The chemical compositions of salted jellyfish by-products, washed by-products, and dried jellyfish samples were analyzed for moisture, protein, fat, and ash according to AOAC methods (AOAC, 2000).

2.5 Statistical analysis

All experiments were performed in triplicate, except for the volatile compound determination that was performed in duplicate. The data were subjected to analysis of variance (ANOVA), and Duncan's multiple range test was used to determine the significant difference ($p<0.05$) using the SPSS (SPSS 22.0 for Windows, SPSS Inc, Chicago, IL USA).

3. RESULTS AND DISCUSSION

3.1 Salt content, total soluble solids content, and pH of salted and washed jellyfish by-products

Typically, the salted jellyfish must be prepared by desalting and rehydration before cooking. The conventional desalting is by washing many times and overnight soaking. In this study, the jellyfish washing machine was used to clean and reduce the salt content. The machine has a circular tank equipped with a rotating blade. Increased the wash cycle changes in the physicochemical properties of desalted jellyfish by-products. The initial salted content of the jellyfish by-products was 14.28±0.03%. Results of salt content were quite similar to the work of Charoenchokpanich et al. (2020), which showed the salt content of 14.21% but different from the works of Huang (1988) and Hsieh and Rudloe (1994) that the salt content of salted jellyfish was 20-25%. The salt content could be due to differences from the salting technique and jellyfish species. After mechanical washing in the 1st, 2nd, and 3rd cycles, the salt content in the washed products was reduced to 3.08±0.11, 1.10±0.11, and 0.85±0.07%, respectively. The salt reduction increased from 78.44, 92.30, and 94.05% as the number of washing cycles increased due to the effect of salt dilution by replacing new tap water each round and facilitating by the mechanical force of circulation in the washing tank. According to the remaining salt content, the 2nd wash cycle was sufficient for washing the jellyfish by-products. The jellyfish washing machine benefits to shorten the production time to only 30 min (for 2nd cycle) and labor cost; however, the water supply cost may increase.

The typical salt determination performed on a manufacturing scale is by a salinity refractometer. The initial total soluble content of salted jellyfish by-products was 19.73±0.11%. The jellyfish washing machine's use significantly reduced salt content in the jellyfish by-products. After the 1st, 2nd, and 3rd wash cycles, the total soluble solids of washed by-products were reduced to 0.00±0.00%. The results agree with the results of Kromfang et al. (2015) and Thumthanaruk and Lueyot (2014). Based on this measurement, in this case, only one cycle of washing was sufficient to reduce salts from the jellyfish by-products due to the use of a large amount of wash water closed to 400 L per 10 kg of the test sample. However, the salinity refractometer measurement did not give accurate results of salt. The titration method should then be used to measure and evaluate salt in the sample.

The pH of salted jellyfish by-products was 3.43±0.05, and pH levels of the washed by-products after 1st, 2nd, and 3rd wash cycles were 7.13±0.05, 7.43±0.05, and 7.73±0.05, respectively, which are approximately osmotic equilibrium to pH of the tap water (7.76±0.05). The pHs of washed jellyfish by-products were similar to Charoenchokpanich et al. (2020), which showed the pH levels of desalted jellyfish's umbrella washed after 1, 2, and 3 cycles were 6.80±0.60, 7.70±0.10, and 7.73±0.06, respectively. The very low pH of salted jellyfish products prevents microbiological growth, causing the jellyfish protein to denature by turning the jelly-like texture to the elastic and transparent sheet of salted jellyfish. The washed product with low salt content and neutral pH will shorten the shelf-life and refrigerate before use.

3.2 Textural and color quality and washing loss of washed jellyfish by-products

The salted jellyfish protein by-products were irregular form, small broken pieces, tight and elastic texture. The wash cycle changed the texture of the jellyfish protein. The parameter of cutting force of the texture analyzer dictates the firmness or hardness of jellyfish flesh. The initial cutting force of salted jellyfish was 5.80±0.04 N/mm. The cutting force values of washed jellyfish by-products decreased to 4.20±0.06, 3.06±0.25, and 2.13±0.11 N/mm as the number of wash cycles increased. During the washing step, the by-products' shape was destroyed by the stirring blade's mechanical force. When the salts become soluble and water penetrates into broken pieces, jellyfish's texture becomes even softer and deteriorates quickly, thereby decreasing cutting force values.

The salted jellyfish by-product color changed as the number of wash cycles increased (Table 1). L*, b*, and total color difference (ΔE) values of the salted jellyfish by-products increased, but a* values (redness) decreased with the increase in wash cycles. The washed jellyfish color appeared to be brighter with a light creamy color (Figure 2) due to the rehydration and osmotic equilibration in the jellyfish sample.

The washing machine's application facilitates the reduction of salt content in the product but causes an increase in washing loss. The washing loss increased from 27.39±0.94, 38.92±0.93, and 42.18±0.85% after the 1st, 2nd, and 3rd cycles of washing. In this study, the small size and irregular shape of by-products damage as the effect of stirring blade in the washing machine, resulting in smaller pieces and soft texture that can pass through the washing machine's sieve hole, causing the loss of jellyfish samples. The washing loss depends on the type of raw material used. Charoenchokpanich et al. (2020) reported that the washing yields of the small size of the umbrella portion of desalted jellyfish after 1, 2, and 3 cycles of washing were 93.75±0.98, 90.49±0.69, and 81.23±0.52%.

Table 1. Color of salted and desalted jellyfish by-products

Sample	L*	a*	b*	ΔE
Salted jellyfish by-products (wet)	49.01±0.00^d	1.70±0.00^a	13.67±0.00^d	-
Desalted jellyfish after 1st cycle (wet)	51.44±0.01^c	1.56±0.00^b	14.13±0.00^c	2.48±0.01^c
Desalted jellyfish after 2nd cycle (wet)	51.92±0.00^b	1.26±0.00^c	14.42±0.01^b	3.04±0.00^b
Desalted jellyfish after 3rd cycle (wet)	52.64±0.01^a	0.72±0.00^d	14.75±0.01^a	3.91±0.00^a

Note: Different superscripts (a, b, c, d) in the same column mean significant difference in value ($p<0.05$)

3.3 Proximate analysis of salted, desalted jellyfish by-products and dried jellyfish protein powder

The moisture, protein, fat, and ash of the initial salted jellyfish by-products had values of 73.63±0.24, 3.61±0.02, 0.91±0.02, and 21.85±0.10%, respectively (Table 2). As the number of wash cycles increased, the ratio of chemical compositions of desalted jellyfish obtained from each wash cycle changed. The wash cycle reduced impurities, mainly salt chemicals, by diluting and increasing salt solubilization from jellyfish flesh, thereby lowering the ash content. As the by-products subjected to the 1, 2, and 3 wash cycles, the osmotic equilibrated jellyfish flesh yielded the moisture content of 91.63±0.09, 93.36±0.09, 93.76±0.03%, the protein content of 4.45±0.05, 5.55±0.00, 6.41±0.07%, and the ash content of 3.66±0.10, 1.19±0.05 and 0.69±0.00%, respectively. The fat content remained at the same value of 0.91%.

As the number of wash cycles increased, the jellyfish protein absorbed more water in its flesh, resulting in increased moisture content and salt diffusion. As a result, the ash content's salt measuring decreased after the wash cycle. However, value changes in moisture and ash slightly affect protein content calculation. The washed jellyfish compositions were different from the other researches by conventional washing, which reported the values of moisture, protein, fat, and ash content 92.75-95.63, 3.49-5.60, <0.01-0.13, and 0.33-3.63%, respectively (Heish et al., 2001; Thumthanaruk and Lueyot, 2014). According to these results, the jellyfish washing machine benefits from discarding the salt and impurities from the jellyfish by-products. However, the reduction of salt in desalted jellyfish caused the product to be prone to microbial growth (Hu et al., 2019).

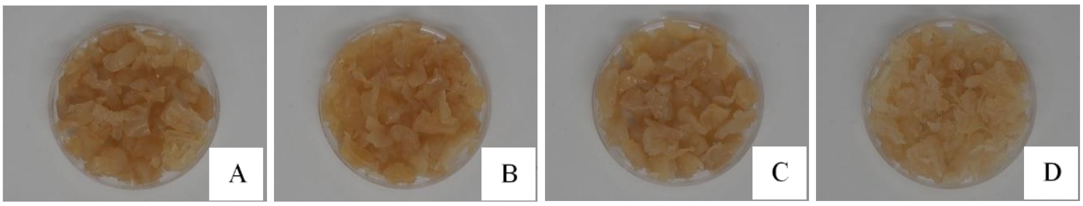

Figure 2. Color of salted jellyfish by-products; **(A)** salted jellyfish, **(B)** jellyfish washed 1 cycle, **(C)** jellyfish washed 2 cycles, and **(D)** jellyfish washed 3 cycles

Table 2. Chemical compositions (%wet basis) of salted and desalted jellyfish by-products

Sample	Moisture	Protein	Fat^{ns}	Ash
Salted jellyfish by-products	73.63±0.24^{d}	3.61±0.02^{d}	0.91±0.01	21.85±0.10^{a}
Desalted jellyfish after 1st cycle	91.63±0.09^{c}	4.45±0.05^{c}	0.91±0.01	3.66±0.10^{b}
Desalted jellyfish after 2nd cycle	93.36±0.09^{b}	5.55±0.00^{b}	0.91±0.03	1.19±0.05^{c}
Desalted jellyfish after 3rd cycle	93.76±0.03^{a}	6.41±0.07^{a}	0.91±0.02	0.69±0.00^{d}

Note: Different superscripts (a, b, c and d) in the same column mean significant difference in value (p<0.05),
ns = Not significant (p<0.05)

The washed by-products were dried and ground for processing as a food ingredient. The drying causes the water to be evaporated, and then the remaining nutrient composition becomes concentrated. The moisture, protein, fat, and ash content of dried salted jellyfish protein powder (no washing step) were 5.90±0.01, 34.00±0.14, 0.94±0.01, and 58.02±0.89%, respectively (Table 3). After the tremendous amount of salt was removed during the washing step, the dried jellyfish products derived from washed by-products showed the protein content ranged from 53.74-79.37%, depending on the wash cycle number. As the number of wash cycles increased, the salt or ash content decreased. The salt in the jellyfish tissue was increasingly leached out by the blade's mechanical circulation effect and a dilution effect of a large quantity of wash water, thereby increasing jellyfish protein powder purity. Apart from water content, protein is an essential component in the jellyfish body. Jellyfish protein has mostly been made of collagen (Hsieh and Rudloe, 1994). Klaiwong et al. (2014) reported the collagen type I and II found in fresh and salted edible jellyfish protein, white type (*Lobonema* smithii), and sand type (*Rhopilema hispidum*) from the umbrella and oral arm. The high protein content in the dried jellyfish powder can indicate jellyfish protein powder. However, in this study, no collagen was measured. The dried samples contained ash at high content of 37.04-11.07% after washing 1-3 cycles. The high ash content may cause the limitation to use in food. For producing purified jellyfish protein powder, the purification step will be needed. The nutrient compositions of dried jellyfish protein powder in this study were slightly different from the works of Silaprueng et al. (2015) and Rodsuwan et al. (2016) that the values of moisture, protein, fat, and the ash content of dried jellyfish powder equal to 9.66-9.88, 69.85-75.09, 5.16-8.76, and <1-8.56%, respectively.

Table 3. Chemical compositions (%wet basis) of salted and dried desalted jellyfish protein powder

Sample	Moisture	Protein	Fat	Ash
Salted jellyfish by-products	5.90±0.01^{d}	34.00±0.14^{d}	0.94±0.01^{d}	58.02±0.89^{a}
Desalted jellyfish after 1st cycle	7.43±0.06^{c}	53.74±0.01^{c}	1.17±0.00^{c}	37.04±0.62^{b}
Desalted jellyfish after 2nd cycle	7.69±0.00^{b}	76.41±0.14^{b}	1.35±0.00^{b}	15.76±0.13^{c}
Desalted jellyfish after 3rd cycle	7.88±0.01^{a}	79.37±0.35^{a}	1.48±0.01^{a}	11.07±0.13^{d}

Note: Different superscripts (a, b, c and d) in the same column mean significant difference in value (p<0.05)

3.4 Color and volatile compounds of dried jellyfish protein powder

The wash cycle minimizes the salt and impurities of the jellyfish by-products. When the washed samples were subjected to drying, results of dried samples showed that the lightness (L^*) decreased, but redness ($+a^*$) and yellowness ($+b^*$) increased as the number of wash cycles increased (Table 4). The changes to intense brown color could be due to the browning effect of the Maillard reaction, in which reducing sugar reacts with a free amino acid at the proper conditions of temperature (Tamanna and Mahmood, 2015; Jiang et al., 2014; Kchaou et al., 2019; Lan et al., 2010). Interestingly, if the sample still has high salt content, the dried jellyfish powder will be a light brown color, resulting from concentrated salt (Figure 3).

Ideally, the food ingredients' quality should have minimal or no odor. Most marine food ingredients are accompanied by a fishy, marine, or salty smell, which must be masked or reduced. In this study, the increased wash cycle reduced unsatisfied odors. Results revealed the major volatile compounds, including hexanal, heptanol, octanal, nonanal, and 2,2-dimethyl-propanoic acid, which gave fishy, fatty, rancid, green, grassy, ether, and pineapple smells, respectively (Table 5) (Figure 4A and Figure 4C). These are typical compounds found in salted jellyfish samples during the salting and storage, according to Kromfang et al. (2015) results. After several wash cycles, the number and quantity of volatile compounds, including hexanal, heptanol, octanal, and nonanal of dried jellyfish protein powder, decreased with increasing numbers of washing cycles (Table 5). Figures 4B and 4D show chromatograms of only the 2nd wash cycle dried sample results. Figure 4D shows no 2,2-dimethyl-propanoic acid in the 2nd wash cycle dried sample. To be used as a food ingredient, the dried jellyfish protein powder needs to be studied further concerning quality improvement in color and odor.

Table 4. Color of salted and desalted dried jellyfish protein powder

Sample	L^*	a^*	b^*	ΔE
Salted jellyfish by-products (dried)	85.70±0.00^a	1.48±0.00^d	11.12±0.00^d	-
Desalted jellyfish after 1st cycle (dried)	77.67±0.00^b	3.39±0.00^c	16.18±0.01^c	9.68±0.00^c
Desalted jellyfish after 2nd cycle (dried)	67.59±0.00^c	5.52±0.01^b	19.47±0.00^b	20.35±0.00^b
Desalted jellyfish after 3rd cycle (dried)	67.24±0.00^d	5.70±0.00^a	20.48±0.01^a	21.12±0.01^a

Note: Different superscripts (a, b, c and d) in the same column mean significant difference in value ($p<0.05$)

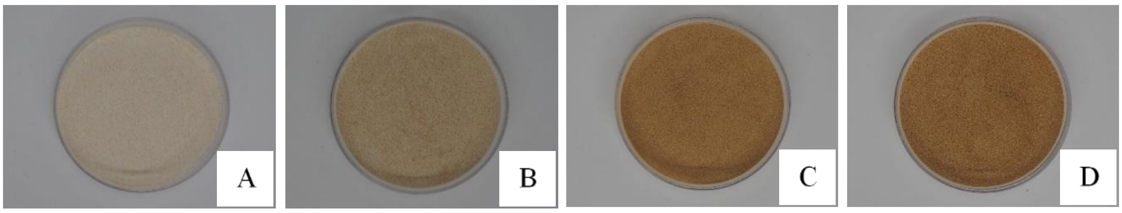

Figure 3. Color of jellyfish protein powder; **(A)** salted jellyfish, **(B)** jellyfish washed 1 cycle, **(C)** jellyfish washed 2 cycles, and **(D)** jellyfish washed 3 cycles

Table 5. Changes in major volatile compounds of salted and desalted dried jellyfish protein powders

Compound	Retention Time (min)	Relative peak area (%)				Odor description[1]
		Salted jellyfish	Desalted jellyfish after 1st cycle	Desalted jellyfish after 2nd cycle	Desalted jellyfish after 3rd cycle	
Hexanal	13.107	1.80	0.99	0.49	0.32	Fishy, grassy, fatty
Heptanol	17.707	1.48	0.38	0.36	0.35	Fishy, fatty, rancid
Octanal	22.671	1.35	0.48	0.39	0.39	Fatty, green
Nonanal	27.530	0.37	0.27	0.20	0.19	Green, fatty
2,2-dimethyl-propanoic acid	36.337	1.41	0.12	-	-	Ether, pineapple

Note: [1]Kromfang et al., 2015; Zhu et al., 2019; Giri et al., 2010

4. CONCLUSION

The jellyfish washing machine in the washing step significantly reduced the total soluble solids and the salt content but increased the loss in washed jellyfish by-products as the number of wash cycles increased. Concerning the economic yield, the second washing cycle was sufficient to reduce the salt content more significant than 92% from the original and to minimize unpleasant volatile compounds of hexanal, heptanal, octanal, nonanal, and no detectable of 2,2-dimethyl-propanoic acid. The dried jellyfish protein powder obtained from the second wash cycle contained protein, fat, ash, and moisture of 76.41, 1.35, 15.76, and 7.69%, respectively, and yielded brownish color of L^*, a^*, b^* of 67.59, 5.52, and 19.47, respectively. The dried jellyfish powder could be a food ingredient to benefit the protein content based on this research. However, more research is needed to improve jellyfish protein powder's quality with color and odor.

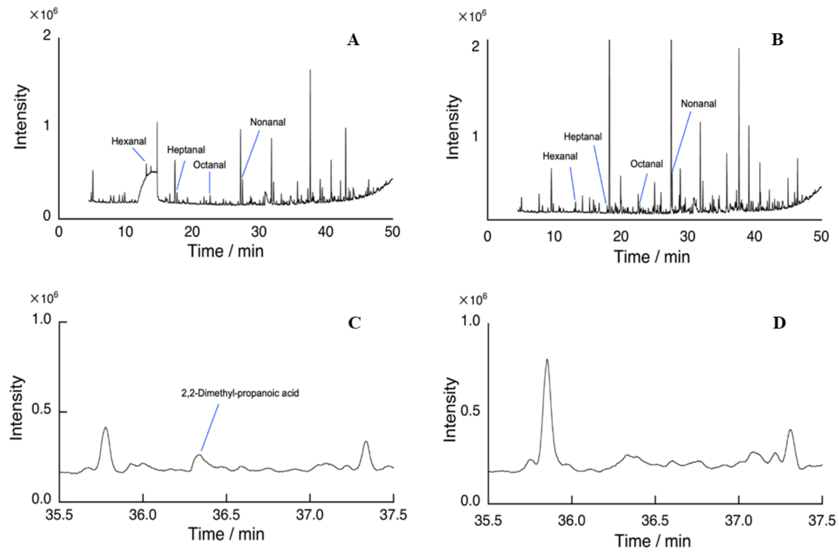

Figure 4. GC/MS spectra (TIC chromatograms) of dried salted jellyfish powder (A, C) and dried 2nd wash jellyfish powder (B, D)

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