Jellyfish: A Promising Resource for Future Bioeconomy Development

Sathish Kumar K, Ezhil Nilavan S, and Ashish Kumar Jha
Veraval Research Centre of ICAR-CIFT, Matsya Bhavan, Bhidia, Gujarat-362269.

India has abundant jellyfish resources, mostly underused, found along both its East and West coasts. These resources present opportunities for food, pharmaceutical, biomedical, and nutraceutical uses. The Gujarat coast is a key region rich in jellyfish, hosting several important *Scyphozoan* species. Commercial jellyfish fisheries operate along the Andhra Pradesh coast, while seasonal catches are common on the coasts of Tamil Nadu and Kerala. Recently, jellyfish have gained recognition as a sustainable and biocompatible source for pharmaceutical and biomedical purposes. Their extracts—such as collagen, peptides, and glycosaminoglycans are especially valued for drug delivery, tissue engineering, and wound healing, owing to their low toxicity and absence of mammalian viral contamination.

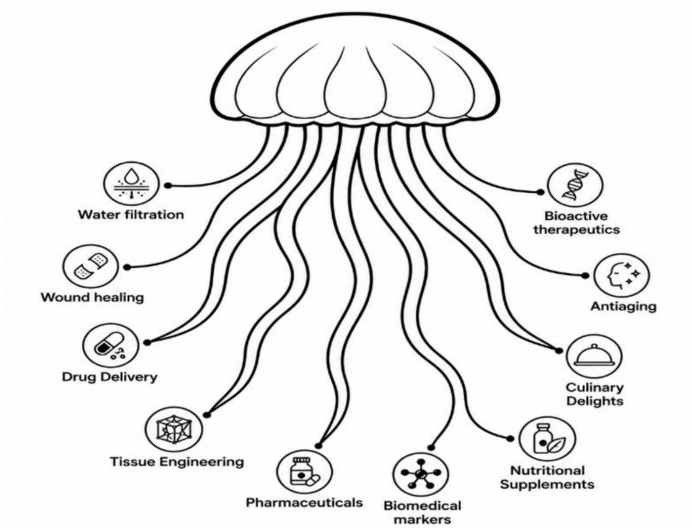

Fig. 1. Jellyfish – A Sustainable Marine Bioresource: Current and Emerging Applications

Table 1. Commercially important Jellyfish resources in India (INCOIS)

Species	Distribution	Potential Use
Rhopilema hispidum	Gujarat, Tamil Nadu	Food and collagen
Crambionella annandalei	Andhra Pradesh coast	Human consumption
Crambionella orsini	Kerala and Tamil Nadu coast	Delicacy food product
Catostylus perezi	Gujarat coast	Biomedical applications
Chrysaora chinensis	Indian coastal waters	Envenomation studies and bioactive compounds

Jellyfish biomass can be utilised as a resource potential for:

- **Water filtration materials**

Jellyfish biomass, rich in collagen, mucin, and polysaccharides within its mesoglea, is gaining recognition as a sustainable resource for water treatment and filtration. Its unique three-dimensional structure, high water retention, biodegradability, and adsorption capabilities facilitate the effective removal of pollutants, dyes, heavy metals, and microplastics from water. For example, mucus from *Aurelia* spp. Jellyfish has shown the ability to remove 65–90% of nanoplastics from wastewater, outperforming traditional chemical coagulants like ferric chloride and polyaluminium chloride (Ben-David et al., 2023). Furthermore, collagen and glycosaminoglycans derived from jellyfish are being developed into biodegradable filtration membranes and bioplastics, advancing eco-friendly wastewater purification techniques.

- **Collagen and gelatin**

Jellyfish are a sustainable, rich source of marine collagen and gelatin due to their rapid growth and high collagen levels in the mesoglea. Collagen from jellyfish offers excellent biocompatibility, biodegradability, low immunogenicity, and promotes cell adhesion, making it ideal for use in wound healing, tissue engineering, regenerative medicine, drug delivery, cosmetics, and health supplements. Gelatin produced by collagen hydrolysis has good gelling, emulsifying, and film-forming properties, suitable for foods, pharmaceutical capsules, edible coatings, hydrogels, and biomedical applications. Unlike mammalian collagen, jellyfish-derived versions do not carry the risks of bovine diseases or religious restrictions. The rise in jellyfish blooms along Indian coasts creates valuable opportunities to develop high-quality collagen and gelatin products for various industries (Addad et al., 2011; Silva et al., 2014; Felician et al., 2018).

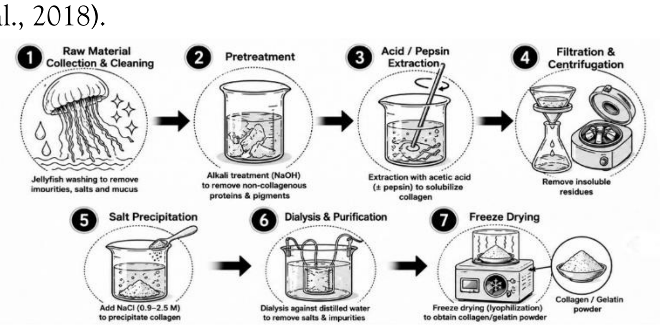

Fig. 2. Extraction process of collagen and gelatin from jellyfish

- **Wound-healing biomaterials**

Jellyfish-derived biomaterials, especially collagen and peptides, show great promise for wound healing because of their biocompatibility, biodegradability, and bioactivity. Jellyfish collagen creates a porous 3D scaffold that supports fibroblast attachment, growth, and movement, boosting extracellular matrix production and tissue regeneration. It also encourages new blood vessel growth and skin cell regeneration, which improves nutrient flow and speeds up wound closure. The high water-retention ability of jellyfish collagen-based hydrogels, films, and sponges helps keep wounds moist, promoting faster healing and reducing scarring. Additionally, collagen peptides have antioxidant, anti-inflammatory, and antimicrobial effects, helping to lower oxidative stress, control inflammation, and prevent infections. These materials can absorb wound exudates and offer mechanical protection, making them promising for advanced dressings and regenerative medicine. Compared to mammalian collagen, jellyfish collagen is a safer, sustainable, and ethically acceptable alternative for wound care and tissue engineering.

- **Drug delivery systems**

Bioactive compounds from jellyfish are gaining interest as advanced drug-delivery materials due to their excellent biocompatibility, biodegradability, low toxicity, and minimal immunogenicity. Jellyfish collagen and gelatin can be engineered into nanoparticles, microspheres, hydrogels, films, nanofibers, and scaffolds that enable controlled, targeted drug release. Their porous structure and high water-binding capacity facilitate efficient drug encapsulation and sustained release, thereby improving bioavailability and reducing dosing requirements. Jellyfish-derived hydrogels have shown promise in delivering antibiotics, anti-inflammatory agents, growth factors, and anticancer drugs for wound healing and tissue regeneration. Additionally, bioactive peptides possess antioxidant, antimicrobial, anti-inflammatory, and anticancer properties, broadening their use in multifunctional drug delivery. Jellyfish mucin and polysaccharides can also form biodegradable matrices that shield sensitive biomolecules, such as proteins, vaccines, and nucleic acids, from degradation. These distinctive features make jellyfish-derived materials attractive options for next-generation drug delivery, regenerative medicine, and pharmaceuticals (Silva et al., 2014; Felician et al., 2018; Leclère et al., 2022).

- **Tissue engineering scaffolds**

Jellyfish-derived collagen has become a promising biomaterial for tissue-engineering scaffolds because of its high biocompatibility, biodegradability, low immunogenicity, and similarity to mammalian collagen. The collagen-rich mesoglea creates a natural extracellular matrix-like structure that facilitates cell adhesion, growth, migration, and differentiation- key processes for tissue regeneration. Research has shown that jellyfish collagen scaffolds support the growth of fibroblasts, chondrocytes, osteoblasts, and stem cells, making them suitable for applications in skin, cartilage, bone, and blood vessel engineering. Moreover, jellyfish collagen has favourable mechanical properties and can be tailored to enhance scaffold stability and functionality. Its biodegradability ensures a gradual breakdown that aligns with tissue development, thereby avoiding surgical removal. Bioactive peptides from collagen further enhance angiogenesis, wound healing, and cell signalling, thereby improving regenerative outcomes. These features position jellyfish collagen as an eco-friendly and viable alternative to mammalian collagen in advanced tissue engineering and regenerative medicine (Addad et al., 2011; Silva et al., 2014; Felician et al., 2018; Leclère et al., 2022).

- **Pharmaceutical ingredients**

Jellyfish are emerging as an important source of pharmaceutical ingredients due to their diverse bioactive compounds, including collagen, gelatin, peptides, glycoproteins, mucopolysaccharides, fatty acids, and venom-derived molecules. Jellyfish collagen is widely investigated for pharmaceutical applications because of its excellent biocompatibility, biodegradability, and low immunogenicity, making it suitable for wound dressings, tissue regeneration, drug delivery systems, and biomedical implants. Bioactive peptides derived from jellyfish exhibit antioxidant, antihypertensive, antimicrobial, anti-inflammatory, and anticancer activities, highlighting their therapeutic potential. Furthermore, jellyfish mucus contains glycoproteins and polysaccharides with antimicrobial and immunomodulatory properties, while sulfated glycosaminoglycans possess anticoagulant and anti-inflammatory effects. Venom proteins from jellyfish nematocysts have also attracted attention for their cytotoxic, analgesic, and neuroactive properties, offering opportunities for novel anticancer and neurological therapies. These unique bioactive compounds make jellyfish a promising and sustainable marine resource for the development of high-value pharmaceutical ingredients and advanced therapeutic products (Addad et al., 2011; Silva et al., 2014; Felician et al., 2018; Morais et al., 2021; Leclère et al., 2022).

- **Biomedical markers**

Jellyfish are increasingly recognised as valuable sources of biomarkers because of their unique proteins, fluorescent molecules, collagen, peptides, toxins, and other bioactive compounds. A notable example is the Green Fluorescent Protein (GFP) from *Aequorea victoria*, which has revolutionised biomedical research by allowing real-time visualisation of gene expression, protein localisation, cell migration, and disease development. GFP and its variants are extensively used in molecular biology, cancer studies, neuroscience, and drug discovery. Jellyfish-derived collagen and extracellular matrix components also serve as important biomarkers and tools in tissue engineering, wound healing, and stem-cell research. Bioactive peptides and venom molecules have potential as molecular probes to study ion channels, neuroreceptors, inflammation, and cellular signalling. Advances in proteomics and genomics have further enabled the identification of jellyfish proteins and metabolites as biomarkers for oxidative stress, immune responses, and disease diagnostics. These unique molecules open up new possibilities for developing diagnostic markers, biosensors, imaging tools, and research reagents (Silva et al., 2014; Felician et al., 2018; Morais et al., 2021; Leclère et al., 2022).

- **Cosmetics**

Jellyfish are emerging as a sustainable source of natural cosmetic ingredients because of their high levels of collagen, gelatin, bioactive peptides, polysaccharides, and antioxidants. Jellyfish collagen is especially valued for its biocompatibility, water-binding capacity, and ability to enhance skin hydration, elasticity, and firmness, making it a popular ingredient in anti-ageing products such as creams, serums, facial masks, and moisturisers. Furthermore, glycoproteins and polysaccharides from jellyfish exhibit film-forming and moisture-retention properties that help keep skin hydrated and shield it from environmental stress. Antioxidant peptides derived from jellyfish can neutralise reactive oxygen species, thereby reducing oxidative damage and slowing skin ageing caused by UV rays and pollution. These properties make jellyfish biomolecules appealing for skincare formulations focused on skin repair, rejuvenation, moisturization, and overall health, emphasising their increasing potential in the cosmetic industry (Silva et al., 2014; Zhuang et al., 2012; Felician et al., 2018; Morais et al., 2021).

- **Functional foods and nutraceuticals**

Jellyfish are increasingly valued as sources of functional foods and nutraceuticals due to their high levels of collagen, gelatin, bioactive peptides, minerals, polyunsaturated fatty acids, and antioxidants. Widely eaten in several Asian countries, edible jellyfish are low in calories and fat but rich in high-quality protein, especially collagen, which supports skin health, joint function, and connective tissue. Collagen hydrolysis produces bioactive peptides with antioxidant, antihypertensive, anti-inflammatory, antimicrobial, and anti-fatigue effects, making them appealing for functional foods and supplements. These peptides can improve skin elasticity, reduce oxidative stress, and promote wound healing. Jellyfish also provide essential minerals such as calcium, magnesium, sodium, and potassium, which aid various bodily functions. Developing collagen supplements, protein powders, functional beverages, and fortified foods from jellyfish offers a sustainable way to leverage underused marine resources, meet increasing demand for natural health products, and support the blue bioeconomy (Zhuang et al., 2012; Raposo et al., 2018; Felician et al., 2018; Morais et al., 2021; Leclère et al., 2022).

- **Edible jellyfish products**

Edible jellyfish have long been part of traditional diets in many Asian countries, valued for their low fat, high moisture, and rich content of collagen, proteins, minerals, and bioactive compounds. Common edible species include *Rhopilema esculentum*, *Nemopilema nomurai*, *Stomolophus meleagris*, and *Rhopilema hispidum*. Traditional processing techniques, such as salting and alum treatment, enhance texture, decrease moisture, and extend shelf life, resulting in a crispy-chewy texture. Jellyfish are sold as salted, dried, marinated, and ready-to-eat products used in salads, soups, noodles, sushi, and other seafood dishes. Recent innovations have broadened their use to collagen-rich beverages, protein powders, nutraceuticals, functional foods, and snacks. Their high collagen content and bioactive peptides with antioxidant and antihypertensive properties increase their health benefits. The rise in jellyfish blooms along Indian coasts presents significant opportunities for product diversification, value addition, export expansion, and improving livelihoods in coastal communities (Hsieh et al., 2001; Felician et al., 2018; Raposo et al., 2018; Morais et al., 2021; Leclère et al., 2022).

Future prospective

Jellyfish are increasingly recognised as a sustainable marine resource with great potential across the food, pharmaceutical, biomedical, cosmetic, and environmental fields. Future efforts are likely to emphasise large-scale use of jellyfish-derived collagen, gelatin, bioactive peptides, and polysaccharides for applications such as wound healing, tissue engineering, drug delivery, functional foods, and anti-ageing solutions. The discovery of new bioactive compounds with antioxidant, antimicrobial, anti-inflammatory, and anticancer effects could further boost their pharmaceutical and nutraceutical value. Moreover, jellyfish biomass could be utilised in biodegradable filters, biosorbents, and bioplastics. In India, sustainably harvesting rising jellyfish populations could benefit coastal communities, promote value addition, and support the growth of the blue economy.

References

Addad, S., Exposito, J.Y., Faye, C., et al. (2011). Isolation, characterization and biological evaluation of jellyfish collagen. *Marine Drugs*, 9, 967–983.

Ben-David, E.A., Habibi, M., Haddad, E., et al. (2023). *Mechanism of nanoplastics capture by jellyfish mucin and its potential as a sustainable water treatment technology*. Science of the Total Environment, 869, 161824. DOI: 10.1016/j.scitotenv.2023.161824.

Felician, F.F., Xia, C., Qi, W., Xu, H. (2018). Collagen from marine biological sources and medical applications. *Chemosphere*, 214, 123–133.

Hsieh, Y.H.P., Leong, F.M., & Rudloe, J. (2001). Jellyfish as food. Hydrobiologia, 451, 11–17.

Leclère, L., et al. (2022). Jellyfish valorization: A sustainable source of collagen, gelatin and bioactive compounds for biotechnology and medicine. Marine Biotechnology, 24, 1–18.

Mariottini, G.L., & Pane, L. (2013). Cytotoxic and pharmacological properties of jellyfish venoms. Marine Drugs, 11, 523–550.

Morais, T., et al. (2021). Jellyfish-derived compounds and their biomedical applications: Current status and future perspectives. Marine Drugs, 19, 561.

Raposo, A., Morais, A.M.M.B., & Morais, R.M.S.C. (2018). Marine polysaccharides from jellyfish and their potential applications in food and nutraceutical industries. Trends in Food Science & Technology, 75, 102–113.

Ricard-Blum, S., Ruggiero, F., Van der Rest, M. (2017). Marine collagen as a biomaterial for tissue engineering and drug delivery. Journal of Structural Biology, 196, 1–13.

Silva, T.H., Moreira-Silva, J., Marques, A.L.P., et al. (2014). Marine origin collagens and their potential applications. *Marine Drugs*, 12, 5881–5901.

Zhuang, Y., Sun, L., Zhao, X., Wang, J., Hou, H., & Li, B. (2012). Antioxidant and melanogenesis-inhibitory activities of collagen peptides from jellyfish. Journal of Food Biochemistry, 36, 222–229.

****