

Effects of post-mortem chilling duration on recovery yield and sensory characteristics of manually deboned cage-cultured milkfish (*Chanos chanos*) butterfly fillets using a modified technique

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Abstract. Milkfish (*Chanos chanos*) is a commercially important aquaculture species in the Philippines, often processed as deboned products to improve consumer acceptance and market value. This study evaluated the effects of post-mortem chilling duration on the recovery yield and sensory characteristics of manually deboned milkfish butterfly fillets using a modified technique. Fresh whole milkfish (400-450 g each) sourced from fish cages were stored at 0–2°C and deboned at 3-hour intervals up to 30 hours post-harvest. The study followed a completely randomized design with four replicates per sampling. The modified method was based on intermuscular pockets creation, improved intermuscular bone removal and reduced flesh tearing. Recovery yields were lowest (75.08–75.57%) and deboning durations longest (14.31–14.63 min) within the first 9 hours chilling duration. Higher yields (77.04–78.52%) and shorter deboning times (10.19–12.50 min) were recorded between 12 and 27 hours of chilling, coinciding with noticeable softening of the flesh. Sensory evaluation was performed by seven semi-trained panelists with a 5-point hedonic scale. The organoleptic evaluation showed that odor, meat color, flesh firmness, cohesiveness, and bone-flesh adhesion were most acceptable from 12 to 24 hours, with significant declines after 27 hours. Strong correlations were observed among recovery yield, deboning duration, percentage loss due to intermuscular bones and attached flesh, and sensory attributes. Based on the findings, deboning *C. chanos* between 12 and 24 hours post-mortem is recommended to optimize recovery yield, efficiency, and product quality. The modified deboning technique offers a low-technology, practical solution for improving processing efficiency and product acceptability in manual deboning milkfish operations.

Key Words: manual processing, low temperature storage, intermuscular bones, deboning efficiency.

Introduction. Milkfish (*Chanos chanos*) is the primary finfish commodity cultured in the Philippines (Gaitan 2022). Milkfish is typically sold in its chilled form, either as a whole or deboned or as a value-added product (BFAR 2022; Molina et al 2024). Due to the presence of numerous intermuscular bones, milkfish is commonly processed to enhance its acceptability and marketability. The most common value-added milkfish product in the Philippines is deboned milkfish, locally known as “boneless bangus” (Yap et al 2007). The technology for deboning milkfish was initially developed in the 1960s by fisheries technologists from the Bureau of Fisheries and Aquatic Resources (BFAR) (Yap et al 2007). Since then, the method has been widely adopted and disseminated throughout the Philippines. By 2020, a total of 37 local processors and 10 BFAR-registered, Hazard Analysis Critical Control Point (HACCP) certified establishments with milkfish product lines were documented as deboned milkfish processing factories (BFAR 2022). In General Santos City and Sarangani Province, the deboning process was adapted from the protocol prescribed by the Department of Science and Technology (Surtida & Buendia 1999). Based on a business program brochure by Department of Trade and Industry (DTI 2021)

entitled “Deboned Milkfish (*Bangus*) Processing”, deboned milkfish has an estimated recovery yield of 75%. Despite the commercial significance of boneless *C. chanos*, there remains a lack of published data on actual recovery yields for milkfish deboning. To date, the only related data on *C. chanos* meat recovery yield pertains to its edible portion which is at 61.63-67.10% (Sulit et al 1953) and 70.56% (Valenzuela 1928). Meat yield is influenced on both intrinsic factors such as fish size and extrinsic factors such as filleting time, particularly in relation to the onset and resolution of rigor mortis (Islami et al 2014; Le et al 2019). Rigor mortis appears after an organism’s death and is a stage when most physicochemical and microbiological changes occur (Kumar et al 2017). It is a period associated with muscle stiffening which can complicate the separation of flesh from bone. The stage at which filleting is done (pre-rigor, in-rigor, or post-rigor) can influence various quality parameters, including meat color, pH, drip loss, texture, and gaping (Le et al 2019).

The onset and duration of rigor mortis vary with species, slaughter stress, and storage conditions, particularly temperature (Islami et al 2014). Denny et al (2021) reported that whole *C. chanos* enters rigor approximately two hours after death and transitions to the post-rigor stage by 12 hours post-mortem, although the temperature at which this was tested is not specified. In other fish species, rigor mortis generally initiates within 30 minutes to 3 hours post-mortem and resolves between 13 to 29 hours, depending on the species and storage temperature (Iwamoto et al 1987; Faruk et al 1994; Islami et al 2014; Le et al 2019). For instance, striped catfish (*Pangasianodon hypophthalmus*) stored at 2°C exhibited rigor onset within 1 hour and resolution at 29 hours, while catla (*Catla catla*) and tilapia (*Tilapia nilotica*) completed rigor within 13 hours at room temperature (Faruk et al 1994; Islami et al 2014). Lower storage temperatures were shown to delay rigor progression, as observed in tra catfish and plaice (*Paralichthys olivaceus*) (Iwamoto et al 1987; Le et al 2019).

Meat quality is directly related to the degree of spoilage, which in turn is influenced by the temperature and handling practices post-harvest. In general, fish are highly perishable products thus proper handling and maximizing their utilization post-mortem is crucial to minimizing quality degradation and post-harvest losses (Adepoju et al 2018; Singh et al 2021). *C. chanos*, classified as a high-protein, low-fat species, is vulnerable to spoilage after death (Sulit et al 1953; Murthy et al 2016; Malle et al 2019; Nopiyanti et al 2023). Spoilage in fish is typically driven by autolytic processes and bacterial action (Duarte et al 2020). Low temperature storage, such as icing and refrigeration, is commonly employed to slow down biochemical and microbial spoilage in fish (Huss 1995; Murthy et al 2017). Moreover, lower temperatures delay the onset and progression of rigor mortis, thereby extending the shelf life of the fish by delaying the deterioration associated with the relaxation from rigor (Islami et al 2014).

Delays in post-harvest processing of fish may lead to perceptible undesirable changes in the final product. Thus, identifying the optimal time post-mortem for deboning milkfish is essential to minimize spoilage and preserve quality. Sensory parameters, such as color, aroma, flavor and texture, alongside physicochemical indicators, including pH, are widely recognized as reliable tools for assessing freshness and meat quality in fish products (El Rammouz et al 2013). Organoleptic evaluation, in particular, offers distinct advantages over some instrumental techniques by recognizing complex sensory attributes and providing more discriminating assessments for specific tasks (Espejo-Hermes 2004).

This study aimed to determine the optimal post-mortem chilling duration for manually deboning *C. chanos* using a modified deboning technique while maintaining acceptable sensory characteristics. Understanding the influence of post-mortem chilling durations on recovery yield and sensory characteristics is essential for improving processing efficiency and product quality. Insights gained from this study may contribute to refining post-harvest handling practices and enhancing the quality and yield of deboned *C. chanos* products.

Material and Method

Sample collection and preparation. A total of 19 kg of fresh, whole *C. chanos* were collected immediately post-harvest from a local fish cage in the municipality of Ronda, Cebu, Philippines in December 2023. Samples were transported to the Post-Harvest Fisheries Laboratory at Cebu Technological University – Moalboal Campus using high-density polyethylene (HDPE) coolers with crushed ice at a 1:1 fish-to-ice ratio. Transport duration was approximately 20 minutes to ensure sample freshness.

Experimental procedure. A total of 44 *C. chanos* weighing approximately 400–450 g each were used in the study. The experimental design followed a completely randomized design (CRD) with four replicates per sampling point. Whole fish were stored and maintained at 0 to 2°C. Sampling was done at 3-hour intervals (0, 3, 6, 9, 12, 15, 18, 21, 24, 27, and 30 h post-mortem). During each sampling, the wet weight of each fish was recorded, followed by manual deboning using the method described by Zalameda et al (2014), with modifications. After following standard butterfly filleting of whole raw milkfish (scales on), which included the removal of gills and internal organs, thorough washing to remove blood and debris, and extraction of the backbone, modifications were implemented. The modified procedure involved slicing at specific locations of the *C. chanos* butterfly fillet, followed by the creation intermuscular pockets at these incision sites, facilitating easier identification and removal of the intermuscular bones (Figures 1-5). Two trained personnel conducted the deboning process and inspected all samples for any residual pin bones detectable by touch. All sampling procedures were carried out at a room temperature of 28°C. The duration of the deboning was also recorded for each sampling point.

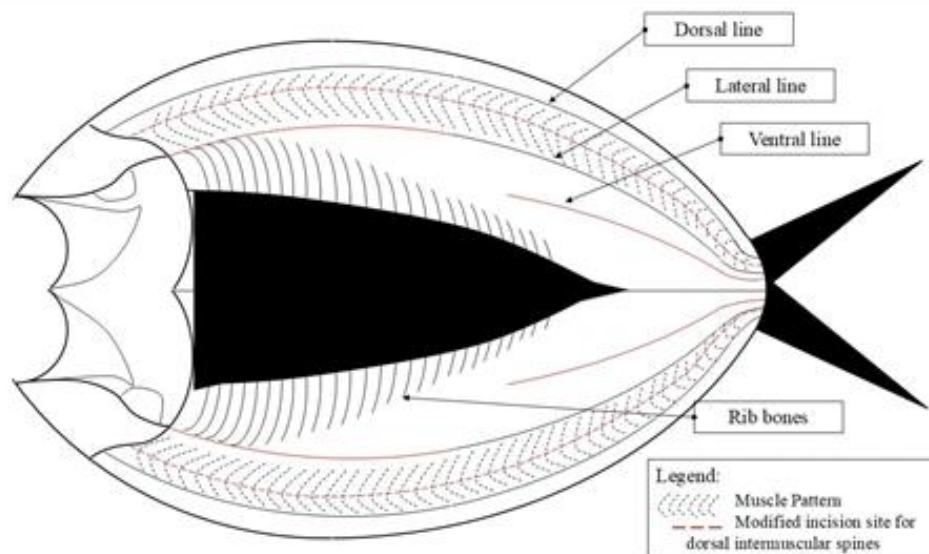


Figure 1. Diagram of a *Chanos chanos* butterfly fillet showing muscle pattern, visible intermuscular boundaries, including dorsal, lateral, and ventral separations, as well as the modified incision sites.

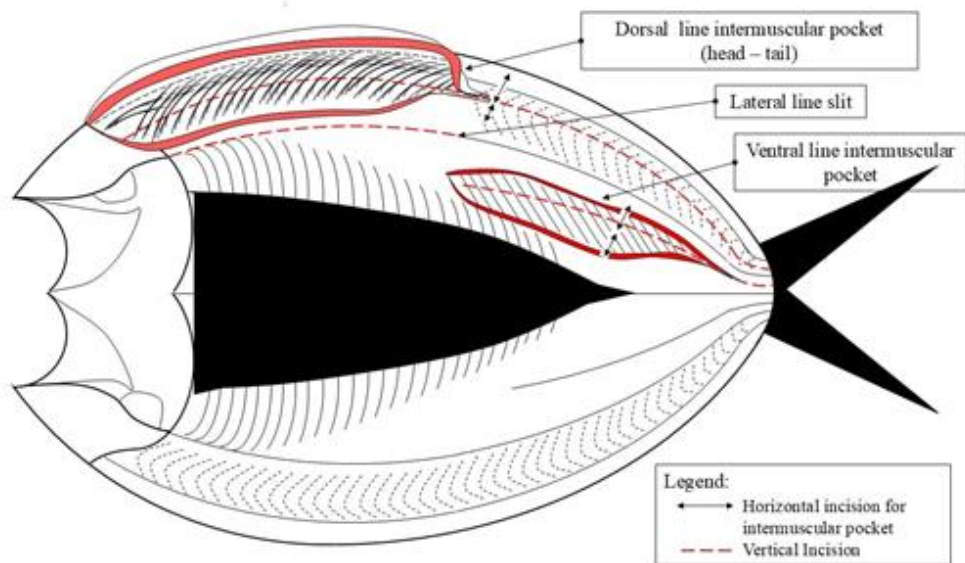


Figure 2. Visualization of intermuscular bone orientation, dorsal and ventral intermuscular pockets, and the lateral line slit, with indicated slicing directions (vertical or horizontal) used in the modified deboning method for *Chanos chanos*.

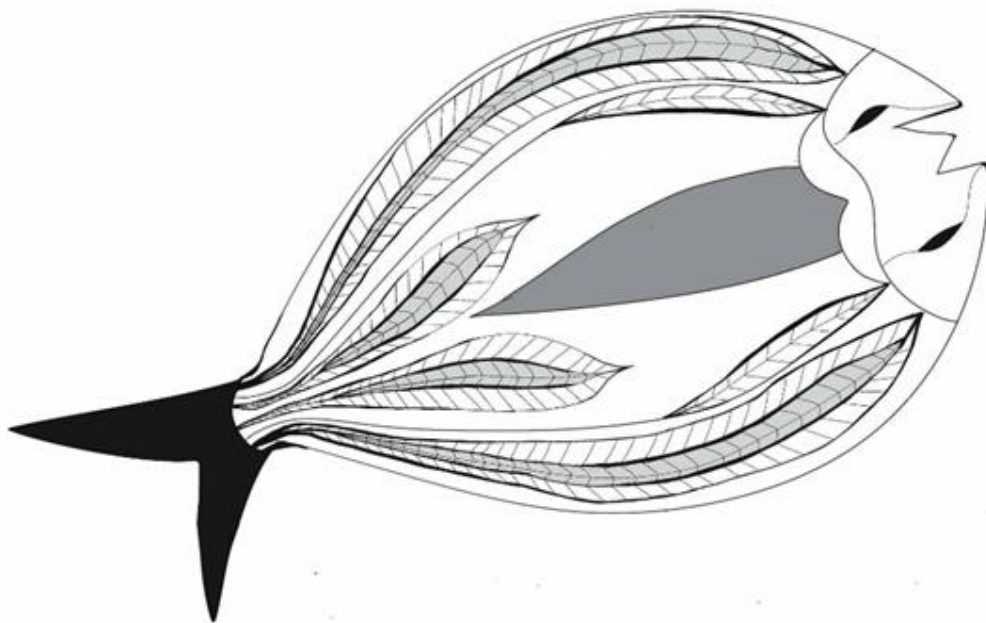
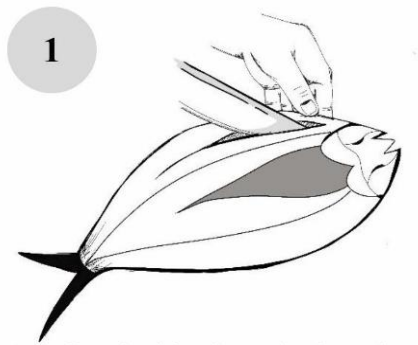
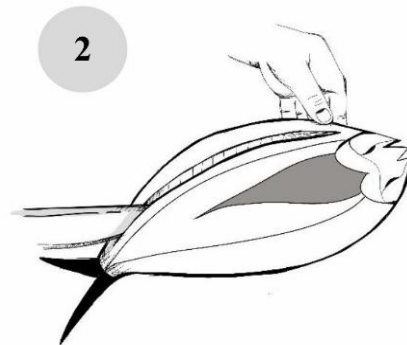


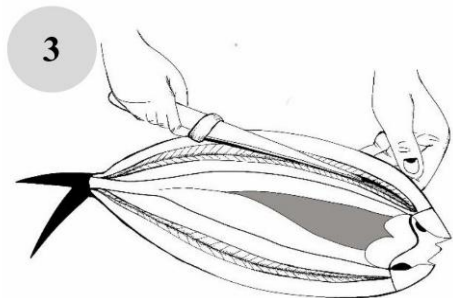
Figure 3. Illustration of a butterfly-cut *Chanos chanos* fillet exhibiting intermuscular pockets along the dorsal and ventral regions, as well as lateral line incisions.



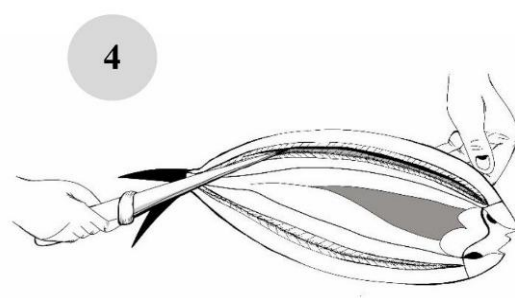
1
A shallow incision is made along the midline between the dorsal and lateral lines



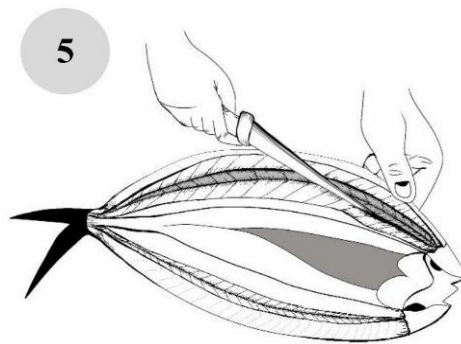
2
The incision is made from the anterior to the posterior of the fish muscle.



3
The knife is held flat and a shallow side incision is performed to form part of the intermuscular pocket.



4
The side incision is made from the anterior to the posterior of the fish muscle.



5
The side incision process is repeated on the opposite side to complete the dorsal intermuscular pocket.

Figure 4. Step-by-step schematic of the modified deboning procedure for *Chanos chanos*, illustrating the creation of a dorsal intermuscular pocket.

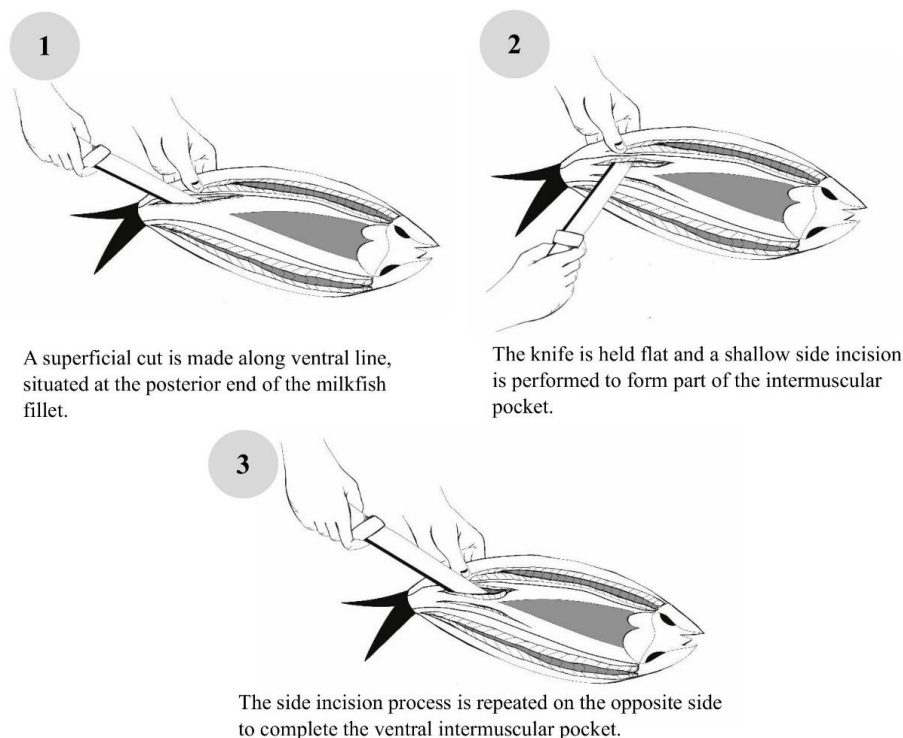


Figure 5. Step-by-step schematic of the modified deboning procedure for *Chanos chanos*, illustrating the creation of a ventral intermuscular pocket.

Recovery yield. Whole milkfish samples were each weighed (wet weight) before and after deboning to determine the recovery yield. The recovery yield was expressed as the proportion of the deboned fillet weight relative to the original whole fish weight, following the general approach used by Islami et al (2014), who computed component yields as the weight percentage of each part in relation to the total fish weight.

pH. During each sampling, pH of the deboned *C. chanos* was measured by collecting a composite 10 g sample of fish muscle then homogenized with 20 mL distilled water for 1 min using a household blender. The pH of the resulting slurry was then measured with a pH meter (Hanna HI98100).

Sensory evaluation. Organoleptic evaluation of raw deboned *C. chanos* was performed after manual deboning. Using a 5-point hedonic scale, the following attributes were assessed: odor, meat color, flesh firmness, flesh cohesiveness, bone-flesh adhesion and general acceptability (Table 1). Sensory evaluation was performed by seven semi-trained panelists (five undergraduate students and two faculty members) for every sampling.

Table 1
5-point hedonic scale used for sensory evaluation for raw *Chanos chanos* butterfly fillets

Score	Sensory characteristics					
	Odor	Meat color	Flesh firmness	Flesh cohesiveness	Bone-flesh adhesion	General acceptability
1	Dislike	Dislike	Very poor	Very poor	Very poor	Dislike
2	Neither like nor dislike	Neither like nor dislike	Poor	Poor	Poor	Neither like nor dislike
3	Like slightly	Like slightly	Fair	Fair	Fair	Like slightly
4	Like moderately	Like moderately	Good	Good	Good	Like moderately
5	Like very much	Like very much	Very good	Very good	Very good	Like very much

Statistical analysis. Data obtained from the experiment were analyzed using a one-way analysis of variance (ANOVA) to estimate the effects of chilling duration on recovery yield, pH, deboning duration and sensory properties. Post-hoc analysis was performed with Tukey's Honestly Significant Difference (HSD) at $p < 0.05$. Pearson's correlation analysis was conducted to examine relationships among pH, recovery yield, and deboning duration as well as among sensory properties at $p < 0.05$, $p < 0.01$, and $p < 0.001$ (two tailed). Statistical analyses were performed with IBM® SPSS® Statistics version 22.

Results

Recovery yield and deboning duration. Whole raw *Chanos chanos* (400–450 g) were deboned at various post-mortem chilling durations using a modified method. From 0 to 9 hours of chilling, recovery yielded ranged from 75.08 to 75.57%, with deboning durations between 14.44 and 14.63 minutes (Table 2). The lowest recovery yield (75.08%) and longest deboning time (14.63 minutes) were both observed at 9 hours.

Table 2
Recovery yield and deboning duration of *Chanos chanos* butterfly fillets at different post-mortem chilling durations using a modified deboning method

Chilling duration (hr)	Average initial weight (g)	Average final weight (g)	Total Loss (g)	Recovery yield (%)	Deboning duration (min)
0	407.5±10.85	308.00±11.17	99.5±1.73	75.57±0.81 ^a	14.44±0.52 ^a
3	420.50±20.89	317.25±18.23	103.25±2.99	75.43±0.64 ^a	14.38±0.43 ^a
6	420.75±20.55	317.00±18.96	103.75±2.50	75.31±0.91 ^a	14.31±0.24 ^a
9	408.50±11.21	306.75±10.90	101.75±1.71	75.08±0.69 ^a	14.63±0.78 ^a
12	413.00±15.03	318.25±13.82	94.75±2.22	77.04±0.67 ^b	12.50±0.46 ^b
15	441.25±10.31	346.00±11.69	95.25±1.71	78.40±0.84 ^b	12.38±0.14 ^b
18	406.00±4.55	316.00±5.29	90.00±0.82	77.83±0.44 ^b	12.25±0.20 ^b
21	410.75±8.54	322.25±8.22	88.50±1.00	78.45±0.42 ^b	12.38±0.32 ^b
24	415.50±22.84	326.00±20.31	89.50±2.65	78.44±0.57 ^b	12.00±0.20 ^b
27	420.50±11.73	330.25±12.89	90.25±1.71	78.52±0.92 ^b	10.19±0.43 ^c
30	416.00±13.44	318.25±12.37	97.75±2.99	76.49±0.78 ^a	8.44±0.24 ^d

Values are presented as mean±SD (n=4). Values with similar superscripts are statistically not significantly different based on one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test ($p < 0.05$).

Between 12 and 27 hours, higher recovery yields (77.04–78.52%) and shorter deboning durations (12.00–12.50 minutes) were recorded. At 27 hours, deboning time further decreased to 10.19 minutes. The shortest deboning duration was observed at 30 hours (8.44 minutes), though corresponding to a slightly lower recovery yield (76.49%). A significant negative correlation was found between recovery yield and deboning duration ($r = -0.49$, $p < 0.001$) (Table 4 and Figure 7).

Percentage losses. Losses during the deboning process were categorized into three components: (1) viscera and gills, (2) backbone and dorsal fin, and (3) intermuscular bones with attached flesh. These are presented as percentage losses in Table 3. Viscera and gills removal consistently accounted for 9.64 to 10.72% loss of the initial fish weight while extraction of the backbone and dorsal fin resulted in losses ranging from 7.25 to 7.80%. There were no significant differences ($p > 0.05$) in these two components across chilling durations. Combined, these two components constituted the majority of total milkfish deboning losses, contributing approximately 73% to 85%. In contrast, the percentage loss (%loss) from intermuscular bones (IB) and attached flesh (AF) showed significant differences ($p < 0.05$). Losses ranged from 6.18 to 6.54% from 0-9 hours, significantly decreased to 4.70–4.95% at 12–15 hours, and reached the lowest values (3.11–3.76%) between 18 and 27 hours. A slight increase (5.52%) was recorded at 30

hours. Correlation analysis revealed %loss IB and AF was significantly negatively correlated with recovery yield ($r=-0.83$, $p<0.001$) and positively correlated with deboning duration ($r=+0.46$, $p<0.01$) (Table 4 and Figure 7). Overall, total losses were highest at 0 to 9 hours and again at 30 hours (23.51 to 26.92%), with the peak observed at 9 hours. Significantly lower total losses (21.48 to 22.96%) were recorded between 12 and 27 hours, with the minimum at 27 hours (21.48%).

Table 3
Percentage losses of *Chanos chanos* components during deboning at various post-mortem chilling durations using a modified method

Chilling duration (hr)	Viscera and gills loss (%)	Backbone and dorsal fin loss (%)	Intermuscular bones and attached flesh loss (%)	Total loss (%)
0	10.50±0.73 ^a	7.75±0.84 ^a	6.18±0.77 ^a	24.43±0.81 ^a
3	10.35±0.76 ^a	7.75±0.70 ^a	6.47±0.53 ^a	24.57±0.64 ^a
6	10.42±0.66 ^a	7.78±0.43 ^a	6.48±0.65 ^a	24.69±0.91 ^a
9	10.60±0.80 ^a	7.77±0.25 ^a	6.54±0.37 ^a	26.92±0.69 ^a
12	10.49±0.68 ^a	7.52±0.64 ^a	4.95±0.71 ^b	22.96±0.67 ^b
15	9.64±0.59 ^a	7.25±0.23 ^a	4.70±0.26 ^b	21.60±0.84 ^b
18	10.72±0.54 ^a	7.70±0.20 ^a	3.76±0.56 ^c	22.17±0.44 ^b
21	10.65±0.37 ^a	7.80±0.63 ^a	3.11±0.26 ^c	21.55±0.42 ^b
24	10.42±0.79 ^a	7.53±0.69 ^a	3.61±0.16 ^c	21.56±0.57 ^b
27	10.23±0.28 ^a	7.50±0.51 ^a	3.75±0.61 ^c	21.48±0.92 ^b
30	10.40±0.35 ^a	7.58±0.39 ^a	5.52±0.81 ^{ab}	23.51±0.78 ^a

Values are presented as mean±SD (n=4). Values with similar superscripts are statistically not significantly different based on one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test ($p<0.05$).

pH. The initial pH at 0 hours was the highest at 6.45, followed by a sharp decline to 5.97 at 3 hours and further to 5.63 at 6 hours (Figure 6). The lowest pH was recorded at 9 hours (5.52). From 12 to 30 hours, pH values increased slightly but significantly, fluctuating between 5.61 to 5.72.

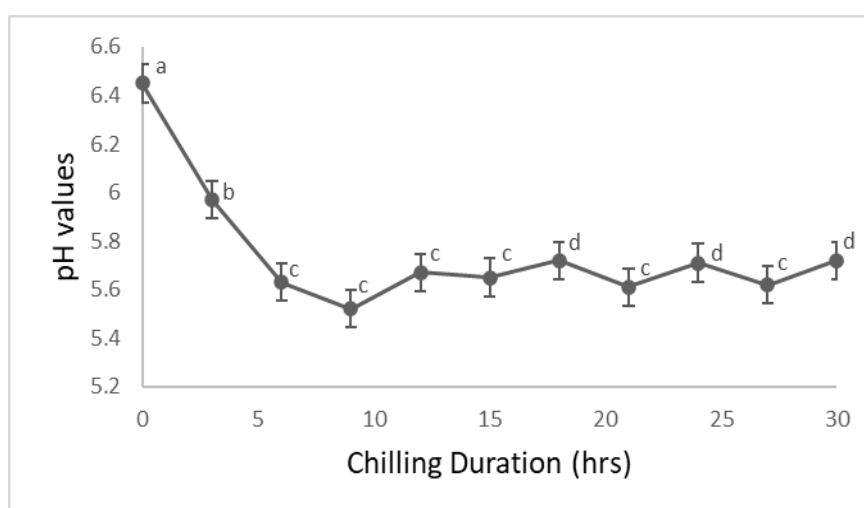


Figure 6. pH of deboned *Chanos chanos* at different post-mortem chilling durations. Values with similar superscripts are not significantly different based on one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test ($p<0.05$).

As shown in Table 4, pH was significantly negatively correlated with recovery yield ($r=-0.31$, $p<0.05$), and significantly positively correlated % loss IB and AF ($r=+0.31$, $p<0.05$) and with deboning duration ($r=+0.30$, $p<0.05$).

Table 4

Correlation matrix among pH, recovery yield (%), deboning duration, and intermuscular bones and attached flesh loss (%) of milkfish butterfly fillets deboned at different post-mortem chilling durations

Variable	pH	Recovery yield (%)	Deboning duration (min)
Recovery yield (%)	-0.31*		
Deboning duration (min)	+0.30*	-0.49***	
Intermuscular bones and attached flesh loss (%)	+0.31*	-0.83***	+0.46**

***Correlation is significant at the 0.001 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

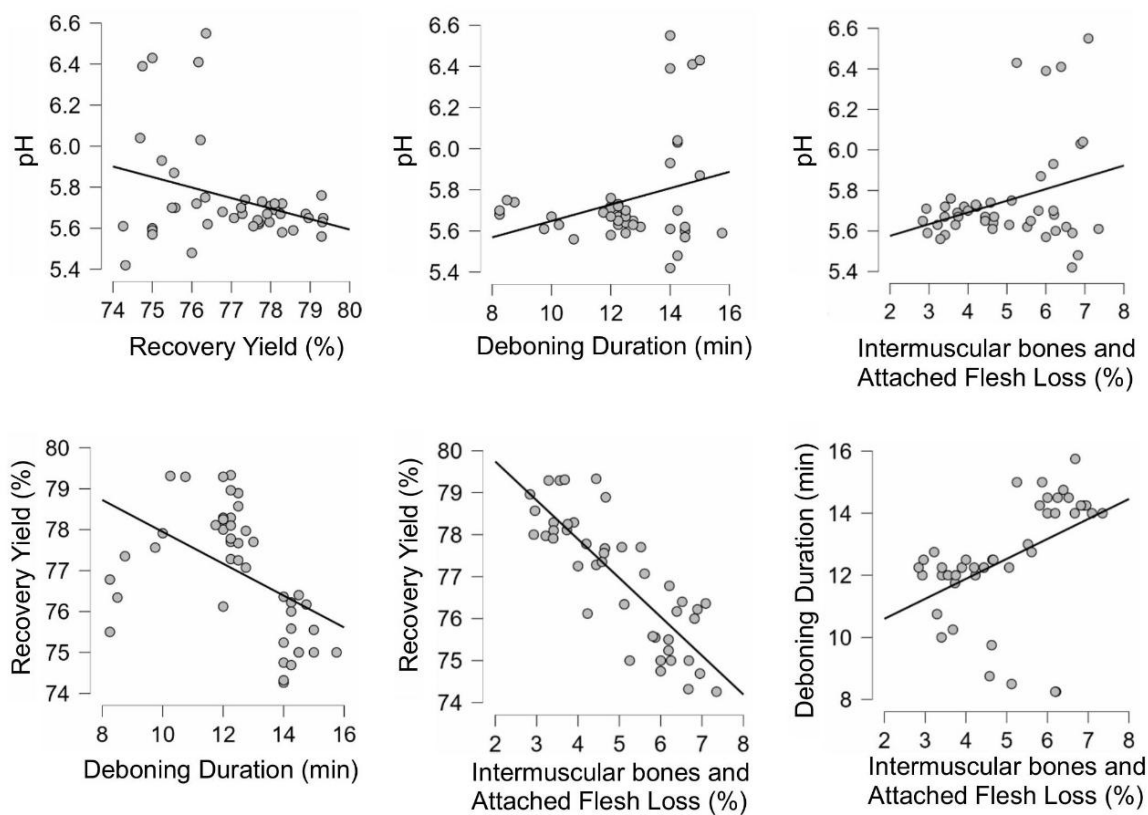


Figure 7. Relationships among post-mortem pH, recovery yield (%), deboning duration and intermuscular bones and attached flesh loss (%) of *Chanos chanos* butterfly fillets deboned at different post-mortem chilling durations.

Sensory characteristics. Sensory properties of deboned *C. chanos* were assessed across various post-mortem chilling durations (Figure 8 and Figure 9). Significant differences ($p < 0.05$) were observed across all sensory characteristics evaluated.

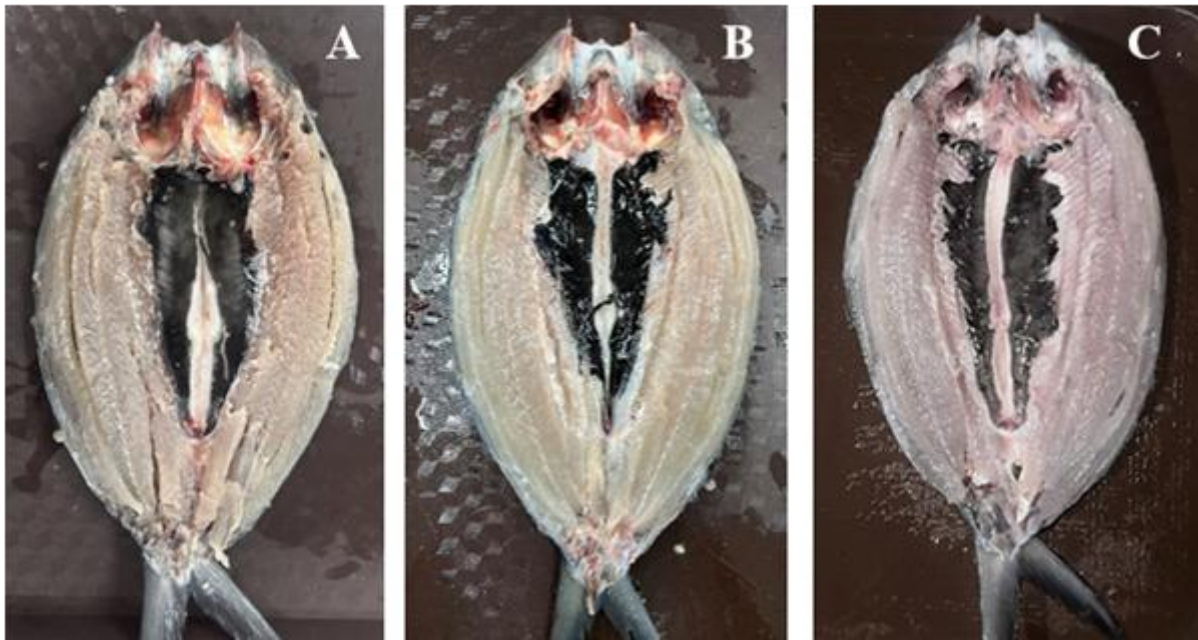


Figure 8. Deboned *Chanos chanos* samples at various post-mortem chilling durations: A) 0 hour, B) 15 hours, C) 30 hours.

Odor scores exhibited a general decreasing trend from 0 to 30 hours. Scores remained relatively high (5.00-4.71) from 0 to 18 hours, with the highest ratings observed at 0 and 3 hours (5.00). Samples chilled beyond 21 hours showed significantly lower odor scores dropping markedly to 2.75 at 27 hours and 2.57 at 30 hours. Similarly, meat color maintained high scores (5.00-4.89) between 0 and 15 hours, with the highest values (5.00) observed from 0 to 6 hours. Significant and gradual decreases occurred from 18 hours onward, reaching the lowest score of 3.75 at 30 hours. Flesh firmness score remained at 5.00 up to 6 hours of chilling, then gradually decreased. A sharper decline was observed beyond 18 hours with the lowest score of 2.68 at 30 hours. Flesh cohesiveness followed a similar pattern, showing a relatively stable cohesiveness (5.00-4.29) up to 18 hours, but it recorded a significant breakdown after 21 hours. The lowest score recorded for flesh cohesiveness was 2.79 at 30 hours. Bone-flesh adhesion also decreased with prolonged chilling durations. Scores were highest at 0 and 3 hours (5.00), then progressively declined to 1.61 at 30 hours—the lowest recorded score. General acceptability initially increased from 3.42 to 3.86 between 0 and 6 hours. Scores significantly improved from 9 hours (4.64) and peaked at 15 hours (5.00). High acceptability was also maintained at 12 and 18 hours (4.93). Scores declined gradually afterward, with the lowest rating (3.39) observed at 30 hours.

Pearson's correlation analysis (two-tailed) revealed strong positive relationships among most sensory parameters (Table 5). The highest correlations were observed between bone-flesh adhesion and flesh firmness ($r=+0.86$), bone-flesh adhesion and both odor and flesh cohesiveness ($r=+0.84$), and between odor and flesh firmness ($r=+0.84$), all statistically significant at $p<0.001$. In contrast, correlations between general acceptability and flesh cohesiveness ($r=+0.09$) as well as bone-flesh adhesion ($r=+0.07$) were weak and not statistically significant.

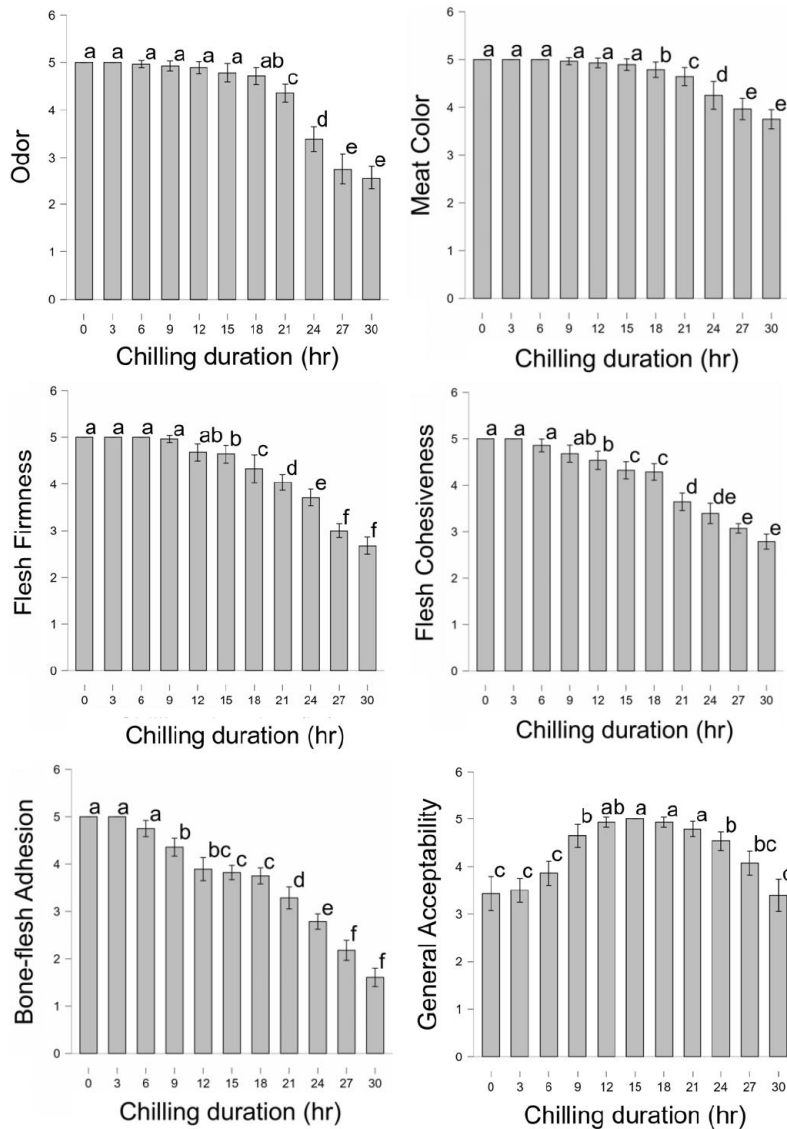


Figure 9. Sensory characteristics of deboned milkfish at different post-mortem chilling durations. Values are presented as mean±SD (n=28) of semi-trained panelists. Values with similar superscripts are not significantly different based on the one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test (p<0.05).

Table 5
Correlation matrix among sensory characteristics of *Chanos chanos* butterfly fillets deboned at different post-mortem chilling durations

Parameter	Odor	Meat color	Flesh firmness	Flesh cohesiveness	Bone-flesh adhesion
Meat Color	+0.80***				
Flesh Firmness	+0.84***	+0.77***			
Flesh Cohesiveness	+0.73***	+0.71***	+0.79***		
Bone-flesh Adhesion	+0.84***	+0.79***	+0.86***	+0.84***	
General Acceptability	+0.28***	+0.33***	+0.19***	+0.09	+0.07

***Correlation is significant at the 0.001 level (2-tailed).

Discussion. This study assessed the recovery yield of deboned *C. chanos* processed at different post-mortem chilling durations using a modified deboning technique. The method was partly based on the standard protocol outlined in the Department of Science and Technology (DOST) manual by Zalameda et al (2014), which has been widely disseminated in the Philippines. These modifications were based on the anatomical characteristics and orientation of the intermuscular bones in milkfish (Figure 2). Specifically, a portion of the dorsal intermuscular bones are branched at the ends and are positioned obliquely, slanting downward from the dorsal edge toward the interior. In contrast, ventral intermuscular bones slant in the opposite direction, while lateral intermuscular bones are oriented vertically.

Modifications focused on the slitting site for dorsal intermuscular bones and the creation of intermuscular pockets. These pockets facilitated the initial manual separation of intermuscular bones from the flesh at both ends, providing a clear visual reference. This differed from the conventional technique, which relies primarily on tactile sensation to locate and remove the bones. This approach improved visibility and handling of the intermuscular dorsal bones, as well as ventral intermuscular spines, reducing bone-flesh adhesion and minimizing bone breakage during extraction. Consequently, this contributed to higher recovery yields. To avoid cutting through the branches of the dorsal bones, the incision was made midway between the dorsal and lateral lines. This incision site allowed personnel to extract the bones at their center, enhancing the precision of removal and reducing the likelihood of leaving bone fragments behind. The intermuscular pockets also enabled easier detection of any remaining bones post-deboning. Furthermore, because the upper flesh layer had already been manually separated, it remained intact during bone removal, preventing it from becoming mushy—a common issue among inexperienced *C. chanos* deboners. After bone extraction, this layer could be folded back to maintain a smooth, intact appearance of the final product. Another advantage of the modified technique is its facilitation of training for new deboning personnel. The improved visibility of the intermuscular bones will allow them to better understand bone alignment and positioning, which vary across dorsal, ventral, and lateral areas. Given the varying sizes of dorsal, ventral, and lateral bones, this clarity will also allow better grip of forceps and pulling strength during bone extraction. Overall, this modified deboning technique not only enhanced recovery yield and reduced post-harvest losses of *C. chanos* flesh but also improved handling efficiency, product presentation and maximizes profitability. These improvements suggest its potential applicability in both small-scale and large-scale processing operations.

The modified deboning technique enabled more efficient removal of intermuscular bones, with recovery yields exceeding 75% across all chilling durations (0 to 30 hours). Despite the commercial importance of deboned *C. chanos* in the Philippines—where it is distributed both domestically and internationally—to the extent of our knowledge, there remains a lack of published data quantifying recovery yield. The Philippine National Standard for Frozen Milkfish (BAFPS 2008) references a recovery yield of 75% or higher but does not provide empirical data to support this figure. Similarly, the DTI (2021) business program brochure on milkfish deboning assumes a 75% yield without documenting actual values. This study contributes to addressing that gap by providing empirical data on the actual recovery yields and percentage losses associated with deboned *C. chanos* processed at various chilling durations. Specifically, milkfish deboned within the first 9 hours of chilling exhibited recovery yields ranging from 75.08 to 75.57%, with corresponding deboning durations of 14.31 to 14.63 minutes. In contrast, significantly higher yields (77.04–78.52%) and shorter deboning times (10.19–12.50 minutes) were observed between 12 and 27 hours of chilling. At 30 hours, recovery yield slightly declined to 76.49%, although this coincided with the shortest recorded deboning time of 8.44 minutes. The lower yields and longer deboning times observed during the initial 9 hours are attributed to processing fish during pre-rigor and rigor mortis stages. The results of this study coincide with a study that investigated milkfish freshness via infra-red spectroscopy reported that rigor mortis in milkfish sets in approximately 2 hours post-mortem and transitions into post-rigor around 12 hours, although the temperature in which milkfish in this study was stored in was not indicated (Denny et al 2021). There

are several studies that support that storage at both icing and room temperature had approximately the same time for onset of rigor mortis in fish (Faruk et al 1994; Islami et al 2014). There are also those that reported pre-rigor periods shortened when stored at chilling temperature (Watabe et al 1989). However, it is evident that rigor mortis progressed differently in different fish species, with an accelerated trend at higher temperatures (Iwamoto et al 1987; Watabe et al 1989; Faruk et al 1994; Islami et al 2014; Le et al 2019). Further research related to the onset and progress of rigor mortis in milkfish at different temperatures is recommended.

In this study, pH was used as an indicator of muscle rigor status in *C. chanos*. Post-mortem leads to glycogen degradation into lactic acid which leads to initial decreases in fish pH (Islami et al 2014). With rigor mortis resolution and prolonged storage, pH increases with the production of amines and other volatile compounds due to autolytic and microbial actions (Gil & Barbosa 2011; Murthy et al 2017; Praveen Kumar et al 2017). At 0 hours, the muscle pH was 6.45. Studies have shown that milkfish has a pH of 6.5 at day 0 of iced storage and 6.43 after thawing from -18°C storage (Murthy et al 2017; Chua et al 2024). Other species have similar results with Atlantic horse mackerel (*Trachurus trachurus*) having an initial pH of 6.2, Indian mackerel (*Rastrelliger kanagurta*) with 5.67 and sardines (*Sardina pilchardus*) with 5.83 (Marrakchi et al 1990; Kayim & Can 2010; Chudasama et al 2018). Lower pH is associated with a good nutritional state of fish (Kayim & Can 2010). By 3 hours, pH had dropped to 5.97, indicating the onset of rigor. The lowest pH value recorded was 5.52 at 9 hours, suggesting the peak of rigor mortis. This coincided with the lowest recovery yield (75.08%), the longest deboning time (14.63 minutes), and the highest %loss IB and AF (6.54%). Notably, recovery yield, pH, deboning duration, and %loss IB and AF are all significantly correlated ($p < 0.05$) (Table 4). These findings support the observation that rigor mortis complicates the deboning process. By 12 hours chilling duration, the fish flesh had significantly softened, marked by a significant increase in recovery yield (77.04%), a reduction in deboning time (12.50 minutes), and a decrease in %loss IB and AF (4.95%). From 12 to 27 hours, pH values stabilized between 5.61 and 5.72. During this period of 12-27 hours chilling duration, recovery yields remained consistent (77.04–78.52%), deboning times plateaued (12.00–12.50 minutes), and %loss IB and AF continued to decrease, reaching 3.75% at 27 hours. At 30 hours, pH was recorded as 5.72, which is still on the lower side of pH indicating that further spoilage has yet to happen which is characterized by significant increases in pH. A low pH contributes to a longer storage shelf-life (Kayim & Can 2010). Following the resolution of rigor, pH tends to increase. A study on milkfish flesh revealed that pH increased with storage time in days (Beza & Sison 1978). Other studies on other fish species show similar pH trends with prolong storage (Marrakchi et al 1990; Kayim & Can 2010; Xu et al 2015). A study on mrigal carp (*Cirrhinus mrigala*) at ambient temperature showed initial decrease in pH from 6.89 to 6.14 at the end of the 12 hours and increase to 6.49 at the end of 24 hours (Kumar et al 2017).

This study conducted the deboning process in ambient temperature and recorded its deboning time. It is preferred that deboning *C. chanos* in ambient temperatures should be done as fast as possible to prevent further spoilage of fish. Study by Peralta & Serrano Jr. (2015) reported that prolonged exposure to ambient temperature (28°-32°C) of deboned milkfish leads to higher histamine content and total viable count with unsafe levels during 6-12 and 8-12 hours, respectively. Processing fish in the post-rigor stage is recommended for industrial use, plus it offers distinct advantages, particularly in terms of filleting ease (Aune et al 2014). During chilled storage, Le et al (2019) found that filleting during the post-rigor stage not only improved ease of processing and meat yield but also prevented contraction upon thawing from frozen storage. Ease of processing in post-rigor is due to muscle softening, which has also been documented to happen in whole and gutted milkfish during iced storage (Murthy et al 2017). Muscle softening facilitates bone removal and is reflected in the stability of both recovery yield and deboning time during the 12–27 hours chilling durations. However, by 30 hours, the flesh had become excessively soft, resulting in a decrease in recovery yield (76.49%) despite a significantly shorter deboning time (8.44 minutes) compared to previous hours. At this stage, the

weakened flesh could not withstand the force applied during bone extraction, leading to increased % loss IB and AF (5.52%).

Sensory evaluation was conducted to assess changes in the organoleptic properties of deboned milkfish across a 30-hour chilling duration. The parameters evaluated included odor (the fishy smell of the final deboned product), meat color (ranging from slightly translucent to opaque), flesh firmness (resistance to pressure and ability to return to its original shape), flesh cohesiveness (the integrity of muscle fibers), bone-flesh adhesion (the extent to which intermuscular bones remain attached to the flesh), and general acceptability. The interpretation of the sensory data is summarized in Table 1, which provides the corresponding descriptive ratings for each numerical score used in the evaluation. A strong positive correlation ($p < 0.0001$, two-tailed) was observed among most of the sensory parameters, with the exception of general acceptability, which was not significantly correlated with flesh cohesiveness and bone-flesh adhesion (Table 5). Odor, meat color, flesh firmness, cohesiveness, and bone-flesh adhesion generally declined with increased chilling duration. Initially (0–3 hours), all five parameters received the highest scores (5.00), indicating "like very much" and "very good" ratings. This is because fish muscle in the pre-rigor phase retains a freshness comparable to that of live fish (Iwamoto et al 1987; Islami et al 2014;). By 6 hours chilling duration, odor, flesh cohesiveness, and bone-flesh adhesion slightly declined to 4.96, 4.86, and 4.75, respectively, while meat color and flesh firmness remained at peak scores. As chilling progressed, further decreases in scores were observed. By 24 hours, odor scored 3.39 and meat color 4.00—both interpreted as "like slightly." Flesh firmness (3.71), flesh cohesiveness (3.64), and bone-flesh adhesion (3.89) had also declined to levels considered "fair." From 27 hours onward, more marked deterioration was recorded: odor score dropped to 2.75 ("neither like nor dislike"), and bone-flesh adhesion scored 2.79 ("poor"). At 30 hours, all parameters had further declined, with odor (2.57) rated as "neither like nor dislike", flesh firmness (2.68), and cohesiveness (2.79) as "poor," and bone-flesh adhesion scoring 1.61, or "very poor." Meat color, though also diminished (3.75), remained the most stable sensory parameter and was rated as "like slightly."

Meat color is a critical indicator in evaluating the freshness, overall quality, and consumer acceptability of raw fish flesh (Singh et al 2021). The coloration of fish muscle is influenced by various factors including oxidation, pH fluctuations, and microbial activity during post-harvest handling and storage (Singh et al 2021). Hemoglobin, particularly in its tightly bound form, contributes to muscle redness and plays a critical role in initiating lipid oxidation. Consequently, as oxidative processes progress during storage, discoloration and loss of redness are typically observed (Singh et al 2021). In the present study, a reduction in redness was visually noted in milkfish samples (Figure 8), with an initial semi-translucent appearance that became greyish and opaque over time. This observation is consistent with Beza & Sison (1978), who reported that milkfish flesh transitions from translucent to waxy white after 21 days of cold storage. Similarly, a decline in redness was observed in Nile tilapia (*Oreochromis niloticus*) stored at 0–1°C as storage time increased (Vázquez-Sánchez et al 2020).

Among the aforementioned evaluated parameters, bone-flesh adhesion showed the most pronounced change across chilling durations, followed by flesh cohesiveness, flesh firmness, odor, and finally, meat color. Bone-flesh adhesion showed strong positive correlations with flesh firmness ($r = +0.86$), cohesiveness ($r = +0.84$), odor ($r = +0.84$), and meat color ($r = +0.79$), all at $p < 0.001$. As the post-mortem storage period extended, softening of the fish flesh resulted in reduced muscle integrity and adhesion between muscle fibers and bones, which affected ease of deboning and product quality. This corresponds with the lower recovery yield and higher %loss IB and AF observed at 30 hours. Post-mortem sensory changes in fish muscle are commonly associated with a loss in muscle rigidity (Gil & Barbosa 2011). Similar findings of progressive softening, reduced muscle elasticity, and diminished springiness and resilience during cold storage have been reported in both milkfish and turbot (*Psetta maxima*) (Beza & Sison 1978; Xu et al 2015; Murthy et al 2017). These changes collectively reflect the declining freshness and quality of milkfish during chilled storage, as previously noted by Agustini et al (2009) and

Murthy et al (2017). Spoilage-related sensory changes were evident by 24–27 hours, with noticeable declines in odor and texture-related parameters. The characteristic fishy odor commonly associated with marine fish is primarily attributed to volatile compounds such as aldehydes, alcohols, and ketones, which are produced through microbial activity, enzymatic reactions, and autoxidation (Liu et al 2021). Since the milkfish used in this study were cultured in marine cages, odor changes during storage are likely associated with these biochemical processes. Murthy et al (2017) also reported odor deterioration and the development of soft, slimy texture in both whole and gutted milkfish stored on ice. Similarly, Denny et al (2021) observed the development of unpleasant odors in whole milkfish after 12 hours of storage. Off-odors, such as those resembling ammonia or sulfur-containing compounds, serve as clear indicators of spoilage and quality deterioration (Duarte et al 2020). The highest general acceptability score (5.00, "like very much") occurred at 15 hours. General acceptability remained stable (4.07–4.93, "like moderately") between 9 and 27 hours, before dropping to 3.39 ("like slightly") at 30 hours. Interestingly, general acceptability was initially low at 0 hours (3.43), due to the difficulty in deboning pre-rigor fish, which resulted in visible tearing of flesh. Photographic documentation (Figure 8) shows that during the early chilling period (0–9 hours), the flesh was prone to tearing due to strong bone-flesh adhesion and the onset of rigor mortis. This led to lower general acceptability and extended deboning durations (14.31–14.63 minutes). In contrast, between 12 and 24 hours, fish flesh has significantly relaxed, resulting in lower bone-flesh adhesion (sensory scores 2.79–3.89), improved yields (77.04–78.52%), shorter deboning times (12.00–12.50 minutes), and reduced %loss IB and AF (3.11–4.95%). These chilling durations yielded the highest overall sensory ratings (general acceptability 4.54–5.00) and are recommended for optimal deboning in terms of both yield and sensory quality. By 27 hours, although recovery yield was highest (78.52%), and deboning was fastest (10.19 minutes) with relatively low flesh loss (3.75%), a significant decline in sensory quality was noted across all parameters. Odor, in particular, was rated as "neither like nor dislike," and bone-flesh adhesion as "poor." As such, 27 hours may represent the upper threshold for acceptable sensory quality in deboned milkfish.

While this study relied on organoleptic methods to assess texture and quality, it should be noted that frozen storage would alter these parameters further. Due to time and facility limitations, no microbial or instrumental texture analyses were conducted. However, sensory methods remain appropriate, particularly as freshly deboned milkfish is commonly consumed frozen or immediately in the country. Future research on frozen deboned milkfish is strongly recommended to incorporate microbiological and biochemical validation of freshness. At 30 hours, general acceptability further declined, and all sensory parameters reached their lowest scores. Although deboning was most efficient at this stage with deboning time at 8.44 minutes, recovery yield decreased (76.49%), and % loss IB and AF increased (5.52%) plus visible tearing of the very softened flesh occurred. Based on these results, deboning beyond 27 hours is not recommended, as both product quality and yield begin to deteriorate noticeably. Declines in sensory attributes have also been documented in other studies of fish species. In particular, Indian mackerel (*Rastrelliger kanagurta*) spoilage was assessed through changes in sensory attributes such as appearance, color, odor, and overall acceptability, which eventually declined to levels categorized as "neither like nor dislike" (Chudasama et al 2018). A similar trend was observed in the present study, wherein milkfish samples stored for 30 hours or more were no longer recommended for deboning, as most sensory scores—except for general acceptability—fell within the "neither like nor dislike" to "poor" range, with bone-flesh adhesion rated as "very poor." Further, Perceka et al (2015) reported declines in organoleptic scores and structural degeneration of milkfish skin stored under chilling conditions, with necrotic changes beginning during the rigor mortis phase.

Conclusions. The study demonstrated the effectiveness of a modified deboning technique for *C. chanos* processed at varying post-mortem chilling durations. By incorporating alterations such as the creation of intermuscular pockets and revised

incision areas along the dorsal region, the modified method facilitated easier spine removal, improved detection of remaining bones, and preserved the integrity of the flesh throughout processing. This study fills a notable gap by documenting actual recovery yields for *C. chanos* deboning. Based on the findings, this study recommends implementing the modified deboning technique between 12 to 24 hours of post-mortem chilling as the optimal window for processing *C. chanos*. During this period, the softened flesh of the fish yielded the most favorable outcomes—recovery yields ranging from 77% to 78%, minimal losses due to intermuscular bones and attached flesh (approximately 3–4%), and reduced deboning durations of 10–12 minutes. Sensory characteristics during this interval remained within acceptable limits, with scores interpreted as ranging from “like very much” to “like slightly,” and descriptors from “good” to “fair.” While acceptable quality was still observed at 27 hours, this point may be considered the upper limit for deboning *C. chanos* under chilled conditions. This deboning method is a low-technology, practical approach that is both accessible and adaptable for industry application, particularly for *C. chanos* processors that rely on manual deboning. Future research is recommended to investigate the effects of frozen storage on deboned milkfish spoilage.

Acknowledgements. The authors gratefully acknowledge the financial support provided by the Cebu Technological University Moalboal Campus through the STF-Research Budget. The authors also extend their sincere thanks to the assistance rendered by Ms. Marianne Gabato, Ms. Lorna Casagan, Ms. Margarita Cuime, Mr. Nicolas Pimentel, Ms. Alik Mae Tabañag during the implementation of the experimental procedure.

Conflict of interest. The authors declare that there is no conflict of interest.

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Received: 24 May 2025. Accepted: 21 July 2025. Published online: 13 August 2025.

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How to cite this article:

Daita H. A. R., Amihan Jr. R. S., Redoble J. L. S., 2025 Effects of post-mortem chilling duration on recovery yield and sensory characteristics of manually deboned cage-cultured milkfish (*Chanos chanos*) butterfly fillets using a modified technique. *AAFL Bioflux* 18(4):1881-1898.