# Nutritional value and characteristics of chitin from slipper lobster (*Thenus orientalis*) for functional food ingredient

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**Abstract.** Slipper lobster lives on the bottom of sandy marine waters. The nutritional content and utilization of its large carapace (50%) can be converted into chitin. However, the potential of it has not been fully utilized due to the lack of biological information and nutritional value. This study aims to determine the nutritional content of Slipper lobster and determine the characteristics of its chitin. This research used a descriptive method. Parameters observed include morphology, proportion, chemical composition, and deacetylation degree. The result showed that Slipper lobster weighs about 80-240 g with a length of 15.2-24.7 cm, with a carapace percentage of 53.85% greater than the percentage of meat at 34.98%. The nutritional values of carapace and meat were protein 37.90%, 88.10%, fat 0.08%, 0,26%, carbohydrate 0.31%, 3.94%, fiber 6.28%, 1.38%, ash 55.43%, 6.32%, and water 41.95%, 77.19%, respectively. Furthermore, deacetylation degree of chitins was 64.10% which had a water content of 3.50%, ash 5.85%, and minerals potassium 6.75 mg/L, calcium 114.95 mg/L, sodium 15.65 mg/L, and iron 0.95 mg/L. This data showed that Slipper lobster has potential as a functional food ingredients, such as a protein isolates and hydrolysates, but the characteristics of chitin can be improved through chitosan extraction process.

## 1 Introduction

The high prevalence of diet-related disease in developed and developing countries has led to realization of the importance of nutritious food for people. It is now popular for people to actively choose healthy foods for better life option. Various scientific studies linking diet to

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the oneset of certain desease such as heart attacks [1-3]. Hence, to provide nutritional information contained in seafood.

Slipper lobster (*Thenus orientalis*) is a seafood (crustacean class) that can be found all over the world. This lobster, is commonly known as Flathead lobster (English), Cigale raquette (French), and Cigarra chata (Spanish). It lives in sandy and muddy areas with a flattened body shape in the head area, resembling a fan shape compared to the body, and is the most popular species among Scyllaridae species [4-7]. Slipper lobster is one type of commodity that has high economic value as seafood in Asia, Europe, and America, especially throughout Indonesian waters (Sumatra, Indian Ocean, Makassar Strait, Java Sea, East Kalimantan, and Kupang [8-11] and accounts for 8% of lobster production globally [12]. It was recently reported that 10 tons of Slipper lobster has successfully been exported worth more than 61,777 USD to Australia [13]. Furthermore, *Thenus* spp. have been successfully bred and reared on a laboratory scale, but have not yet been commercially cultured on a large scale [14-15].

Slipper lobsters continue to be extensively researched due to overexploitation because of the lack of biological information about this species [16]. This condition will also threaten the life of the lobster, even in terms of the environment, it has the potential to pollute the environment due to the increasing amount of Crustacean carapace waste, so it is necessary to convert these biomaterials into functional food ingredients such as chitin. Chitin from crustaceans is around 89.59% [17] which can be utilized by releasing acetyl groups. The higher deacetylation degree, the better biocompatibility, biodegradability, bioactivity and muchoadesin [18][19]. From these properties, Slipper lobster has potential in the fields of medicine, dental care, food processing chemistry, biotechnology, agriculture, and environmental protection. In addition, it can be used for food raw materials, cosmetics, antibacterial animal feed, textiles and other pharmaceutical products [20-23]. However, there is still little information regarding the nutritional value and chitin characteristics of Slipper lobster *(Thenus orientalis)* from Indonesian waters. Therefore, this study focused on the proportion, chemical composition and characteristics of chitin as a potential functional food ingredient.

## 2 Materials and methods of research

### 2.1 Materials and Tools

The main material used in this study was Slipper lobster *(Thenus orientalis)* obtained in the Sibolga Waters area, North Sumatra Province. The weight of the slipper lobster used is 50-250 g. Chemicals used PP (phenolpthalein) indicator, perchloric acid, 65% nitric acid, concentrated sulfuric acid ($H_2SO_4$), Kjeldhal Tab catalyst, 45% NaOH, 20% boric acid ($H_3BO_3$), methyl blue and methyl red indicators, $HNO_3$, $HClO_4$, $K_2CO_3$, mineral standard solution (Ca, Mg, P, Fe, Na, K), 50% acetonitrile, 90% acetone, cotton, tissue, aluminum foil, filter paper, Whatman 42, distilled water, gloves and mask. The tools used in this study were AAS spectrophotometer (PerkinElmer AAnalyst 400), *waterbath* (memmert), refrigerator, oven (binder), incubator (binder), grinder, analytical balance (0.0000 g) (boeckel), digital balance (0.00 g) (BC ohaus), Kjeldahl tube (velp scientifica), Soxhlet tube (MS-EAM favorite), *furnace* (barnstead thermolyne).

### 2.2 Carapace Preparation

Slipper lobsters were separated into carapace, meat, entrails, and each part was weighed. The carapace was washed using running water and brushed to remove the remnants of meat attached to the carapace. Each body part of the fan shrimp was weighed. Then, the carapace

was dried in an oven for 5 days at 40°C. Next, it was pulverized by grinding (grinder). Meat and carapace were analyzed proximately including analysis of total protein content (kjeldahl method), fat (soxhlet method), water, ash, fiber, carbohydrates [24] and yield [25].

### 2.3 Extraction of Chitin

Chitin extraction refers to the procedure of [26], that is the initial process of chitin preparation including demineralization, deproteination and drying. Furthermore, chitosan is obtained from chitin deacetylation. The smooth fan shrimp carapace was demineralized with 1N HCl solution (ratio of shell and HCl solution 1:7 b/v), for 1 hour at ± 90°C. The results of the demineralization process were then precipitated to separate the solids and liquids by letting them solid. The solids obtained were washed 3 times with distilled water to neutralize the pH close to pH 7. The solids were then deproteinated with 3N NaOH solution (ratio of solids and NaOH solution 1:10 (b/v) for 1 hour at ± 90°C. The results of the deproteination process were then precipitated to separate the solids and liquids by allowing the solids to separate from the liquid. The solids obtained were washed repeatedly with tap water to neutralize the pH to close to pH 7. The solids were dried in an oven at 60°C for 6 hours. The chitin formed was analyzed for mineral K, Ca, Na [27], water, ash [24], and deacetylation degree [28].

### 2.4 Statistical Analysis

The proportion of body parts, chemical composition, mineral chitin values were determined descriptively using Microsoft Excel (version 16), presenting the average ± standard deviation.

## 3. Result and Discussion

### 3.1 Description of Slipper Lobster

The shrimp used in this study was the slipper lobster (*Thenus orientalis*) which had an average consumption size of around 80-240 g with a length of 15.2-24.7 cm. Adult slipper lobster with consumption size has a length of 10-25 cm [11]. The morphology of the slipper lobster from Sibolga waters is shown in Figure 1.

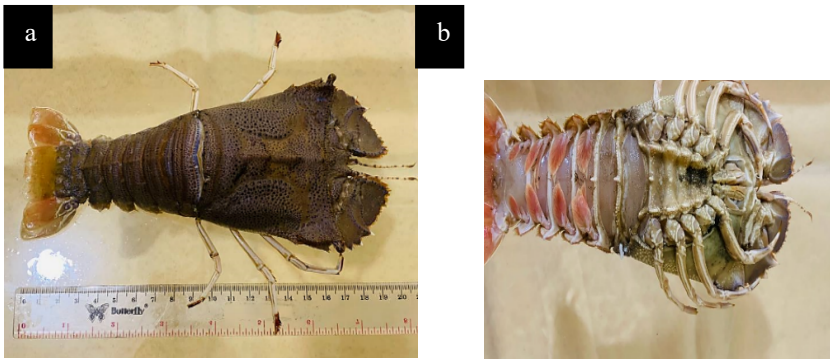


**Fig. 1.** Slipper lobster (*T. orientalis*) (a. dorsal and b. ventral views)

On dorsal views, observation results showed the slipper lobster was dark brown with a rough skin appearance and black spots on the head. Compared to the ventral views the head was white, the tail and pleopods are pink. Morphology of slipper lobster shows that the head (cephalothorax) was flat and wide (flathead) resembling a fan, flatter, harder and thicker than the body. At the end of slipper lobster head has two hard and thorny protrusions, it is long and rounded. The abdomen was covered with small spines that are hard and coated with calcareous, then the tail (telson) was upright and the number of legs was eight.

Differences in the types of females and males in slipper lobsters, it can be seen that females have larger pleopods, equipped with setae (hair), larger size, wider abdomen, longer tail (telson) and brighter colors compared to males [29]. Differences in shrimp species depend on morphological, morphometric, meristic, ecological and evolutionary characteristics) [30] and generally depend on the habitat of the shrimp from different countries.

### 3.2 Proportion of body parts

Each part of slipper lobster body consists of carapace, meat, gonads, and leftover food. The percentage and weight of its body is shown in Figure 2 and Table 1. In general, the ratio of carapace, meat, gonads and food waste was 14:9:2:1 (w/w). The highest percentage was a carapace, which reached 53.85%. The slipper lobster carapace is an exoskeleton with a hard and thick shape to protect all internal organs such as the head cover (cephalothorax), body (abdomen) and tail (telson) which are attached by the muscles of the shrimp body. The muscles of the shrimp can be moved due to the connection of ganglion nervous system from the brain and two circumesophageal connectives [31].

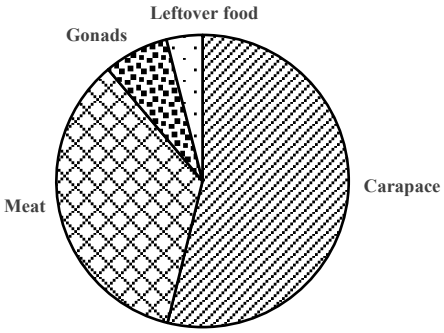


**Fig. 2.** Body parts slipper lobster

**Table 1.** Weight of slipper lobster (*T. orientalis*) body parts

| Body parts | Weight (g) |
|---|---|
| Carapace | 71.31 ± 21.01 |
| Meat | 46.33 ± 13.58 |
| Gonads | 9.53 ± 4.92 |
| Leftover food | 5.26 ± 4.54 |
| Total | 132.43 ± 44.05 |

Slipper lobster meat was covered on the outside of the body by the carapace with a percentage of 34.98%. The inner body is dominated by meat, which is an array of white elastic muscles formed from the structural units that make up the body. This indicates a relatively large meat ratio in slipper lobster. The potential of shrimp meat contains beneficial proteins, fats, minerals, and vitamins when consumed to build and repair body tissues, increase hemoglobin levels, protect body from cell damage, and maintain bone health [32].

The percentage of slipper lobster gonad parts was 7.20%, indicating that some slipper lobsters were undergoing gonads maturation for spawning. Maturation of female gonads is characterized by the presence of rounded yellow eggs that expand in the body (ventral position), while the maturation of male gonads is observed through the development of white-colored petasma [33].

For more, there was 3.97% of residual food waste, originated from the digestive tract within the stomach contents. The digestive system of shrimp starts from the mouth, esophagus, stomach, intestines, and anus. The digestive tract also contains enzymes such as protease and lipase to aid in breaking down food into nutrients that can be absorbed by the shrimp's body [34].

### 3.3 Chemical Composition

The nutritional values in this study were analyzed through proximate test of meat and carapace of slipper lobster, as shown in Table 2.

**Table 2.** The proximate contents of carapace and meat of slipper lobster (%)

| Parameters | Carapace | Meat |
|---|---|---|
| Protein (dw) | 37.90 ± 2.29 | 88.10 ± 0.62 |
| Fat (dw) | 0.08 ± 0.00 | 0.26 ± 0.00 |
| Carbohydrate (dw) | 0.31 ± 0.02 | 3.94 ± 0.03 |
| Fiber (dw) | 6.28 ± 0.02 | 1.38 ± 0.00 |
| Ash (dw) | 55.43 ± 1.36 | 6.32 ± 0.05 |
| Moisture | 41.95 ± 1.28 | 77.19 ± 0.61 |

The protein content of slipper lobster is higher than that found in previous studies which reported meat at 79.91% (dw) [35] and carapace at 25.69% (dw) [36]. This condition indicates that the protein in shrimp meat undergoes numerous formations of new tissues as regulatory substances and muscle formation through amino acid synthesis [37]. The high protein content can be utilized for functional foods, such as protein concentrates [38].

Fat serves as a reserve energy source to maintain and enhance bodily functions. The fat content of slipper lobster was quite low, with fat in the meat being 0.26% and the carapace being 0.08%. Marine organisms such as fish, shrimp, and crabs have relatively low fat content ranging from 0.20% to 3.34% [39], and lower than the same research, which is the slipper lobster (*T. orientalis*) with 3.02% fat content [40]. The fat content of shrimp varies widely, depending on the type of food, shrimp species, age, season, and habitat.

The carbohydrate content of slipper lobster meat was 3.94% which was higher than its carapace, which was 0.31%. Based on the research the carbohydrate content of shrimp ranges from 3% to 10% [41], Meanwhile, the fiber content of the carapace was 6.28%, higher than

the meat at 1.38%. High fiber content of the carapace is due to the presence of chitin and chitosan polysaccharide derivatives, which make up more than 26% of the exoskeleton. These components, along with sulforaphane and selenium, can inhibit the growth of cancer cells, prevent infections, boost immune system, and lower cholesterol levels [42].

The ash content of slipper lobster carapace was notably high, measuring 55.43%, compared to the meat which had an ash content of 6.32%. The high ash content of carapace signifies a substantial presence of minerals within it. The abundant mineral content formed from both the carapace and meat of slipper lobster includes Ca, K, Na, Mg, Fe, and P [43]. Nevertheless, the presence of carapace ash can also be utilized for functional foods such as chitin, chitosan, chitooligosaccharides and glucosamine.

The moisture content in the slipper lobster meat was 77.19%, and the carapace had a slightly high value of 41.95%. The wet nature of the meat indicates a high moisture content, which is characteristic of fresh food items, containing a moisture level of around 70-80%. Additionally, the high moisture content of the carapace allows for the attachment of bodily tissues, residue, water, and mud within the carapace tissue.

### 3.4 Chitin Characteristic

The spectra of chitin and chitosan in this study are shown in Figure 3 and mineral contents in Table 3. In this study, the characteristic amine peaks around 3300 to 3500 cm-1 with N-H stretching. The bending vibration observed around 1450 to 1480 cm-1 is attributed to the N-H bending vibration of the R-NH2 functional group indicating an increasing deacetylation degree. Typical alcohol peaks (OH and COH) were observed to occur at about 3500 cm-1 and just before 1000 cm-1. The peaks observed between 2400 and 2800 cm-1 indicate basic C-H vibrations of $CH_2$ [44]. Literature studies revealed chitin derivatives have similar characteristic peaks obtained in this study [45-46].

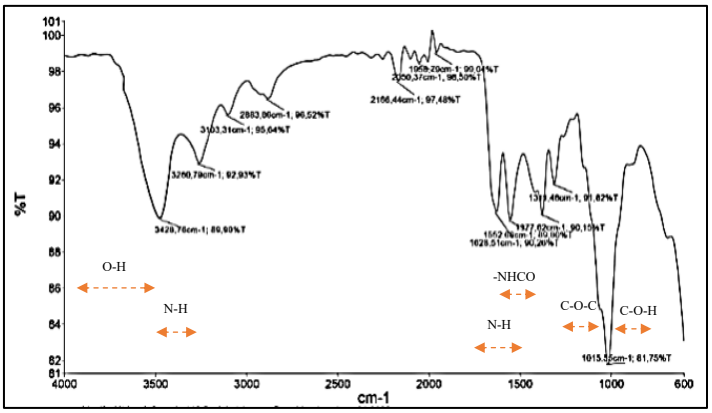


**Fig. 3.** Spectrum FTIR of slipper lobster chitin

Based on the amine bending in this study, the deacetylation degree was 64.10%, relatively low from the fan shrimp species of 65%, mantis shrimp 68%, and king crab 70% [47]. The reason is also proven by deacetylation degree of chitin which is relatively low from the SNI standard, which is > 65% [48]. It is suspected that the ash content and chitin minerals are still high because of not decrease during the demineralization process, as attested by the ash content (5.85%) which is higher than the SNI standard maximum 5% [48]. Nevertheless, the mineral, ash, moisture content of chitin in this study is lower than the slipper lobster chitin

reported by [49] which is 3.96% (moisture) and 8.27% (ash). Deacetylation degree in this study, can be increased through the chitosan process to be applied as a functional food ingredient.

**Table 3.** Mineral contents of chitin of slipper lobster (*T. orientalis*)

| Parameters | Amount |
|---|---|
| Water (%) | 3.50 ± 0,14 |
| Ash (%) | 5.85 ± 0.07 |
| Calium (mg/L) | 6.75 ± 0.06 |
| Calcium (mg/L) | 114.95 ± 1.34 |
| Natrium (mg/L) | 15.65 ± 0.07 |
| Zinc (mg/L) | 0.95 ± 0.09 |

## 4 Conclusion

Slipper lobster weighs about 80-240 g with a length of 15.2-24.7 cm, with a carapace percentage of 53.85% greater than the percentage of meat at 34.98%. The nutritional values of carapace and meat were protein 37.90% and 88.10%. Furthermore, deacetylation degree of chitins was 64.10% which had a water content of 3.50% and ash 5.85%. This data showed that Slipper lobster has potential as a functional food ingredient, such as a protein isolates and hydrolysates, but the characteristics of chitin can be improved through chitosan extraction process.

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## References

1. W. C. Willet, The role of dietary n-6 fatty acids in the prevention of cardiovascular disease, J Caridovasc Med. **8**, 1, 42-45 (2007). https://doi.org/10.2459/01.JCM.0000289275.72556.13
2. E. Ekpenyong, I.O. Williams, U.U. Osakpa, Variation in the proximate, energy and mineral compositions of different body parts of macrobrachium macrobranchion (Prawn). J. of Food Research. **2**, 2 (2013). https://doi.org/10.5539/jfr.v2n2p150
3. S.T. Mergelsberg, R.N. Ulrich, S. Xiao, P.M. Dove, Composition Systematics in the Exoskeleton of the American Lobster, Homarus americanus and Implications for Malacostraca. Front. Earth Sci, **7**, 69 (2019). https://doi.org/10.3389/feart.2019.00069
4. D. Latrouite, J.D. Booth, G.S. Jamieson, Evaluation of crystalline amino acids as potent stimulatory chemoattractants for the slipper lobster Thenus orientalis. Fisheries and aquaculture. **2**, 2 (2009). https://doi.org/10.7717/peerj.15607

5. T.Y. Chan, Updated checklist of the world's marine lobsters, (Lobsters: Biology, Fisheries and Aquaculture, Springer, 2019)
6. K.L. Lavalli, E. Spanier, F. Grasso, Behavior and sensory biology of slipper lobsterm, (New York CRC Press, Taylor & Francis Group, 2007)
7. K. Ueda, T. Yanagimoto, S. Chow, M. Kuroki, T. Yamakawa, molecular identification of mid to final stage slipper lobster phyllosoma larvae of the genus chelarctus (Crustacea: Decapoda: Scyllaridae) Collected in the Pacific with Descriptions of Their Larval Morphology. Zool. Stud. **7**, 60-75 (2021). https://doi.org/10.6620/ZS.2021.60-75
8. K L. Lavalli, E. Spanier, J.S Goldstein, Scyllarid, Lobster biology and ecology, crustacea, (Intech Open, 2019)
9. B. Indradinata, P.L. Samputra, Lobster clear seeds smuggling's threats and modes through the customs side in Indonesia. Interdisciplinary Soc. Stud. **2**, 8, 2204-2213 (2023.) https://doi.org/10.55324/iss.v2i8.448
10. Y. Wardiatno, A.H. Agus, M. Ali, A.B. Nurlisa, A. Luky, Gene cloning and protein expression of Koi Herpesvirus ORF25. HAYATI of Biosciences. **23**, 3 (2016). https://doi.org/10.4308/hjb.23.3.143
11. Wiadnyana, N. N. Wijopriono, Dharmadi, A. Suman A, Efektifitas implementasi kebijakan pelarangan ekspor produk hiu appendik ii cites. Jurnal Kebijakan Perikanan Indonesia. **11**, 1 (2019). https://doi.org/10.15578/jkpi.11.1.2019.1-10
12. E.V. Radhakrishnan, J.K. Kizhakudan, M. Vijayakumaran, P. Vijayagopal, M. Koya, Evaluation of crystalline amino acids as potent stimulatory chemoattractants for the slipper lobster Thenus orientalis, Jeena. Springer Nature. **1**, (2019). https://doi.org/10.7717/peerj.15607
13. D.P. Donatus, E. Elza, BKIPM Pangkalpinang ekspor perdana 10 ton udang kipas ke Australia. Accesed on August 17, (2023) in accessed of https://babel.antaranews.com/berita/358695/bkipm-pangkalpinang-ekspor-perdana-10-ton-udang-kipas-ke-australia.
14. E.V. Radhakrishnan, J.K. Kizhakudan, Health management in lobster aquaculture. Lobsters: Biology, Fisheries and Aquaculture. Springer. (2019). https://doi.org/10.1007/978-981-32-9094-5
15. C.F. Teoh, A.D. Tuzan, A.S.K. Yong, K.S. Liew, L.S. Lim, H.J. Liew, Evaluation of crystalline amino acids as potent stimulatory chemoattractants for the slipper lobster Thenus orientalis. Peer. J. **11**, e15607 (2023). https://doi.org/ 10.7717/peerj.15607
16. I. Alborés, C. García-Soler, L. Fernández, Reproductive biology of the slipper lobster Scyllarus arctus in Galicia (NW Spain): Implications for fisheries management. Fisheries Research. **212**, 1-11 (2019). https://doi.org/10.1016/j.fishres.2018.12.001
17. M. Manimohan, R. Mostafizur, P. Saravanan, T. Muthu, P. Sivashanmugam, Exploring biological activity and In-vitro anticancer effects of a new biomaterial derived from Schiff base isolated from Homarus americanus (Lobster) shell waste P. Sustainable Chemistry and Pharmacy. **37,** (2024). https://doi.org/10.1016/j.scp.2023.101363
18. A.Z. Hameed, J. Kandasamy, M.A. Baghdadi, M.A. Shahzad, Chitosan: A Sustainable Material for Multifarious Applications Polymers. Basel. **14**, 12 (2022) https://doi.org/10.3390/polym14122335
19. P. Mura, F. Maestrelli, M. Cirri, N. Mennini, Multiple Roles of chitosan in mucosal drug delivery: an updated review. Mar. Drugs. **20**, 335 (2022) https://doi.org/10.3390/md20050335

20. J.O. Tavares, J. Cotas, A. Valado, L. Algae, Food products as a healthcare solution, pereira, marine drugs. **21**, 11 (2023). https://doi.org/10.3390/md21110578
21. A. Blasi, A. Verardi, C.G. Lopresto, S. Siciliano, P Sangiorgio, Lignocellulosic agricultural waste valorization to obtain valuable products: an overview. Recycling. **8**, 4 (2023). https://doi.org/10.3390/recycling8040061
22. E. Tamburini, The blue treasure: comprehensive biorefinery of blue crab (*Callinectes sapidus*). Foods. **13**, 13 (2024). https://doi.org/10.3390/foods13132018
23. G. Sollai, A. Giglio, P.G. Giulianini, R. Crnjar, P. Solari, Topic: arthropod biodiversity: ecological and functional aspects. Insects. **15,** 10, 766 (2024). https://doi.org/10.3390/insects15100766
24. Association of Official Analytical Chemists, *Official Methods of Analysis of AOAC International. 18th Edition*, Effect of Partial Fat Replacement by Whey Protein, Oat, Wheat Germ and Modified Starch on Sensory Properties, Viscosity and Antioxidant Activity of Reduced Fat Ice Cream, Gaithersburg International (2007) https://doi.org/10.4236/ce.2020.118106
25. R. Karnila, S. Made, Sukarno, W. Tutik, Analisis kandungan nutrisi daging tepung teripang pasir (*Holothuria scabra* J.) Segar. Terubuk. **39**, 2 (2011) http://repository.ipb.ac.id/handle/123456789/69838
26. P. Suptijah, A.M. Jacoeb, D. Rachmania, Karakterisasi nano kitosan cangkang udang vannamei (*Litopenaeus Vannamei*) dengan metode gelasi ionik, pengolahan hasil perikanan Indonesia. **17**, 2 (2011) https://doi.org/10.17844/jphpi.v14i2.5315
27. American Public Health Association, Standard Methods for The Examination of Water and Wastewater**, (**21st ed, New York American Public Health Association, Locally Isolated Bacterial Strains with Multiple Degradation Potential Capabilities on Petroleum Hydrocarbon Pollutants, Inc, 2005)
28. D.I. Sánchez-Machado, L.C. Jaime, A.E.G Ana, N.C.B. Olga, M.M.I. Diana, R.L. Salvador, Measurement of the degree of deacetylation in chitosan films by FTIR, $^{1}$H NMR and UV spectrophotometry. MethodsX. **12**, 102538 (2024)
29. R. Pratiwi, Sebaran kepiting mangrove (Crustacea: Decapoda) yang terdaftar di koleksi rujukan pusat penelitian oseanografi-lipi. Jurnal Oseanografi-LIPI. **46**, 2, 1960-1970 (2011).https://doi.org/10.14203/beritabiologi.v14i2.1854
30. L.B. Holthuis, Introduction to the biology and fisheries of slipper lobsters, a revision of the family Scyllaridae (Crustasea: Decapoda: Macrura) 1 Subfamily Ibacinae. Zool. Verhand. **218,** (1985). https://doi.org/10.1201/9781420005165.pt1
31. R. Heinrich, A. Wirmer, Regulation of acoustic sensory-to-motor processing in insects, (Academic Press Neuroendocrine Regulation of Animal Vocalization, 2021)
32. M. Brancaccio, C. Mennitti, A. Cesaro, F. Fimiani, M. Vano, B. Gargiulo, M. Caiazza, F. Amodio, I. Coto, G. Alicandro, C. Mazzaccara, B. Lombardo, R. Pero, D. Terracciano, G. Limongelli, P. Calabrò, V. Argenio, G. Frisso, O. Scudiero, The biological role of vitamins in athletes' muscle, heart and microbiota. Int. J. Environ. Res. Public Health. **23**, 3 (2022) https://doi.org/10.3390/ijerph19031249
33. Y.T. Adiputra, M. Zairin, M.A. Suprayudi, W. Manalu, Widanarni, M. Brite, Feeding ecology analysis of sand lobsters (*Panulirus homarus*). Malaysian Journal of Science. **39**, 1 (2020). https://doi.org/10.29103/aa.v11i1.13258
34. H. Rahmi, Hariyanti, P.A. Rina, D. Wulandari, Analisis hasil fraksinasi protease dan lipase yang berasal dari saluran pencernaan udang vaname (*Litopenaeus Vannamei*). Jurnal Bioteknologi dan Biosains Indonesia. **7**, 2 (2020) https://doi.org/10.29122/jbbi.v7i2.3994

35. M.Z. El-Faer, T.N. Rawdah, K.M. Attar, M. Arab, Mineral and proximate composition of some commercially important fish of the Arabian Gulf, Food Chemistry **45**, 2, 95-98 (1992). https://doi.org/10.1016/0308-8146(92)90016-U
36. A.O. Toliba, M.A. Rabie, G.M. El-Araby, Effect of organic calcium spraying and Nano Chitosan fruits coating on yield, fruit quality and storability of peach cv 'Early swelling. Zagazig. J. Agric. Res. **41**, 5, 737-749 (2016). https://doi.org/10.13140/RG.2.2.30115.60965
37. R. Karnila, Edison, Dewita, D. Yoswaty, T. Putri, A.A. Yunus, Antioxidant activity on protein hydrolysate peptide of mudskipper fish (*Periophthalmodon schlosseri*) using alcalase enzyme. Food Science and Technology. **43**, (2023). https://doi.org/10.5327/fst.122222
38. B. Dewita, Syahrul, Desmelati, Characteristics of hydrolysate protein from malong fish (*Congresox Talabon*) which hydrolized by using papain enzyme. International J. of Oceans and Oceanography. **12**, 1, 186 (2018). https://doi.org/10.31258/terubuk.47.2.186-193
39. S.L. Artono, T. Agus, T.S. Nur, S. Agus, Subagiyo, P. Delianis, D. Rignolda, T. Aiyen, Degradasi karbohidrat pada pakan udang oleh isolat kapang endofit mangrove. Jurnal Kelautan Tropis. **26**, 1 (2023) https://doi.org/10.14710/jkt.v26i1.17292
40. Y. Xu, Y. Du Y, Effect of molecular structure of chitosan on protein delivery properties of chitosan nanoparticles. Int. J. of Pharmaceutics, **250**, 4, 215-226. (2003). https://doi.org/10.1016/S0378-5173(02)00548-3
41. Z. Liu, Q. Liu, D. Zhang, S. Wei, Q. Sun, Q. Xia, W. Shi, H. Ji, S. Liu, Comparison of the proximate composition and nutritional profile of byproducts and edible parts of five species of shrimp. Foods. **10**, 11, 2603 (2021). https://doi.org/10.3390/foods10112603
42. P.G. Vivanco, P. Taboada, A. Coelho, The Southern European atlantic diet and its supplements: the chemical bases of its anticancer properties. Nutrients. **15**, 19, 4274 (2023). https://doi.org/10.3390/nu15194274
43. F.A.A. Sagheer, M.A. Al-Sughayer, S. Muslim, M.Z. Elsabee, Extraction and characterization of chitin and chitosan from marine sources in Arabian Gulf. Carbohydrate Polymers. **77**, 2 (2009). https://doi.org/10.1016/j.carbpol.2009.01.032
44. I. Sivanesan, M. Muthu, J. Gopal, N. Hasan, A.S. Kashif, J. Shin, J.W. Oh, Nanochitosan: commemorating the metamorphosis of an exoskeletal waste to a versatile nutraceutical, nanomaterials. Basel. **11**, 3, 821 (2021). https://doi.org/10.3390/nano11030821
45. S. Kumari, A.S.H. Kumar, S. Abanti, R.P. Kumar, Physicochemical properties and characterization of chitosan synthesized from fish scales, crab and shrimp shells. Int. J. Biol. Macromol. **104**,1697-1705 (2017). https://doi.org/10.1016/j.ijbiomac.2017.04.119
46. M. Triunfo, E. Tafi, A. Guarnieri, R. Salvia, C. Scieuzo, T. Hahn, S. Zibek, A. Gagliardini, L. Panariello, M.B. Coltelli, A.D. Bonis, P. Falabella, Characterization of chitin and chitosan derived from Hermetia illucens, a further step in a circular economy process. Sci. Rep. **12**, (2022). https://doi.org/10.1038/s41598-022-10423-5
47. K. Mohan, T. Muralisankar, R. Jayakumar, C. Rajeevgandhi, A study on structural comparisons of α-chitin extracted from marine crustacean shell waste. Carbohydrate Polymer Technologies and Applications. **2**, (2021). https://doi.org/10.1016/j.carpta.2021.100037
48. Standarisasi Nasional Indonesia, Syarat Mutu Kitin dan Kitosan, (Badan Standarisasi, 2013) in accessed https://pesta.bsn.go.id/produk/detail/9710-sni79492013

49. H.S. Putra, B. Hasan, R. Karnila, T.M. Ghazali, Mineral content profile of carapace flour, chitin, and chitosan slipper lobster (*thenus orientalis*). Asian Journal of Aquatic Sciences. **7**, 2 (2024). https://doi.org/10.31258/ajoas.7.2.192-199