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Research Paper

Yield and product quality of processed sandfish *(Holothuria scabra)* using different processing techniques

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Abstract. Four different techniques in processing sandfish: a) MB-method described by Brown *et al.* (2010), b) MN- from NFRDI, per Pardua *et al.* (2018), and two variations of method from Purcell (2014), c) MP1, and d) MP2 which were slightly modified and tried to compare resulting product quality and yield from freshly gutted sandfish. This demonstration was to encourage sandfish ranch managers to add value to their sandfish and ensure better earnings. Twenty-four sandfish individuals (350 to 870 g) harvested from the sea ranch site at Maliwaliw Island were used for processing at six individuals per technique. Results show that live sandfish weight was reduced to 45% after gutting. MB had the highest weight percent recovery from gutted weight at 10.75%, not significantly different ($p > 0.05$) from MN at 9.65% but significantly higher ($p < 0.05$) from MP1 (9.38%) and MP2 (9.50%). In terms of product quality, bigger sandfish >600 g produced good quality products when processed correctly. *Bêche-de-mer* is priced based on three criteria: quality of the product, size length, and weight. Although there is no single best-practice method for processing sandfish, sea ranch managers may opt to adopt the MB and MN for a simpler procedure to save time and resources, and higher product yield for better income.

Keywords: Sandfish, processing techniques, yield, balat, product quality.

INTRODUCTION

Sea cucumbers are worm-like echinoderms that live on the seafloor. Species like sandfish (*Holothuria scabra*) are regarded as one of the highest-valued commodities globally where they are utilized mostly for food and perceived medicinal benefits (Esmat *et al*., 2013). People across Asia have been using sea cucumbers to treat joint problems such as arthritis (Bordbar *et al*., 2011; Kiew and Don, 2012). More recently in Europe, sea cucumbers are also used to treat cancers and to reduce blood clots as sea cucumbers are found to exhibit anticoagulant, antioxidant, anticancer, antimicrobial, and antiviral properties (Rasyid *et al.*, 2021; Kareh *et al.*, 2018; Khotimchenko, 2018). According to Purcell *et al.* (2018), the price of sea cucumbers in the international market increased sharply as demand for this Asian delicacy, as well as the new interest from western pharmaceutical businesses, increased.

Sandfish and other sea cucumber species have been harvested and sold as dried, non-perishable items for a long time (Ram *et al*., 2016; Purcell *et al.*, 2014). Dried sea cucumber products are called *bêche-de-mer* (BDM) in India and the Pacific, *trepang* in Indonesia and northern Australia, and *balat* in parts of Malaysia and the Philippines (Akamine 2013). Premium-size and premium-quality dried sandfish have an average price of 369 US dollars per kilogram and extra-large premium-quality specimens can fetch up to USD 1898/kilo in the international market (Bassig *et al*., 2021). The thick body wall of sandfish, which primarily makes it more valuable (Akamine, 2002), is composed of bio-medically important compounds such as peptides, collagen, gelatin, polysaccharide, and saponin (Oh *et al*., 2017). China, Hong Kong, Taiwan, Singapore, and Malaysia are among the major Asian markets for Trepang (Purcell *et al.*, 2018; Perez and Brown, 2012).

The Philippines whose coastal waters are home to about 200 sea cucumber species, plays a major role in the dried sea cucumber trade in the world market (Juinio-Meñez and Samonte, 2016; Brown *et al.*, 2010). Among the 35 commercially important species listed in the Philippines National Standards for sea cucumber (BAFPS, 2013), sandfish is the most expensive at Php 5326.00 or USD108/kg in the local market (Pardua *et al*., 2018). In the central Philippines, particularly in the Eastern Visayas, sandfish are commonly found in the coastal waters of Samar and Leyte (de la Cruz *et al.*, 2015). However, spurred by high international market prices, fishing pressure has increased in the poorly managed sea cucumber fishery nationwide (Purcell *et al.*, 2018; Perez and Brown, 2012). The unregulated gathering of sea cucumbers depleted the resource and consequently a decline in export volume (Choo, 2008).

To enhance the recovery of depleted stocks of sandfish in the wild, extensive research on the production technologies for sandfish have been carried out in the Philippines (Juinio-Meñez *et al.*, 2017). In the North-western part of the country, the University of the Philippines-Marine Science Institute (UP-MSI) piloted sea ranching to provide a supplemental source of income to municipal fishers and at the same time allow the wild stocks to recover (Juinio-Meñez *et al.*, 2012).

Replicating good practices employed by UP-MSI, Maliwaliw Island in Eastern Samar became the pilot site of the sandfish sea ranching in the Eastern Visayas to address the collapsed sea cucumber fisheries in the area (Villamor *et al*., 2021). The Maliwaliw community that once experienced local extinction has successfully brought back the sandfish in the area seven years after the implementation of the ACIAR-funded community-based sandfish sea ranching. Recently, sea ranch co-managers are able to produce marketable size (320 g) to premium size sandfish (>600 g). However, the lack of knowledge in the proper processing of sandfish to satisfy the export market has forced them to sell their sandfish fresh at low prices. Hence, middlemen and local processors take advantage of the fishers selling their sandfish fresh. To help the sandfish ranch managers, four different processing techniques were tried to evaluate the resulting product quality and yield of processed sandfish.

METHODOLOGY

Study site

This study was conducted on Maliwaliw Island, Salcedo, Eastern Samar (11.098714°N, 125.585800°E), the pilot site of sandfish sea ranching in Eastern Visayas (Figure 1).

Sample collection and preparation

A total of 24 live and uninjured sandfish individuals weighing 300 to 870 g collected from the sea ranch were bought from a sandfish co-manager. Six pieces of sandfish were used per processing technique. Sandfish were washed clean using seawater and arranged in a single layer on a flat surface for about 5 minutes to allow the animals to relax and expel water before their wet weights were recorded. Sandfish were then patted dry using a paper towel and weighed individually before degutting and then re-weighed individually using a kitchen scale.

The materials and utensils needed for processing such as a weighing scale, sharp knife, large wok, wooden ladle with a long handle, strainer with a long handle, commercially available brush with plastic bristles, containers with cover, a container with slits, basins, polypropylene resealable bags, papaya leaves, coarse-grade salt, and clean seawater were made ready.

Processing

Four different established techniques in processing sandfish: a) MB (Brown *et al*., 2010), b) MN (NFRDI, per Pardua et. al., 2018), and two variations of the method from Purcell (2014), c) MP1, and d) MP2, were employed to compare resulting product quality and product yield from fresh/gutted sandfish. MB processing steps were adopted from the commonly used techniques of sea cucumber processors in Palawan, Philippines. Steps involved in the MN technique were based on a procedure developed by the National Fisheries Research & Development Institute (NFRDI) of the Department of Agriculture also in the Philippines. Whereas MP1 and MP2 were based on the Manual for processing sea cucumbers into *beche-de-mer* designed for fishers in the Pacific Islands (Purcell, 2014). Detailed steps of each processing technique are shown in Figure 2.

Post-harvest processing requires a relatively simple and traditional technique that involves post-capture handling, cleaning, cooking, and drying. Suggested steps for processing sandfish from the four techniques were followed with slight modifications.

Degutting

At the ventral side of the anus, a 1-inch incision was made using a sharp stainless knife. The internal organs and water were then squeezed out of the opening. Subsequently, gutted samples were placed on a flat surface to allow them to retain their original shape. Each sandfish was again weighed to obtain the gutted weight.

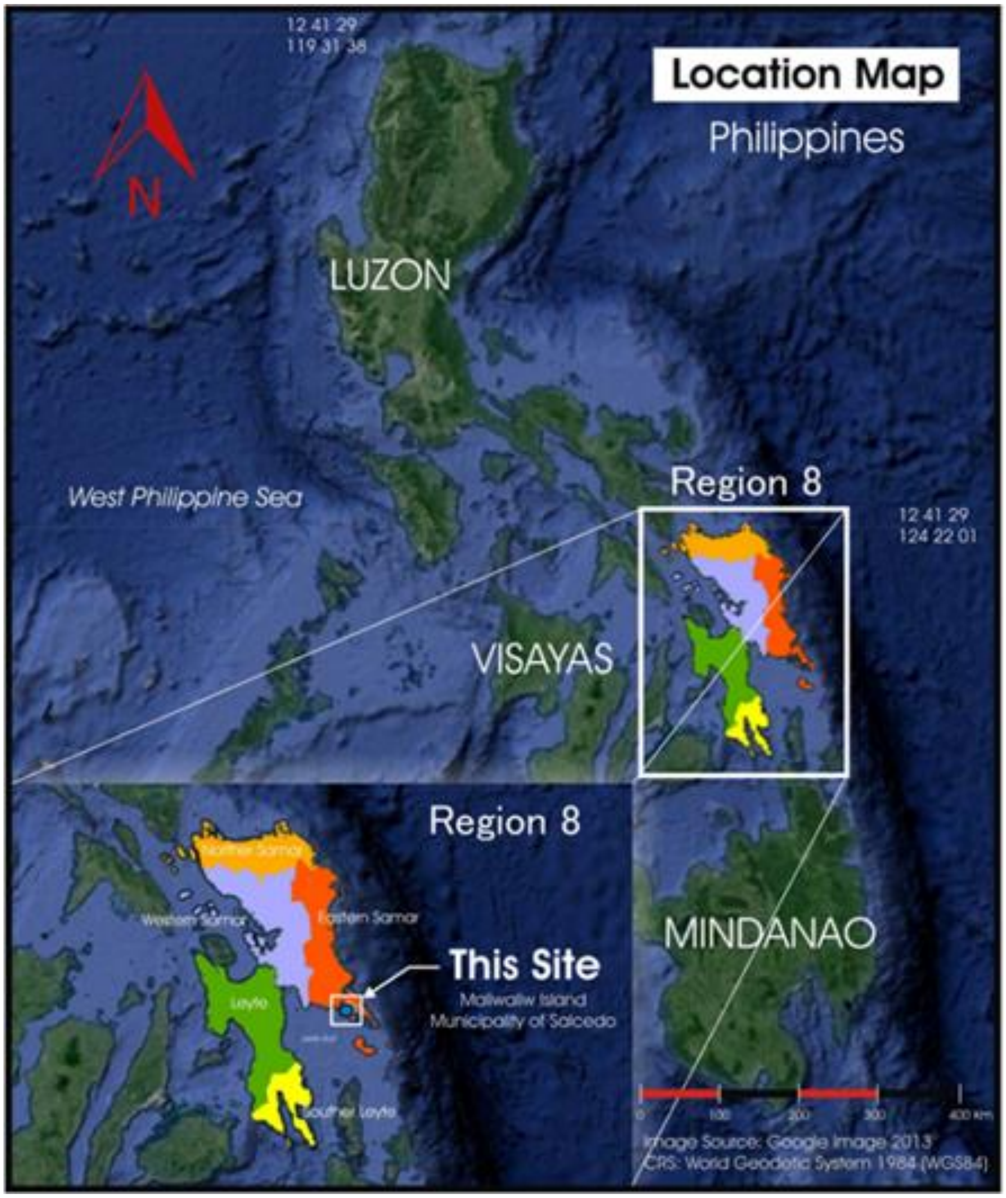

Figure 1. Location of sandfish sea ranch site in Maliwaliw Island, Salcedo, Eastern Samar, Philippines. Map image source: Google image 2013. CRS: World Geodetic System 1984 (WGS84).

Cooking

All samples in the four techniques have undergone the process of first and second cooking at varying times. MN and MB samples were first cooked in a wok with pre-heated seawater at 60°C until the temperature gradually increased to 100°C for one and two hours, respectively. MP1 and MP2 samples were first cooked in pre-heated seawater at 60°C for 30 min. For the second cooking, MN and MB samples were cooked again in pre-heated seawater for an hour while MP1 and MP2 were cooked for another 30 min only. However, MP1 and MP2 samples were subjected to third cooking for another 30 minutes after smoke-drying for three hours. The total cooking time for MB was three hours, MN was two hours, and MP1 and MP2 were an hour and a half each. Clean seawater was used in cooking the sandfish for all four processing techniques. According to Purcell (2014), saltwater retains the color of sea cucumber and keeps the skin from being damaged. All cooking processes were also done with constant stirring using a wooden ladle.

Ossicle removal

All techniques vary when it comes to softening and removing sandfish ossicles or calcareous deposits. After the first cooking, samples were taken out of the wok and

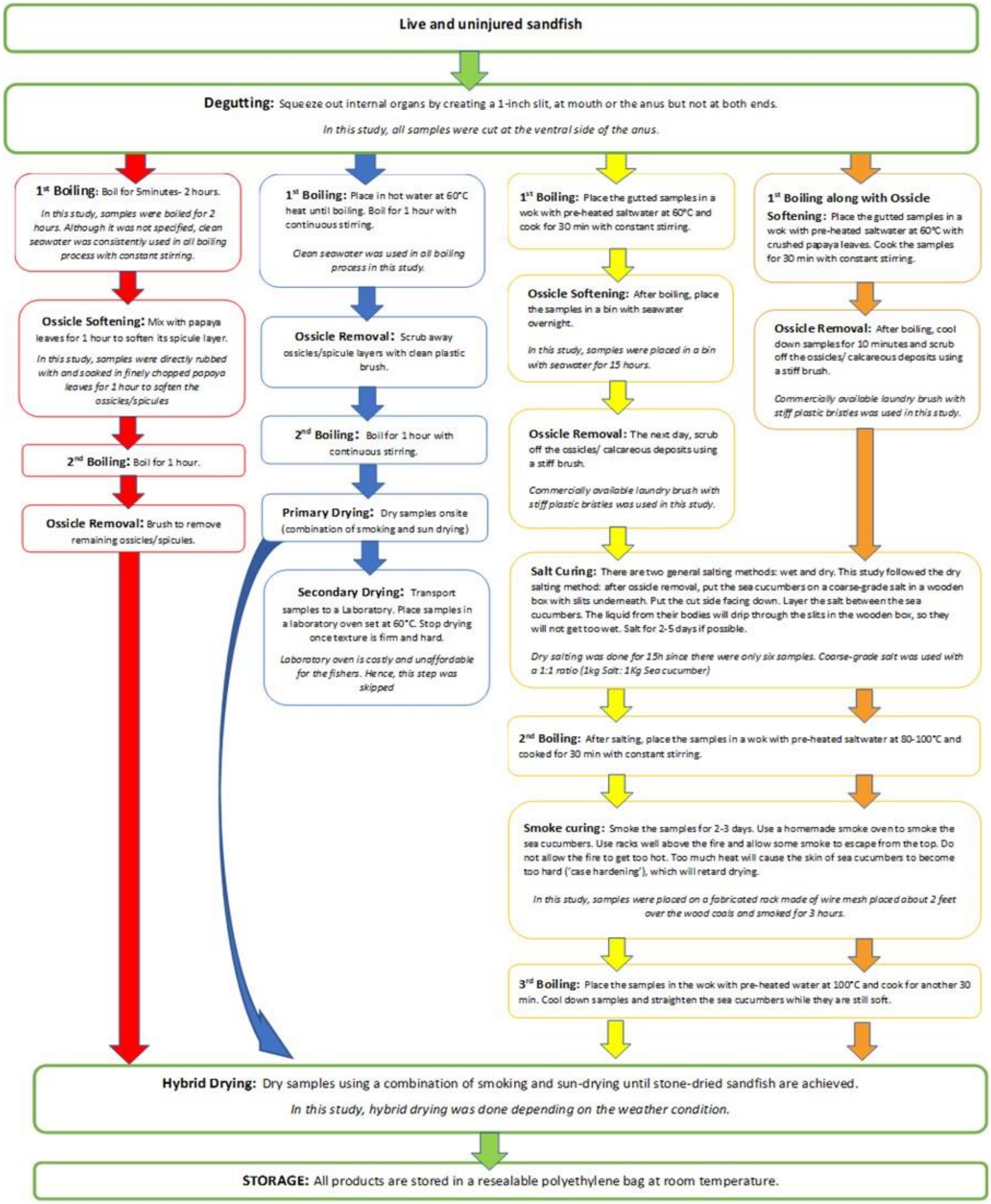

Figure 2. The steps followed were adopted from the four established techniques in processing sandfish: MB (Brown *et al.*, 2010) in red, MN (NFRDI) in blue, MP1 (Purcell, 2014) in light yellow, and MP2 (Purcell, 2014) in orange. Boxes and arrows in green means that all samples were subjected to the same action. Fonts in italics are some of the modifications applied step.

cooled for 5 min. For MB, samples were directly rubbed with and then soaked in finely chopped papaya leaves for an hour to soften the ossicles after the first cooking. Scrubbing off the ossicles was carried out after the second cooking. For the MN technique, ossicles were directly scrubbed off right after the first cooking using a commercially available brush with stiff plastic bristles. In MP1, samples were soaked in a container with seawater overnight after the first cooking. The ossicles were then scrubbed off the next day using a stiff brush. In MP2, crushed papaya leaves were added during the first cooking to soften the ossicles. The cooked sandfish were then allowed to cool before scrubbing the ossicles off. There are four ways of removing calcareous deposits under Purcell's technique, but only two variations were adopted in this study.

Salt-curing

Among the four techniques, only the two variations reported by Purcell use salt-curing. Two general salting methods are highlighted in Purcell's (2014) manual, but in this study, dry salting was employed for MP1 and MP2. After the first cooking, sandfish were placed in a container with slits underneath. A plastic container was fitted with bamboo slats and coarse-grade salt was layered on the slats. After the first cooking, the sandfish were arranged on the layered salt with the cut side facing down. Salt was layered again between each sample and on top at a ratio of 1:1 (1 part salt to 1 part sandfish) by weight. Moisture from the cooked sandfish will drip through the bamboo slats to the container. In Purcell's (2014) manual, salt-curing is done for 2 to 5 days, but in this study, salt-curing was done overnight (15 hours) since there were only six samples per procedure.

Drying

All techniques employed hybrid drying which is a combination of smoke curing and sun-drying depending on the suitability of prevailing weather conditions. However, MP1 and MP2 samples were also smoked for three hours after the second cooking and alternately smoke-cured and sun-dried after the last cooking process. Hybrid drying was done until the stone-dried product was produced (Figure 2).

Smoke curing.

After the last cooking process of each technique, samples were placed in a fireplace over a fabricated rack positioned about 2 feet over the burning wood coals. The 2-foot distance between the wood coals and the rack was maintained to avoid case hardening, which retards drying (Purcell 2014) and hasten the decay of the product. Smoke curing helps sea cucumber products to dry properly during the rainy season.

Sun drying

During fine weather, samples were laid outside on a clean rack and placed on an elevated platform. Samples were kept in storage after sundown.

Storage

Stone-dry sandfish were placed in labeled dry resealable bags separately by technique and stored at room temperature.

Product evaluation and pricing

Three local buyers/processors from three municipalities in Eastern Samar were requested to evaluate the product quality from the trials in terms of its sensory attributes such as size (length and weight), appearance, odor, color, texture, etc. using a descriptive sensory evaluation form adapted from *Beche-de-mer* grading features used in Hongkong (Bassig *et al*., 2021). Information on selling prices for live sandfish and buying prices for different grades of dried sandfish was also obtained from informal interviews with local buyers/processors. Limitations on the product quality evaluation include measurement of moisture content using a moisture analyzing device and structural microscopy of tissue samples.

Data and statistical analysis

Descriptive statistics including mean, standard deviation, and standard error of the mean, were presented in a table and graph. The results of the percentage recovery for the final weight were averaged (n = 6) per processing technique. The statistical difference among the four processing techniques was determined using One-Way ANOVA, and a Tukey HSD test was run as a post hoc test. Analyses of data were done using IBM® SPSS® Statistics version 21.

RESULTS AND DISCUSSION

Product yield

Despite allowing sandfish to relax to be able to expel water before weighing, a variable amount of water was retained in the live animal. After degutting, all live weights of the sandfish were reduced by 53-58%, or roughly 57% on average (Table 1). It was observed that the gutted weight of bigger sandfish was generally higher. Water makes up around 60% of the sea cucumber's body wall and a big percentage of this is lost during processing (Ram *et al*., 2016). However, the thickness of the body wall, which is mostly protein (Dong *et al*., 2011), also affects gutted weight. As shown in Table 1, samples from MB and MN showed high gutted weight recovery. However, MP1

Table 1. Sandfish weight recovery after degutting (n = 6).

Techniques	Live wt. ± SD (g)	Gutted wt. ± SD (g)	% wt. Recovery
MB	3585 ± 137.47	1655 ± 66.36	46.16
MN	3420 ± 190.39	1600 ± 54.01	46.78
MP1	2080 ± 36.29	976 ± 19.62	46.91
MP2	2435 ± 95.21	1014 ± 32.21	41.63

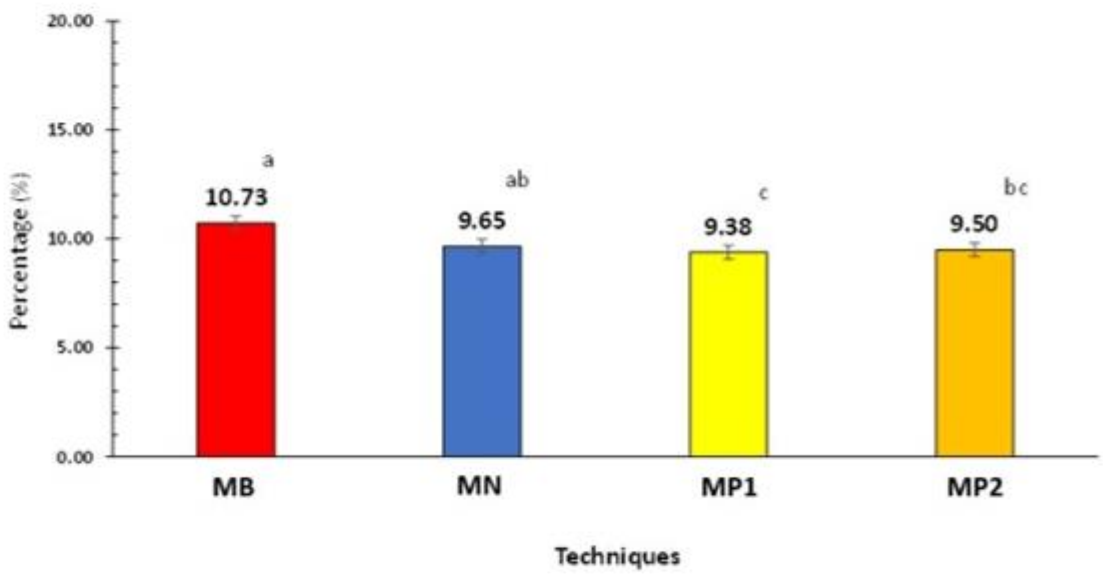

Figure 3. Percent recovery of sandfish (*n*=6) from its gutted-fresh weight after the application of four processing techniques: MB=Brown *et al.* 2010, MN= NFRDI, MP1= Purcell 1, and MP2= Purcell 2. Different letters labelled on the values show significant differences using the Tukey's honestly significant difference (HSD) post hoc test (subset for alpha = 0.05).

samples which are smaller than MP2 and much smaller than MB and MN, produced the highest % gutted weight recovery. It was also observed that sandfish with more pronounced grooves (usually attributed to age or nutrition), had thicker body wall and higher gutted weight recovery. This suggests that only sandfish >600 g with more pronounced grooves should be harvested and processed to maximize profits from the BDM trade.

The stone-dry product yield significantly differs (ANOVA, $p < 0.05$) for some techniques (Figure 3). Product yield from the MB technique had the highest weight percent recovery from gutted weight at 10.75%. Product recovery in the MB technique is significantly higher (Tukey's Test, $p < 0.05$) from MP1 and MP2 but did not significantly differ (Tukey's Test, $p > 0.05$) from the MN technique at 9.65%. The two methods by Purcell (MP1 and MP2) which yielded 9.38 and 9.50% recovery, respectively did not significantly differ from each other. Both MP1 and MP2 required salt-curing, a process that makes the sea cucumber product heavier (Purcell 2014). Ram *et al.* (2016) explained that salting causes salt-soluble proteins to leach and allow the salt to enter the tissues. The salt entering the tissues binds to the triple-helix collagen structure resulting in the increased weight of the final product (Gómez-Guillén *et al.*, 2011; Bao *et al*., 2010; Dong *et al.*, 2011, 2008). Even though it was noted that MP1 had the highest gutted percentage weight recovery among all sample sets despite having the smallest animals and having undergone salting which helps increased product weight, the MP1 product still had the lowest percentage yield among the four techniques at the end of the drying process. Therefore, harvesting larger sandfish >600 g is preferable to maximize income in the sea cucumber trade.

Product quality

The results of the sensory evaluation of BDM products from the local traders and processors in Eastern Samar are shown in Table 2 and backed with photographs in Figures 4 and 5. Among all the sensory attributes evaluated, size, appearance, and texture were found to have varying results.

BDM products were larger in MB and MN (70 to 80 mm and 26 to 30 g) compared to MP1 and MP2 (55 to 60 mm and 15 to 16 g) which could imply that larger sandfish have

Table 2. Descriptive evaluation of dried sandfish (*H. scabra*) from the buyers/processors in Eastern Samar.

Attribute	Product quality of sandfish subjected in four processing methods			
	MB	**MN**	**MP1**	**MP2**
Size				
Ave length (mm)	80	70-80	55	55-60
Ave weight (g)	29.6	25.7	15.26	16.04
Appearance	Straight, distinct groves, 2 out of 6 samples have slightly dented upper side, clean	Straight, distinct groves, slightly wrinkled, dented upper side, clean	Straight, 1 out of 6 samples is wrinkled, slight presence of chalky deposits	Slightly bent, mostly wrinkled, slight presence of chalky deposits
Odor	Slight smokey odor	Slight smokey odor	Slight smokey odor	Slight smokey odor
Color				
Upper side	Black	Black	Black	Black
Underside	Dark Brown	Dark Brown	Dark Brown	Dark Brown
Texture	Hard and almost dry	Hard and almost dry	Hard and Dry	Hard and Dry
Cut	1 small slit through anus	1 small slit through anus	1 small slit through anus	1 small slit through anus

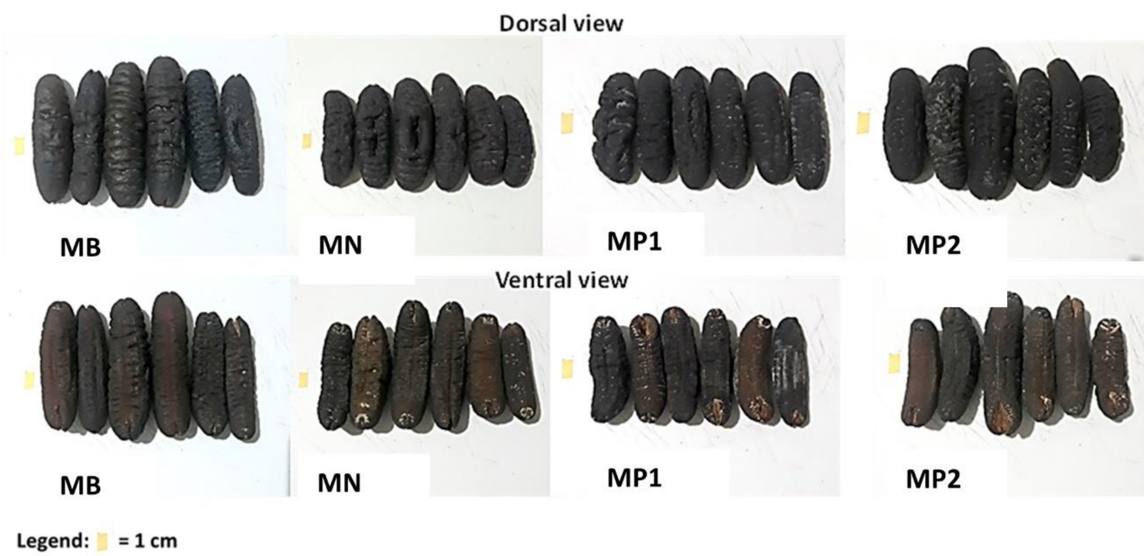

Figure 4. Stone-dried sandfish after the application of four processing techniques: MB = Brown *et al.* (2010), MN = NFRDI, MP1 = Purcell 1, and MP2 = Purcell 2.

thick body wall with lesser water content compared to smaller ones. In terms of appearance, most of the products were straight except for P2 which was slightly bent. Grooves were also found to be distinct in larger products (70-80 mm). Some of the product samples were also noted to have hollow dents (MN) as well as a wrinkled dorsal side most especially in MP2. However, during the cooking process, it was observed that the hollows or dents formed at the dorsal part of the sandfish may have been the result of not being submerged in the water during the first cooking and not due to the specific processing method used.

Smaller products most especially in MP1 and MP2 were also harder to clean as a slight presence of chalky deposits was noted. Among the four processing techniques, the MB technique required the least amount of time for the removal of ossicles or calcareous deposits. After the second cooking, it was observed that sandfish which were directly

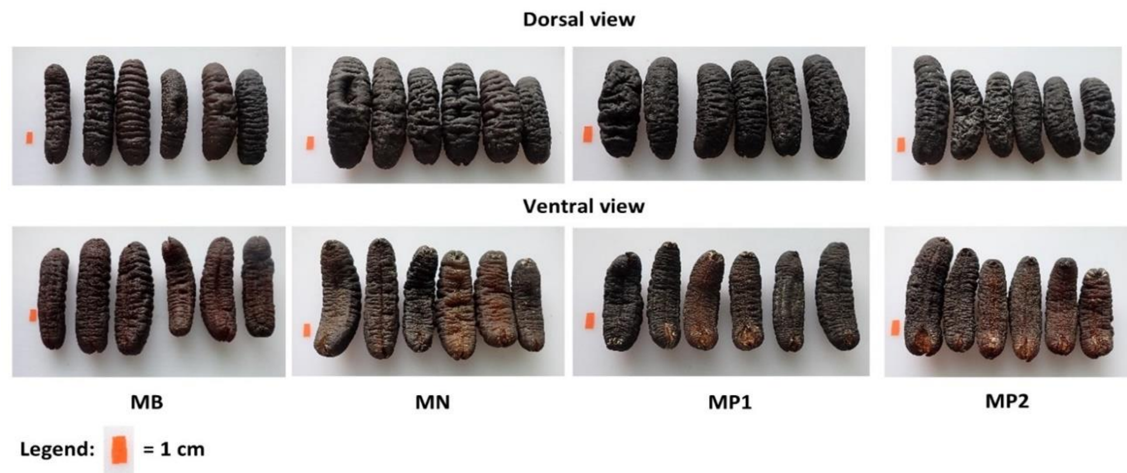

Figure 5. Stone-dried sandfish at 1.3 years after the application of four processing techniques: MB = Brown *et al*. (2010), MN = NFRDI, MP1 = Purcell 1, and MP2 = Purcell 2.

Table 3. Price of sandfish in Eastern Samar as of April 2021.

Gutted weight (per piece)	Price (fresh)	Price (dried)/kg.	
		(Php)	(USD)
<200-300 g	Php70.00/kg	1,200	24
500 g	Php100.00/pc.	2,000-2,500	40-50
600 g	Php200.00/pc	3,500-4,000	70-80

rubbed with and soaked in finely chopped papaya leaves had almost completely lost their ossicles. Only minimal brushing was needed to completely brush off the remaining ossicles. Papaya leaves have been used to remove ossicles not only in the Philippines (Gajelan-Samson *et al.*, 2011; Brown *et al*., 2010), but also in Indonesia, Malaysia (Choo, 2012), and Madagascar (Lavitra *et al.*, 2008; Rasolofonirina *et al*., 2004), among other places. Papaya leaves contain papain, a proteolytic enzyme that is commonly used to tenderize meat (Moy 2003; Quaglia and Gennaro 2003). However, Lavitra *et al*. (2008) also noted that papaya leaves must be used with care since the integumentary layer of the sandfish can be damaged by the papain in it.

Traders also noted that there was a slight smoke odor from all the products. It was expected since all products were subjected to hybrid drying which included smoke-drying. For color attribute, all products had uniformly black and dark brown colors on their dorsal and ventral side, respectively. Evaluators also noted that P1 and P2 products were completely dried compared to M1 and M2. It is most probable that larger products (70 to 80 mm) take more time to dry compared to smaller ones (55 to 60 mm). Both MP1 and MP2 were also subjected to salt-curing, other than making the product heavier, it was also found that salting increases the drying rate of BDM products (Purcell, 2014).

Studies also showed that salt-curing helps minimize both length and weight losses during processing (Lavitra *et al.*, 2008), protects the product from spoilage, and prolongs shelf life (Ram *et al*., 2016). Yaptenco *et al*. (2017) found that properly processed sandfish packed in polypropylene plastic and stored at 30 to 35°C may have a shelf life of 5 to 12 months. Interestingly, like those of MP1 and MP2 samples, all samples from the MB and MN techniques that did not undergo a salt-curing process have not shown visible signs of molds and decay even over a year of storage (Figure 5). This may imply that the natural salt in seawater used in cooking the sandfish is also sufficient to preserve the product for more than a year. In addition, hybrid drying may also be a factor in effectively reducing the moisture content of the product thereby prolonging its shelf life. According to Purcell (2014), smoke curing is a good preservation method when sea cucumbers are not salted.

Pricing

Live sandfish can be sold on a per individual or kilogram basis (Table 3). Based on the information obtained from the sandfish traders in Eastern, Samar, fishers/collectors receive the lowest net income by selling their sea cucumber fresh or processing it poorly (Tables 3 and 4). According to the local sea cucumber buyers and processors, dried sea cucumbers or BDM products are

Table 4. Dried sandfish prices, size, and grade at local traders in Eastern Samar, Philippines as of April 2021.

Code	Measurement in length (mm)	No. of pieces to reach 1 kilo	Price good quality		Price Class B/Reject	
			(Php)	(USD)	(Php)	(USD)
XL	≥85	40	4000-5000	80-100	1800	36
L	80	40-60	3500	70	1700	34
M	70	60-80	3000	60	1500	30
S	55	80-120	2500	50	1200	24
PSS	30	120-160	1800	36	600	12
PSSS	25	160-240	1300	26	300	6
PSSSS	20	240-280	800	16	300	6

priced based on the quality of the product, size length and weight. Deformed and damaged individuals are considered “rejects” and priced at 30 to 50% lower than specimens that are in better condition. The way by which the primary processing of sandfish is carried out is very important as it determines the resulting product quality and consequently the price that the product can command in the market (Perez and Brown, 2012). The market offers a high price for well-dried premium-size/large sandfish (Pardua *et al.*, 2018; Ram *et al*., 2016). Having tested and experienced the different processing methods, ranch co-managers can now carry out primary processing properly. Dried sandfish can be stored for a period until sufficient volume is accumulated before selling for a better price thus, adding value to their sandfish and earning a better income.

CONCLUSION

Properly processed, stone-dry premium-size sandfish fetch a very good price in the export market. However, sandfish gatherers and small sandfish sea ranch owners opt to sell their sandfish fresh at low prices because 1) they lack the knowledge on how to properly process sandfish to meet export market requirements, and 2) they feel that processing is too tedious and requires a lot of time and effort. The different methods tested during this study showed that sandfish sea ranch owners can earn more by processing premium-size sandfish. Although there is no single best-practice method for processing sandfish, MB and MN may be adopted, as the process is simpler and produces a higher yield. Since the product can be kept for over a year, sandfish can be processed by batch, stored, and sold when a good volume is reached to get the best price for the product.

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DISCLOSURE STATEMENT

All authors have read and approved the final manuscript and declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The authors confirm that all relevant data and supporting information are within the manuscript.

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