



Ethnopharmacology, chemical constituents, and pharmacological activities of edible mud crab *Scylla serrata* (Forskål, 1775): a review

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Abstract

Scylla serrata (Forskål, 1775), or mud crab or mangrove crab, is an euryhaline edible crab belonging to the family Portunidae. This edible crustacean is used as a delicious foodstuff throughout the world and plays a role in traditional medicine for the treatment of various diseases such as tuberculosis, rheumatism, dropsy, bone fracture, asthma, insomnia, rickets, epilepsy, and convulsions. This review compiles and critically examines the reported ethnopharmacological uses, chemical constituents, and pharmacological activities of *Scylla serrata*. All data presented in this paper were collected by utilizing the online databases during 2015–2025. Chemical analysis on *Scylla serrata* resulted in the presence of proteins, amino acids, polyunsaturated fatty acids, monounsaturated fatty acids, and minerals. Chemical constituents will fluctuate depending on the sex, size, and season. Antioxidant, anti-anemic, anticancer, antimicrobial, and neuroprotective activities are reported from the crab. A significant study conducted on *Scylla serrata* evaluated its antimicrobial activity. *Scylla serrata* antimicrobial protein (SSAP), chitin, haemocyanin (HC), *Scylla serrata* beta-glucan binding protein (Ss- β -GBP), scygonadin, *Scylla*-anti-lipopopolysaccharide (Sc-ALF), *Scylla* crustin (Sc-crustin), lectin, antibacterial haemocyanin (AB-Hcy), and Ss-arasin are the significant antimicrobial compounds isolated from the crab. In vitro research found substantial evidence that *Scylla serrata* has antioxidant, antianemic, anticancer, antibacterial, and neuroprotective properties. However, all described pharmacological activities were conducted in vitro, indicating a need for further pre-clinical and clinical research. Potential chemical compounds from different parts of the crab may need to be identified, and their pharmacological properties must be established.



Keywords

functional food, chemical constituents, ethnopharmacological uses, pharmacological properties, *Scylla serrata* F., mud crab, traditional medicine

Introduction

Marine-derived natural products have received great attention today, and recent studies on molecules originating from marine sources have shown novel bioactive compounds with nutraceutical and pharmaceutical potential [1-5]. Compared to terrestrial ecosystems, marine ecosystems are more diverse in biodiversity and offer a wealth of supplies for human nutrition and health [6]. Recently, functional food, pharmaceutical, and nutraceutical industries have begun to focus on the extraction and identification of value-added products from marine sources such as bacteria, microalgae, macroalgae, bryozoans, mollusks, sponges, tunicates, and cyanobacteria. These organisms create compounds that have high selectivity for target molecules, typically enzymes, and are useful for treating both infectious and non-infectious diseases [7, 8]. Owing to the distinctive features of the marine environment, including variations in salinity, temperature, and exposure to light, a broad spectrum of marine bioactive substances can be obtained from diverse sources, each possessing a unique collection of biomolecules. These consist of proteins, peptides, hydrolysates of proteins, enzymes, polyunsaturated fatty acids, polysaccharides, phenolic compounds, natural pigments, vitamins, and minerals [9].

Mud crab genus *Scylla* (*Scylla serrata*, *Scylla tranquebarica*, *Scylla olivacea*, and *Scylla paramamosain*) is more significant than other crustaceans in mangrove ecosystems because of their primary roles in preserving and expanding mangrove forests, namely, biological burrowing and the production of bioturbations [10, 11]. Mud crabs are generally found in the mangrove forests of India, Japan, China, South Africa, Indonesia, and the Philippines of Indo-Pacific places. Likewise, Malaysia, Singapore, Western Samoa, Solomon Islands, Fiji, and New Caledonia are big mud crab habitats [11]. In the international market, mud crab, *Scylla serrata* (Figure 1), has a high demand among the coastal aquatic species due to its nutritional richness, size, and meat quality [12]. This review aims to critically assess a range of publications relevant to *Scylla serrata* to better understand the ethnopharmacological significance and supposed pharmacological properties of *Scylla serrata*, and this information will be useful in developing bioactive therapeutic strategies.



Figure 1. *Scylla serrata* (Forskål, 1775).

Ethnopharmacological use

Since ancient times, remedies derived from animal sources have become a part of the traditional systems, among traditional healers. But in this modernized era, due to the lack of scientific validations, some of the effective traditional approaches have become dormant. To evaluate the claims of traditional healers, standardized methods for the evaluation of such treatments are essential. Some reported ethnomedicinal uses of *Scylla serrata* are tabulated below (Table 1).

Methodology design

The databases, Web of Science, Scopus, PubMed, ScienceDirect, and SpringerLink were used to do an extensive literature search. Approximately 80% of the chosen research was published between 2015 and 2025, which is when the search was conducted. When supported by scientific evidence, earlier pertinent papers were included. The terms “*Scylla serrata*”, “ethnopharmacological uses”, “chemical constituents”, “antioxidant”, “anticancer”, and “neuroprotective” were all utilized.

Inclusion criteria

Studies that satisfied the following requirements were included: peer-reviewed scholarly publications, published in English, concentrated on marine organisms, especially *Scylla serrata*, and chemical components, pharmacological actions, or reported ethnopharmacological applications.

Exclusion criteria

The following were not included: abstracts of conferences, duplicates, research that only uses animal testing, and articles that are irrelevant and unrelated to the review’s goals.

A total of 400 records were found. 380 studies were evaluated after duplicates were eliminated, and 150 of them were eliminated. After 230 articles’ full texts were evaluated, 153 were eliminated. The review ultimately comprised 77 studies (Figure 2). ToxRTool for in vitro studies and SYRCLE for animal studies were used to evaluate methodological quality and bias risk. Additionally, a simplified rubric was used to evaluate study design, data dependability, and reporting transparency.

Biochemical constituents

Proteins, fatty acids, bioactive peptides, amino acids, carbohydrates, and minerals are a few value-added nutrients present in the muscle of *Scylla serrata*. The attention-grabbing fact is that their chemical constituents will fluctuate depending on the sex, size, and season. The reported biochemical constituents are tabulated (Table 2).

According to a study on *Scylla serrata*, its muscle tissue has a significant amino acid profile and high-quality protein, with substantial concentrations of glycine, lysine, serine, and tyrosine that significantly improve its nutritional value. Glycine was found to be a significant amino acid that gives crab flesh its distinctive sweet flavor. *Scylla serrata* was discovered to have significant levels of vitamins A, B-complex, and C in addition to being abundant in proteins and carbohydrates [27]. The shell of the crab from the Merauke mangrove contained basic bioceramic materials such as 19.78% carbon (C), 24.53% oxide (O), 4.81% magnesium oxide (MgO), 3.98% phosphorus pentoxide (P₂O₅), and 71.42% calcium oxide (CaO). There was 6.27% carbon, 28.96% oxide, 5.78% MgO, 5.65% P₂O₅, and 82.3% CaO during the calcination phase at 1,000°C [28]. It was observed that the amount of carbon had reduced after calcination. About 53 compounds were identified from steamed mangrove crab meat by the GC-GC-Olfactometry method, and among them, 31 compounds were documented. The 5 important compounds were 2,3-butanedione (1), 2,5-dimethyl pyrazine (2), 3-methyl butanal (3), 2-acetyl-1-pyrroline (4), and 2-acetyl thiazole (5) (Figure 3) [29].

Crab shell was found to contain chitin (6), chitosan (7), and submicron-sized chitosan particles, and the amount was calculated on a dry weight basis (Figure 3) [30–32]. Because of their cationic composition, chitin and chitosan have shown potent antibacterial effects [33] and have useful biomedical applications in

Table 1. Reported ethnopharmacological uses of *Scylla serrata*.

S.L. No.	Part(s) used	Preparation(s)	Ethnomedicinal uses	Route of administration	Locale/Region	Source type	Plausible bioactive class	Proposed mechanistic rationale	Reference
1.	Fleshy tissue	Cook with telakucha (<i>Cephalandra indica</i>) leaf juice.	Pulmonary tuberculosis	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
2.	Fleshy tissue	Cook with the juice of tomato (<i>Solanum esculentum</i>).	Rheumatism of the elbow joint	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
3.	Fleshy tissue juice	Boil for 15 minutes with gulanacha (<i>Tinospora cordifolia</i>) stem bark juice.	Urticaria and skin burns	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
4.	Fleshy tissue juice	Boil for 15 minutes with punarnava (<i>Boerhavia diffusa</i>) stem bark juice.	Dropsy and body swelling	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
5.	Fleshy tissue juice	Boil for 15 minutes with ash sheora (<i>Arista indica</i>) root bark in the ratio of 3:1.	Stomatitis and abdominal pain	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
6.	Carapace ash	Combine with kurchi (<i>Hollerhena antidysenterica</i>) stem bark dust and apply with cow ghee.	Dropsy	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
7.	Dried and powdered leg	Combine with kurchi (<i>Hollerhena antidysenterica</i>) stem bark dust.	Boils	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
8.	Ashes of legs and carapace	Combine with lajjabati (<i>Mimosa pudica</i>) and prepare like a paste.	Haemorrhoids pain, burns, and bleeding	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
9.	Fleshy tissue	Combined with the root of alkushi (<i>Mucuna pruriens</i>).	Dropsy	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
10.	Paste of the burned crab	Combine with leaves of alkushi (<i>Mucuna pruriens</i>).	Bone fracture	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
11.	Fleshy tissue juice	Combined with the halud (<i>Lindenbergia indica</i>).	Chronic bronchitis and asthma	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]

Table 1. Reported ethnopharmacological uses of *Scylla serrata*. (continued)

S.L. No.	Part(s) used	Preparation(s)	Ethnomedicinal uses	Route of administration	Locale/Region	Source type	Plausible bioactive class	Proposed mechanistic rationale	Reference
12.	Ashes of legs and carapace	Combined with the stem bark juice of am (<i>Mangifera indica</i>).	Haemorrhage and haemoptysis	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
13.	Fleshy tissue juice	Combine with an equal quantity of leaf juice of susni shak (<i>Marsilea minuta</i>) and boil for 15 minutes.	Insomnia	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
14.	Entire body content	Combine with unripe kala (<i>Musa paradisiaca</i>) and boil.	Skin burns	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
15.	Fleshy tissue	Cook with kulekhara (<i>Hygrophila spinosa</i>) leaves.	Rickets	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
16.	Entire body content	Combine with karabi (<i>Nerium indicum</i>) leaf juice and boil for 15 minutes.	Ophthalmia and copious lachrymation	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
17.	Fat	Combine with the seed powder of nata (<i>Caesalpinia bonducella</i>).	Measles	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
18.	Fleshy tissue juice	Combine with piyara (<i>Psidium guajava</i>) leaf juice and prepare a paste.	Ulcer and wound	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
19.	Entire crab	Boil the carb with young shoots or leaves of piyara (<i>Psidium guajava</i>).	Epilepsy and chorea	Oral	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
20.	Entire body content	Combine with the leaf paste of piyara (<i>Psidium guajava</i>) and prepare a paste.	Convulsion	External application	Sundarban, West Bengal, India	Ethnomedicinal survey among tribals	Not reported	Not reported	[13]
21.	Entire body content	Not reported	Old age, diabetes, and skin diseases	Not reported	Mizoram & Arunachal Pradesh	Primary fieldwork (empirical learning with traditional knowledge holders), and	Not reported	Not reported	[14]

Table 1. Reported ethnopharmacological uses of *Scylla serrata*. (continued)

S.L. No.	Part(s) used	Preparation(s)	Ethnomedicinal uses	Route of administration	Locale/Region	Source type	Plausible bioactive class	Proposed mechanistic rationale	Reference
22.	Entire crab	Cook or roast	Abdominal obesity in children	Oral	Rural Bangladesh—specifically floodplain freshwater (<i>Maimals</i>) and coastal (<i>Jaladas</i>) communities	Direct interviews and observations	Not reported	Not reported	[15]
23.	Flesh soup	Mix with lime and green pineapple.	Manage hookworm	Oral	Rural Bangladesh—specifically floodplain freshwater (<i>Maimals</i>) and coastal (<i>Jaladas</i>) communities	Direct interviews and observations	Not reported	Not reported	[15]
24.	Crab bone powder	Paste	Odeoma	Not reported	Rural Bangladesh—specifically floodplain freshwater (<i>Maimals</i>) and coastal (<i>Jaladas</i>) communities	Direct interviews and observations	Not reported	Not reported	[15]
25.	Entire crab	Flesh soup	Dysentery, muscle aches, aphrodisiac, enhancing eyesight, children's urinary incontinence at night, and slight arthritis	Not reported	Rural Bangladesh—specifically floodplain freshwater (<i>Maimals</i>) and coastal (<i>Jaladas</i>) communities	Direct interviews and observations	Not reported	Not reported	[15]
26.	Flesh and bone	Ayurveda preparations (<i>Karkataka bhasma</i> -bone powder).	Constipation, rakta pitta, headache, tuberculosis, chronic cough, anemia, sexual debility, obstructed micturition, general debility, and neurological disorders	Not reported	Not reported	Not reported	Not reported	Not reported	[16]
27.	Bone	“Arq-e-Sartan” and “Safuf-e-Sartan” (Unani medicine).	Chronic cough and tuberculosis	Not reported	Not reported	Not reported	Not reported	Not reported	[16]
28.	Ash	Not reported	Biliousness, debility, haemoptysis, renal calculi, dysuria, and breast cancer	Not reported	Not reported	Not reported	Not reported	Not reported	[16]
29.	Ash	Mix with ass milk	Scorpion and wasp stings	Not reported	Not reported	Not reported	Not reported	Not reported	[16]
30.	Ash	Mix with honey	Dog bite wounds, vitiligo, piles, and inflammation	Not reported	Not reported	Not reported	Not reported	Not reported	[16]

Table 1. Reported ethnopharmacological uses of *Scylla serrata*. (continued)

S.L. No.	Part(s) used	Preparation(s)	Ethnomedicinal uses	Route of administration	Locale/Region	Source type	Plausible bioactive class	Proposed mechanistic rationale	Reference
31.	Ash	Prepare an aqueous solution	Sore throat and diphtheria	Not reported	Not reported	Not reported	Not reported	Not reported	[16]
32.	Entire crab	Soup	Reduce the symptoms of dengue fever	Oral	Not reported	Not reported	Not reported	Not reported	[17]
33.	Crabmeat	Nutritious soup	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	[18]

tissue engineering, orthopedic and periodontal applications, drug delivery systems, and wound healing [34]. Also, chitin and chitosan compounds could be further used as derivatives for the production of glucosamine hydrochloride (8) (Figure 3) [35], which has anti-inflammatory, antioxidant, antiaging, cardioprotective, chondroprotective, hepatoprotective, and cytoprotective properties [36].

The polyunsaturated fatty acids present in the chelate leg (4.82%) and ovary (8.07%) of the mud crab were linolelaidic acid (9), linolenic acid (10), eicosadienoic acid (11), arachidonic acid (12), and eicosapentaenoic acid (13) (Figure 4).

Palmitoleic acid (14), heptadecanoic acid (15), and arachidic acid (16) (Figure 4) were also found in the chelate leg (4%) and ovary (7%) as monounsaturated fatty acids [37]. The lipid content of wild *Scylla serrata* was $0.65 \pm 0.1\%$, and it was slightly greater than cage fattened crab ($0.56 \pm 1\%$). Polyunsaturated fatty acids (39–43%) were the most common fatty acids in *Scylla serrata*, with oleic acid (17) being the most abundant (16–21%). At the stocking and harvest stages of the fattening process, the contents of oleic acid, gondoic acid (18), docosatetraenoic acid (19), and docosahexaenoic acid (20) varied greatly between crabs (Figure 5) [38].

Pharmacological activities

Antioxidant activity

Reactive oxygen species like superoxide anion (O_2^-), perhydroxy radical (HOO^*), hydrogen peroxide (H_2O_2), hydroxyl radical (*OH), alkoxy radical (RO^*), and peroxy radicals (ROO^*) can cause oxidative stress in cells. All organisms have either enzymatic or non-enzymatic antioxidant defensive systems for protecting the cells from various injuries [39]. Compared to terrestrial organisms, marine organisms are very sensitive to oxidative stress due to climate change in the sea, and the stress could be heat or ultraviolet radiation and this stress leads to the production of metabolites for their defense mechanism [40].

The antioxidant potential of *Scylla serrata* by DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS [2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)] assay methods has been determined and was found as 35% and 41% for soluble chitosan, 19% and 33% for haemolymph, and 49% and 61% for muscle extract, respectively. The muscle extract exhibited the highest activity [41]. Using molecular modeling and docking techniques, a recent study revealed the molecular basis of the interactions between SOD (superoxide dismutase) inhibitors and extracellular-SOD in the *Scylla serrata*. According to the GOLD findings, Pro72, Asp102, and Thr103 are commonly the sites where SOD inhibitors and Ec-SOD of *Scylla serrata* interact [42]. In *Scylla serrata*, SOD is an important antioxidant enzyme that promotes innate immunity and guards against oxidative stress. The SOD gene's crucial function in stress protection and evolutionary adaptation was established

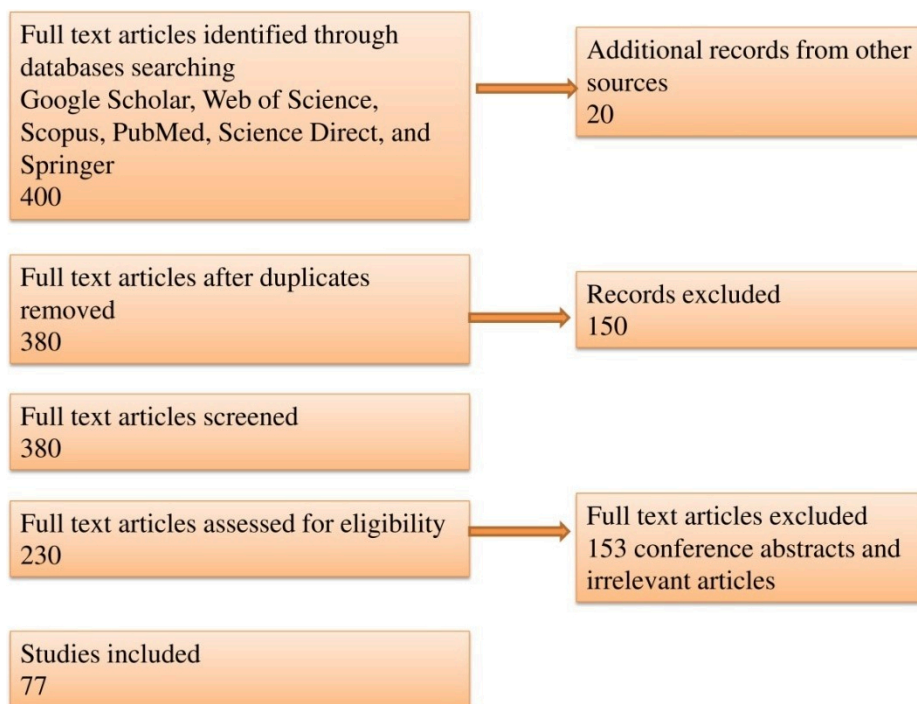


Figure 2. Study selections for review.

Table 2. Biochemical constituents from crab *Scylla serrata* F.

Study location/area	Protein	Lipid	Carbohydrates	Reference
Coringa mangroves	♂ = 31.98% ♀ = 31.97%	-	-	[19]
Pulicat Lake, Chennai	Haemolymph = 22.5%, thoracic muscle = 3.25%, claw muscle = 14.5% and leg muscle = 5.0%	Haemolymph = 0.10%, thoracic muscle = 0.20%, claw muscle = 0.25% and leg muscle = 0.20%	Haemolymph = 1.8%, thoracic muscle = 2.7%, claw muscle = 3% and leg muscle = 2.2%	[20]
Philippines	♂ = 12.10% Intermediate sex = 13.0% ♀ = 17.38%	-	-	[21]
Andhra Pradesh	22.14 ± 1.25%	-	-	[22]
Gujarat and Maharashtra	47.7 ± 21.74%	4.03 ± 2.83%	11.72 ± 2.35%	[23]
Sundarban mangrove, Bangladesh	♂ = 18.78 ± 0.22% ♀ = 24.54 ± 1.32%	♂ = 1.75 ± 0.42% ♀ = 2.62 ± 0.12%	-	[24]
Vellar estuarine	10.97%	-	-	[25]
Kovalam	♂ = 18.26% ♀ = 14.02%	-	-	[26]

by its isolation and sequencing [43]. In a study, using *Scylla serrata* shell flour, the average output of astaxanthin produced with varying acetone concentrations was 3.29 g. The antioxidant activity at the optimal acetone concentration of 65% had the IC₅₀ value of 805.837 µg/mL [44]. *Scylla serrata* extract had an IC₅₀ value of 2.25 ppm, indicating very significant antioxidant activity. This finding suggests that 50% of DPPH radicals can be inhibited by a small amount of the extract [45]. A study revealed that soil and water characteristics like temperature, salinity, and mineral load had a significant impact on *Scylla serrata*'s oxidative stress and antioxidant enzyme activity. The highest antioxidant enzyme activity was found in the hepatopancreas, which rose in dry seasons and had a positive correlation with physicochemical stresses [46].

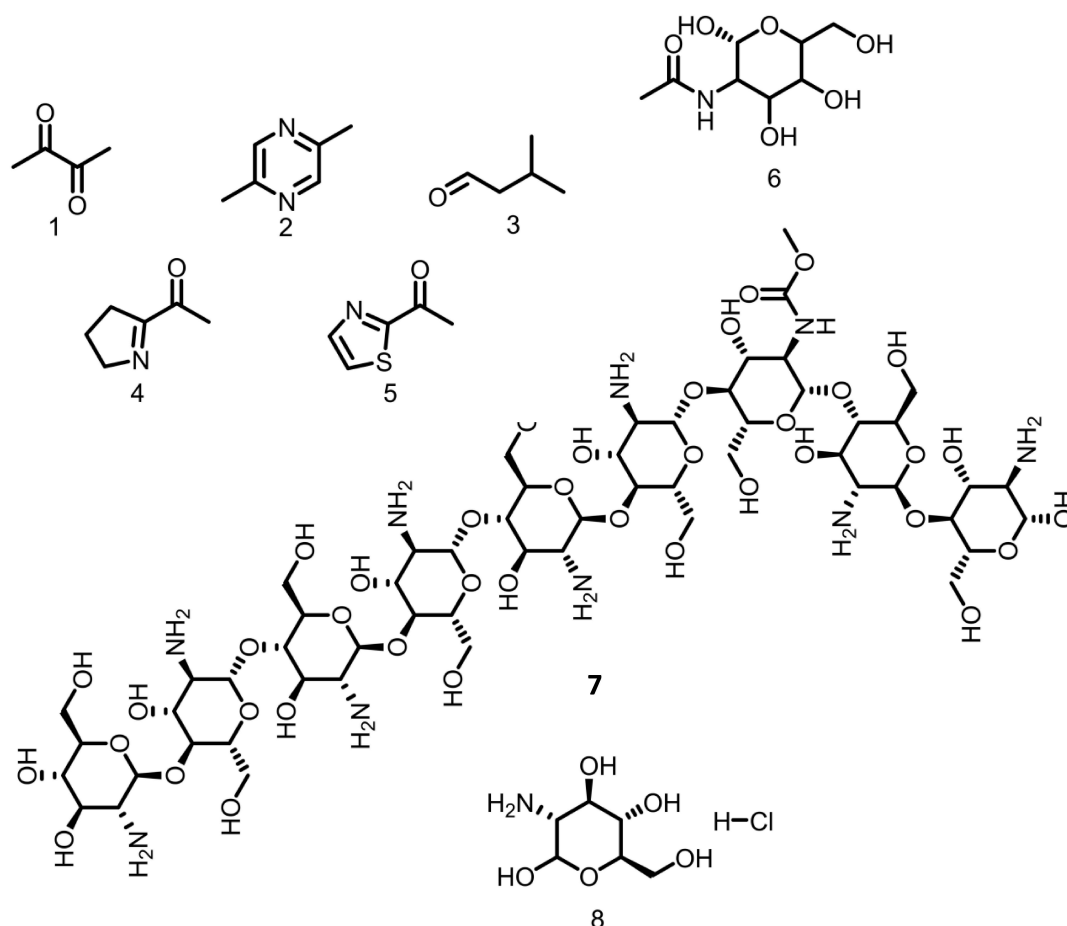


Figure 3. Structures of compounds 2,3-butanedione (1), 2,5-dimethyl pyrazine (2), 3-methyl butanal (3), 2-acetyl-1-pyrroline (4), 2-acetyl thiazole (5), chitin (6), chitosan (7), and glucosamine hydrochloride (8). Drawn using ChemDraw Professional 19.0.

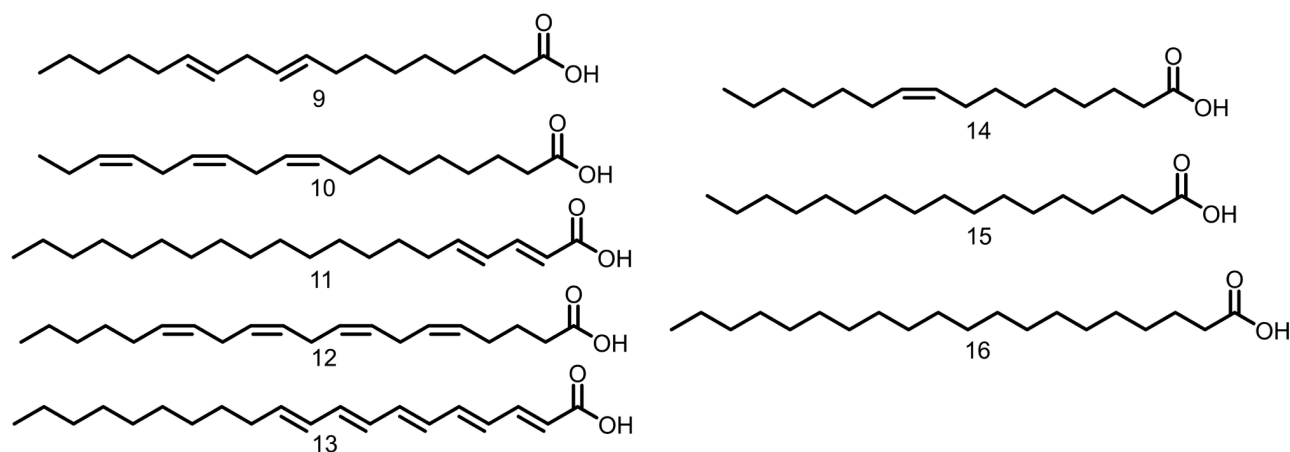


Figure 4. Structures of compounds linolelaidic acid (9), linolenic acid (10), eicosadienoic acid (11), arachidonic acid (12), eicosapentaenoic acid (13), palmitoleic acid (14), heptadecanoic acid (15), and arachidic acid (16). Drawn using ChemDraw Professional 19.0.

With an IC_{50} of 65.25 ppm, *Scylla serrata* ethanol extracts demonstrated dose-dependent antioxidant activity in the DPPH experiment, suggesting high antioxidant potential [47]. Allantoin, CAT, and GR were important regulators of oxidative stress, and allantoin plays a part in *Scylla serrata*'s seasonal antioxidant homeostasis [48]. Crab-derived antioxidants have shown potential activity in various in vitro models. In the future, oxidative stress-related diseases like cardiovascular, neurodegenerative, and metabolic disorders may be treated with the isolated compounds from the crab.

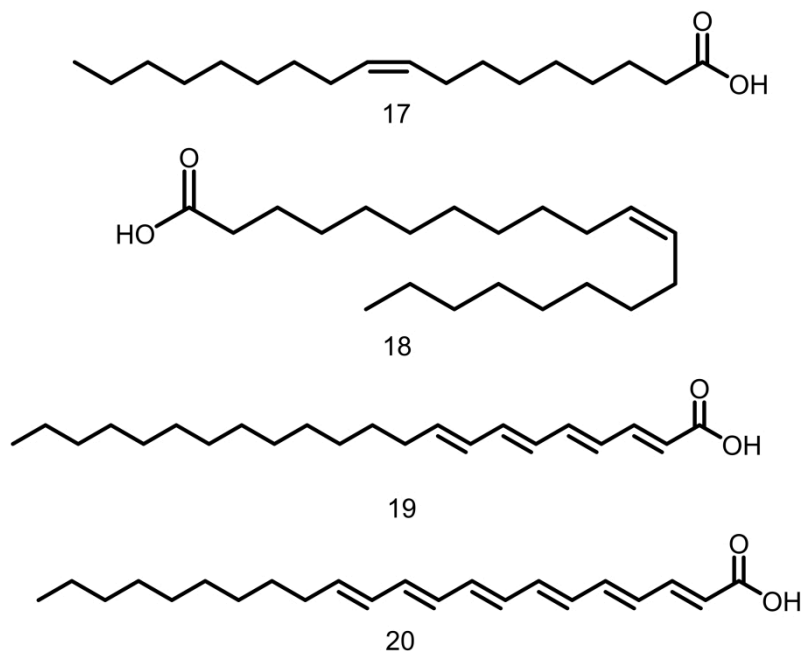


Figure 5. Structures of compounds oleic acid (17), gondoic acid (18), docosatetraenoic acid (19), docosaheptaenoic acid (20). Drawn using ChemDraw Professional 19.0.

Anticancer activity

Many bioactive compounds from different marine sources have been found to inhibit the proliferation of several cancer cells. The mud crab soup *Scylla serrata* has shown antiproliferative and anticancer properties on the Jurkat leukemic T-cell line by MTT colorimetric technique with an inhibitory concentration of 35% (v/v) in a dose and time-dependent manner compared to the standard drug cisplatin [49]. Strong antibacterial activity and the formation of homogeneous spherical chitosan/silver nanocomposites were demonstrated by the chitosan derived from *Scylla serrata* shells, which also demonstrated anticancer potential against the MCF-7 cell line [50]. High molecular weight (HMW) chitosan and low molecular weight (LMW) chitosan have been found effective against breast cancer (MCF-7), cervical cancer (HeLa), and osteosarcoma (Saos-2) cell lines at IC_{50} values of 1.68, 1.0, 1.7 mg/mL for HMW and 1.76, 1.0, and 1.63 mg/mL for LMW chitosan, respectively [51]. Haemocyanin (HC) (95 kDa), a copper-containing respiratory protein, was isolated from the haemolymph of the mud crab *Scylla serrata*. The IC_{50} of HC was found at 80 μ g/mL against lung cancer (A549) cell lines [52].

Lectins are a group of glycoproteins of non-immune origin, specific to carbohydrates, and have at least two carbohydrate-binding sites. They are found in plants, animals, and microorganisms. Lectins' precipitating and agglutinating properties are similar to antibodies, but like antibodies, they do not synthesize immunoglobulins. Due to their specificity to a certain type of carbohydrate, they can be used as a target in the drug delivery system and as a cancer biomarker for recognizing malignant tumor cells for the diagnosis and prognosis of cancer [53, 54]. Scylliin-2 (calcium-dependent monomeric lectin; 75 kDa) from the haemolymph of mud crabs had high sensitivity towards polyvalent Tn/T containing glycoproteins, a type of antigen present on the surface of the tumor cells. The mitogenic property of isolated Scylliin-2 was tested against BALB/c splenocytes, and 10 μ g/mL of Scylliin-2 showed significant activity against BALB/c splenocytes. The IC_{50} value of Scylliin-2 on HepG2 was 80 μ g/mL [55]. Chitin was evaluated for cytotoxicity at doses of 1, 25, 50, 75, and 100 μ g/mL. It has shown cytotoxicity with an IC_{50} of 64.39 ± 1.315 μ g/mL against HepG2 cells [56].

Antidyslipidemic agent

In comparison to pravastatin ($IC_{50} = 6.95 \pm 0.189$ μ g/mL; 92.82% inhibition), chitin derived from mangrove crab shells demonstrated modest HMG CoA reductase inhibition ($IC_{50} = 36.65 \pm 0.082$ μ g/mL; 68.73% inhibition at 100 μ g/mL). Enzyme inhibition was indicated by the decrease in mevalonate synthesis. Strong

binding affinities (-3.6 to -5.8 kcal/mol) to important targets of lipid metabolism were found by in silico research. The blood-brain barrier permeability and non-toxicity were verified by ADMET analysis. Stable binding to HMG CoA reductase was demonstrated using molecular dynamics simulations [56].

Anti-anaemic activity

In a three-week in vivo study, oral administration of *Scylla serrata* extract (7.0 mg protein/kg and 52 mg protein/kg) has shown an antianemic effect in Wistar rats through alleviation of RBC, Hb, haematocrit (HCT), and mean corpuscular haemoglobin (MCH) levels [57].

Antimicrobial activity

Crabs and other aquatic organisms have the property to release antimicrobial peptides, as part of their innate immune system, since they are exposed to various bacterial strains and live in numerous contaminated environments. These peptides are released not only from the crab haemolymph but also from the exoskeleton. Recently, many researchers have exclusively studied and reported the antibacterial properties of the mud crab *Scylla serrata*. Six crab species' haemolymph extracts exhibited antibacterial efficacy against ten bacterial strains ($n = 3$). The most significant zone of inhibition (ZOI) was demonstrated by *Scylla tranquebarica* (10 mm, *V. cholerae*), *Scylla serrata* (6–6.5 mm, maximum against *L. delbrueckii* subsp. *bulgaricus*), and *Macrophthalmus depressus* (5 mm) [58]. An antibacterial protein, SSAP (*Scylla serrata* antimicrobial protein; 11 kDa), from granular hemocytes, was isolated, characterized, and evaluated against gram-negative and gram-positive bacterial strains. The inhibitory concentration (MIC) of SSAP was in the order *P. aeruginosa* (12.5–25 µg/mL), *E. coli* (25–50 µg/mL), *S. pyogenes* (25–50 µg/mL), and *S. aureus* (50–100 µg/mL) [59].

The natural polysaccharide chitin, which was extracted from the carapace, chelate legs, and walking legs of crabs, had antibacterial action against *S. aureus* (8.4–10.4 mm), *S. epidermidis* (7.9–9.7 mm), *B. subtilis* (7.5–9.1 mm), *P. aeruginosa* (5.6–7.2 mm), and *P. mirabilis* (5.3–6.8 mm). Disk diffusion was used to measure activity (4.5 mm discs, nutritional broth, 1×10^8 CFU/mL, 37°C, 17 h, $n = 3$), with DMSO and penicillin serving as the negative and positive controls, respectively. Millimeters were used to measure the zones of inhibition [60]. After being extracted from *Scylla serrata* haemolymph (β -GBP: 100 kDa), β -GBP and HC were structurally confirmed using FTIR, XRD, CD, and HPLC. At 50–100 µg/mL, *Scylla serrata* beta-glucan binding protein (Ss- β -GBP) demonstrated dose-dependent antibiofilm effects and immunomodulatory action (yeast agglutination, phagocytosis, PO enhancement). When tested against both gram-positive (*E. faecalis*, *S. aureus*) and gram-negative (*E. coli*, *P. aeruginosa*) bacteria, its antibacterial activity revealed MICs < 60 µg/mL. At 100 µg/mL, HC also produced zones of inhibition against *V. harveyi* (17 mm), *V. alginolyticus* (16.5 mm), *V. vulnificus* (16 mm), and *V. parahaemolyticus* (14.5 mm), demonstrating bacteriostatic actions. Although in vivo and clinical validation are still needed, our results demonstrate the therapeutic potential of *Scylla serrata* haemolymph proteins [61].

Scygonadin (10.8 kDa) is an anionic antimicrobial peptide isolated and purified from the seminal plasma of *Scylla serrata*, which has shown potent activity against *Micrococcus luteus* at IC₅₀ of 0.125 mg/mL [62]. Two antimicrobial peptides, Sc-ALF (*Scylla*-anti-lipopopolysaccharide) and Sc-crustin (*Scylla* crustin), from the haemocytes of the mud crab with molecular weights of 11.17 kDa and 10.24 kDa, respectively have been reported for the first time [63]. Haemolymph was extracted from the dactylus area of the walking legs of *Scylla serrata*, allowed to clot, centrifuged (450 g, 10 min, 4°C), and the serum that resulted was used right away. Under controlled conditions, the MTT colorimetric test was used to measure the antibacterial activity against crustacean pathogens (*V. harveyi*, *V. vulnificus*, *V. alginolyticus*, *V. parahaemolyticus*, and *V. anguillarum*) and bacteria obtained from crabs (*Bacillus* sp., *B. flexus*, *E. coli*, and *P. aeruginosa*). Crab serum (1.224 mg protein) has shown potent antibacterial properties against *Bacillus* sp. N1, *B. flexus* N3, *E. coli*, and some of the pathogenic strains of crabs like *V. harveyi*, *V. alginolyticus*, and *V. vulnificus*, and found that a 14 kDa protein in the serum was responsible for the activity [64].

Chitosan derived from the shell of *Scylla serrata* showed significant antibacterial action against both gram-positive and gram-negative bacteria, such as *Bacillus*, *Pseudomonas*, *E. coli*, and *Staphylococcus*. Along with advantageous structural and physicochemical traits, the isolated chitosan demonstrated robust antibacterial qualities, especially against *E. coli*, indicating its possible uses in microbiology and medicinal science [65]. Antibacterial haemocyanin (AB-Hcy) from the serum of the mud crab *Scylla serrata* was characterized, and AB-Hcy (15 µg/mL) has shown bacteriolytic properties against *Bacillus* sp. N1, *B. flexus* N3, *E. coli*, *P. aeruginosa*, *V. harveyi*, *V. parahaemolyticus*, and *V. vulnificus*. The highest activity has been shown against *V. harveyi* (0.248 units·min⁻¹·mg protein) and *E. coli* (0.202 units·min⁻¹·mg protein). The growth of crustacean pathogenic bacteria was also significantly inhibited by AB-Hcy [66]. Some of the reported antimicrobial compounds from mud crab *Scylla serrata* are tabulated (Table 3).

Table 3. Antimicrobial compounds from *Scylla serrata* F.

Parts used	Name of antimicrobial compound	Molecular weight (kDa)	Reference
Haemolymph extract	-	-	[58]
Granular haemocytes	<i>Scylla serrata</i> antimicrobial protein (SSAP)	11	[59]
Shell	Chitin	-	[60]
Haemolymph	Haemocyanin (HC)	-	[61]
Haemolymph	<i>Scylla serrata</i> beta-glucan binding protein (Ss-β-GBP)	100	
Seminal plasma	Scygonadin	10.8	[62]
Hemocytes	Sc-ALF (<i>Scylla</i> -anti-lipopolsaccharide) and <i>Scylla</i> crustin (Sc-crustin)	11.17 & 10.24	[63]
Serum	-	14	[64]
Shell	Chitosan	-	[65]
Serum	Antibacterial haemocyanin (AB-Hcy)	-	[66]
Haemolymph	Ss-arsasin	7	[67]
Gill	MC-crustin	10.164	[68]

Although these compounds have shown antibacterial activity in vitro, indicating the possibility of further investigation as therapeutic agents, their safety and efficacy in vivo have not been investigated, and translational applications should be handled carefully with additional preclinical validation.

Neuroprotective activity of *Scylla serrata* edible crab Rasayana

Traditional medicine has long utilized Karkataka Taila (KT), a classic Ayurvedic Rasayana made from *Scylla serrata* for neurological health and regeneration. It has long been thought to promote nervous system function and increase vitality. According to current experimental research, KT may have neuroprotective and anti-Parkinson's benefits. In vitro experiments with human neuroblastoma (SH-SY5Y) cells showed that KT decreased oxidative stress (ROS and SOD) and neuroinflammatory markers (IL-6, IL-1β, TNF-α, and nitrite) while raising dopamine levels. Studies conducted in vivo on male Wistar rats showed protective effects on behavioral performance as well as improvements in oxidative stress, neuroinflammation, and dopamine levels [69]. However, it is too early to determine whether these findings are relevant to humans. Dosimetry issues and the formulation's standardization caused by variations in the marine and herbal components present major obstacles to clinical translation. For KT to be safe, effective, and reproducible in possible therapeutic applications, strict pharmacological validation and consistent preparation procedures are required. The key pharmacological activities of *Scylla serrata* based on published scientific evidence are illustrated in Figure 6.

Toxicology

The lack of adequate toxicity studies on *Scylla serrata* has hindered its advancement toward medicinal application and clinical trials by failing to demonstrate its safety and effectiveness. A thorough toxicity

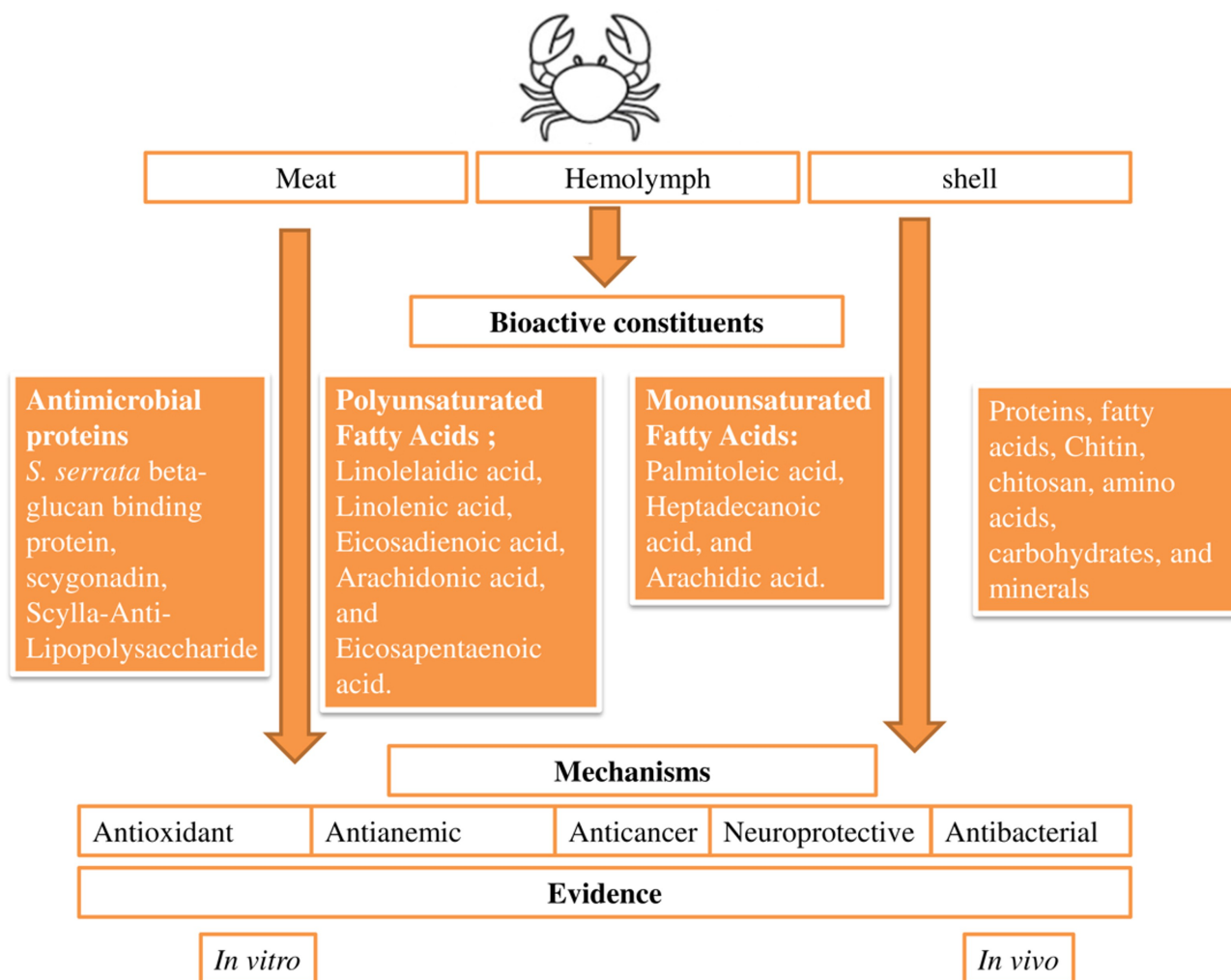


Figure 6. Mechanism map.

evaluation is lacking in the majority of investigations, despite the fact that a number of pharmacological activities, including antioxidant, anti-anemic, and antibacterial properties, have been documented. While an acute oral toxicity study in Swiss albino mice at 2,000 mg/kg revealed no negative effects, a Rasayana preparation made from the crab (KT) demonstrated cytotoxicity toward human neuroblastoma (SH-SY5Y) cells at high dosages in an in vitro MTT assay [69, 70]. Further safety concerns have been raised by reports of environmental pollution of *Scylla serrata* habitats, with higher amounts of copper, chromium, and cadmium found in related sediments [71]. In carefully planned clinical trials, pharmacokinetic and pharmacodynamic profiles are also still mostly unknown. Furthermore, reproducibility and study comparison are jeopardized by the absence of standardized extraction and formulation preparation techniques. Therefore, before *Scylla serrata*-derived products can be evaluated for therapeutic uses, regulatory evaluation based on standardized production, verified toxicity testing, and quality control is necessary.

Allergenicity and contamination

Concerns about food safety and health have been raised by reports that *Scylla serrata* can bioaccumulate heavy metals, including lead, mercury, and cadmium, from contaminated surroundings as well as microplastics, primarily polypropylene (PP) and high-density polyethylene (HDPE) [72]. Furthermore, the main causes of allergic reactions linked to eating crabs are the 36 kDa heat-stable protein tropomyosin and the 41 kDa heat-labile protein arginine kinase, both of which can cause IgE-mediated hypersensitivity in vulnerable people [73, 74]. Before *Scylla serrata*-derived products are produced for food or nutraceutical

uses, regulatory evaluation is necessary to ensure safety, quality, and compliance. These findings further highlight the significance of standardized preparation procedures to limit impurities and allergen content.

Limitations and future directions

Edible crustaceans such as shrimps, crabs, lobsters, and prawns are globally important both nutritionally and economically. Shrimps dominate global aquaculture and trade, contributing about 45% of Indonesia's total fishery exports and nearly 80% of cultivated shrimp worldwide, mainly represented by *Penaeus monodon* and *Litopenaeus vannamei*. Crabs account for approximately 20% of the marine crustacean species captured and cultured globally, with *Portunus pelagicus* comprising nearly one-fifth of this production. Lobsters, particularly *Panulirus versicolor*, *Homarus gammarus*, and *Homarus americanus*, are among the most valuable crustaceans due to their higher market price compared with other animal protein sources. Freshwater prawns of the genus *Macrobrachium* (e.g., *M. rosenbergii*, *M. nipponense*, and *M. malcolmsonii*) represent the primary cultivated freshwater crustaceans.

Compared with these widely consumed crustaceans, smaller crustaceans such as krill, copepods, and branchiopods play a crucial ecological role by linking phytoplankton to higher trophic levels and are increasingly exploited for aquaculture feed and pharmaceutical applications. However, although extensive data exist on the production, nutritional value, and bioactive components of shrimp, crabs, and lobsters, mechanistic evidence explaining their pharmacological actions and robust clinical validation remains limited across crustacean groups [75].

In this context, the mud crab *Scylla serrata* has considerable potential for further exploration, particularly for the isolation and characterization of lead compounds using bioactivity-guided fractionation. Although several pharmacological activities have been reported, most findings are based on preliminary in vitro or in vivo studies, and the underlying molecular mechanisms of action remain largely unexplored. Moreover, systematic toxicity evaluation of extracts and isolated compounds in appropriate in vitro and in vivo models is necessary prior to clinical investigation and commercialization. The existing data are therefore insufficient to conclusively support the therapeutic effectiveness of *Scylla serrata* as a drug source. Additionally, only a limited number of qualitative and quantitative studies have characterized its chemical constituents. Consequently, comprehensive biochemical profiling, mechanistic studies, and well-designed pre-clinical investigations are essential to establish the therapeutic relevance of mud crab-derived compounds. There is a need for an extensive mechanistic investigation into pharmacological activities that have the ability to investigate the precise mechanism of these extracts or pure chemicals in the treatment of many ailments indicated in traditional knowledge. Prerequisites for clinical research and commercialization include toxicity assessment of the extract and isolated chemicals in various in vitro and in vivo models. Research on the chemical constituents, both qualitative and quantitative, is currently lacking. Therefore, the most crucial recommendations for examining the crab's therapeutic efficacy are more biochemical analysis and pre-clinical research.

Conclusion

Based on traditional use and early scientific data, *Scylla serrata* has a rich biochemical composition that includes proteins, amino acids, and polyunsaturated fatty acids. This composition supports documented antibacterial, antioxidant, neuroprotective, anticancer, and antidyslipidemic effects. The preponderance of in vitro and preclinical data, the lack of molecular knowledge, and the lack of clinical safety and efficacy validation, however, continue to limit its translational potential. Major challenges include inadequate standardization of preparations, insufficient toxicological and pharmacokinetic data, and variability arising from environmental contamination and allergenicity. Prior to conducting clinical feasibility studies, future research should follow a structured translational framework that includes bioassay-guided fractionation → target identification → thorough pharmacokinetic and toxicological evaluation → validation in pertinent in vivo disease models → the creation of standardized extracts. To transform *Scylla serrata* from an

ethnomedicinal resource into a scientifically proven marine-derived therapeutic candidate, these issues must be resolved.

Abbreviations

AB-Hcy: antibacterial haemocyanin

HC: haemocyanin

HMW: high molecular weight

KT: Karkataka Taila

LMW: low molecular weight

Sc-ALF: *Scylla*-anti-lipopolysaccharide

Sc-crustin: *Scylla* crustin

SOD: superoxide dismutase

SSAP: *Scylla serrata* antimicrobial protein

Ss- β -GBP: *Scylla serrata* beta-glucan binding protein

Declarations

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Author contributions

DN: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Visualization, Writing—original draft, Writing—review & editing, Funding acquisition. RS and BD: Supervision, Writing—review & editing. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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Consent to participate

Not applicable.

Consent to publication

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