Product Recovery After Processing and Drying of Philippine Sandfish (*Holothuria scabra*) into Trepang

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ABSTRACT

The sandfish (Holothuria scabra) is processed and dried into a high-value product known as trepang that is used as a food ingredient, primarily for markets in Hong Kong and beyond. Due to high demand, populations in the wild are over-exploited from indiscriminate harvesting and undersized trepang in the Philippines is common. Mass balance analysis of sandfish samples from Coron (Palawan province) and Bolinao (Pangasinan province) was conducted to demonstrate the benefits of observing size limits during harvesting. Individual weights of sandfish from Coron and Bolinao had ranges of 557 – 1,237 g and 89 – 590 g, respectively. Based on degutted weight of each animal, the product recovery was significantly greater for larger animals (8.8%) compared to smaller animals (6.2%). For the same number of specimens, the estimated total value for Coron and Bolinao samples was PhP3,351.73 and PhP431.95, respectively. The higher value of Coron samples was due to the larger saleable weight, higher product recovery, and premium prices paid for large and well-dried trepang. On a per-kg basis, the value of Coron samples (PhP4,269.72 kg^{-1}) was 1.8 times higher compared to Bolinao samples (PhP2,385.15 kg^{-1}). A field trial of prototype equipment for mechanized processing and drying of sandfish in Pagbilao (Quezon province) showed that it was possible to produce well-cleaned and well-dried trepang from large sandfish that compared well with competing products in Hong Kong markets.

Keywords: Sandfish, mass balance, sea cucumber, processing, drying

INTRODUCTION

Sea cucumbers are animals belonging to the class *Holothuroidea*. These animals are exploited primarily for use as a food ingredient, with countries in tropical and temperate regions harvesting numerous species commercially. The majority of the harvested species are destined for processing and drying. The fully-dried product is known as *beche-de-mer* or *trepang*. Sea cucumber can also be consumed in raw, cooked, or pickled form; extracts from these animals are also thought to have pharmacological applications (Purcell *et al.* 2012; Mayer *et al.* 2011).

The three major markets for sea cucumber are Hong Kong, Singapore, and Taiwan (Conand 2004). In Hong Kong, imported sea cucumber products come from 64 countries; in order of importance, the top five producing countries are Japan, the Philippines, Indonesia, Fiji and the USA. These imported products are mainly in the form of live, fresh, chilled, frozen, dried, salted, and smoked sea cucumber. Dried sea cucumber makes up 64% of these imports; frozen products are the second largest imports at 34%. About 91% of all imports are re-exported to other countries (Conand *et al.* 2014), indicating that Hong Kong serves as an important transshipment point for this commodity. High-, and medium-, value species are often given as gifts, especially during the Chinese New Year or Spring Festival. Shape, color, and form are the prime considerations for sea cucumber offered as gifts (Purcell *et al.* 2014).

Purcell (2014a) observed that species and size affect prices of dried sea cucumber in China. *Holothuria scabra* and *H. lesson*i were considered as high-value species, with larger specimens being sold at higher prices. For example, the selling price of sandfish (*H. scabra*) was predicted at US\$165 kg^{-1} for 8-cm long trepang, while 12-cm specimens would sell at US\$840 kg^{-1}. At present, the minimum size of any species of sea cucumber that can be marketed in dried form in the Philippines is 5 cm (BFAR, 2013). Product standards also require that only sandfish with a live weight of more than 300 g should be used for processing into *trepang* (BAFPS 2013). However, the exponential relationship between market price and product size of *H. scabra* can be the basis for raising the minimum harvest weight to more than 600 g (Purcell *et al.* 2018).

In the Philippines, there are about 100 species of sea cucumber with 25 species harvested regularly for processing; these include *H. scabra*, *Bohadschia marmorata*, *Actinopyga lecanora*, *H. fuscocinera*, *H. atra*, and *Stichopus hermanni*. The most valued species are *A. lecanora, H. nobilis, H. whitmaei, H. scabra* and *Stichopus* spp (Schoppe 2000). Annual capture volume peaked in 1990 at 4,000 metric tons, but by 1998, the volume had dropped to 1,000 tons or less due to overharvesting (Figure 1). Globally, there is a high level of over-exploitation (38% of fisheries) and depletion (20% of fisheries) of sea cucumber; the Philippine industry itself is classified as over-exploited. About 66% of these fisheries worldwide are on a small scale, such as in the Philippines; furthermore, multiple species are harvested in tropical countries compared to temperate countries (Purcell *et al.,* 2011). The demand for sea cucumber products and widespread depletion of the resource has driven the value to increase at a faster pace (more than 3.5 times) compared to other marine products such as crustaceans and cephalopods (Figure 2).

The peak period for collecting sea cucumber is from March to June when warmer waters allow for longer diving periods. Gathering is a night-time activity done during low tide. Since shallow waters are already depleted, more effort is needed to collect sea cucumbers from greater depths; they can also be

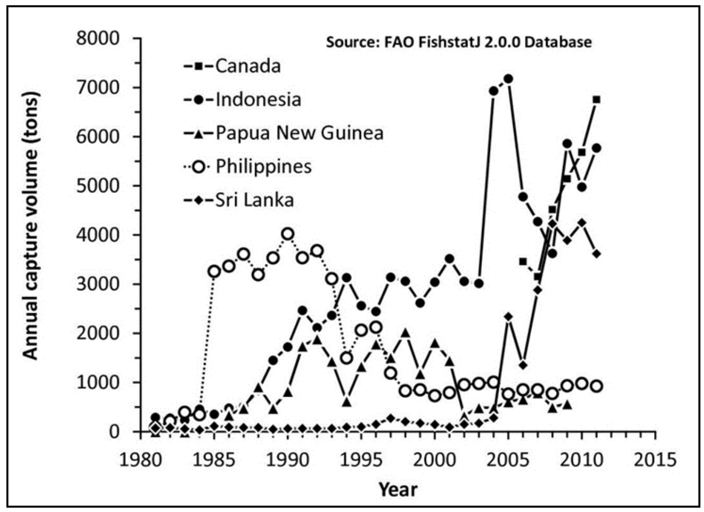

Figure 1. Comparison of production volumes of sea cucumber of leading producers.

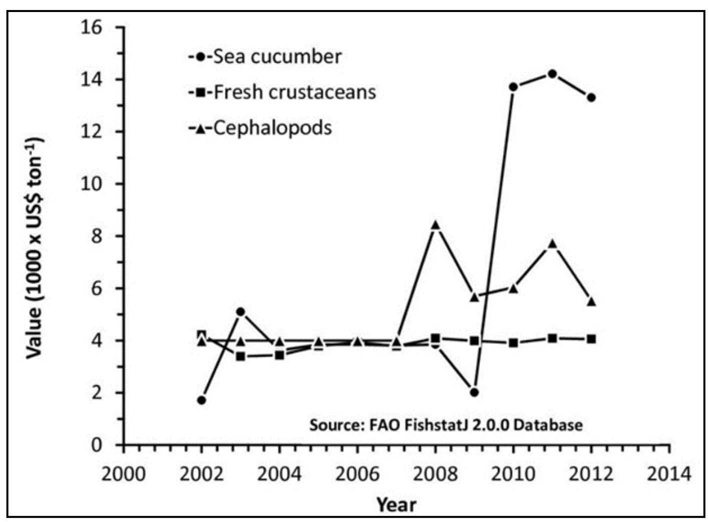

Figure 2. Comparison of value of sea cucumber products with other marine products

collected from deeper areas by skin diving or with the use of air compressors connected to a breathing tube (Schoppe , 2000). The fresh catch is then sold to local residents acting as assemblers whose role is to process the sea cucumber and sell to Manila-based agents or to exporters. Trading between assemblers may also occur when volumes are too small and cash is needed. Traders deal mainly with dried products and are based in key towns or cities; dried products are procured from assemblers and sold to exporters (Brown *et al.* 2010).

The general procedure for processing and drying of sandfish is degutting, boiling for up to 2 hrs, soaking in water with papaya leaves, brushing to remove the spicule layer, smoking and sun-drying. After drying, the product is brought to buying stations of exporters for receiving and classification by species, followed by weighing and grading. The product is then packed in sacks with a polyethylene liner; once enough volume has been accumulated, the product is shipped to Manila. Processing and drying of sea cucumber is the most important determinant of quality. Most Philippine sea cucumber products are of poor quality due to inappropriate processing practices, and are undersized since size limits are not followed (Brown *et al.* 2010).

Ngaluafe and Lee (2013) observed a wide range in product recovery for different species of sea cucumber. The samples that were studied included three *Actinopyga*, three *Bohadschia*, three *Holothuria*, and one *Thelenota* species. After degutting, salting, and drying, the final product on average was 12% of the initial body weight, with a range of 5-20%. For the Philippine sandfish, value chain analysis has showed that 1 kg of good-quality dried product creates PhP5,326 of total wealth. This is based on an assumed product recovery of 10%, where 2-3 animals make up 1 kg of fresh weight (Brown *et al.* 2010). This figure is close to the estimated product recovery of 9.4% of degutted fresh weight determined by Skewes *et al.* (2004). However, these figures need to be verified, since recovery may vary between large and small animals. Hence, this study aimed to (1) document the present handling and processing practices for sandfish in the Philippines, and (2) establish recovery rate of sandfish processing and drying into *trepang*.

METHODOLOGY

Documentation of Present Handling and Processing Practices for Sandfish

The project team conducted site visits to interview processors, and document processing and drying practices for sandfish. These sites included Calatagan (Batangas), Cebu City, Coron (Palawan), Digos (Davao del Sur), Pagbilao (Quezon), Lopez Jaena (Misamis Occidental), Bongao (Tawi-Tawi), Puerto Princesa City, and Zamboanga City. Key informants in these sites included fisherfolk and traders; price information was also obtained from the staff of two buying stations in Coron. Dried samples were obtained from Anda (Pangasinan), Bolinao (Pangasinan) and Coron (Palawan) for microbial analysis, and determination of ash and salt content. A pack of dried sea cucumber (of unknown species) from China was also provided by Dr. Annette Meñez (Professor, Marine Science Institute, UP Diliman) to the project team to be analyzed for comparison. Samples were analyzed by the Institute of Food Science & Technology (IFST) of UP Los Baños, and the Analytical Services Laboratory of the National Institute of Molecular Biology and Biotechnology (BIOTECH).

Information on selling prices for live sandfish and buying prices for different grades and species of dried sea cucumber (including sandfish) were obtained during visits to Lopez Jaena and Coron, respectively. Smoked samples of several species from Digos and sandfish from Puerto Princesa were also purchased to determine the moisture content. The Digos samples were of unknown species and only identified by their local names as *black beauty, chocolate powder, legs, hanginan, lawayan, buli-buli , tres kantos, red powder, taba*, and *sus-an*. Tissue samples were obtained along the length of each specimen and from the inner and outer layers for moisture content determination. The Arranque public market in Sta. Cruz, Manila was also visited to document retail practices for ready-to-cook sandfish.

Material Balance for Sandfish Processing

Two trials were conducted to establish the material balance for processing of sandfish. The first trial was conducted in May 2013 and used 18 live sandfish collected in a sea ranching site (around Baquid Island, Coron) of the Palawan Aquaculture Corporation (PAC) with the assistance of PAC staff. The samples were accumulated over three days and were placed in aerated holding tanks kept at ambient temperature prior to processing. Processing of sea cucumber was based on a procedure developed by the National Fisheries Research & Development Institute (NFRDI) of the Department of Agriculture. The general procedure involved slitting and degutting, first boiling, removal of the chalky spicule layer, second boiling, and drying. The detailed procedure is shown in Figure 3. Degutting, boiling, cleaning and primary drying were conducted on-site; a prototype hybrid dryer was used for primary drying. The hybrid dryer could be heated with biomass waste, or used as a solar dryer under sunny conditions. Drying temperature was maintained at a nominal temperature of 60^{o}C. Once a semi-dry state was reached (tough rubbery texture), the samples were stored in sealed plastic trays and brought to IAE-CEAT, UPLB for secondary drying using a laboratory hot-air oven set at 60^{o}C. Samples were considered sufficiently dry once the texture was firm and hard (cannot be bent or compressed by hand). At this stage, the moisture content (wet basis) should be at 15% or below (BAFPS 2013); on a dry basis, this translates to 0.18 g g^{-1} dry matter. Dried sandfish is stable at a moisture content of 0.12-0.18 g g^{-1} dry matter when kept at room temperature and a relative humidity of 60% (Yaptenco *et al.* 2017).

The second trial was conducted in June 2014 and used 18 live sandfish samples from Bolinao for processing and drying into *trepang*. Samples were provided by the Bolinao Marine Laboratory of the University of the Philippines–Marine Science Institute. Slitting and degutting were performed on-site; degutted samples were kept on ice during transit to UP Los Baños. Upon arrival at UPLB, samples were stored at -18^{o}C prior to further processing. After thawing and warming to room temperature, samples were boiled and cleaned as described previously. Primary drying was performed using the hybrid dryer heated with biomass waste to a nominal temperature of 60^{o}C. After reaching a semi-dry condition, the samples were divided into

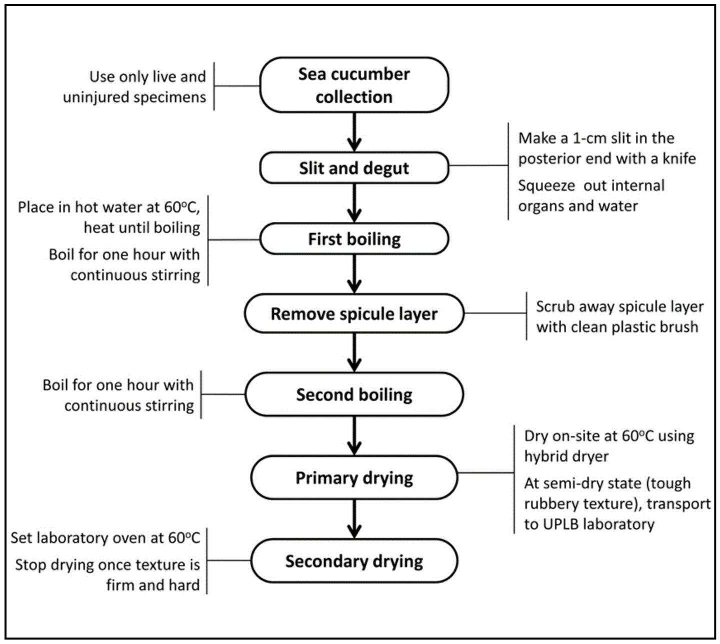

Figure 3. Flowchart of processing and drying of sandfish

three groups for secondary drying using three methods: by using a forced hot air oven set at 60^{o}C, by sun-drying, or by solar drying using the hybrid dryer. Drying was terminated once the product had achieved a firm and hard texture. Final moisture content of the Coron and Bolinao samples was determined by drying at 105^{o}C for three days.

Each sample was tagged and labeled prior to processing; at each stage of processing, samples were weighed with a digital weighing scale before going to the next stage. Since live sandfish may retain significant amounts of water inside its body cavity (Sewell 1991), material balance and product recovery were based on the degutted weight of each sample to provide a more consistent basis. Skewes *et al.* (2004) also observed that live weight was less reliable as an estimate of true body weight compared to degutted weight. Product recovery (PR) was calculated using Equation 1, where w_{dr} = weight of the dried product once it reaches a stone-hard texture, and w_{dg} = weight of degutted sandfish.

$$PR = \frac{w_{dr}}{w_{dg}} x100\% \qquad (1)$$

To determine the value of dried sandfish samples from Bolinao and Coron, size assessments by Jun (2002) were used to generate weight ranges for nominal size classes (Table 1). Five size classes were used for the study, namely extra small (XS), small (S), medium (M), large (L), and extra large (XL). Weight ranges were generated by taking the midpoint between each size class; midpoints were computed as half the difference between the weight per piece of two adjacent size classes. For example, the weight per piece of S and M size classes was computed as 16.7 g and 25.0 g, respectively. Hence, the maximum weight for a small piece (or minimum weight for a medium piece) was computed as 16.7 – (25.0 – 16.7)/2 or 21.0 g. The value of each size class was based on price data obtained from a Coron buying station.

Field Trial for Sandfish Processing

Sandfish was harvested in Pagbilao, Quezon with the assistance of a fisherfolk association. Samples were processed and semi-dried on-site; a prototype mechanical cleaner fitted with a rotating brush roller was used for removing spicules. Cleaned and boiled sandfish was dried using the hybrid dryer at a nominal temperature of 60°C. Members of the association were requested to estimate selling price of the semi-dry product. Afterwards, samples were oven-dried in a laboratory oven at 60°C until the requisite firm and hard texture was reached.

Dried product from Pagbilao was also compared with trepang sold in a Hong Kong wet market; feedback from a retailer was obtained in an informal interview regarding the quality of the Pagbilao sample. Shape, texture, and moisture content were the quality attributes discussed during the interview.

RESULTS AND DISCUSSION

Handling and Processing Practices for Sandfish

Interviews with fisherfolk showed that each site has its own methods of processing and drying sea cucumber. Basic steps include slitting and removal of internal organs, boiling in clean water, removal of spicules (specific to *H. scabra*), soaking, and drying (Figure 4a to 4f). Slitting method may vary according to size of the animal. For small ones, a small cut in the anal end is made and the internal organs are squeezed out of this opening; large individuals are slit along the back and the organs are scooped out. At present, the internal organs are mostly discarded after degutting. However, since sea cucumbers are known to have large amounts of

Table 1. Size classes and corresponding weight range for dried sandfish

SIZE CLASS	SIZE ASSESSMENT[z]		WEIGHT RANGE[y] (g)		
	N	W (g)			
XS	80	12.5	15.3	<	
S	60	16.7	15.3	-	21.0
M	40	25.0	21.0	-	37.5
L	20	50.0	37.5	-	58.5
XL	15	66.7		>	58.5

[z]N = nominal number of pieces to reach 1 kg (June 2002); W = weight of one piece of dried product
[y]Ranges computed from size assessments of June (2002)

Figure 4. Steps in processing and drying of sandfish as practiced by small fishers: (A) slitting, (B) degutting, (C) boiling, (D) spicule removal, (E) smoking, (F) sun-drying.

bioactive compounds with medicinal benefits, the composition and processing of internal organs merit further study. Bioactivity includes anti-angiogenic, anti-coagulant, anti-hypertension, anti-inflamma-tory, anti-microbial, anti-oxidant, and anti-thrombotic activities (Bordbar *et al.* 2011). After degutting, sandfish is boiled in clean seawater or fresh water until thoroughly cooked. Boiling times vary according to local practices, and may be repeated two to three times until the right texture is achieved. Large steel woks are commonly used for boiling.

Table 2. Moisture content of semi-dried and fully-dried sea cucumber products procured from local processors

SOURCE	SPECIES OR LOCAL NAMES	TEX-TURE	MOISTURE CONTENT	
			Wet basis (%)	Dry basis ($g\ g^{-1}$ dry matter)
Cebu	*H. scabra*	Fully dried	14.4 - 19.0	0.17 - 0.23
Digos, Davao del Sur	*black beauty, chocolate powder, legs, hanginan, lawayan, buli-buli, tres kantos, red powder, taba, sus-an*	Semi-dry	24.8 - 50.3	0.33 - 1.01
Puerto Princesa, Palawan	*H. scabra*	Semi-dry	42	0.72
	H. scabra	Fully dried	4.4 - 5.6	0.05 - 0.06

For *H. scabra*, removal of the spicule layer is a requirement of buyers; if done improperly, the price of the dried product is downgraded. The spicule layer can be softened by pretreatment, usually by scrubbing with papaya leaves, overnight soaking, or burying overnight in sand. The spicules are then removed by scraping with coral stone, rubbing over a rough surface such as concrete or vigorous scraping with coral rock, or using nylon or steel brushes. It should be noted that these practices are not hygienic and may introduce physical hazards (e.g. steel particles from broken bristles) during processing.

Small fishers usually produce trepang in a semi-dried condition (e.g. the material can be bent or squeezed by hand, but has a tough rubbery texture). Initial or primary drying is done by placing boiled sea cucumber over hot coals (about 30 cm above the coals to avoid scorching); this practice is also known as smoking, although the primary objective is to remove the moisture of the product as quickly as possible. The simplest method of smoking is simply to use a piece of steel mesh as a tray for holding the material over hot coals. In some cases, an enclosed structure (known locally as tapahan) may be constructed with concrete walls and fitted with several screened trays for drying larger volumes of product (Figure 4e). Wood is the primary source of fuel for drying which is purchased from vendors. Moisture content of semi-dried samples procured from processors in Cebu, Digos and Puerto Princesa are shown in Table 2; average MC was 38% wet basis or 0.61 g g-1 dry matter.

Once the product is semi-dried, it is sun-dried on trays or other suitable surfaces (Figure 4f) to further reduce the moisture content. During sun-drying, the material is fully exposed to weather, insects, pests and other animals. A properly dried sea cucumber feels stone-hard (i.e. it cannot be bent, squeezed, or broken by hand). However, fisherfolk in need of immediate cash sell their semi-dried product to traders or exporters who re-process and re-dry the material to the proper moisture content. On average, moisture content of fully-dried samples procured from processors was 12% wb (Table 2) or 0.14 g g-1 dry matter. Fully-dried products are stored in sacks at ambient temperature.

Table 3 gives a summary of the processing and drying practices documented during the study; observations by Brown *et al.* (2010) are also provided, as well as details of the NFRDI method to provide a side-by-side comparison. Due to the artisanal nature of the industry in the Philippines,

Table 3. Comparison of different methods of processing and drying sandfish

PROCESSING STEPS	TRADITIONAL METHOD[z]	BROWN ET AL (2010)[y]	NFRDI METHOD[x]
Degutting	Slit small sandfish at the anal end and squeeze out internal organs and water; large sandfish are slit along the dorsal side and organs are scooped out.	Slit the mouth with a knife	Slit the anus with a knife on the ventral side; only a 1 -1.5 cm cut is needed
First boiling	Boil in clean seawater or fresh water; boiling time varies according to local practice. Steel woks are commonly used for this process, with some processors cooking different species together.	Boiled from 5 min to 2 hours	Preheat water to 60°C, place degutted sandfish and heat water to boiling temperature. Cook for 1 hr with continuous stirring.
Cleaning	Scrub away spicule layer by rubbing on concrete floor, using steel brushes or coral. Some fishers scrub boiled sandfish with papaya leaves, soak in water or bury in sand overnight to soften spicule layer	Mixed with papaya leaves for 1 hr to soften spicule layer, boiled with salt for 1 hr, then brushed to scrub off spicules	Scrub away spicule layer for 20 min using a scrubbing pad
Second boiling	Repeat boiling if needed; cooking time varies according to local practice		Boil cleaned sandfish for 1 hr with continuous stirring; cool in tap water
Primary drying	Keep cooked sandfish about 30 cm over hot coals	Smoked for 1 hr to 1 day using wood coals	Sun drying on racks until firm and hard
Secondary drying	Sun drying until firm and hard	Dried for 3-5 days until firm and hard	

[z]Documented by this study based on site visits to processors and traders in the provinces of Batangas, Cebu, Palawan, Davao del Sur, Quezon, Misamis Occidental, Tawi-Tawi, and Zamboanga del Sur.
[y]Documented in Palawan province
[x]Source: Bassig RA (2012, personal communication); Head, Chemical & Microbiological Section of the National Fisheries R&D Institute - Department of Agriculture (www.nfrdi.da.gov.ph)

the processing and drying methods vary with location but generally follow the sequence of operations shown in Figure 3. There are many variations documented by other investigators; Bassig *et al.* (2010) was able to document 11 different processing methods used in the provinces of Pangasinan, Palawan and Davao.

Results of proximate and microbial analysis of samples that were processed and dried using traditional or improved methods are shown in Table 4. Moisture

Table 4. Quality comparison of dried *H. scabra* samples processed by traditional and improved methods

PROPERTY	SOURCE			PRESCRIBED LEVELS[w]
	BOL[z]	COR[y]	Commercial product[x]	
Moisture content (% wb)	15.54	10.80		15
NaCl content (% wb)	19.14	4.43	20.91	2.5
Ash content (% wb)	21.42	5.57	40.71	2.5
Total plate count (CFU g^{-1})	5.97E+03	5.20E+04	1.30E+03	1.00E+05
Yeast and mold count (CFU g^{-1})	< 10	< 10	<100	1.00E+03

[z]Processed and dried by fisherfolk in Bolinao (BOL), Pangasinan using traditional methods
[y]Processed and dried by research team in Coron (COR), Palawan using improved methods
[x]Product of China, provided by Dr. Annette Meñez (professor, UP Marine Science Institute); yeast count only
[w]Based on PNS / BAFPS 128:2013; for microbial analysis, values represent the maximum achievable levels under good manufacturing practices for dried and salted fish under PNS / BFAD 04:2006

content was comparable to or lower than the maximum specified by Philippine standards for dried sandfish. However, salt and ash content of trepang produced by Bolinao fishers were much higher than the maximum level prescribed. Microbial loads were comparable to recommended levels.

Trepang produced in Coron using improved methods also showed levels of salt and ash that were higher than the recommended levels (Table 4), although these were much lower compared to Bolinao samples; however, since these methods do not involve burying the material in sand (prior to cleaning the spicule layer) or use salting to aid the drying process, these levels may be natural for dried sea cucumber. Further sampling and analysis are recommended to confirm these results. Microbial analysis also showed levels below the maximum for dried fish. For comparison, total plate count and yeast and mold count of dried *H. scabra* using processing methods developed by the NFRDI were 4.0 x 103 CFU g-1 and 6.2 x 103 CFU g-1(Bassig *et al.* 2010). Trepang product from China also showed high levels of salt and ash; the ash content was almost double the levels found in traditionally processed product from Bolinao (Table 4).

Live sandfish can be sold individually or on a per kg basis. In Lopez Jaena, live *H. scabra* was sold for PhP70 kg^{-1}. In Pagbilao, *H. scabra* was sold at PhP100 per piece. Price information from interviews with two consolidator-exporters in Coron showed that species and size of trepang were the main considerations in determining price, followed by quality. Main defects that were considered in determining price included presence of decay and excessive moisture content. For example, *H. scabra* products that were greater than 70 g per piece and properly dried were classified as Class A–Extra Large and priced at PhP5,300 per piece (Table 5). Dried specimens weighing 40-69 g were considered as Class A–Large and priced at PhP4,300 per piece. Weight ranges for other size classes could not be determined. If the product was in a semi-dry condition, then 30-40% of the weight was deducted and the buying price adjusted accordingly.

Majority of trepang products observed during the survey appeared to be of lower grades (Figure 5a to 5d). The defects observed included undersized product, deformities (twisting, presence of holes and cracks) and presence of decay. In contrast, the sample trepang from China is relatively straight,

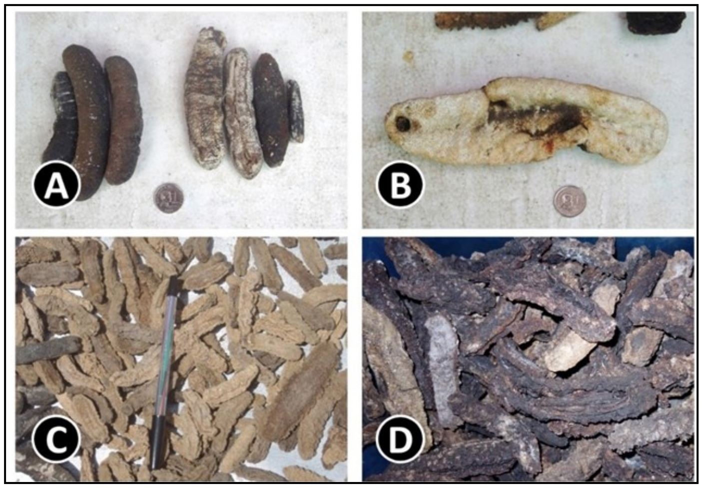

Figure 5. Quality of traditionally processed sea cucumber: (A) visible traces of spicule layer, (B) cracked and decaying, (C) undersized, (D) twisted shapes.

Table 5. Buying prices of dried sandfish in Coron, Palawan according to size and quality

Class[z]	Size	Buying Price[y] (PhP kg^{-1})	(US$ kg^{-1})
A	XL	5,300	124.85
	L	4,300	101.30
	M	3,100	73.03
	S	2,350	55.36
	XS	2,050	48.29
	XXS	1,500	35.34
B	L	1,350	31.80
	M	1,200	28.27
	S	1,100	25.91
	XS	1,000	23.56
	XXS	700	16.49

[z]*Class A - well dried, no cuts or cracks, no odor of decay, straight and has shape characteristic of the species; Class B - semi-dried, may have cuts, cracks, decay, twisted shape, scorching*
[y]*2013 prices obtained from a Coron buying station; currency exchange rate of PhP42.45 to US$1 (Antweiler 2018)*

although the material also exhibits shrinkage and collapse of the body wall (Figure 6).

Sandfish is also sold in chilled form in the stalls of Arranque public market in Sta. Cruz, Manila. The sandfish is displayed in plastic tubs containing a mixture of ice and water (Figure 7a). Prices vary according to size. If unsold, the sandfish is stored frozen for sale the next day. According to retailers, the sandfish can be kept and handled in this manner for several months without spoilage. The product is ready to cook and is preferred by local restaurants in the area rather than the dried form. Only a few stalls sell sea cucumber in dried form since this takes more time to prepare for cooking; possible mold was observed in some products indicating inadequate drying and/ or improper storage (Figure 7b).

Figure 6. Retail pack of dried sea cucumber product from China. Product is well dried and straight, although body wall is also shrunken and collapsed similar to Philippine products. Sample provided by A. Meñez.

Material Balance for Sandfish Processing

Coron samples had a minimum and maximum live weight of 557.0 g and 1,237.0 g, respectively. The average weight after degutting was 57% of the live weight. In contrast, Bolinao samples were much smaller than sandfish from Coron, with a minimum and maximum live weight of 88.8 g and 590.4 g, respectively. When degutted, the average remaining weight was 52% of the live weight (Table 6). Similarly, Skewes *et al.* (2004) determined that body weight of sandfish after degutting was 52.3% of the live weight.

Table 6. Profile of sandfish samples for mass balance analysis

PARAMETER	SOURCE[z]	
	COR	BOL
Live animal weight (w_{lv}, g)		
Minimum weight	557.0	88.8
Maximum weight	1237.0	590.4
Average weight	839.0	293.0
Standard deviation	191.6	142.5
Degutted sample weight (w_{dg}, g)		
Minimum weight	291.0	39.4
Maximum weight	665.0	364.3
Average weight	476.1	155.9
Standard deviation	109.7	86.5
$w_{dg} : w_{lv}$ ratio	0.57	0.52
Product recovery (%)[y]		
Minimum	6.56	4.41
Maximum	11.14	8.22
Average	8.82	6.19
Standard deviation	1.28	1.19

[z]COR = Coron (Palawan); BOL = Bolinao (Pangasinan)
[y]Calculated as the ratio of product weight to degutted weight x 100

Figure 7. Sea cucumber is sold in the Arranque wet market of Sta. Cruz, Manila in chilled ready-to-cook form (left) for the use of local restaurants. Only a few shops sold sea cucumber in dried form (right); white or grayish areas on trepang could indicate the presence of mold, indicative of inadequate drying or re-absorption of moisture.

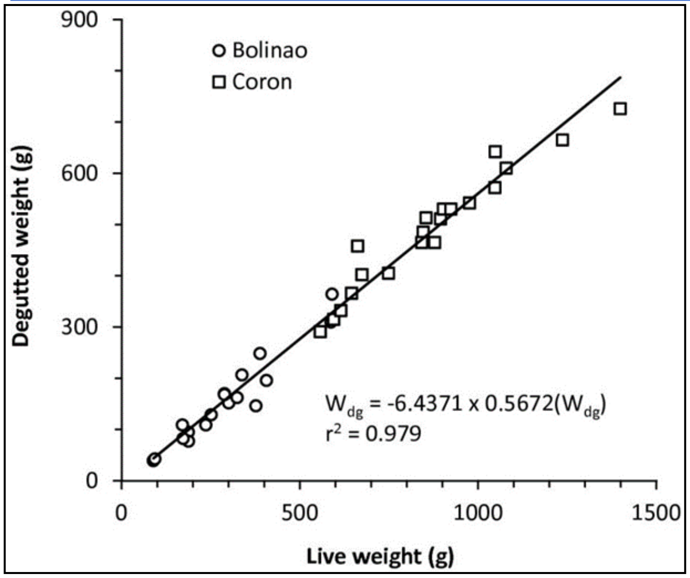

Figure 8. Relationship of degutted weight of sandfish to live weight

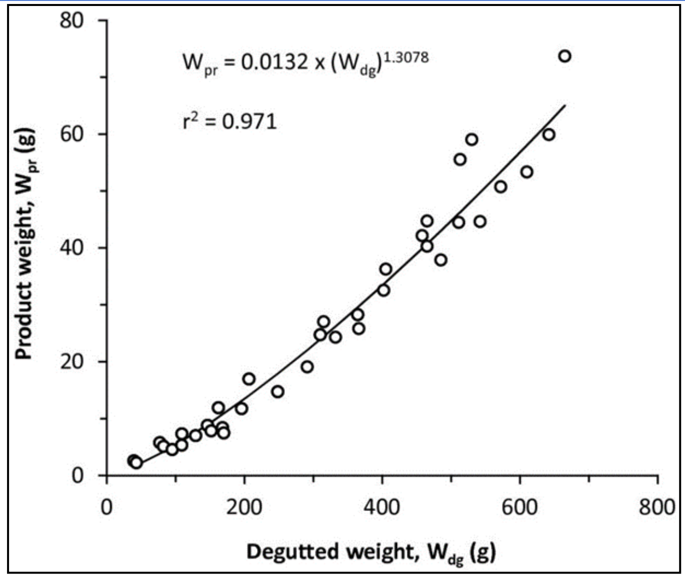

Figure 9. Relationship of product recovery or dry matter content of sandfish to degutted weight.

Simple linear regression analysis showed that degutted weight correlated well with live weight (r2 = 0.979); the relationship is shown in Figure 8 for pooled samples from Coron and Bolinao. Product recovery increased with degutted weight (r2 = 0.966) as shown in Figure 9; as degutted weight increased (i.e. animals with larger sizes), product recovery per unit degutted weight increased. Based on the Bolinao samples, there was no significant difference in yield of trepang between the secondary drying methods used ($p > 0.05$); the average material recovery of trepang was 6.19%. The final moisture content of trepang from Bolinao was 0.251 ± 0.058 g g-1 dry matter.

Average product recovery for Coron samples was 8.82%; this was significantly greater ($p < 0.05$) compared to samples from Bolinao (Table 6). These results imply that higher income could be realized by allowing sandfish to grow to larger sizes before harvesting. The benefits are twofold: higher product recovery leads to a higher saleable weight, and the larger sizes command higher prices. However, the higher figure for material recovery was still lower than the assumed value of 10% by Brown *et al* . (2010). Using degutted weight as the basis, the largest weight loss during processing occurs during the first and second boiling stages, followed by primary drying (Figure 10). Table 7 shows published values of product recovery for different species of sea cucumber of the genus *Holothuria* for comparison.

Valuation of Dried Sandfish produced from Field Trials

The size profile and estimated value for dried samples from Coron and Bolinao are shown in Table 8. Sizes of most Coron samples fell in the large category with a total product weight of 785 g; in comparison, Bolinao samples were mostly medium and extra-small with a total product weight of 181 g. Hence, for the same number of samples, the estimated total value for Coron and Bolinao samples was PhP3,351.73 and PhP431.95, respectively; this corresponds to an almost 8-fold increase in total value. On an overall weight basis, the value of Bolinao samples was estimated at PhP2,385.15 kg^{-1}; in comparison, the corresponding value of Coron samples was more than 1.8 times higher at PhP4,269.72 kg^{-1}.

Fishers in Pagbilao classified semi-dried sandfish into Classes A, B and C based on size, shape, appearance and texture. Class A samples were priced at PhP4,285-5,000 per kg, while Class B samples were priced at PhP2,143 per kg. In comparison, small deformed samples were priced at PhP1,000 per kg (Figure 11). In Hong Kong, trepang made from sandfish can be found being sold in wet markets or high-end shops located in tourist districts (Figure 12); in one shop, dried sandfish was priced at PhP10,954 – 11,606 per kg (PhP6.52 = HK$1 in 2017) depending on the size.

Dried sea cucumber coming from the Philippines has a reputation for very poor quality. This has been a long-standing perception of Philippine products which was confirmed by a retailer in a Hong Kong wet market; interviews conducted by Clarke (2002) also show that traders in Hong Kong believe that the best trepang products come from Japan, South Africa, Australia and the Pacific coast of South America. Trepang from Indonesia, the Philippines

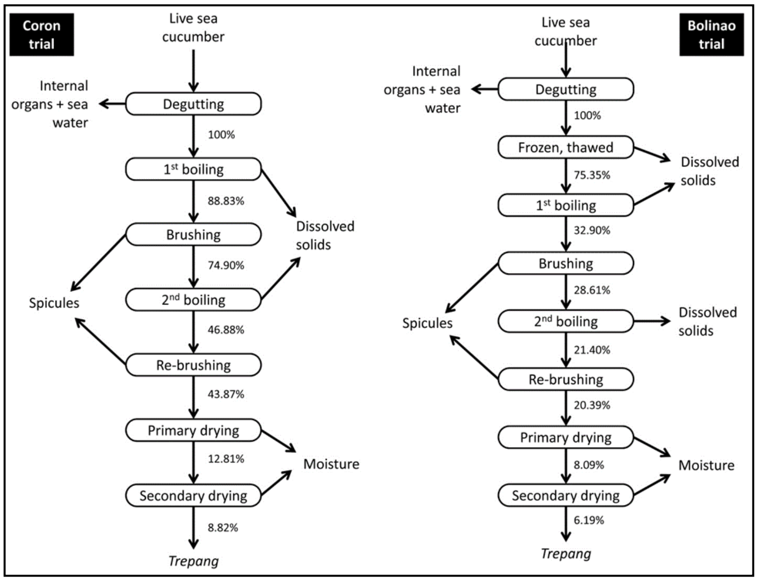

Figure 10. Mass balance analysis of sandfish processing and drying for Coron (left) and Bolinao (right) trials.

Note: Figures in percent represent the fraction of the original degutted weight of 18 sandfish samples for each field trial.

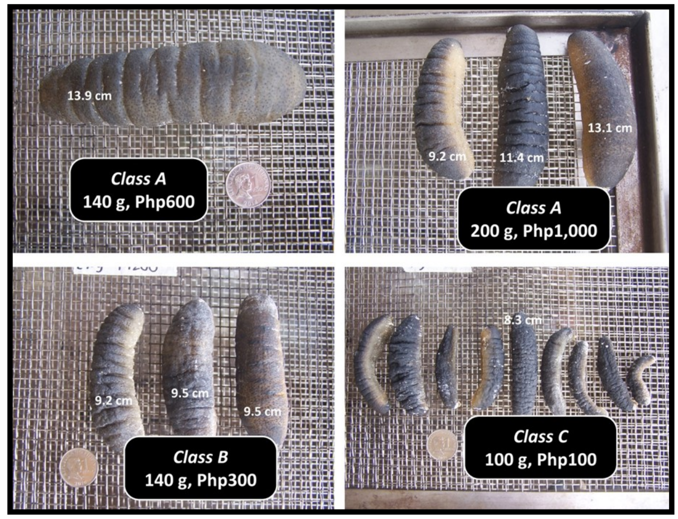

Figure 11. Semi-dried *H. scabra* samples, classified and priced by members of a fishers' association in Pagbilao, Quezon.

Note: Based on the valuation, Class A, B and C samples were worth PhP4,286-5,000, PhP2,143, and PhP1,000 per kg, respectively. The coin in the photos has a diameter of 24 mm. Length of all Class A and B samples is indicated on each specimen, except for Class C where only the length of the largest specimen is given.

Table 7. Published yield of dried product based on degutted weight of some sea cucumbers of the genus *Holothuria*

COMMON NAME	RECOVERY (%)^{z}	REFERENCE
Lollyfish	14.7	Ngaluafe and Lee (2013)
Snakefish	15.1	Ngaluafe and Lee (2013)
White teatfish	23.3	Ngaluafe and Lee (2013)
Elephant trunkfish	24.2	Skewes et al (2004)
Golden sandfish	15.2	Purcell et al (2009)
Sandfish	9.4	Skewes et al (2004)
	8.1	
Black teatfish	18.1	Purcell et al (2009)

^{z}Computed as the ratio of weight of dried product to fresh degutted weight

Table 8. Size profile and estimated value of *trepang* produced from sandfish samples

SIZE CLASS^{z}	% OF TOTAL MASS OF SAMPLES		% of TOTAL VALUE^{x} OF SAMPLES	
	COR^{y}	BOL	COR	BOL
XL	24.8	0.0	30.8	0.0
L	53.6	0.0	54.0	0.0
M	19.1	29.3	13.8	38.1
S	2.5	9.4	1.4	9.2
XS	0.0	61.3	0.0	52.7
Total (%)	100.0	100.0	100.0	100.0
	Total Mass (g)		Total Value (PhP)	
	COR	BOL	COR	BOL
	785.0	181.1	3,351.73	431.95

^{z}XL-extra large, L-large, M-medium, S - small, XS - extra small
^{y}COR = Coron (Palawan), BOL = Bolinao (Pangasinan)

and China are perceived to have poor quality due to low-value species and poor processing methods. However, when a Pagbilao trepang sample was shown to the Hong Kong retailer, both moisture content and visual quality of the product were considered acceptable. Only the slightly flattened shape of the sample was undesirable in the opinion of the retailer; in comparison, trepang imported from Australia had a rounded cross-section but showed very visible traces of spicules (Figure 12). To gain better acceptability, retention of a rounded shape in dried sandfish needs further investigation. A survey of chefs, wholesalers and retailers in Singapore by Lo (2004), however, did not indicate that roundness was a significant consideration. For these stakeholders, exterior appearance, size, moisture content, flesh thickness and species were more important attributes. A comparison of the Pagbilao trepang with examples of well-processed sandfish illustrated by Purcell (2014b) also shows that color and appearance is similar.

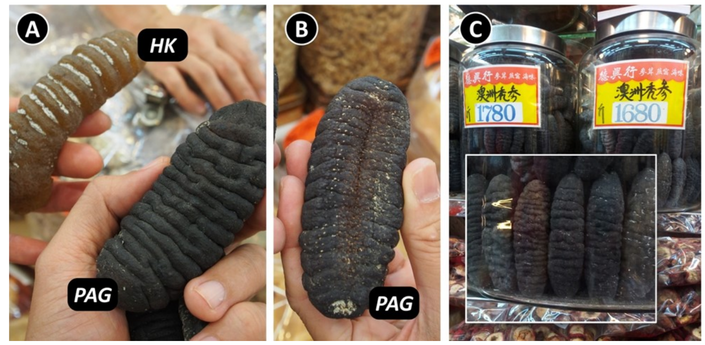

Figure 12. Comparison of dried sandfish sold in a wet market in Hong Kong (HK) (A) with sandfish processed and dried in Pagbilao (PAG), Quezon, Philippines (A, B).

Note: The HK product (imported from Australia) exhibits visible traces of spicules, while the PAG sample is practically spicule-free on both dorsal (A) and ventral sides (B). The visual quality of the PAG sample is similar to trepang sold in tourist shops of Hong Kong that are priced at PhP10,954 – 11,606 per kg (PhP6.52 = HK$1 in 2017) (C).

SUMMARY AND CONCLUSION

A simple survey of processing, drying, and handling methods for producing trepang from sandfish (*H. scabra*) was conducted in municipalities and cities of the Philippine provinces of Batangas, Cebu, Palawan, Davao del Sur, Quezon, Misamis Occidental, Tawi-Tawi, and Zamboanga del Sur. The survey confirmed that the industry in the Philippines is still primarily artisanal and multi-species in nature, with gathering, processing and drying mostly conducted on a small scale by fisherfolk. Processing and drying methods were simple and used rudimentary implements and facilities; improvements to these methods are needed for better food safety and quality of the final product.

Mass balance analysis showed that each kilogram of degutted sandfish that was processed and dried gave a product recovery of less than 9%. Since live weight of sandfish was generally halved after degutting, then about 2 kg of live sandfish was needed to produce 180 g of trepang. Allowing sandfish to grow to larger sizes (600 g or higher) before harvesting gives a higher recovery of high-value product; buying prices are also higher as size increases. Delaying harvest also allows sandfish more opportunities to spawn, giving sufficient time for wild stocks to recover. With improved processing and drying methods, proper resource management, and sustainable harvesting practices, it is possible for Philippine trepang made from sandfish to be competitive in international markets.

The estimated price of semi-dried sandfish that was mechanically processed and dried locally showed a significant increase in value compared to trepang that was produced using traditional methods. Locally produced trepang showed comparable quality with products sold in Hong Kong for more than PhP10,000 per kg; texture, moisture content and appearance (absence of spicules) were considered acceptable. However, further studies are needed to achieve the rounder shape preferred by retailers of the dried product. A survey of sea cucumber products sold in the wet markets and tourist shops of Hong Kong could also be done to serve as a benchmark for Philippine products. In addition, internal organs represent a significant byproduct that is currently discarded or eaten as a local delicacy in some areas; further studies on utilization and processing of this byproduct for production of valuable bioactive products need to be conducted. Lo (2004) also recommended a similar direction for future research.

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LITERATURE CITED

ANTWEILER, W. (2018). Foreign Currency Units per 1 U.S. Dollar, 1950-2016. Available at https://www.icaew.com/library/subject-gateways/financial-markets/knowledge-guide-to-exchange-rates/historical-exchange-rates. Accessed on 13 October 2018.

BAFPS [Bureau of Agriculture & Fishery Product Standards]. 2013. PNS/BAFPS 128: Philippine National Standard – Dried Sea Cucumber.

BASSIG R.A., OBINQUE A.V., RAGAZA R.J., SALEM G.M., CABIGAO J.S. (2010). Assessment and improvement of processing methods for high commercial value sea cucumber in the Philippines. Paper presented at the 2nd National Forum on Sea Cucumber Fisheries Management. 23-24 Sept 2010; Quezon City.

BFAR [Bureau of Fisheries & Aquatic Resources]. (2013). BFAR Administrative Circular No. 248: Size Regulation for Sea Cucumber Collection and Trade. Available at http://www.bfar.da.gov.ph/LAW?id=251-240. Accessed on 03 April 2016.

BORDBAR S., ANWAR F., SAARI N. 2011. High-value components and bioactives from sea cucumbers for functional foods – a review. Marine Drugs. 9: 1761-1805. doi:10.3390/md9101761

BROWN, E.O., M.L. PEREZ, L.R. GARCES, R.J. RAGAZA, R.A. BASSIG AND E.C. ZARAGOZA. (2010). Value Chain Analysis for Sea Cucumber in the Philippines. Studies & Reviews 2120. The WorldFish Center, Penang, Malaysia. 44 pp.

CLARKE S. (2002). Trade in Asian Dried Seafood: Characterization, Estimation and Implications for Conservation. WCS Working Paper No. 22. Wildlife Conservation Society: Bronx, New York. Available from https://library.wcs.org/search.aspx?Search=beche+de+mer. Accessed on 28 May 2018.

CONAND C. (2004). Present status of world sea cucumber resources and utilization: an international overview. In: Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A. (editors). FAO Fisheries Technical Paper: Advances in Sea Cucumber Aquaculture and Management. 463: 13-23.

CONAND, C, SHEA S, TO A. (2014). Beche-de-mer trade statistics for Hong Kong in 2012. SPC Beche-de-Mer Info. Bull. 34: 43-46.

JUN A. (2002). Trepang exploitation in the Philippines: updated information. SPC Beche-de-Mer Info. Bull. 17:17–21.

LO TH. (2004). Valuation of sea cucumber attributes through laddering. SPC Beche-de-Mer Info. Bull. 20: 34-37.

MAYER, A.M.S., RODRIGUEZ, AD, BERLINCK, RGS, FUSETANI N. (2011). Marine pharmacology in 2007-8: Marine compounds with antibacterial, anticoagulant, antifungal, anti-inflammatory, antimalarial, antiprotozoal, antituberculosis, and antiviral activities affecting the immune and nervous system, and other miscellaneous mechanisms of action. Comp Biochem Physiol, Part C. 153: 191-222.

NGALUAFE, P., and LEE J. (2013). Change in weight of sea cucumbers during processing: Ten common commercial species in Tonga. SPC Beche-de-Mer Info Bull. 33: 3-8.

PURCELL S.W., GOSSUIN H., AGUDO N.S. (2009). Changes in weight and length of sea cucumbers during conversion to processed beche-de-mer: Filling gaps for some exploited tropical species. SPC Beche-de-Mer Info. Bull. 29: 3-6.

PURCELL S.W., MERCIER, A., CONAND C., HAMEL J.F., TORAL-GRANDA MV, LOVATELLI A, UTHICKE S. (2011). Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. Fish and Fisheries. DOI: 10.1111/j.1467-2979.2011.00443.x

PURCELL, S.W., SAMYN, Y., CONAND, C. (2012). Commercially Important Sea Cucumbers of the World. FAO Species Catalogue for Fishery Purposes No. 6. UN-FAO, Rome. 124 p. Available at http://www.fao.org/docrep/017/i1918e/i1918e.pdf. Accessed on 27 February 2016.

PURCELL S.W. (2014a). Value, Market Preferences and Trade of Beche-De-Mer from Pacific Island Sea Cucumbers. PLoS ONE 9(4): e95075. doi:10.1371/journal.pone.0095075

PURCELL S.W. (2014b). Processing Sea Cucumbers into Beche-de-Mer: A Manual for Pacific Island Fishers. Southern Cross University, Lismore, and the Secretariat of the Pacific Community, Noumea. 44 p.

PURCELL S., CHOO P.S., AKAMINE J., FABINYI M. (2014). Alternative product forms, consumer packaging and extracted derivatives of tropical sea cucumbers. SPC Beche-de-Mer Information Bulletin. 34: 47-52.

PURCELL S.W., WILLIAMSON D.H., NGALUAFE P. (2018). Chinese market prices of beche-de-mer: Implications for fisheries and aquaculture. Marine Policy. 91: 58-65.

SCHOPPE S. (2000). Sea cucumber fishery in the Philippines. SPC Beche-de- Mer Info. Bull. 13: 10-12.

SEWELL M.A. (1991). Measurement of size in live sea cucumbers. SPC Beche-de-Mer Info. Bull. 3:4-5.

SKEWES T., SMITH L., DENNIS D., RAWLINSON N., DONOVAN A. and ELLIS N. (2004). Conversion ratios for commercial beche-de-mer species in Torres Strait. Australian Fisheries Management Authority, Torres Strait Research Program, Final Report. 20 p.

YAPTENCO K.F., PARDUA S.N., DUQUE J.A.C., PANGAN, R.S, (2017). Moisture sorption isotherms and shelf life prediction for whole dried sandfish (*Holothuria scabra*). Agric Eng Int: CIGR J Open. 19: 176-186. ■