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REVIEW

Exploring gastropods in drug discovery: a review of their bioactive compounds and pharmacological applications

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Abstract Mollusc species are an abundant source of secondary metabolites with numerous biological activities. Approximately eighty percent of mollusks are gastropods, which are used in various ways, including as food and traditional medicine, due to their high protein content. The use of various gastropods has grown rapidly in the last decades, particularly in the pharmaceutical, nutraceutical, and cosmetic products industries. This review focuses on the various bioactive compounds derived from gastropods and their corresponding biological activities. A list of essential factors for discovering and developing novel therapeutic drugs has also been discussed, along with a roadmap for further research on marine-derived products. This review provides a detailed discussion of the various metabolites isolated from different gastropod species, including 40 bioactive compounds and their reported biological activities. However, we aim to analyze the evidence for the traditional use of gastropods in controlling various clinical problems. This study suggests that isolated bioactive compounds are valid leads for medical biotechnologists and pharmaceutical chemists to design novel drug molecules.

Keywords Bioactive compounds . Gastropods . Biological activities . Natural product . Pharmaceutical

Introduction

Gastropods are a significant class of mollusks found in both terrestrial and aquatic ecosystems, characterized by remarkable biological and chemical diversity. The marine environment is a huge source for discovering bioactive natural products. Traditional human populations have utilized numerous natural bioactive compounds from marine animal species to treat various ailments and enhance their healthcare. These bioactive compounds are regarded as potential candidates for affordable drug therapy worldwide. Mollusks are considered the second-most-diverse phylum of living creatures; they are characterized into eight classes, including Bivalvia, Scaphopoda, Cephalopoda, Polyplacophora, Monoplacophora, Caudofoveata, and Solenogastrea (Lydeard et al. 2004). They are known to be pharmacologically significant organisms of the Animal Kingdom. Among them, gastropod species are the most abundant class of mollusks, including various snails and slugs. Gastropod extracts are usually a complex combination of biochemically and pharmacologically active compounds, including proteins, peptides, lipids, steroids, alkaloids, terpenoids, and other organic compounds, which exhibit significant pharmacological properties, such as antimicrobial, anti-inflammatory, and anticancer activities. An in vitro antibacterial assay was conducted using the agar well diffusion method to analyze the hemolymph of *Buccinum undatum* and *Crepidula fornicata* against

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gram-positive and gram-negative bacterial strains. Furthermore, in vitro tests using Vero cells have demonstrated the antiviral effects of acidic extracts from gastropod species against Herpes simplex virus type 1 (HSV-1) (Blunt et al. 2009; Margret et al. 2013). Despite growing interest, many gastropod species remain underexplored in terms of their bioactive potential and therapeutic applications. This review aims to consolidate current findings on gastropod-derived bioactive compounds, highlighting their mechanisms of action and potential roles in modern drug development. Gastropod-derived natural metabolites have generally provided significant leads to the development of pharmaceutical medications that may exhibit more effective activity and benefits with fewer side effects. This study covers various scientific research on gastropods and their importance in pharmacology. The Scopus database, PubMed, ScienceDirect, Google Scholar, MarinLit, Web of Science, and other online scientific literature search engines were used to retrieve all published peer-reviewed scientific papers. Information was collected from published research articles, books, review articles, and regional-specific ethnomedical research about the significant use of gastropods' natural bioactive compounds. According to the World Register of Marine Species (WoRMS) database, the gastropod specimen nomenclature and family classification were described in this review article. The following information about gastropod-isolated compounds was obtained from chemical structure databases, such as PubChem and ChemSpider. In this study, Table 1 presents numerous species that contain various bioactive compounds and their corresponding bioactivities, including antimicrobial, anti-inflammatory, antioxidant, and anticancer properties, as determined through in vitro and in vivo experiments. This review is unique in that it offers the first comprehensive perspective on bioactive compounds derived from gastropods. It connects their pharmacological mechanisms and structural diversity with potential future directions in translational applications, high-throughput screening, metabolomics, and sustainable bioprospecting.

Bioactive compounds

Bioactive compounds are metabolites extracted from natural sources that can be protective against various diseases and metabolic disorders. These compounds provide significant leads for the development of pharmaceutical agents. Jiménez-Romero et al. (2014) have evaluated that a diterpene secondary metabolite, dactyloditerpenol acetate, was isolated from sea hare *Aplysia dactylomel,* which was screened for its in vitro anti-neuroinflammatory activity by inhibiting the production of thromboxane B2 (TXB2) and superoxide anion (O2(-)). This substance was discovered to have cytotoxic action against the prostate cancer cell lines DU-145 and A2058 melanoma cells. It was also shown to have antituberculosis activity against *Mycobacterium tuberculosis* H37Rv, with a minimum inhibitory concentration (MIC) of 59.4 μg/mL. Furthermore, *Cadlina luteomarginata* is a prevalent type of nudibranch, commonly found in the habitats of British Columbia. Secondary metabolites, such as sesterterpenoids and Ansellone A, were identified in the skin extract of *C. luteromarginata*, which stimulates the cAMP signaling pathway in HEK293 cells (Daoust et al. 2010). Muricidae family gastropods are an excellent source for producing synthetic brominated indoles and choline ester compounds. Bioactive compounds, including tyrindoxyl, 6-bromoindole, tyrindolinone, murexine, enecioylcholine, dihydromurexine, tyrindoxyl sulphate, tyriverdin, 6,6′-dibromoindigo, indirubin, 6-bromoindirubin, isatin, 5-bromoisatin, 6-bromoisatin, and 7-bromoisatin, were derived from both hypobranchial gland extracts and egg masses of *Dicathais orbita* species. These compounds have been shown to exhibit potent anti-inflammatory effects both in vitro and in vivo, inhibiting the production of tumor necrosis factor-alpha (TNF-α), nitric oxide (NO), and prostaglandin E2 (PGE2). In addition, brominated isatin and 6-bromoisatin have also demonstrated both in vitro and in vivo antiproliferative activity against HT29 and Caco-2 cancer cells (Valles-Regino et al. 2016; Ahmad et al. 2017). Besides this, Chakraborty et al. (2019) investigated another secondary metabolite, ramosane, a sesquiterpenoid derivative obtained from the organic extract of the muricid gastropod *Chicoreus ramosus.* This isolated metabolite exhibits in vitro anti-inflammatory and antioxidant properties, making it beneficial for use in nutritional supplements and medicinal formulations. Dhahri et al. (2020) demonstrated that an active sulfated polysaccharide isolated from sea hare *Bursatella leachii* viscera exhibited in vitro anticoagulant activity using partial thromboplastin time and thrombin time.

Pharmaceutical applications of bioactive compounds

Wound healing properties

In a study, Tsoutsos et al. (2009) reported Elicina® (Locafar, Chile), a cosmetic skin repair cream made from *Cornu (Helix) aspersum* mucus extracts. This cream offers effective treatment with skin-healing properties, working more quickly than other burn ointments used by adult patients to improve tissue regeneration and healing. Various components, including polyunsaturated fatty acids, amino acids, sterols, vitamin E, and aromatic compounds, were found in the flesh of the muricid *Rapana venosa* lipid extracts. These compounds induced skin burns in animal models by regenerating the skin's dermis and epidermis tissues, along with the formation of new blood vessels, epithelium, and collagen fibers. Such compounds are also considered as potential therapeutic anti-inflammatory agents (Badiu et al. 2008). In another study, El Mubarak et al. (2013) demonstrated that the mucus extract from *Helix aspersa* is utilized as a component of cosmetic skin treatments, which is a rich source of bioactive substances like glycolic acid and allantoin.

Anti-cancer properties

Considering the prevalence of cancer worldwide, anticancer substances are extremely important therapeutics. Marine gastropods have been identified as a novel source of bioactive compounds with promising anticancer potential. Numerous gastropod species' whole-body extracts have been tested for their activity on lymphocyte proliferation and antiproliferative assay on various human cancer cell lines. A drug named Brentuximab vedotin, isolated from the marine gastropod *Dollabella auricularia,* was FDA-approved and used as a medicine to treat Hodgkin's disease and lymphoma (Ciavatta et al. 2017). Nevertheless, achacin, a glycoprotein separated from the *Achatina fulica* snail's body mucus, has demonstrated anticancer efficacy against kidney epithelial and breast cancer cell lines in vitro (Ehara et al. 2002). Furthermore, bioactive cyclic and linear peptides were derived from the *D. auricularia* species, which exhibit anticancer properties against several cancer cell lines. Peptides such as dolastatins 10 and dolastatins 15, isolated from *D. auricularia* extracts. Both metabolites prevent the proliferation of liver and breast cancer cell lines. Dolastatin 10 is a unique structure with a pentapeptide subunit, while dolastatin 15 is a seven-subunit depsipeptide, and both peptides have been clinically tested for cancer therapy. Dolastatin 10 interferes with tubulin polymerization, leading to cell cycle arrest. LU-103793 (cematodin) and ILX651 (synthadotin) are derivatives of dolastatin 15; these two synthetic analogs have been formulated as anticancer medications for cancer therapy (Kang et al. 2018). Furthermore, Pla et al. (2006) reported that most lamellarin compounds were identified in the marine gastropod Lamellaria species, which have been reported to exhibit various pharmacological activities, including antimicrobial, antioxidant, and cytotoxic properties. For example, Lamellarin D, a bioactive alkaloid lead, exhibited in vitro cytotoxicity in human cancer cells, such as A-549 lung, MB-231 breast, and HT-29 colon cell lines. It was also shown to have potent inhibitory effects on human topoisomerase I. Some other cytotoxic bioactive metabolites, including jorunnamycin A, jorunnamycin B, jorunnamycin C, renieramycin M, renieramycin O, renieramycin Q, and mimosamycin, were isolated from the mantle, egg ribbons, and visceral organs of the nudibranch *Jorunna funebris.* These compounds were found to show cytotoxic activity in P388 lymphoma, A549 lung cancer, HT29 colon cancer, and MEL28 human skin cancer cell lines (Charupant et al. 2007). Similarly, Van et al. (2008) have reported diterpenes 6β,7α-diacetoxylabda-8,13E-dien-15-ol, 2α,6β,7α-triacetoxylabda-8,13E-dien-15-ol, 6β,7α,15-triacetoxylabda-8,13E-diene, 3α,11-dihydroxy-9,11-seco-cholest-4,7-dien-6,9-dione, Cholest-7-en-3,5,7-triol, which were isolated from *Timusculus costatus*. The findings reported that compounds such as 6β,7α-diacetoxylabda-8,13E-dien-15-ol (IC50 value: 25 μM), 2α,6β,7α-triacetoxylabda-8,13E-dien-15-ol (IC50 value: 24 μM), 6β,7α,15-triacetoxylabda-8,13E-diene (IC50 value: 84 μM), and 3α,11-dihydroxy-9,11-seco-cholest-4,7-dien-6,9-dione (IC50 value: 3 μM) have shown cytotoxicity against the human esophageal cancer cell line WHCO1. Besides this, the extracts of this nudibranch specimen yielded compound epoxygoniolide-1 and compounds of the gracilin family, including aplytandiene-3, gracilin A, gracilin B, gracilin C, gracilin G, and gracilin M. All of these compounds were screened against human colorectal cancer and lung and liver cancer cell lines (Hirayama et al. 2016; Forster et al. 2017).

Anti-inflammatory properties

Gastropods' whole-body, flesh, and shell extracts contain bioactive compounds that are utilized as anti-inflammatory agents to treat osteoarthritis, rheumatoid arthritis, fever, lethargy, and joint discomfort. Marine gastropod *Cypraea arabica* methanolic extracts have shown potent analgesic, antipyretic, and anti-inflammatory activity in Wistar albino rats (Subavathy and Thilaga 2018). The venom of cone snails provides pain-relieving toxins. For example, Ziconotide (Prialt) is the first painkiller derived from the conotoxin in the venom of the marine carnivorous cone snail *Conus magus*. The Food and Drug Administration (FDA) has approved it after clinical testing, and it is used to treat neurological diseases and chronic pain. Ziconitide is a drug designed from naturally occurring conopeptides (Joseph et al. 2011). According to Joshi et al. (2016), the hexapeptide C-II is derived from *Harpa ventricosa* visceral mass extracts and acts as an anti-inflammatory peptide. This protein fraction exhibited an anti-inflammatory assay that inhibits the synthesis of TNF-α and IL-1β. Furthermore, the purified peptide also showed cytotoxicity against the THP-1 leukemia cell line. Thus, the peptide is utilized in medicinal applications for the treatment of inflammatory and cancer diseases. Moreover, Bhattacharya et al. (2014) reported that lipid extracts were made from the footpads of the edible snail *Bellamya bengalensis*, which is used by tribal people as a potential medicine to prevent rheumatism-like joint and bone inflammation, inhibit macrophage activation, and reduce cellular hypersensitivity in a rat model. Similarly, Oliveira et al. (2015) have investigated the digestive gland extracts of *Aplysia depilans* Gmelin, which consist of eight carotenoids and twenty-two long-chain polyunsaturated fatty acids. These compounds have been shown to have significant anti-inflammatory effects and reduce nitric oxide (NO) production.

Antimicrobial properties

An antimitotic and antiviral agent, kelletinin A (KA), is a naturally occurring substance extracted from the marine gastropod *Buccinulum corneum*. In addition to its antimitotic action on HTLV-1-infected MT2 cells, KA demonstrated antiviral activity against the human T-cell leukemia virus type 1 (HTLV-1) and suppressed the production of cellular DNA and RNA (Silvestri et al. 1995). Benkendorff et al. (2001) extracted brominated indole metabolites, such as tyriverdin, 6-bromoisatin, and tyrindolenin, from the egg mass of the *Dicathais orbita* species. Additionally, another compound, 6-bromo-2-methylmercaptoindoxyl-3-sulfate, was obtained from the hypobranchial glands of this species. These compounds have exhibited antimicrobial properties against various pathogens, including *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Candida albicans, Enterococcus sericolicida,* and *Vibrio angillarium*, as determined by a disk diffusion assay. Similarly, Zhong et al. (2013) reported that mytimacin-AF peptide was identified from the mucus extract of the giant African snail *Achatina fulica.* These compounds have shown promising antimicrobial activity against gram-positive pathogens, including *Staphylococcus aureus, Bacillus megatherium*, and gram-negative pathogens such as *Escherichia coli, Bacillus pyocyaneus, Bacillus dysenteriae,* and *Klebsiella pneumoniae*, as well as the fungal strain *C. albicans*, by using disk diffusion methods. The results showed that *S. aureus* was the most sensitive to mytimacin-AF among all the strains, with a minimum inhibitory concentration (MIC) of 1.9 µg/ml. Furthermore, other antimicrobial compounds, such as pseudoephedrine, hexanal-2-methyl, 2,2-dimethylpropionic acid, hexadecyl ester, and 1,2-benzenedicarboxylic acid diisooctyl ester, were isolated from *Phalium glaucum* whole-body tissue extracts. The extracted bioactive compounds were tested for antibacterial activity using the disc diffusion method against the pathogens *Escherichia coli, Klebsiella pneumoniae, Proteus vulgaris, Salmonella typhi, Shigella flexneri,* and *Staphylococcus aureus*. The results showed that the highest activity was exhibited against the *S. typhi* strain, with an MIC of 12 mm, and the lowest activity was observed against the *E. coli* strain, with an MIC of 5 mm (Thilaga et al. 2014).

As shown in Table 1, gastropod-derived metabolites exhibit a broad spectrum of biological activities, with the majority demonstrating cytotoxic and anticancer potential (e.g., aplyronines, elisidepsin, zalypsis, dendocarbins). Several compounds also display antimicrobial and antifungal effects (e.g., deoxymanoalide, scutinins, aglajne-1), while bromotriterpenes such as aplysqualenols broaden this scope to include antiviral and antiplasmodial activity. Notably, certain alkaloids and terpenes exhibit anti-inflammatory, antifouling, and antimalarial properties, underscoring the structural and functional diversity

Table 1 Pharmacological activity of bioactive compounds reported from gastropod species.

SL. No.	Compound Name (Gastropod Species); Chemical Class	Molecular Formula; Chemical Database ID	Chemical Properties	Biological Effect	Reference
1	Aurilol *(Dolabella auricularia)*; Bromotriterpene	MF:$C_{30}H_{53}BrO_7$ PubChem ID:11365474	MW:605.6[g/mol] XLogP3:3.6 H-bd:3; H-ba:7	Cytotoxic	Suenaga et al. (1998)
2	Laurinterol *(Aplysia kurodai)*; Sesquiterpene	MF: $C_{15}H_{19}BrO$ PubChem ID: 11471955	MW: 295.21[g/mol] XLogP3:5.3 H-bd:1; H-ba:1	Cytotoxi Antibacterial	Tsukamoto et al. (2005)
3	Debromolaurinterol *(Aplysia kurodai)*; Sesquiterpene	MF: $C_{15}H_{20}O$ PubChem ID: 466442	MW: 216.32[g/mol] XLogP3:4.6 H-bd:1; H-ba:1	Cytotoxic Antibacterial	Tsukamoto et al. (2005)
4	Aplysqualenol A *(Aplysia dactylomela)*; Bromotriterpene	MF: $C_{31}H_{53}BrO_7$ PubChem ID: 44551049	MW: 617.7 [g/mol] XLogP3:4.5 H-bd:2; H-ba:7	Antivira Antitumor	Vera et al. (2009)
5	Aglajne-1 *(Bulla occidentalis)*; Polypropionate	MF: $C_{25}H_{40}O_3$ PubChem ID: 13917442	MW: 388.6 [g/mol] XLogP3:6.8 H-bd:0; H-ba:3	Antibacterial	Arrieche et al. (2019)
6	Deoxymanoalide *(Chromodoris willani)*; Sesterterpene	MF: $C_{25}H_{36}O_4$ ChemSpider ID:27024351	Avg. mass: 400.551 [Da] XLogP3:6.07 H-bd:1; H-ba:4	Antimicrobial	Uddin et al. (2009)
7	Fusaripyrone A *(Haminoea fusari)*; Pyrone	MF: $C_{32}H_{48}O_3$ PubChem ID: 101446903	MW: 480.7[g/mol] XLogP3:10.7 H-bd:1; H-ba:3	Antifouling	Cutignano et al. (2007)
8	Fusaripyrone B *(Haminoea fusari)*; Pyrone	MF: $C_{32}H_{48}O_4$ PubChem ID: 101446904	MW: 496.7[g/mol] XLogP3:9.3 H-bd:2; H-ba:4	Antifouling	Cutignano et al. (2007)
9	Malyngamide S *(Bursatella leachii)*; Alkaloid	MF: $C_{26}H_{42}ClNO_5$ PubChem ID: 643654	MW: 484.1 [g/mol] XLogP3:4.6 H-bd:2; H-ba:5	Anti-inflammatory Antimicrobial Cytotoxicity	Appleton et al. (2002)
10	Scutinin A *(Scutus antipodes)*; Epimer	MF: $C_{48}H_{38}O_{18}$ PubChem ID: 132850622	MW: 902.8 [g/mol] XLogP3:7.7H-bd:6; H-ba:18	Antimicrobial	Chand et al. (2017)
11	Glandulaurencianol A *(Aplysia punctata)*; Diterpene	MF: $C_{20}H_{33}BrO_2$ ChemSpider ID:32675113	Avg. mass:385.379 [Da] XLogP3:6.10 H-bd:1; H-ba:2	Antibacterial	Kladi et al. (2014)
12	Glandulaurencianol C *(Aplysia punctata)*; Diterpene	MF: $C_{20}H_{32}O_2$ ChemSpider ID:32675115	Avg. mass:304.467 [Da] XLogP3:5.77 H-bd:1; H-ba:2	Antibacterial	Kladi et al. (2014)
13	Diemenensin A *(Siphonaria diemenensis)*; Polypropionate	MF: $C_{21}H_{32}O_3$ PubChem ID: 54715959	MW: 332.5 [g/mol] XLogP3:6.5 H-bd:1; H-ba:3	Antimicrobial	Hochlowski and Faulkner (1983)
14	Actinofide *(Actinocyclus papillatus)*; Terpenoid	MF: $C_{21}H_{35}N_3O$ PubChem ID: 132606933	MW: 345.5 [g/mol] XLogP3:6.2 H-bd:2; H-ba:2	Anticancer	Carbone et al. (2017)
15	Kulokekahilide-2 *(Philinopsis speciosa)*; Cyclic depsipeptide	MF: $C_{44}H_{67}N_5O_{10}$ PubChem ID: 11491350	MW: 826.0 [g/mol] XLogP3:6 H-bd:4; H-ba:10	Anticancer	Nakao et al. (2004)
16	Keenamide-A *(Pleurobranchus forskalii)*; Cyclic hexapeptide	MF: $C_{30}H_{48}N_6O_6S$ ChemSpider ID:10200275	Avg. mass: 620.804 [Da] XLogP3: -0.95 H-bd:4; H-ba:12	Anticancer	Wesson et al. (1996)
17	Zalypsis *(Joruna funebris)*; Alkaloid	MF: $C_{37}H_{38}F_3N_3O_8$ PubChem ID: 16061448	MW: 709.7 [g/mol] XLogP3:5 H-bd:3; H-ba:13	Antitumor	Malve (2016)
18	Elisidepsin *(Elysia rufescens)*; Cyclic depsipeptide	MF: $C_{75}H_{124}N_{14}O_{16}$ PubChem ID: 9855343	MW: 1477.9 [g/mol] XLogP3:7.4 H-bd:14; H-ba:17	Anticancer	Hamann et al. (1996)
19	Tyrindoleninone *(Dicathais orbita)*; Brominated indole	MF: C_9H_6BrNOS PubChem ID: 618037	MW: 256.12 [g/mol] XLogP3:2.6 H-bd:0; H-ba:3	Anticancer	Edwards et al. (2012)
20	Aplyronine A *(Aplysia kurodai)*; Alkaloid	MF: $C_{59}H_{101}N_3O_{14}$ PubChem ID: 11840920	MW: 1076.4 [g/mol] XLogP3:9.1 H-bd:2; H-ba:16	Cytotoxic	Yamada et al. (1993)
21	Aplyronine H *(Aplysia kurodai)*; Alkaloid	MF: $C_{58}H_{99}N_3O_{14}$ PubChem ID: 102037441	MW: 1062.4 [g/mol] XLogP3:8.7 H-bd:3; H-ba:16	Cytotoxic	Yamada et al. (2000)
22	Neoaplaminone *(Aplysia kurodai)*; Alkaloid	MF: $C_{26}H_{40}BrNO_4$ ChemSpider ID8431248	Avg. mass:510.504 [Da] XLogP3:4.99 H-bd:2; H-ba:5	Cytotoxic	Kigoshi et al. (1990)
23	Phidianidine A *(Phidiana militaris)*; Indole alkaloid	MF: $C_{17}H_{22}BrN_7O$ PubChem ID: 59053149	MW: 420.3 [g/mol] XLogP3:2.8 H-bd:4; H-ba:5	Cytotoxic	Carbone et al. (2011)
24	Phidianidine B *(Phidiana militaris)*; Indole alkaloid	MF: $C_{17}H_{23}N_7O$ PubChem ID: 60150771	MW: 341.4 [g/mol] XLogP3:2.1 H-bd:4; H-ba:5	Cytotoxic	Carbone et al. (2011)
25	Ergosinine *(Pleurobranchus forskalii)*; Ergot alkaloid	MF: $C_{30}H_{37}N_5O_5$ PubChem ID: 10030389	MW: 547.6 [g/mol] XLogP3:1.8 H-bd:3; H-ba:6	Cytotoxic	Wakimoto et al. (2013)
26	Cycloforskamide *(Pleurobranchus forskalii)*; Macrocylic dodecapeptide	MF:$C_{54}H_{86}N_{12}O_{11}S_3$ PubChem ID: 71747326	MW: 1175.5 [g/mol] XLogP3:4.8 H-bd:9; H-ba:17	Cytotoxic	Tan et al. (2013)

Table 1 Continued

27	Reticulidin A *(Reticulidia fungia)*; Sesquiterpene	MF: $C_{16}H_{22}C_{l3}NO$ PubChem ID: 10337976	MW: 350.7 [g/mol] XLogP3:5.6 H-bd:1; H-ba:2	Cytotoxic	Tanaka and Higa (1999)
28	Jorumycin *(Jorunna funebris)*; Alkaloid	MF: $C_{27}H_{30}N_2O_9$ PubChem ID: 9849761	MW: 526.5 [g/mol] XLogP3:0.1 H-bd:1; H-ba:11	Cytotoxicity	Fontana et al. (2000)
29	Tambjamine K *(Tambja ceutae)*; Alkaloid	MF: $C_{15}H_{21}N_3O$ PubChem ID: 135934866	MW: 259.35 [g/mol] XLogP3:2.8 H-bd:2; H-ba:2	Cytotoxic	Carbone et al. (2010)
30	Dendocarbin A *(Dendrodoris carbunculosa)*; Sesquiterpene	MF: $C_{15}H_{22}O_3$ PubChem ID: 10911949	MW: 250.33 [g/mol] XLogP3:3.5 H-bd:1; H-ba:3	Cytotoxicity	Sakio et al. (2001)
31	Dendocarbin N *(Dendrodoris carbunculosa)*; Sesquiterpene	MF: $C_{15}H_{24}O_4$ PubChem ID: 21592441	MW: 268.35 [g/mol] XLogP3:1.8 H-bd:2; H-ba:4	Cytotoxicity	Sakio et al. (2001)
32	Isodrimeninol *(Dendrodoris carbunculosa)*; Sesquiterpene	MF: $C_{15}H_{24}O_2$ PubChem ID: 11322321	MW: 236.35 [g/mol] XLogP3:3.1 H-bd:1; H-ba:2	Cytotoxicity	Sakio et al. (2001)
33	11-epivaldiviolide *(Dendrodoris carbunculosa)*; Sesquiterpene	MF: $C_{15}H_{22}O_3$ PubChem ID: 10354740	MW: 250.33 [g/mol] XLogP3:3.2 H-bd:1; H-ba:3	Cytotoxicity	Sakio et al. (2001)
34	Furodysinin *(Hypselodoris infucata)*; Sesquiterpene	MF: $C_{15}H_{20}O$ PubChem ID: 155517	MW: 216.32 [g/mol] XLogP3:3.9 H-bd:0; H-ba:1	Cytotoxicity	Mudianta et al. (2016)
35	Lovenone *(Adalaria loveni)*; Triterpenoid	MF: $C_{29}H_{48}O_4$ ChemSpider ID:8225484	Avg. mass: 460.689 [Da] XLogP3:5.60 H-bd:2; H-ba:4	Cytotoxicity	Graziani et al. (1995)
36	Aplykurodin A *(Aplysia kurodai)*; Sesquiterpene	MF: $C_{20}H_{34}O_3$ PubChem ID: 21674181	MW: 322.5 [g/mol] XLogP3:5.1 H-bd:1; H-ba:3	Cytotoxicity	Lee et al. (2020)
37	Aplysiasecosterol A *(Aplysia kurodai)*; Steroid	MF: $C_{27}H_{44}O_7$ PubChem ID: 102367614	MW: 480.6 [g/mol] XLogP3:1.9 H-bd:5; H-ba:7	Cytotoxicity	Kawamura et al. (2015)
38	Tritoniopsin A *(Tritoniopsis elegans)*; Diterpenoid	MF: $C_{24}H_{38}O_5$ PubChem ID: 101960706	MW: 406.6 [g/mol] XLogP3:3.3 H-bd:1; H-ba:5	Cytotoxicity	Ciavatta et al. (2011)
39	Tritoniopsin C *(Tritoniopsis elegans)*; Diterpenoid	MF: $C_{24}H_{38}O_6$ PubChem ID: 54671808	MW: 422.6 [g/mol] XLogP3:2.3 H-bd:2; H-ba:6	Cytotoxicity	Ciavatta et al. (2011)
40	Tritoniopsin D *(Tritoniopsis elegans)*; Diterpenoid	MF: $C_{26}H_{40}O_7$ PubChem ID: 54671895	MW: 464.6 [g/mol] XLogP3:2.8 H-bd:1; H-ba:7	Cytotoxicity	Ciavatta et al. (2011)

MF: Molecular formula; MW: Molecular weight; Avg. mass: Average mass; H-bd: Hydrogen bond donor; H-ba: Hydrogen bond acceptor

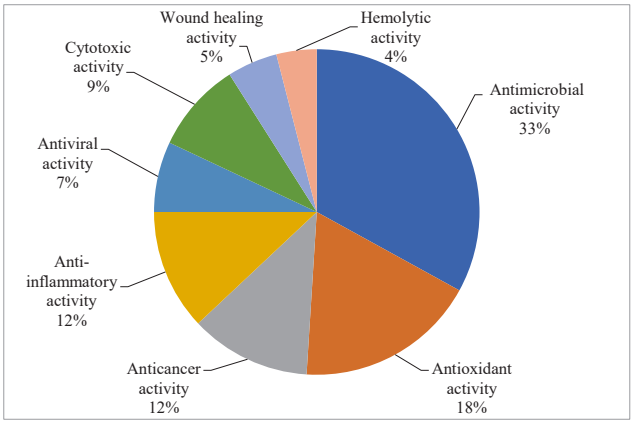

Fig. 1 Distribution of bioactivities studied from various species of gastropod

of these metabolites. collectively, these findings highlight gastropods as a rich reservoir of bioactive compounds with strong promise for drug discovery and therapeutic development.

Limitations and challenges

Despite the impressive pharmacological potential of secondary metabolites produced from gastropods, their translational potential is limited by several significant constraints. Initially, many of these metabo-

lites are found in extremely low natural yields, making it challenging to isolate them on a large scale and frequently impossible to replicate due to seasonal or ecological fluctuations. A reliable supply is further challenged by the reliance on wild harvesting, which raises concerns about sustainability and ethics. Furthermore, the structural complexity of many compounds derived from gastropods, particularly peptides and alkaloids, poses significant challenges to their scalable manufacture, as it limits chemical modification and synthetic replication. Environmental effects, such as the overuse of marine resources, underscore the need for synthetic biology techniques, aquaculture systems, and non-lethal sampling methods. Lastly, regulatory obstacles that hinder the transition from discovery to therapeutic application include the lack of thorough toxicological data, inconsistent pharmacokinetic investigations, and stringent clinical approval requirements. Addressing these barriers will be crucial for advancing gastropod-derived compounds from the bench to the bedside.

Future perspectives

This study provides information on the bioactive characteristics of gastropod species and their extracted chemicals, which are essential for developing new, powerful medications to treat various infectious disorders and inflammations. In the future, drugs such as antibiotics and anticancer agents may be discovered from compounds derived from gastropods. Several studies have reported the presence and potential importance of bioactive compounds, while the bioactive compounds of some species and their biological applications have yet to be explored. Therefore, further studies are required to isolate and structurally elucidate the bioactive compounds of gastropods. Detailed structural characterization facilitates rational drug design and enables structure-activity relationship (SAR) studies, which are critical for optimizing potency, selectivity, and safety. Researchers can employ advanced techniques, such as proteomics and transcriptomics, to identify rare and novel genes and proteins. However, recombinant techniques can also be used to express the proteins and peptides in gastropod species that may serve as a potential source for synthesizing novel drug formulations. There are limited silico investigations and human clinical trials on gastropod-derived bioactive compounds. This highlights the need for computational modeling, pharmacokinetic studies, and well-designed clinical evaluations to validate their therapeutic potential. Future investigations should also focus on *in silico* approaches using advanced bioinformatics tools and quantitative structure-activity relationship (QSAR) methods, which can enhance the identification, characterization, and function of unknown bioactive proteins or peptides within a shorter timeframe. This investigation will enable researchers to explore the critical aspects of the medicinal properties of gastropods and provide new insights into their pharmacological properties. Furthermore, to ensure long-term resource availability, future studies on compounds derived from gastropods should focus on advanced metabolomic profiling to identify new metabolites, combining this with high-throughput screening to link metabolites to their corresponding bioactivities. Employing sustainable bioprospecting techniques will also be crucial in translating promising leads into applications in pharmaceuticals, cosmeceuticals, and nutraceuticals.

Conclusion

This review highlights the increasing importance of gastropods as a promising yet underexplored source of bioactive compounds with diverse pharmacological applications. Particularly, we reviewed key compounds, including peptides, alkaloids, sterols, and polysaccharides, many of which exhibit potent mechanisms of action, such as antimicrobial, anticancer, anti-inflammatory, and cytotoxic effects. The evidence underscores their therapeutic value in addressing pressing health challenges ranging from infectious diseases to cancer and metabolic disorders. Future efforts integrating advanced metabolomics, high-throughput bioactivity screening, structural elucidation, sustainable bioprospecting, and translational studies will be essential to unlock their full potential. In conclusion, gastropods represent an efficient source of natural products that could be of tremendous therapeutic value in the new millennium. Therefore, by bridging traditional natural product research with modern technologies, gastropods could emerge as a vital resource in the discovery and development of next-generation therapeutics.

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References

Ahmad TB, Rudd D, Smith J, Kotiw M, Mouatt P, Seymour LM, Liu L, Benkendorff K (2017) Anti-inflammatory activity and structure-activity relationships of brominated indoles from a marine mollusk. Mar Drugs 15:133

Appleton DR, Sewell MA, Berridge MV, Copp BR (2002) A new biologically active malyngamide from a New Zealand collection of the sea hare *Bursatella leachii*. J Nat Prod 65:630-631

Arrieche D, Ugarte A, Salazar F, Villamizar JE, Michelangeli F, Fraile S (2019) Isolation, characterization and antibacterial activity of aglajne-1: Polypropionate isolated from the marine mollusk *Bulla occidentalis*. MOJ Bioorg Org Chem 3:61-63

Badiu DL, Balu AM, Barbes L, Luque R, Nita R, Radu M, Tanase E, Rosoiu N (2008) Physico-chemical characterisation of lipids from *Mytilus galloprovincialis* (L.) and *Rapana venosa* and their healing properties on skin burns. Lipids 43:829-841

Benkendorff K, Bremner JB, Davis AR (2001) Indole derivatives from the egg masses of muricid molluscs. Molecules 6:70-78

Bhattacharya S, Chakraborty M, Bose M, Mukherjee D, Roychoudhury A, Dhar P, Mishra R (2014) Indian freshwater edible snail *Bellamya bengalensis* lipid extract prevents T cell-mediated hypersensitivity and inhibits LPS-induced macrophage activation. J Ethnopharmacol 157:320-329

Blunt JW, Copp BR, Hu WP, Munro MHG, Northcote PT, Prinsep MR (2009) Marine natural products. Nat Prod Rep 26:170-244

Carbone M, Irace C, Costagliola F, Castelluccio F, Villani G, Calado G, Padula V, Cimino G, Cervera JL, Santamaria R, Gavagnin M (2010) A new cytotoxic tambjamine alkaloid from the Azorean nudibranch Tambja ceutae. Bioorg Med Chem Lett 20:2668-2670

Carbone M, Li Y, Irace C, Mollo E, Castelluccio F, Di Pascale A, Cimino G, Santamaria R, Guo YW, Gavagnin M (2011) Structure and cytotoxicity of phidianidines A and B: First finding of 1, 2, 4-oxadiazole system in a marine natural product. Org Lett 13:2516-2519

Carbone M, Ciavatta ML, Mathieu V, Ingels A, Kiss R, Pascale P, Mollo E, Ungur N, Guo YW, Gavagnin M (2017) Marine terpenoid diacylguanidines: Structure, synthesis, and biological evaluation of naturally occurring actinofide and synthetic analogues. J Nat Prod 80:1339-1346

Chakraborty K, Salas S (2019) Antioxidant drimane-type sesquiterpenoid from muricid gastropod *Chicoreus ramosus* attenuates pro-inflammatory 5-lipoxygenase and carbolytic enzymes. J Food Biochem 43:e12991

Chand S, Karuso P (2017) Isolation and total synthesis of two novel metabolites from the fissurellid mollusc *Scutus antipodes*. Tetrahedron Lett 58:1020-1023

Charupant K, Suwanborirux K, Amnuoypol S, Saito E, Kubo A, Saito N (2007) Jorunnamycins A-C, new stabilized renieramycin-type bistetrahydroisoquinolines isolated from the Thai nudibranch *Jorunna funebris*. Chem Pharm Bull 55:81-86

Ciavatta ML, Manzo E, Mollo E, Mattia CA, Tedesco C, Irace C, Guo YW, Li XB, Cimino G, Gavagnin M (2011) Tritoniopsins A-D, cladiellane-based diterpenes from the South China Sea nudibranch *Tritoniopsis elegans* and its prey *Cladiella krempfi*. J Nat Prod 74:1902-1907

Ciavatta ML, Lefranc F, Carbone M, Mollo E, Gavagnin M, Betancourt T, Dasari R, Kornienko A, Kiss R (2017) Marine mollusk-derived agents with antiproliferative activity as promising anticancer agents to overcome chemotherapy resistance. Med Res Rev 37:702-801

Cutignano A, Blihoghe D, Fontana A, Villani G, d'Ippolito G, Cimino G (2007) Fusaripyrones, novel polypropionates from the Mediterranean mollusc *Haminoea fusari*. Tetrahedron 63:12935-12939

Daoust J, Fontana A, Merchant CE, de Voogd NJ, Patrick BO, Kieffer TJ, Andersen RJ (2010) Ansellone A, a sesterterpenoid isolated from the nudibranch *Cadlina luteromarginata* and the sponge Phorbas sp., activates the cAMP signaling pathway. Org Lett 12:3208-3211

Dhahri M, Sioud S, Dridi R, Hassine M, Boughattas NA, Almulhim F, Al Talla Z, Jaremko M, Emwas AM (2020) Extraction, characterization, and anticoagulant activity of a sulfated polysaccharide from *Bursatella leachii* Viscera. ACS Omega 5:14786-14795

Edwards V, Benkendorff K, Young F (2012) Marine compounds selectively induce apoptosis in female reproductive cancer cells but not in primary-derived human reproductive granulosa cells. Mar Drugs 10:64-83

Ehara T, Kitajima S, Kanzawa N (2002) Antimicrobial action of achacin is mediated by l-amino acid oxidase activity. FEBS Lett 531:509-512

El Mubarak MA, Lamari FN, Kontoyannis C (2013) Simultaneous determination of allantoin and glycolic acid in snail mucus and cosmetic creams with high performance liquid chromatography and ultraviolet detection. J Chromatogr A 1322:49-53

Fontana A, Cavaliere P, Wahidulla S, Naik CG, Cimino G (2000) A new antitumor isoquinoline alkaloid from the marine nudibranch *Jorunna funebris*. Tetrahedron 56:7305-7308

Forster LC, Pierens GK, White AM, Cheney KL, Dewapriya P, Capon RJ, Garson MJ (2017) Cytotoxic spiroepoxide lactone and its putative biosynthetic precursor from *Goniobranchus splendidus*. ACS Omega 2:2672-2677

Graziani EI, Allen TM, Andersen RJ (1995) Lovenone, a cytotoxic degraded triterpenoid isolated from skin extracts of the North Sea dorid nudibranch *Adalaria loveni*. Tetrahedron Lett 36:1763-1766

Hamann MT, Otto CS, Scheuer PJ, Dunbar DC (1996) Kahalalides: bioactive peptides from a marine mollusk *Elysia rufescens* and its algal diet *Bryopsis* sp. J Org Chem 61:6594-6600

Hirayama Y, Katavic PL, White AM, Pierens GK, Lambert LK, Winters AE, Kigoshi H, Kita M, Garson MJ (2016) New cytotoxic norditerpenes from the Australian nudibranchs *Goniobranchus splendidus* and *Goniobranchus daphne*. Aust J Chem 69:136-144

Hochlowski JE, Faulkner DJ (1983) Antibiotics from the marine pulmonate *Siphonaria diemenensis*. Tetrahedron Lett 24:1917-1920

Jiménez-Romero C, Mayer AM, Rodriguez AD (2014) Dactyloditerpenol acetate, a new prenylbisabolane-type diterpene from *Aplysia dactylomela* with significant in vitro anti-neuroinflammatory activity. Bioorg Med Chem Lett 24:344-348

Joseph B, Rajan SS, Jeevitha MV, Ajisha SU, Jini D (2011) Conotoxins: A potential natural therapeutic for pain relief. Int J Pharm

Pharm Sci 3:1-5
Joshi I, Su dhakar S, Nazeer RA (2016) Anti-inflammatory properties of bioactive peptide derived from gastropod influenced by enzymatic hydrolysis. Appl Biochem Biotechnol 180:1128-1140
Kang HK, Choi MC, Seo CH, Park Y (2018) Therapeutic properties and biological benefits of marine-derived anticancer peptides. Int J Mol Sci 19:919
Kawamura A, Kita M, Kigoshi H (2015) Aplysiasecosterol A: A 9, 11-Secosteroid with an unprecedented tricyclic γ-Diketone structure from the sea hare *Aplysia kurodai*. Angew Chem Int Ed 54:7073-7076
Kigoshi H, Imamura Y, Yoshikawa K, Yamada K (1990) Three new cytotoxic alkaloids, aplaminone, neoaplaminone and neoaplaminone sulfate from the marine mollusc *Aplysia kurodai*. Tetrahedron Lett 31:4911-4914
Kladi M, Ntountaniotis D, Zervou M, Vagias C, Ioannou E, Roussis V (2014) Glandulaurencianols A-C, brominated diterpenes from the red alga, *Laurencia glandulifera* and the sea hare, *Aplysia punctata*. Tetrahedron Lett 55:2835-2837
Lee J, Zhou W, Na M, Oh S (2020) Cytotoxic Activity of Aplykurodin A Isolated From *Aplysia kurodai* against AXIN1-Mutated Hepatocellular Carcinoma Cells by Promoting Oncogenic β-Catenin Degradation. Mar Drugs 18:210
Lydeard C, Cowie RH, Ponder WF, Bogan AE, Bouchet P, Clark SA, Cummings KS, Frest TJ, Gargominy O, Herbert DG, Hershler R, Perez KE, Roth B, Seddon MB, Strong EE, Thompson FG (2004) The global decline of nonmarine mollusks. Bioscience 54:321-330
Malve H (2016) Exploring the ocean for new drug developments: marine pharmacology. J Pharm Bioallied Sci 8:83-91
Margret MS, Santhiya M, Mary MT, Jansi M (2013) Comparative study on the biochemical composition of four gastropods along the Kanyakumari coast. World J Fish Mar Sci 5:637-640
Mudianta IW, Martiningsih NW, Prasetia IN, Nursid M (2016) Bioactive terpenoid from the balinese nudibranch *Hypselodoris infucata*. Indones J Pharm 27:104
Nakao Y, Yoshida WY, Takada Y, Kimura J, Yang L, Mooberry SL, Scheuer PJ (2004) Kulokekahilide-2, a cytotoxic depsipeptide from a cephalaspidean mollusk *Philinopsis speciosa*. J Nat Prod 67:1332-1340
Oliveira AP, Lobo-da-Cunha A, Taveira M, Ferreira M, Valentão P, Andrade PB (2015) Digestive gland from *Aplysia depilans* gmelin: leads for inflammation treatment. Molecules 20:15766-15780
Pla D, Marchal A, Olsen CA, Francesch A, Cuevas C, Albericio F, Álvarez M (2006) Synthesis and structure-activity relationship study of potent cytotoxic analogues of the marine alkaloid lamellarin D. J Med Chem 49:3257-3268
Sakio Y, Hirano YJ, Hayashi M, Komiyama K, Ishibashi M (2001) Dendocarbins A-N, new drimane sesquiterpenes from the nudibranch *Dendrodoris carbunculosa*. J Nat Prod 64:726-731
Silvestri I, Albonici L, Ciotti M, Lombard MP, Sinibald P, Manzari V, Orlando P, Carretta F, Strazzullo V, Grippo P (1995) Antimitotic and antiviral activities of kelletinin A in HTLV-1 infected MT2 cells. Experientia 51:1076-1080
Subavathy P, Thilaga RD (2018) Analgesic, anti-pyretic and anti-inflammatory activities of marine gastropod, *Cypraea arabica* (Linnaeus, 1758). J Exp Zool India 21:1033-1037
Suenaga K, Shibata T, Takada N, Kigoshi H, Yamada K (1998) Aurilol, a cytotoxic bromotriterpene isolated from the sea hare *Dolabella auricularia*. J Nat Prod 61:515-518
Tan KC, Wakimoto T, Takada K, Ohtsuki T, Uchiyama N, Goda Y, Abe I (2013) Cycloforskamide, a cytotoxic macrocyclic peptide from the sea slug *Pleurobranchus forskalii*. J Nat Prod 76:1388-1391
Tanaka J, Higa T (1999) Two new cytotoxic carbonimidic dichlorides from the Nudibranch *Reticulidia fungia.* J Nat Prod 62:1339-1340
Thilaga RD, Vimala S, Subavathy P (2014) Isolation and characterization of bioactive compounds and antibacterial activity of marine gastropod Phalium Glaucum (L). Int J Pure Appl Zool 2:218-222
Tsoutsos D, Kakagia D, Tamparopoulos K (2009) The efficacy of *Helix aspersa* muller extract in healing partial thickness burns: a novel treatment for open burn management protocols. J Dermatol Treat 20:219-222
Tsukamoto S, Yamashita Y, Ohta T (2005) New cytotoxic and antibacterial compounds isolated from the sea hare, *Aplysia kurodai*. Mar Drugs 3:22-28
Uddin MH, Otsuka M, Muroi T, Ono A, Hanif N, Matsuda S, Higa T, Tanaka J (2009) Deoxymanoalides from the nudibranch Chromodoris willani. Chem Pharm Bull 57:885-887
Valles-Regino R, Mouatt P, Rudd D, Yee LH, Benkendorff K (2016) Extraction and quantification of bioactive tyrian purple precursors: a comparative and validation study from the hypobranchial gland of a muricid *Dicathais orbita*. Molecules 21:1672
Van AW, Gray CA, Whibley CE, Osoniyi O, Hendricks DT, Caira MR, Davies-Coleman MT (2008) Bioactive metabolites from the South African marine mollusk *Trimusculus costatus*. J Nat Prod 71:420-425
Vera B, Rodriguez AD, Aviles E, Ishikawa Y (2009) Aplysqualenols A and B: Squalene-derived polyethers with antitumoral and antiviral activity from the Carribean sea slug Aplysia dactylomela. Eur J Organ Chem 31:5327-5336
Wakimoto T, Tan KC, Abe I (2013) Ergot alkaloid from the sea slug *Pleurobranchus forskalii*. Toxicon 72:1-4
Wesson KJ, Hamann MT (1996) Keenamide A, a bioactive cyclic peptide from the marine mollusk *Pleurobranchus forskalii*. J Nat Prod 59:629-631
Yamada K, Ojika M, Ishigaki T, Yoshida Y, Ekimoto H, Arakawa M (1993) Aplyronine A, a potent antitumor substance, and the congeners aplyronines B and C isolated from the sea hare *Aplysia kurodai*. J Am Chem Soc 115:11020-11021
Yamada K, Ojikab M, Kigoshi H, Suenagaa K (2000) Cytotoxic substances from opisthobranch mollusks. In: Fusetani N (ed) Drugs from the Sea. Karger, Basel, pp 59-73
Zhong J, Wang W, Yang X, Yan X, Liu R (2013) A novel cysteine-rich antimicrobial peptide from the mucus of the snail of *Achatina fulica*. Peptides 39:1-5