Biology and pharmaceutical applications of actinomycetes from marine and mangrove ecosystem

Nisha R.I. and Samuel Gnana Prakash Vincent

Research scholar CMST

[1]*Center For Marine Science and Technology, ManonmaniamSundanar University,Rajakkamangalam, Tamilnadu-629502, India.*

Email(nishabio13@gmail.com)

Abstract

Actinomycetes are an abundant group of microorganisms found in soil that are known for producing antibiotics to combat other microorganisms. In today's medical world, discovering novel drugs to treat infectious diseases is a significant challenge. Researchers have employed various methods to isolate new antibiotics from different sources, specifically marine and mangrove sediments, utilizing different culture media. The need for novel and broad-spectrum antimicrobial agents is essential to control and eradicate infectious diseases, particularly those caused by emerging, multiple drug-resistant pathogens. Actinomycetes play a significant role in producing new antibiotics, thus presenting numerous opportunities for biomedical and biotechnological research. Analyzing microbial bioactivity from marine sources can help identify new and potential microbes with high specificity for various applications. In this review, the identification of marine actinomycetes and the application of bioactive compounds in pharmaceutical applications were explained.

Index Terms: Marine Actinomycetes, Antibiotics, Diseases, Pharmaceutical.

Introduction

Actinomycetes are one of the ubiquitous dominant groups of gram-positive bacteria. Actinomycetes have been commercially exploited for the production of pharmaceuticals, nutraceuticals, enzymes, antitumor agents, and enzyme inhibitors (Remya and Vijayakumar,2008). Actinomycetes are a group of prokaryotic microorganisms that are gram-positive bacteria with high guanine+ cytosine of their DNA (Adegboyea and Babalola, 2012)which have thread-like filaments within the soil actinomycetes are part of the normal soil microflora and are an important component of the soil microbial community because they produce secondary metabolites with antimicrobial properties(Bhatti*et et al.*, 2017). Soil microorganisms are a fantastic resource for isolating and identifying therapeutically important products. Actinomycetes are a significant group among them (Wader and Patil, 2013). Actinomycetes have produced over 4,000 naturally occurring antibiotics, many of which are important in medicine (Berdy, 2005). Microorganisms have long been shown to be sources of natural products with industrial and medical applications. Soil microorganisms, in particular, have been widely studied for their ability to produce diverse compounds such as enzymes and biologically active secondary metabolites (Okami*et al* ., 1998). Actinomycetes are responsible for earthy smell of the soil(Das *et al* .,2014) They are ubiquitous in nature, found both in terrestrial and aquatic habitats (Veig*et al.,* 1983), including mangroves and sea sediments(Wilson 1992). They belong to both mesophilic and thermophilic groups(Jensen*et al*., 2005) which broaden the range of habitats inhabited by them. Actinomycetes are known to produce an extensive range of bioactive compounds including various enzymes having multiple biotechnological applications. Actinomycetes are widely distributed in nature and have been isolated from aquatic and terrestrial environments. They are part of the normal microflora of the soil and constitute a significant component of the soil microbial community. They are known to be responsible for the production of about half of the discovered biologically active secondary metabolites with antimicrobial activities (Liu*et al*., 2012). Actinomycetes are abundant producers of antibiotics, which produce about 45% of the total antibiotics currently in use and they produce diverse natural products that would be approx. 10,000 compounds (Ara ismet*et al*.,2007). Marine and mangrove actinomycetes are potent sources of antibiotics, besides vitamins and enzymes and such antagonistic actinomycetes are being regularly reported(Romera*et al*.,1997). Different reports state that the majority ofisolates from different mangroves mostly belong to the genera *Streptomycetes* followed by genera, *Nocardia* and *Micromonospora*. Very few rare actinomycetes have been reported to date. Mangroves from the southern region of Tamil Nadu and Kerala. The mangroves from the eastern belt of Sunderbans showed minimal results. The actinomycetes isolated from the different mangroves such as Sunderban of West Bengal, Bhitarkanika of Orissa, Coringa of Andhra Pradesh, Pichavaram of Tamil Nadu, and some areas of Kerala have a notable antagonistic effect towards different pathogenic organisms. These qualities can be further investigated to obtain the targeted compound and further drug discovery studies(William *et al.*,2012).

Structure of actinomycetes

The actinomycetes are a large group of aerobic, high G-C percentage gram-positive bacteria that form branching filaments or hyphae and asexual spores. These bacteria closely resemble fungi in overall morphology. Actinomycetes spores during germination have been confined to the genera *Streptomyces*(Kalkoustwl and Agre, 1973).

The classical approaches for classification build the use of physiological, morphological, and biochemical characters.

1.Aerial Mass Color

The colour of the mature sporulating aerial mycelium is recorded in an exceedingly straightforward method (White, grey, red, green, blue and violet). Once the aerial mass color falls between two colors series, both the colors are recorded

2. Reverse Side Pigments

The strains were divided into two groups, consistent with their ability to provide characteristic pigment and divided into distinctive and non-distinctive.

3. *Spore Chain Morphology*

With relevancy to spore chains, the strains are sorted. The species belonging to the genus Streptomyces are divided into three sections particularly rectiflexibiles (RF), retinaculiaperti (RA) and Spirales (S). Once a strain forms two types of spore chains, both are noted

4.*Melanoid Pigments*

The grouping is formed on the assembly of melanoid pigments (brown black or distinct brown, pigment changed by alternative colour) on the medium. The strains are grouped as melanoid pigments created

5. Soluble Pigments

The strains are divided into two groups by their ability to provide soluble pigments apart from melanin: particularly, produced (+) and not produced (-). The color is recorded (orange, red, blue and yellow).

Identification of antimicrobials from actinomycetes isolates

For the isolation of actinomycetes various methods can be performed on the basis different source and medium sample collected from the several source performed to study different strain of actinomycetes in figure 1.

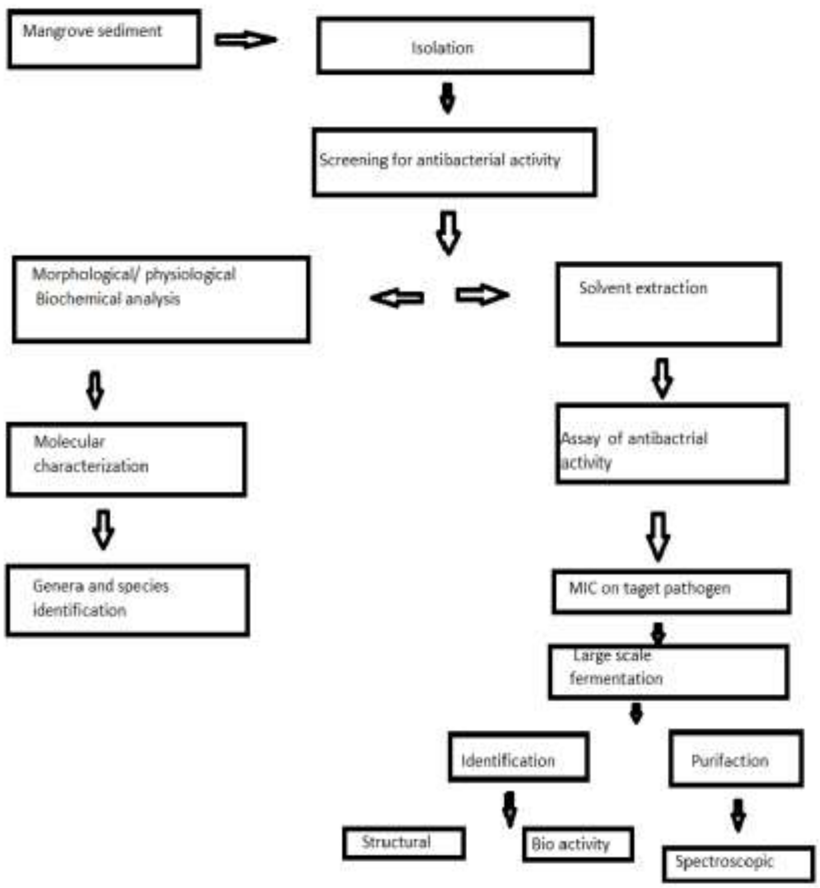

Figure 1 Identification of antimicrobial from actinomycetes isolatess

Application of actinomycetes

Ecological importance actinomycetes are abundant in soil and are responsible for much of the digestion of resistant carbohydrates such as chitin and cellulose. They are liable for the pleasant odor of freshly turned soil. Several actinomycetes and other actinobacteria are renowned as degraders of toxic materials and are used in bioremediation.

Antibiotics

Actinomycetes are produced many antibiotics, are best recognized and most valuable. These antibiotics include amphotericin, chloramphenicol, gentamycin, erythromycin, vancomycin, tetracycline, novobiocin, neomycin, etc. These antibiotics usually do not influence human cells that reason have fewer side effects. On the other hand actinomycetes metabolites, for example,adriamycin, prevent DNA replication, because of thisused in treating cancer, although rapamycin is used to repress the immune system to facilitate organ transplants.

Actinomycetes as source of Agroactive compounds

Actinomycetes are the most fruitful source of microorganisms for all types of bioactive metabolites, including agro active. Over one thousand secondary metabolites from actinomycetes were discovered during 1988-1992. Most of these compounds are produced by various species of the genus *Streptomyces.* Actinomycetes produce a variety of antibiotics with diverse chemical structures such as polyketides, b-lactams and peptides addition to a variety of other secondary metabolites that had anti-tumor, and immunosuppressive activities (Behal 2000).

Actinomyccetes as plant growth promoting Agent

In attempts to develop commercial biocontrol and plant growth promoting products using rhizobacteria, it is important to recognize the specific challenges they present. To begin with, the interaction between PGPR species and their plant appears to be specific, even crop or cultivar (Chanway*et al*.,1998) While a rhizomebacterium screened for growth promotion may reveal the positive effects This is mainly attained through biocontrol, or the antagonism of pathogens soil plant. Specifically, colonization or the biosynthesis of antibiotics (Fenton *et al* .,1992) and other secondary metabolites prevent pathogen establishment and invasion.

Actinomycetes as Biopesticide Agents

As the environmental contamination by toxic chemicals increases, different approaches for controlling pest populations becomeanalyzed. Severalmicroorganisms including fungi, bacteria, and viruses that are antagonistic to insects are reported as methods to biologically control them. Actinomycetes play a significant role in the biological control of insects for the production of insecticidal active compounds (Hussain*et al*., 2002) Actinomycetes vital cluster of microorganisms, organic matter within the natural environment, but as producers of antibiotics and valuable compounds of commercial interest (Saugar et al.,2002)

Proteins involved in biocontrol

Actinomycetes have the capability to produce a wide variety of extracellular enzymes that permit them to degrade varied biopolymers in soil. The capability of actinomycetes to produce extracellular enzyme attention because of the vital role in biocontrol. Especially, various correlations between fungal antagonism and bacterial production of chitinases orglucanases have been noted (Fayad*et al*.,2001)

Overview of biological activity

Many secondary metabolites of microorganisms have antibacterial, antifungal, antiviral, antitumor, anti-protozoaand various activities. They are commonly used in medicine, veterinary surveillance, agriculture, and commerce. Approximately 14,000 microbial-derived compounds show antibacterial activity. Among them, 66% are against gram-positive bacteria, 30% against gram-negative bacteria, 5% against myco-bacterium 34% of compounds have antifungal effects, 21% against yeasts, 11% against phytopathogenic fungi, and 24 % against various fungi. Among the microbial products, the fermentation product of Streptomyces is the most abundant source of antibiotics and various industrial compounds (watve*et al*.,2001)

Antimicrobial properties of novel antibiotics

The antibacterial activity of secondary metabolites is currently receiving more and more attention (Berdy, 2005). This is due to the urgent need to discover new antibiotics to combat the spread of the multi-drug resistant clinical strains, and the treatment of the following diseases has failed. Due to the chemical and functional diversity, biologically active metabolites are the subject of scientific research, which may lead to the development of new and more effective antibacterial drugs(Solecka*etal*.,2012). Approximately, 70% of the known antibiotics are from actinomycetes, most of which are from the genus,*Streptomyces*(Himabindu and Jetty 2006). Streptomycin is a group of antibacterial compounds derived from *streptomyces.*

Anticancer activity of metabolites

Actinomycin D isone of the main natural metabolites used to treat tumors. It is isolated from antibiotics. Actinomycin D works by binding to the DNA in the transcription initiator complex and preventing the transcription extension of RNA polymerase(Cockerill, 2010). Actinomycin D is still used to treat tumors in children, but its many side effects limit its use (Waksman and Woodruff, 1941)Leomycin, isanother anticancer agent. This metabolite, *Streptococcus rotatum*, was approved by the FDA for clinical treatment in 1973.

Antifungal activity of actinomycetes

Amphotericin B is one ofthe most famous metabolites of actinomycetes. It is a polyenemacrolide antibiotic that was isolated from the broth of *Streptococcus nodus* in 1955(Schatt and Waksman, 1994) It is a broad-spectrum antifungal antibiotic, but its many side effects limit its clinical application.

Actinomycetes as a source of industrialenzymes

Actinomycetes for the production of pharmaceuticals,enzymes, antitumor agents, enzyme inhibitors, and so forth These bioactive compounds are of high commercial value, actinomycetes are regularly screened for the production of novel bioactive compounds. A wide array of enzymes and products applied in biotechnological industries and biomedical fields has been reported from various genera of actinomycetes. Amylase is an important group of enzymes is the amylases which are employed in the starch processing industry for the conversion of starch to high fructose(Ammar *et al*.,2002).Cellulase enzymes not only hold a biotechnological promise but can be economical due to their low cost of production. Their production can be carried out on cheap substrates like rice and wheat straw (El Sersy*et al*.,2010) and fruit peels.Inthe food industry, pectinases are used particularly in fruit juices, in the degumming of fibers, winemaking, and retting of bast fiber. Pectinases from *Streptomyces sp.* are reported(Rathan and Ambili, 2006). An array of other enzymes with industrial potential were reported from actinomycetes including lignin peroxidases, laccases, and tyrosinases which are effective in the treatment of textile dyes (Hellmann*etal*.,2006).

CONCLUSION

Actinomycetes gained immense importance for their pharmacological property for many years. Due to the contributions to health care,agriculture and soil system. The current study shows that actinomycetes have been a novel source for many antibiotics and effective secondary metabolites with anti-microbial functions from marine as well as mangrove sediments.

ACKNOWLEDGMENT

I wish to thank the Center for Marine Science and Technology, ManonmaniamSundanar University, Rajakkamangalam for the support in carrying out the research.

REFERENCES

Adegboye, M. F., & Babalola, O. O. (2012). *Taxonomy and ecology of antibiotic Producing actinomycetes*. Afr J Agric Res, 7(15), 2255-2261

Ara Ismet, Kudo Takuji, Matsumoto Atsuko, Takahashi Yoko and Omura Satoshi(2007).Kitasato Nonomuraeamaheshkhaliensis sp. nov., a novel actinomycete isolated from mangrove rhizosphere mud. J. *Gen. Appl. Microbiol*. 53: 159–166

Behal, V.(2000). Bioactive products from Streptomyces. *Adv. Appl. Microbiol*. 47 : 113-157

Berdy, J. (2005). Bioactive microbial metabolites. *The Journal of antibiotics*, 58(1), 1-26

Bhatti, A. A., Haq, S., & Bhat, R. A. (2017). Actinomycetes benefaction role plant health. *Microbialpathogenesis*, 111, 458-467

Chanway, C.P., F.B. Holl, and L.M. Nelson. (1988). Cultivar spécifie growth promotion of spring wheat (Triticum aestivum) by co-existent Bacillus species. Can. *J. Microbiol*. 34: 924-929

D. B. Wilson,(1992)"Biochemistry and genetics of actinomycete cellulases," *Critical Reviews inBiotechnology*, vol. 12, no. 1-2, pp. 45–63

Demain, A. L., & Sanchez, S. (2009). Microbial drug discovery: 80 years of progress. *The Journal ofantibiotics*, 62(1), 5-16

Fayad, K., A.M. Simao-Beaunoir, A. Gauthier, C. Leclerc, H. Mamady, C Beaulieu, and R. Brzézinski.(2001). Purification and properties of a b-1, 6-glucanase from Streptomycessp. EF-14, an actinomycete antagonistic to Phytophthora spp.*Appl. Microbiol. Biotechnol*.57 : 117-123

Himabindu, M., & Jetty, A. (2006). Optimization of nutritional requirements for gentamicin production by Micromonosporaechinospora. *Indian journal of experimental biology*, 44(10), 842-848

H. M. Rifaat, Z. A. Nagieb, and Y. M. Ahmed,(2006) “Production of xylanases by Streptomyces species and their bleaching effect on rice straw pulp,” *Applied Ecology and Environmental Research*, vol. 4, no. 1, pp. 151–160

H.S. Chaudhary, B. Soni, A. R. Shrivastava, and S. Shrivastava(,2013) “Diversity and versatility of actinomycetes and its role in antibiotic production,” *Journal of Applied Pharmaceutical Science*, vol. 3, no. 8, supplement 1, pp. S83–S94

Liu X., Bolla K., Ashforth E.J., Zhuo Y., Gao H., Huang P., Stanley S.A., Hung D.T. and Zhang L. (2012). *Systamatic bioprospecting for bioactive natural products*.101: 55-66

M. Veiga, A. Esparis, and J. Fabregas(1983) “Isolation of cellulolytic actinomycetes from marine sediments,” *Applied and Environmental Microbiology*, vol. 46, no. 1, pp. 286–287

N. A. El-Sersy, H. Abd-Elnaby, G. M. Abou-Elela, H. A. H. Ibrahim, and N. M. K. El-Toukhy, “Optimization, economization and characterization of cellulase produced by marine Streptomyces ruber,” *African Journal of Biotechnology*, vol. 9, no. 38, pp. 6355

Nonomura, H. (1974). Key for classification and identification of 458 species of the Streptomycetes included in ISP. J. Ferment. Technol., 52(2): 78 -92

P. Das, R. Solanki, and M. Khanna(2014) “Isolation and screening of cellulolytic actinomycetes from diverse habitats,” *International Journal of Advanced Biotechnology and Research*, vol. l5, no. 3, pp. 438–451, 2014

R. K. Rathan and M. Ambili,(2011) “Cellulase Enzyme Production by Streptomyces Sp. Using Fruit Waste as Substrate,” *Australian Journal of Basic and Applied Sciences*, vol. 5, no. 12, pp. 1114–1118

Remya and R. Vijayakumar(2008), *Isolation and characterization“of marine antagonistic actinomycetes fromwest coast of India*,” Medicine and Biology, vol. 15, no. 1, pp. 13–19

Romero, F., Espliego, F., Baz, J.P., De Quesada, T.G., Gravalos, D., De La Calle, F., Fernandez-Puentes, J.L.(1997) Thiocoraline, a new depsipeptide with anti-tumour activity produced by a marine micromonospora. *J. Antibiot.*, 50: 734-737

S. Heumann, A. Eberl, H. Pobeheim et al.,(2006) “New model substrates for enzymes Hydrolyzing polyethyleneterephthalate and polyamide fibres,” *Journal of Biochemical and BiophysicalMethods*, vol. 69, no. 1-2, pp. 89–99

Saugar, I., E. Sanz, M.A. Rubio, J.C. Espinosa and A. Jimenez,(2002.) Identification of a set of genes involved in the biosynthesis of the aminonucleoside moiety of antibiotic A201A from Streptomyces capreolus. European *J. Biochem*., 269: 5527–35

Schatz, A., Bugle, E., & Waksman, S. A. (1944). Streptomycin, a Substance Exhibiting Antibiotic Activity Against Gram-Positive and Gram-Negative Bacteria..*Proceedings of the Society forExperimental Biology* and–63 64

Shirling, E.B. and Gottlieb, D. (1966). Methods for characterization of Streptomycetes species.
Int. *J. Syst. Bacteriol.*, 16: 313 - 340

Solecka, J., Zajko, J., Postek, M., &Rajnisz, A. (2012). Biologically active secondary metabolites from Actinomycetes. *Open Life Sciences*, 7(3), 373-390

Wader A. T. Patil, "Isolation and characterization of bioactive actinomycetes from soil in and around S. Sadhu an. Md T Kaiti,(2013) "Cellulase production by bacteria: a review," *BritishMicrobiologyResearch Journal*, vol. 3, no. 3, pp. 235–258

Waksman, S. A., & Woodruff, H. B. (1941). Actinomyces antibioticus, a new soil organism antagonistic to pathogenic and non-pathogenic bacteria. *Journal of bacteriologymedicine 42(2*), 231

Watve, M. G., Tickoo, R., Jog, M. M., &Bhole, B. D. (2001). How many antibiotics are produced by the genus Streptomyces? *Archives of microbiology*, 176(5), 386-390

Y. B. Ammar, T. Matsubara, K. Ito et al.(,2002) "New action pattern of a maltose-forming α-amylase from Streptomyces sp. and its possible application in bakery " *Journal of Biochemistry and MolecularBiology*, vol. 35, no. 6, pp. 568–575