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Potentials Compounds from Marine Invertebrates against Gram Negative Multi Drug Resistant (MDR) Pathogens

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ABSTRACT

Globally, the occurrences of multi-drug resistant gram-negative bacteria have been created an imperative crisis. These bacteria have the restricted treatment preference resulting serious human health threats. Therefore, there is a need for searching an alternative measure should be taken against multidrug resistant bacteria immediately. Consequently, in this review, we focused on the marine antibacterial compounds which are documented from marine invertebrates like sponges, corals, bryozoans and tunicates with potent activity against these drug resistant bacteria were investigated. Marine network is a known as well as significant ecological niche for the discovery of promising bioactive compounds (peptides, macrocyles, terpenes, alkaloids, quinines etc.,) along with strong antibacterial potency against these resistant bacteria. This triggered us to review the marine bioactive compounds with excellent potency to fight against multi drug resistant bacteria.

Key words: Marine Invertebrates, Multi drug resistance, Sponges, Corals, Tunicates, Bryozoans

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INTRODUCTION

The antibiotics are an amazing invention in field of modern medicine which rules the entire world by saving the human lives. Unfortunately, antibiotic resistant strains are reported, owing to the extreme use of antibiotics resulting multi drug resistant [1]. The earlier report says, in 2050, 300 million deaths will be arising due to the infection caused by multidrug resistant organisms [2]. Presently, many of the bacterial strains were developed resistant to an antibiotic which leads to high morbidity and mortality [3]. Particularly, the occurrences of multidrug drug resistant gram-negative bacteria are becoming a world crisis [4-6]. Multidrug resistant refers; it is a reaction of organism to antimicrobial agents can occur through a variety of mechanisms like mutation in chromosomes, alteration in the target site, gene transfer [7]. The resistant strains are gaining much attention as well as the research focus for the development of new antibiotics or bioactive compounds which will fight against multi drug resistant organisms since of their "priority status" [8]. In these circumstances, the progress or establishment of novel antimicrobial agents with evident bioactivity with scientific importance is needed [9,10] to fight against multi drug resistant gram-negative bacteria. Consequently, in this review emphasize the antibacterial compounds from marine invertebrates against gram negative bacteria which are resistant to multiple drug of choice.

Marine ecosystems are varied and prosperous environment that contains huge range of different life structure with diverse chemical and physical states represents the significance of the invention of extensive choice of natural bioactive products by means of distinctive quality [11,12]. This marine product showed a wide variety of biological properties which has the probable relevance in the field of pharmaceutical and healthcare settings. The marine products obtained from marine invertebrates (sponges, soft corals, bryozoans and tunicates) are attracted owing to their structural as well as bioactive diversity which is not found in the terrestrial surroundings [13-15]. Till date, more than 40,000 marine compounds were isolated and identified with potent biological properties and many of them are patented and it has been approved [16].

Moreover, marine compounds with excellent biological activity from marine invertebrates have proved that these are precious source for the drug development and discovery. Importantly, many of the approved commercial drugs are from marine invertebrates particularly from sponges. So far, eight marine drugs were approved by European Medicines Agency and FDA (food and drug administration) [17]. Hence, in this review, we emphasized the antibacterial compounds produced by marine invertebrates (sponges, corals, bryozoans and tunicates) against multi-drug resistant gram-negative bacteria such as *Acinetobacter baumanii, Enterobacteriaceae, Neisseria gonorrhoeae, Helicobacter pylori, Pseudomonas aeruginosa*, *Campylobacter sp., Salmonella sp., Shigella sp.* are urgently needed the new antibiotics to deal with them.

Antibacterial compounds from marine invertebrates

Sponges

Sponges, belonging to Phylum porifera are important sessile marine invertebrates, survive in the harsh marine environmental conditions which provide the way for the finding of novel biological materials with different biological performance like anti-inflammatory, antimicrobial, anticancer, etc., owing to the carbon moiety present in the structure make them perfect candidate for the drug discovery [18]. Still, more than 8000 sponge species were identified [19] and approximately, 5000 natural marine compounds were discovered [20,21]. The compounds obtained from sponges have various chemical structures including terpenes, alkaloids, peptides, sterols and nucleosides leads to various biological activities [22]. With this background, Kubota et al. (2016) [23] isolated a compound hyrtinadine D from marine sponge Hyrtios erecta exhibited antimicrobial actions against *E. coli* and Gram-positive bacterium at 16 µg/ml MIC concentrations. In contrast, the compounds namely Hyrtiosenolides A and B identified in red sea sponge Hyrtios species showed minimum inhibitory effect against *E. coli* when tested at 100 µg/ml concentration [24]. The compounds agelasidine C and D have been isolated from marine sponge genus Agelas clathrodes had the antibacterial activity against *Proteus vulgaris* and *Klebsiella pneumoniae* [25]. Kobayashi, et al. [26] were isolated the Ageliferin and bromoageferin from marine sponge *A. conifera* and investigated the antimicrobial activity against bacteria and found that, the compounds have the potency to inhibit *E. coli* with the concentrations at 10 µg/disk.

Walker and his co-workers [27] identified the compound sceptrin from marine sponge *A. sceptrum* and investigated for its antimicrobial activity human pathogens such as *Pseudomonas aeruginosa*. Consequently, a study from Konuklugil [28] group reported the antimicrobial activity of thirty-three methanolic extracts which were obtained from the turkey sea marine sponges against multi-drug resistant gram-negative pathogens *P. aeruginosa* and *Proteus vulgaris* and identified the most effective compounds based on the collection area. This recommends that, the secondary metabolites production can be affected by surrounding environment. The antimicrobial compounds were identified from Mediterranean Sea sponge Axinella verrucosa in Syria. The antibacterial activity of methanolic extract was tested against *Acinetobacter septicus*, *P. vulgaris* and *P. aeruginosa* using disc diffusion method. The spectroscopic analyses of the extracted compounds were identified as hymenialdisine, 10E hymenialdisine and spongiacidine and these compounds were revealed the synergistic actions between the compounds [29]. In the same way, a study reported the extract (ethyl acetate) of marine sponge, *A. damicorins* from the Monasir was tested against the *P. aeruginosa* and other human pathogens. The same group investigated the antibacterial activity of marine sponge Agelas oroides (Demospongiae) against the multi drug resistant pathogens and revealed the broad spectrum activity. These studies suggest that, the extracts of both sponges have complex mixture of structurally diverse brominated pyrrole alkaloids [30].

Besides to Demospongiae, another group of sponge is known for their wide production of biological active compounds. As a result, a calcispongia known as Clathrina clathrus was collected in Mediterranean Sea located in France were evaluated for their antimicrobial compounds. The antimicrobial compounds were extracted using methanol and the NMR study has shown the existence of clathridimine, a novel alkaloid two aminoimidazole, clathridine along with preclathridine and clathridine-zinc complex. Here, the compound clathridimine exhibited the antibacterial activity against *E. coli* [31]. Alam, et al. [32] evaluated the antibacterial activity of Siphonocholin marine steroid recognized in red marine sponge, Siphonochalina siphonella against multidrug resistant *P. aeruginosa* and *A. baumannii* biofilm formation. The marine compound was able to decrease the virulence function resulting inhibition of biofilm formation at 64 and 256 µg/ml for *P. aeruginosa* and *A. baumanii* respectively. Constantly, bioactive compounds such as sipholenone A, sipholenol A, neviotine A and sipholenol L have been isolated and identified from the red sea sponge S. siphonella was evaluated for their antibacterial property against *P. aeruginosa* and *E. coli* [33].

Seven new cyclic peptides callyaerins were isolated from ethyl alcoholic fraction of red sea sponge Callyspongia aerizusa and examined for their diverse biological activity such as antibacterial, cytotoxic and antifungal activity. Callyaerins E has the antibacterial property against *E. coli* [34]. The peptide obtained from marine sponge has the distinct structures with specific amino acid which is uncommon or not present in other sources [35]. Several researches say the marine sponge peptide are safe, economical and has the broad range of biological properties [36,37].

Likewise, alkaloid-based compound is another group of metabolites which has been broadly documented in marine sponges particularly, bromopyyrole alkaloids-based compounds only found in the marine sources.

Consequently, El-Hawary and his co-workers (2019) [38] evaluated the antibacterial of two brominated indole alkaloids compounds from red sea sponge Callyspongia siphonella against *P. aeruginosa*. Moreover, a sponge A. ingens collected from the southeast Sulawesi marine park produced a novel compound 3-alkylpiperdine alkaloid that showed a specific antibacterial activity against *E. coli* by inhibiting amyloid beta 42 productions which is induced by aftin 5 at 26 µM concentration. Esposito and his team (2019) [39] isolated eleven alkaloid compounds have been recognized from the marine sponge A. ingens in the same location. Out of eleven alkaloids, compound Halicyamine showed antibacterial activity against *E. coli* at 100 µg/disc. In the same way, the bioactive bis- indole alkaloids, spongosoritins A–D and spongocarbamides A were identified from marine sponge Spongosorites sp and evaluated for the antibacterial activities against multi drug resistant gram-negative bacteria such as *E. coli, K. Pneumonia* and *Salmonella sp* and displayed a strong activity against all the tested organisms [40]. Also, the same group of compound Myrindole A was recognised in the marine sponge, Myrmekioderma sp and displayed the antibacterial activity against *E. coli* at 37.5 µM [41]. A compound, Zamamidine D collected from a marine sponge, Okinawan Amphimedon sp showed potent antibacterial against *E. coli* [42].

Similarly, a dimeric compound strongylophorine was isolated from Philippine marine sponge Strongylophora (Petrosia) exhibited anti *Salmonella typhi* activity [43]. The antimicrobial compounds 9-diynoic acid, 11E-tetradecadiene-5, C14 acetylenic acid 7E were isolated from Peninsula marine sponge of Oceanapia which contains CH=CH-C unit. These compounds displayed inhibitory effect against both gram positive and gram-negative bacteria [44]. The glycolipid compound Caminosides BD was identified from the Marine Sponge (Caminus sphaeroconia) showed antibacterial activity against *E. coli* [45] and the antibacterial activity of nitrogen heterocyclic marine sponge compound cribrostatin was tested against multidrug resistant *Neisseria gonorrhoeae* [46]. Four alkaloid toxins were identified from Arenosclera brasiliensis (marine sponge) evaluated against antibiotic resistant bacteria *P. aeruginosa* [47]. Urban et al. (1999) [48] studied the antibacterial activity of Axinellamines which is isolated from the marine sponge *Axinella sp* in Australia against *Helicobacter pylori*. The penaresidin compounds were isolated from Penares sponges evaluated the antibacterial potency and exhibited the good activity against *E. coli* [49]. The compounds identified in marine sponges are summarized in Table 1 and Figure 1.

Corals

Corals are one of the most important marine resources for the production of secondary metabolites such as steroids, terpenes, alkaloids and prostaglandins which provides lead for drug discovery. Keeping this in mind, bioactivity of two new cerebrosides, ceramide, sarcoehrenosides A and B, and three cerebrosides 3, 5, and 6 isolated from the Taiwan Donhsha Islands octocoral *Sarcophyton ehrenbergi* was investigated for their antibacterial activity *Salmonella Enteritidis* and *Shigella sonnei* [50]. Krishna and his team (2004) [51] isolated the compounds namely; two new sphingosines from Pseudopterogorgia australiensis, in Indian Ocean and their structures were analysed using spectral analysis. Compounds 2S,3S,4R-2-((2'R)-2'-hydroxy nonadecanoyl amino) nonadecane-1,3,4-triol, (2S,3R,4E)-2-(heptadecanoylamino) octadec-4-ene-1,3-diol and 2-(docosanoyl amino nonadecane-1,3-diol exhibited medium antibacterial activity against *P. aeruginosa, P. vulgaris* and *E. coli*,. The antibacterial activity of Two sphingolipids, (2S,3S,4R)-1,3,4-triacetoxy-2-l((R)-20–acetoxy octadecanoyl) amino] octadecane and (2S,3S,4R)-1,3,4-trihydroxy- 2-[((R)-20-hydroxytetradecanoyl) amino] tricosane which were

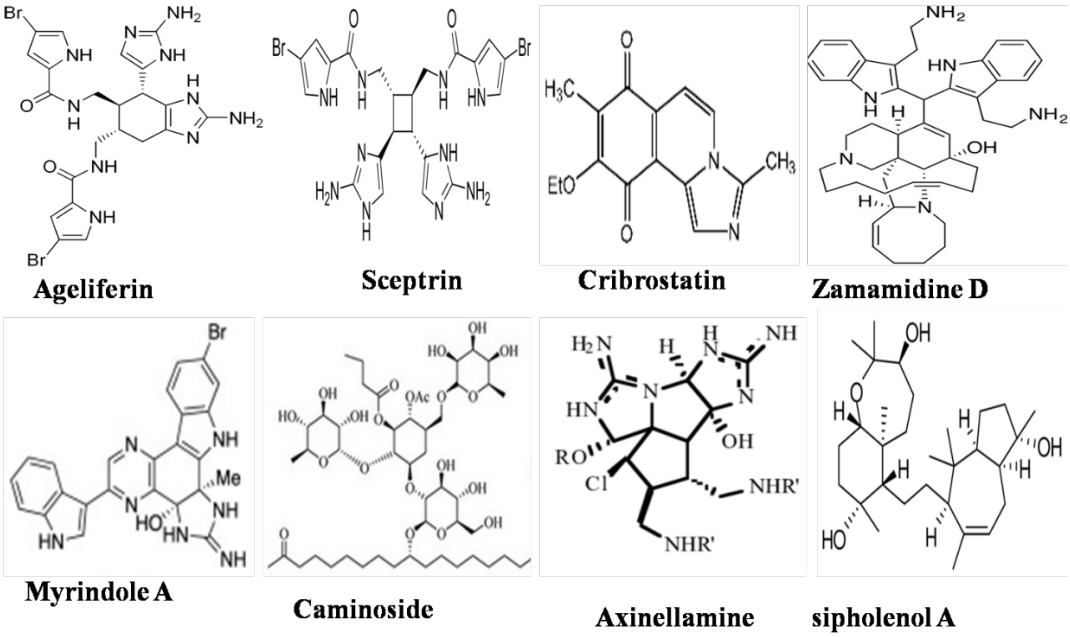

Figure 1: Some important compounds isolated from marine sponges.

Table 1: Antibacterial compounds isolated from marine sponges.

Compound Name	Sponge Name	Target Organism	References
Hyrtinadine D	Hyrtios erecta	*E. coli*	Kubota, et al. [23]
Hyrtiosenolides A and B	Hyrtios sp	*E. coli*	Youssef, et al. [24]
Agelasidine C and D	Agelas clathrodes	*Proteus vulgaris* and *Klebsiella pneumoniae*	Medeiros, et al. [25]
Ageliferin and bromoageferin	A. conifera	*E. coli*	Kobayashi, et al. [26]
Sceptrin	A. sceptrum	*Pseudomonas aeruginosa*	Walker, et al. [27]
Methanolic extracts	the turkey sea marine sponges	*P. aeruginosa and Proteus vulgaris*	Konuklugil, et al. [28]
Hymenialdisine, 10E hymenialdisine and spongiacidine	Axinella verrucosa	*Acinetobacter septicus, Proteus vulgaris and Pseudomonas aeruginosa*	Yassin, et al. [29]
Ethyl acetate extract	A. damicorins	*P. aeruginosa* and other human pathogens	Ines, et al. [30]
Brominated pyrrole alkaloids	Agelas oroides	Multi drug resistant pathogens	Ines, et al. [31]
New 2 aminoimidazole alkaloid and clathridine	Clathrina clathrus	*E. coli*	Roué, et al. [32]
Siphonocholin	Siphonochalina siphonella	*Acinetobacter baumannii* and *P. aeruginosa*	Alam, et al. [33]
Sipholenone A, sipholenol A, neviotine A and sipholenol L	Siphonochalina siphonella	*E. coli* and *P. aeruginosa*	Al-Massarani, et al. [34]
New cyclic peptides callyaerins E	Callyspongia aerizusa	*E. coli*	Ibrahim, et al. [35]
Brominated indole alkaloids	Callyspongia siphonella	*P. aeruginosa*	El-Hawary, et al. [36]
3-alkylpiperdine alkaloid	A. ingens	*E. coli*	Dewi, et al. [37]
Halicyamine	A. ingens	*E. coli*	Esposito, et al. [38]
Strongylophorine	Strongylophora	*Salmonella typhi*	Balbin, et al. [39]
11E-tetradecadiene-5, 9-diynoic acid, C14 acetylenic acid 7E	Oceanapia	*Gram negative organism*	Matsunaga, et al. [40]
Caminosides BD	Caminus sphaeroconia	*E. coli*	Linington, et al. [41]
Cribrostatin	Marine sponge	*Neisseria gonorrhoeae*	Pettit, et al. [42]
Alkaloid toxins	Arenosclera brasiliensis	*P. aeruginosa*	Torres, et al. [43]
Axinellamines	Axinella	*Helicobacter pylori.*	Urban, et al. [44]
Zamamidine D	Okinawan Amphimedon	*E. coli*	Kubota, et al. [45]
Myrindole A	Myrmekioderma	*E. coli*	Moosmann, et al. [46]

isolated from Sinularia leptoclados evaluated against human pathogens and exhibited kind antibacterial effect against Gram-negative bacterias [52]. A soft coral Sarcophyton troheliophorum isolated from red sea produced the secondary metabolite compounds Sarcotrocheliol acetate and Sarcotrocheliol exhibited the potent antibacterial activity against Acinetobacter sp at 4.34 μM MIC concentration [53]. Antibacterial activity of steroids compounds was exhibited the potent activity against *E. coli* [54].

A Diterpene compound isolated from Sarcophyton sp in Borneo showed the potent antibacterial activity against Vibrio sp [55]. Novel Cembranoid Diterpene compound Sarcophytol B from the sea soft coral Sarcophyton sp in China was displayed the antibacterial activity against Vibrio sp [56]. S. trocheliophorum from red sea produced the novel compounds trocheliane (tetracyclic biscembrane hydrocarbon) and sarcotrocheldiol A and B and diterpene cembrene-C that was evaluated for their antibacterial activity against multi drug resistant *A. baumanii* [57]. Furthermore, the antibacterial activity of xeniumbellal and penta hydroxygorgosterol isolated from the soft coral Xenia umbellate was assessed against A. baumannii and showed the potent antibacterial activity at 0.22 and 0.28 mM MIC concentration [58].

The diterpenoids compounds namely 9-deoxyxeniolide-A and B which were isolated from the Philippines sea soft coral Xenia sp exhibited the antibacterial activity [59]. Similarly, another study reported the seven novel diterpenoids which are xenicane type compounds like xeniolides I–K and novaxenicins A–D. The compounds were separated *X. novae-britanniae* in southern Kenya and displayed the antibacterial activity against E. *coli* at 1.25g/ml [60]. The antibacterial activity of ethyl acetate extract of J. Juncea collected from Indian Ocean was evaluated against *E. coli* and exhibited the activity which shows the gorgonian is the main basis for interesting compounds [61].

A group of novel diterpenoids, gemmacolides N–S with known already existing compounds isolated in the genus gorgonian *Dichotella gemmacea* in China and their biological activity was evaluated. The compounds juncenolide D, and juncins R, S, U and gemmacolides N, O, Q displayed the activity against *E. coli* [62]. Similarly, the same group has isolated the six novel briarane diterpenoids namely gemmacolides T-Y with already existing compounds from the same soft coral sea gorgonian *D. gemmacea* in China and those were exhibited the antibacterial activity against *E. coli* [63]. Likewise, the antibacterial activity of novel gemmacolides AZ–BF (briarane diterpenoids) those were isolated from gorgonian *Dichotella gemmacea* in china and evaluated for their bioactivity. The compound dichotelllides O was active against *E. coli* [64]. These Briarane diterpenoids are the interesting group of oxidized molecules consists of bicyclic carbon structure with γ-lactone ring combined with the 10-membered ring which is mainly isolated from gorgonians that are

Table 2: Antibacterial compounds isolated from marine corals.

Compound Name	Coral Name	Target Organism	References
Cerebrosides and ceramide	Sarcophyton ehrenbergi	*Salmonella Enteritidis and Shigella sonnei*	Cheng, et al. [50]
Sphingolipids	Sinularia leptoclados	*Gram negative bacteria*	Bala, et al. [51]
Sphingosines	Pseudopterogorgia australiensis	*E. coli, Proteus vulgaris, and P. aeruginosa*	Krishna, et al. [52]
Xeniolide I	X. novae-britanniae	*E. coli*	Bishara, et al. [53]
Sarcotrocheliol acetate and Sarcotrocheliol	Sarcophyton troheliophorum	*Acinetobacter sp*	Al-Footy, et al. [54]
11 α -acetoxy-cholesta-24-en-3β,5α,6β-triol	Sarcophyton sp	*E. coli*	Wang, et al. [55]
Cembradiene	Sarcophyton sp	*Vibrio sp*	Kamada, et al. [56]
Sarcophytol B	Sarcophyton sp	*Vibrio sp*	Cao et al. [57]
Trocheliane (tetracyclic biscembrane hydrocarbon) and sarcotrocheldiol A and B and diterpene cembrene-C	S. trocheliophorum	*A. baumanii*	Zubair, et al. [58]
Xeniumbellal and penta hydroxygorgosterol	Xenia umbellate	*A. baumanii*	Ayyad, et al. [59]
Gemmacolides N, O, Q	Dichotella gemmacea	*E. coli*	Li, et al. [60]
Gemmacolides T-Y	D. gemmacea	*E. coli*	Li, et al. [61]
Dichotelllides O	D. gemmacea	*E. coli*	Li, et al. [62]

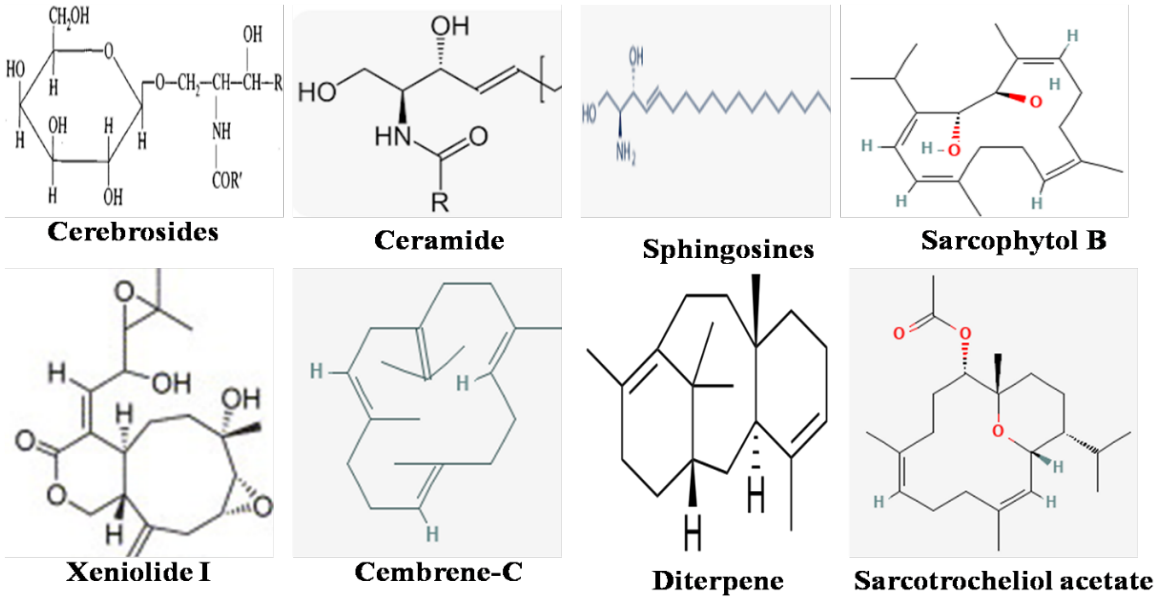

Figure 2: Important compounds from marine corals.

reported for wide varieties of bioactivities [65,66]. The compounds isolated from marine corals are summarized in Table 2 and Figure 2.

Tunicates

In Didemnidae family, an ascidian called Polysyncraton lithostrotum produced the compound namenamicin consisted of enediyne warhead and S-methyl group with sugar was evaluated for its bioactivity and the compound showed the excellent bioactivity against K. pneumonia at 0.25 µg/mL which suggesting that, this compound is more potent than the penicillin G [67]. A novel poly unsaturated amino alcoholic compound Crucigasterins was isolated from a tunicate Pseudodistoma Crucigaster and exhibited the strong antibacterial activity against gram negative organism *E. coli* at 100 g/ml [68]. Other amino alcoholic compounds Pseudoaminols A–G from tunicate Pseudistoma sp obtained in Korean coast and their structure was similar to the above compound crucigasterins. The isolated compound has the glycine based amino alcohol along with the carboxymethyl group and showed the important activity against *E. coli* and *S. typhimurium* [69]. The other antibacterial amino alcoholic compound distaminolyne A isolated from P. opacum exhibited the activity against *E. coli* at 64 µg/ml [70]. Two spiroketals compounds Didemnaketals F and G were obtained from an Ascidian Didemnum sp in red sea and displayed the antibacterial activity against *E. coli* [71]. Spiroketal molecule is an important molecule occurred in natural products particularly, in case of marine ecosystem, Didemnum sp have been the significant source of spiroketal molecules [72].

Styelin, an antimicrobial peptide was isolated from a tunicate Styela clava showed a broad-spectrum activity against variety of pathogens such as gram positive and gram-negative pathogens (*P. aeruginosa*, *S. typhimurium* and *E. coli*) [73,74]. Saude and his team (2014)

[75] was isolated a antimicrobial peptide clavanin consists of approximately 18 to 23 aminoacide and phenylalanine residues in their structure and exhibited the antibacterial activity against multi-drug resistant *E. coli*, K. Pneumonia and *P. aeruginosa*. Similarly, from the Halocynthia Papillosa in solitary sea, two cationic peptides namely papillosin and halocyntin were evaluated against a library of gram-negative bacteria. The authors explored the mechanism of action of two peptides wherein the protein interaction indicating the affinity with membrane lipids [76]. The compound homodimer dicynthaurin containing two cysteine helical peptides has been isolated from H. aurantium which is similar to marine ascidian peptide heteromer halocidin [77] and showed an antibacterial activity against multi drug resistant *E. coli* and *P. aeruginosa* at 140 µg/ml [78]. Similarly, turgencins a novel peptide was recognized from a tunicate Synoicum turgens in Arctic region and displayed activity against *E. coli* at 0.8 µM [79]. Consequently, the peptide like compounds halocyamines A and B consist L- DOPA and a 6- bromoindole DOPA were identified from H. roretzi in Japan and evaluated their biological activity against *P. aeruginosa* [80].

From the Micronesian Eudistorma sp, Eudistomins W and X were isolated and tested for their biological efficacy against various pathogens. The Eudistomins X was active against *E. coli* at 5-10 µg/disk [81]. The antibacterial alkaloid compounds Didemnolines A–D has been recognised in the Didemnum sp collected from islands of Mariana which were evaluated for biological activity and displayed the efficacy against *E. coli* [82] and also an alkaloid compound Ascididemin was displayed an activity against *E. coli* at 2.6 µM [83]. The compounds isolated from marine tunicates are summarized in Table 3 and Figure 3.

Bryozoans

A novel steroid compounds ponasterone and ponasterone were identified from the bryozoans Alcyonidium gelatinosum in Arctic region exhibited the strong activty against *E. coli* and *P. aeruginosa* [84]. Another group identified six new alkaloids compounds pterocellins A-F from the bryozoans *Pterocella vesiculosa* and evaluated for their bioactivity. The result suggested that, a compound Pterocellins A and B inhibits the growth of two human pathogens such as *E. coli* and *P. aeruginosa* [85,86].

Table 3: Antibacterial compounds isolated from marine tunicates.

Compound Name	Tunicate Name	Target Organism	References
Namenamicin	Polysyncraton lithostrotum	*K. pneumonia*	McDonald, et al. [67]
Crucigasterins	Pseudodistoma Crucigaster	*E. coli*	Jares, et al. [68]
Pseudoaminols A–G	Pseudistoma sp	*E. coli and S. typhimurium*	Won, et al. [69]
Distaminolyne A	*P. opacum*	*E. coli*	Wang, et al. [70]
Didemnaketals F and G	Didemnum sp	*E. coli*	Shaala, et al. [71]
Styelin	Styela Clava	*P. aeruginosa, E. coli and S. typhimurium*	Lee, et al. [72]
Papillosin and halocyntin	Halocynthia Papillosa	*E. coli*	Galinier, et al. [73]
Dicynthaurin	H. aurantium	*E. coli and P. aeruginosa*	Jang, et al. [74]
Halocyamines A and B	H. roretzi	*P. aeruginosa*	Azumi, et al. [75]
Turgencins	Synoicum turgens	*E. coli*	Hansen, et al. [76]
Eudistomins X	Eudistorma sp	*E. coli*	Schupp, et al. [77]
Didemnolines A–D	Didemnum sp	*E. coli*	Schumacher, et al. [78]
Ascididemin	Cystodytes	*E. coli*	Lopez, et al. [79]

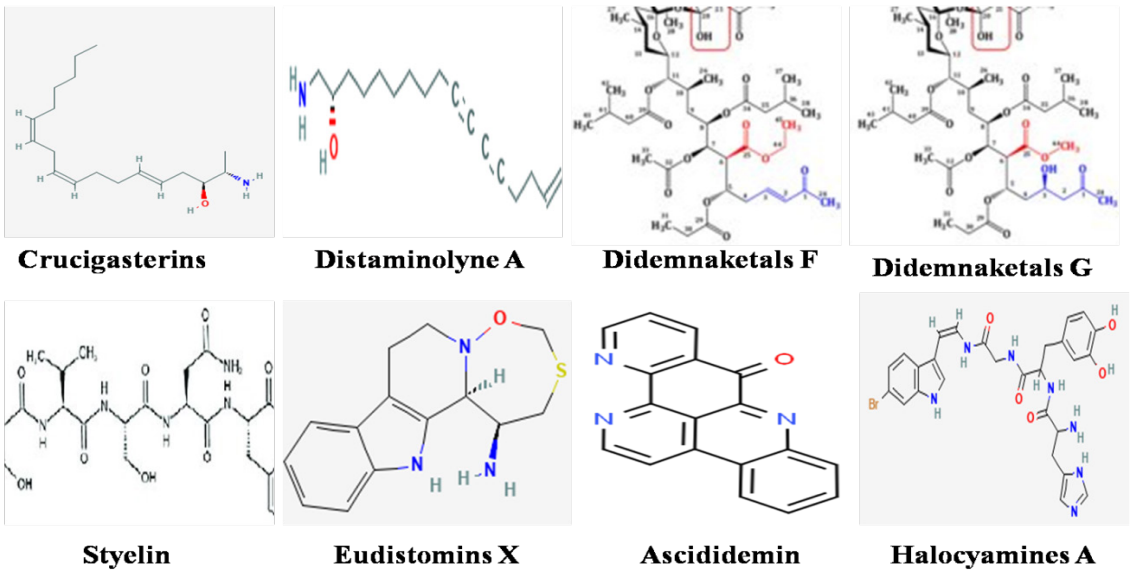

Figure 3: Major compounds isolated from marine tunicates.

CONCLUSION

The marine antibacterial compounds identified in marine invertebrates (sponges, corals, tunicates and bryozoans) tested against gram negative multidrug resistant bacteria are concise in table 1, 2 and 3. It is suggested that, these marine compounds are distinct, lavish and effectively fight against the drug resistant bacteria. Most of the antibacterial compounds were isolated from marine sponges and corals. These marine compounds were effective against gram negative organisms and also have other biological properties which are not discussed here. These compounds may be entered into the clinical trials resulting discovery of distinct and novel compound with antibacterial potency to fight against drug resistant bacteria.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest relevant to this article.

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