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Bacteria: A multifaceted microbe

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Abstract- In past few decades, expansion has clearly been observed in the field of microbiology. Bacteria are prokaryotic organisms that have played crucial role in the upgradation of therapeutic industries. Morphological and genetic features makes it suitable for various modifications and thus can be used according to the need. Though bacteria are cosmopolitan but it has widely found to be present in symbiotic relation with the gut of animals. In the studies of gut microflora is has clearly been found that it provides various health benefits to its host and these bacteria are commonly categorized as probiotics. Expansion of research have now revealed that some bacteria also has the ability to treat the diseases like cancer and diabetes. Apart from this, it has also been reported that bacteria are able to naturally produce vitamins and antibiotics. Ability of producing extracellular enzymes makes them suitable even for textile, paper, food and beverage industries. In this paper an attempt has been made to discuss the role of bacteria in varieties of fields and its contribution for the betterment of human lives.

Key words: Bacteria, vitamins, antibiotics, enzymes

INTRODUCTION

Invention of microscope revolutionized the understanding of living world by allowing the researchers to explore their realms of the very small. It revealed the intricate structure of organism that were previously invisible to the naked eye such as bacteria cells and other microbes. Such microscopic organisms are collectively known as microbes.[1,2] Among all types of microbes, bacteria are the unicellular prokaryotic cells that are believed to be cosmopolitan.[3] Though there were preconceived notion that they are harmful and cause damage but recent researchers have revealed that they have beneficial properties as well and thus now been in use for various fields like health, food, textile etc.[4,5] In this review an attempt has been made to explore the area where bacteria are playing crucial role and ultimately providing benefits to the humankind.

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Bacteria in pharmacology

Since bacteria have long been used in pharmacology, it is now evident that they not only have a wide range of importance but also useful applications. The thing that cannot be overlooked is the ability of bacteria to produce various extracellular enzymes.[6] These enzymes helps in the digestion of the food items that human consumes. Let's say cellulose, cellulose is a carbohydrate made-up of beta glucose. Human body does not produce any enzyme to digest this biomolecule.[7] Here, in some studies it has been reported that certain bacteria like *Cellulomonas flavigena, Terendinibacter turnerae, Bacillus spp. etc.* can produce enzyme cellulase that can digest the cellulose.[8,9]

In biotechnology, bacteria are widely used for producing various antibiotics[10-12] because the epigenetic

modification and gene editing can easily be performed using restriction endonucleases.[13] It is important to note that the specific genes involved in antibiotic production may vary widely among different bacterial species and the antibiotics they produce. As a defense mechanism, bacteria naturally produce antibiotics to compete with other microbes for resources. These natural producers of antibiotics serve as a source of antibiotic producing genes and pathways.[14]

Bacteria are highly amenable to genetic manipulation. Its gene can be modified through genetic engineering to enhance desired antibiotic production or engineered bacteria to produce antibiotics they would not produce naturally.[15,16] The possibility of success enhances when bacterial strains used in antibiotic production are well characterized and their genetic and growth condition are well understood. This knowledge helps optimize production processes and yield. The biggest and one of the most pragmatic things is that bacteria can be cultured in a controlled condition by maintaining optimum temperature, pH, oxygen and nutrients supply.[17,18]

Bacteria can be manipulated to produce high yield of antibiotics making the process efficient and economically viable. Overall, bacteria provide an effective and versatile platform for antibiotic production by making it compatible to produce the crucial components in large quantities for medical use. However, it is essential to maintain strict quality control and safety measures. Fecal microbiota transplantation (FMT) is another technique that helps to administer the fecal matter in the form of solution from donor to the intestine of the recipient. This technique helps to directly change the microbial composition of gut to confer the health benefit. It is widely used in the treatment of *Clostridium difficile* infection.[19,20]

Cancer treatment

Cancer is among the deadliest and one of the most devastating diseases around the globe. Estimation says that by 2030 more than 26 million people would be at high risk of cancer.[21] Though surgery, radiation therapy, chemotherapy, immunotherapy etc. are in trend and solves the issue to certain extent however, these treatments are unable to completely eradicate cancerous cells.[22] In such case bacteria and its unique properties provides a new dimension to explore for cancer treatment.

In some reported studies by Guo *et al.* (2020)[23] and Duong (2019)[24], it has been discovered that bacteria could cause regression in tumors and along with that tumor microenvironment (TME) itself favor the growth of such bacteria. The bacterial based tumor therapies did not just stop here. In recent studies of 'tumor biotherapy' bacteria are found to be used as drug delivery vehicle and modulators of immunity i.e., "immunomodulators." Apart from these, the unique property of disease site localization as well as therapeutic agent production made it a boon for pharmaceutic world.[25,26] Another remarkable feature of bacteria is to modify their genetic material according to the requirements to produce specific toxin to initiate an effective immune response that ultimately leads to tumor regression.[27]

Some bacteria has also been reported to colonize in various body sites specifically in mammals, such as skin, the gut, the urogenital system and even the disease sites i.e., tumor tissues Liang *et al.* (2022)[28]. Apart from this, Zhu C. *et al.* (2021)[29] has also been reported that for the cargo delivery cell surface of bacteria can be loaded with various nanomaterial and therapeutic agents. Beside this, mini cells, outer membrane vesicle (OMVs) and nanovesicle have been reported to have effective drug carrying potential Ding *et al*., (2020)[30]. The bacterial strains that are commonly used as anti-cancer agents are *Clostridium species*, *Salmonella species, E. coli* species and *Listeria spp.* Dróżdż *et al.*, (2020)[31].

An interesting finding has also been reported by Vivek *et al*. (2016)[32] which revealed that gut of a freshwater fish *Zacco koreanus* bears are potent bacteria in its gut namely *Lactobacilli sakei*. They stated that the isolated bacteria have anti-diabetic and anti-melanogenic potential. Moreover, it has also been stated that the isolated bacteria *Lactobacillus sakei* displayed anti-cytopathic effect on MDCK cell line and hence confirmed its antiviral efficacy against influenza virus H1N1. Vivek opined that *Lactobacilli sakei* that was isolated from the intestine of *Zacco koreanus* might be suitable for pharmacological preparation as an effective drug.

Probiotics

Gut of human being especially the intestinal portion is loaded with diverse microflora that actually maintains the healthy gut environment. Probiotics are live microbes and considered as good or beneficial bacteria that can have health benefits when consumed in adequate amount. Probiotics helps in maintaining a balanced gut microbiota, which plays a crucial role in digestion, nutrient absorption

and prevention of gastrointestinal disorders. Such microbes are believed to exert beneficial effect through other mechanism as well, including production of bio-active components or secondary metabolites, competitive exclusion of harmful pathogens and by modulating the immune system.[33] Although probiotic contains a wide variety of microbes but the most common among them are bacteria belonging to the group of *Lactobacillus* and *Bifidobacterium*.[34]

So far, the safety is concerned a number of *Bacillus* species have also designated as GRAS (Generally recognized as safe) by FAO (American Food and Drug administration) helps in improvement of growth and immunity in aquaculture.[35,36] A promising result have been shown by the probiotics for varieties of health purposes. Benefits were reported in conditions like antibiotic associated diarrhea, sepsis in infants and necrotizing enterocolitis.[37] Some bacterial strains were also claimed to produce vitamins which is in harmony with the finding of LeBlanc *et al.* (2015)[38].

In animal husbandry it has been observed that animals are generally reared in contaminated cages. Contamination makes the animals susceptible to opportunistic diseases and thus treated with heavy dose of antibiotics which is ultimately harmful for humans. In various studies, convincing evidence has also been presented which claims to replace antibiotics with probiotics.[39-41] This is because of the fact that bacteria itself has the ability to produce specific antimicrobial peptide known as "bacteriocins" that acts as antibiotics. Some of the common examples of such bacteriocins are Nicin A produced by *Lactobacillus lactis*, Lactocin S by *Lactobacillus* sake, Enterocin by *Enterococcus facium* etc.[42,43]

Bacteria and environment

A wide variety of microbes are present in the environment depending upon their traits. Number of bacteria successfully dwells not just in its favorable condition but also in extreme environmental conditions i.e., *Archaea*. Bacteria serve a significant purpose of maintaining the environment the biogeochemical cycle via biodegradation in which microbes breaks organic matter into simpler substances. There are certain bacteria that perform an essential process of nitrogen fixation. Nitrogen fixing bacteria are a group of microorganisms that plays a vital role in nitrogen cycle by converting atmospheric nitrogen gas (N_2) into ammonia (NH_3) or related compounds. It is important to note that most plants cannot use atmospheric nitrogen directly for its metabolic processes. Some of the examples of such bacteria are *Rhizobium, Azotobacter* etc.[44,45]

Study of Koshila (2019)[46] suggested that some bacteria also participate in weathering of rock influencing soil composition and geological processes. Root microorganisms are reported to promote mineral dissolution by releasing ligands (siderophores and organic acid) that affects the pH. Beside that *Rhizosphere* bacteria also promote weathering activity performed by plants. Inoculation of weathering bacteria in soil and plants in combination with crushed rocks increases the fertility of soil.[47]

Bacteria has multi-faceted impacts on the environment affecting almost everything from nutrient cycle climate regulation and ecosystem health. Woraruthai (2020)[48] and Zeikus (1977)[49] suggested that bacteria can also produce greenhouse gas (GHG) that is methane, which is produced by methanogenic bacteria. So far, the aquatic environment is concerned bacteria can also be seen to exhibit benefits to the various aquatic system. Some aquatic organisms have been reported to form symbiotic relationship with bacteria. For instance, coral reefs depend on symbiotic bacteria to help recycle nutrient and provide energy to coral polyps.[50]

Industrial use

The ability of bacteria to produce extracellular enzymes (ECE) makes them suitable for various industrial uses. Different bacteria can produce different enzymes Ray (2012)[51] and Cheng (2020)[52]. For instance, catalase is an enzyme produced by the bacteria like *Bacillus, Leuconostoc, Streptococci* etc. Catalase is widely used in fabric industry to remove excess hydrogen peroxide (H_2O_2) from fabrics. This enzyme is extensively used for food preservation as it eliminates the oxygen from wine before bottling. Another enzyme that has been reported to be produced by bacteria is cellulase. Cellulase is extensively used in textile industry, paper and pulp industry and food industries. Cellulase mediated extraction of juice is widely used to get high yield and lessens the processing time and heat damage.[53,54]

CONCLUSION

Diversity of microbes enables the researchers to explore the fathoms of the possibilities in the field of microbiology. The beneficial role that microbes play in field

like health, food and beverage, paper and pulp industries etc. has opened the idea to explore the more. Apart from this, microbes like bacteria plays a significant role in maintaining the balance in the environment and ultimately in ecosystem. It is important to note that without these bacteria decomposition process would also get severely affected. Bacteria are cosmopolitan and can be found from land to water (both fresh and marine).

The genetic make up of bacteria also make them suitable for the epigenetic modifications and thus are been used for antibiotics production and various disease treatment. The bacteria have multifaced role and with keen observation and studies new traits and strains of it can be found which will ultimately be beneficial for humankind.

REFERENCES

1. **Rieder R., Wisniewski P. J., Alderman B. L. & Campbell S. C. 2017.** Microbes and mental health: A review. *Brain, behavior, and immunity*, **66:** 9-17.
2. **West S. A., Diggle S. P., Buckling A., Gardner A. & Griffin A. S. 2007.** The social lives of microbes. *Annu. Rev. Ecol. Evol. Syst.*, **38:** 53-77.
3. **Lachance M. A. 2004.** Here and there or everywhere?. *Bioscience*, **54(10):** 884-884.
4. **Harman G. E., & Uphoff N. 2019.** Symbiotic root-endophytic soil microbes improve crop productivity and provide environmental benefits. *Scientifica*, *2019*.
5. **Arora B. & Bose D. 2022.** Role of microbes in industries. *World Scientific News*, **165:** 180-196.
6. **Yahiaoui M. 2021.** Characterization of endospore-forming bacteria producing extracellular enzymes isolated from Djurdjura Mountains in Algeria. *Algerian journal of Biosciences*, **2(1):** 046-055.
7. **Cleveland L. R. 1924.** The physiological and symbiotic relationships between the intestinal protozoa of termites and their host, with special reference to Reticulitermes flavipes Kollar. *The Biological Bulletin*, **46(5):** 203-227.
8. **Maki M., Leung K. T. & Qin W. 2009.** The prospects of cellulase-producing bacteria for the bioconversion of lignocellulosic biomass. *International journal of biological sciences*, **5(5):** 500.
9. **Shanmugapriya K., Saravana P. S., Krishnapriya M. M., Mythili A. & Joseph S. 2012.** Isolation, screening and partial purification of cellulase from cellulase producing bacteria. *Int J Adv Biotechnol Res*, **3(1):** 509-514.
10. **Sanchez S., Rodríguez-Sanoja R., Ramos A. & Demain A. L. 2018.** Our microbes not only produce antibiotics, they also overproduce amino acids. *The Journal of antibiotics*, **71(1):** 26-36.
11. **Abdulkadir M. & Waliyu S. 2012.** Screening and isolation of the soil bacteria for ability to produce antibiotics. *European Journal of applied sciences*, **4(5):** 211-215.
12. **Clardy J., Fischbach M. A. & Currie C. R. 2009.** The natural history of antibiotics. *Current biology*, **19(11):** R437-R441.
13. **Furuta Y., & Kobayashi I. 2022.** Restriction-modification systems as mobile epigenetic elements. In *Bacterial integrative mobile genetic elements* (pp. 85-103). CRC Press.
14. **Takahashi K. 2014.** Influence of bacteria on epigenetic gene control. *Cellular and Molecular Life Sciences*, **71:**1045-1054.
15. **Thomason L. C., Sawitzke J. A., Li X., Costantino N. & Court D. L. 2014.** Recombineering: genetic engineering in bacteria using homologous recombination. *Current protocols in molecular biology*, **106(1):** 1-16.
16. **Lindow S. E., Panopoulos N. J. & McFarland B. L. 1989.** Genetic engineering of bacteria from managed and natural habitats. *Science*, **244(4910):** 1300-1307.
17. **Okwadha G. D. & Li J. 2010.** Optimum conditions for microbial carbonate precipitation. *Chemosphere*, **81(9):** 1143-1148.
18. **Kim J. H. & Lee J. Y. 2019.** An optimum condition of MICP indigenous bacteria with contaminated wastes of heavy metal. *Journal of Material Cycles and Waste Management*, **21:** 239-247.
19. **Drekonja D., Reich J., Gezahegn S., Greer N., Shaukat A., MacDonald R., ... & Wilt T. J. 2015.** Fecal microbiota transplantation for Clostridium

difficile infection: a systematic review. *Annals of internal medicine*, **162(9):** 630-638.

20. **Cammarota G., Ianiro G., & Gasbarrini A. 2014.** Fecal microbiota transplantation for the treatment of Clostridium difficile infection: a systematic review. *Journal of clinical gastroenterology*, **48(8):** 693-702.

21. **Siegel R. L., Miller K. D. & Jemal A. 2018.** Cancer statistics, 2018. *CA: a cancer journal for clinicians*, **68(1):** 7-30.

22. **Wicki A., Witzigmann D., Balasubramanian V. & Huwyler J. 2015.** Nanomedicine in cancer therapy: challenges, opportunities, and clinical applications. *Journal of controlled release*, **200:** 138-157.

23. **Guo Y., Chen Y., Liu X., Min J. J., Tan W., & Zheng J. H. 2020.** Targeted cancer immunotherapy with genetically engineered oncolytic *Salmonella typhimurium. Cancer letters*, **469:** 102-110.

24. **Duong M. T. Q., Qin Y., You S. H., & Min J. J. 2019.** Bacteria-cancer interactions: bacteria-based cancer therapy. *Experimental & molecular medicine*, **51(12):** 1-15.

25. **Yu Y. A., Shabahang S., Timiryasova T. M., 2004.** Visualization of tumors and metastases in live animals with bacteria and vaccinia virus encoding light-emitting proteins. *Nature Biotechnology*. **22(3):**313–320.

26. **Górska A., Przystupski D., Niemczura M. J. & Kulbacka J. 2019.** Probiotic bacteria: a promising tool in cancer prevention and therapy. *Current microbiology*, **76:** 939-949.

27. **Forbes N. S. 2010.** Engineering the perfect (bacterial) cancer therapy. *Nature Reviews Cancer*. **10(11):**785–794.

28. **Liang S., Wang C., Shao Y., Wang Y., Xing D. & Geng Z. 2022.** Recent advances in bacteria-mediated cancer therapy. *Frontiers in Bioengineering and Biotechnology*, **10:** 1880.

29. **Zhu C., Ji Z., Ma J., Ding Z., Shen J., & Wang Q. 2021.** Recent advances of nanotechnology-facilitated bacteria-based drug and gene delivery systems for cancer treatment. *Pharmaceutics*, **13(7):** 940.

30. **Ding Y., Wang L., Li H., Miao F., Zhang Z., Hu C., ... & Shao G. 2022.** Application of lipid nanovesicle drug delivery system in cancer immunotherapy. *Journal of Nanobiotechnology*, **20(1):** 1-22.

31. **Drózdz, M., Makuch, S., Cieniuch, G., WoŸniak, M., & Ziókowski, P. 2020.** Obligate and facultative anaerobic bacteria in targeted cancer therapy: Current strategies and clinical applications. *Life sciences*, **261:** 118296.

32. **Bajpai V. K., Han J. H., Nam G. J., Majumder R., Park C., Lim J., ... & Park Y. H. 2016.** Characterization and pharmacological potential of Lactobacillus sakei 1I1 isolated from fresh water fish Zacco koreanus. *DARU Journal of Pharmaceutical Sciences*, **24:** 1-12.

33. **Iqbal M. S. & Ansari M. I. 2019.** Biotechnological exercises in the production of secondary metabolites and its significance in healthcare practices. *Natural Bio-active Compounds: Biotechnology, Bioengineering, and Molecular Approaches*, **3:** 183-204.

34. **Sharma M., Wasan A., & Sharma R. K. 2021.** Recent developments in probiotics: An emphasis on Bifidobacterium. *Food Bioscience*, **41:** 100993.

35. **Galano M., van den Dungen M. W., van Rij T., & Abbas H. E. 2021.** Safety evaluation of food enzymes produced by a safe strain lineage of *Bacillus* subtilis. *Regulatory Toxicology and Pharmacology*, **126:** 105030.

36. **Lee N. K., Kim W. S., & Paik H. D. 2019.** *Bacillus* strains as human probiotics: characterization, safety, microbiome, and probiotic carrier. *Food science and biotechnology*, **28:** 1297-1305.

37. **Dani C., Biadaioli R., Bertini G., Martelli E. & Rubaltelli F. F. 2002.** Probiotics feeding in prevention of urinary tract infection, bacterial sepsis and necrotizing enterocolitis in preterm infants: a prospective double-blind study. *Neonatology*, **82(2):**103-108.

38. **LeBlanc J. G., Laiño J. E., del Valle M. J., de Giori G. S., Sesma F., & Taranto M. P. 2015.** B group vitamins production by probiotic lactic acid bacteria. *Biotechnology of lactic acid bacteria: Novel applications*, 279-296.

39. **Neveling D. P. & Dicks L. M. 2021.** Probiotics: an antibiotic replacement strategy for healthy broilers and productive rearing. *Probiotics and Antimicrobial Proteins*, *13*, 1-11.

40. **Reid G. & Friendship R. 2002.** Alternatives to antibiotic use: probiotics for the gut. *Animal Biotechnology*, **13(1):** 97-112.

41. **Cheng G., Hao H., Xie S., Wang X., Dai M., Huang L., & Yuan Z. 2014.** Antibiotic alternatives: the substitution of antibiotics in animal husbandry? *Frontiers in microbiology*, **5:** 217.

42. **Duhan J. S., Nehra K., Gahlawat S. K., Saharan P., & Surekha D. 2013.** Bacteriocins from lactic acid bacteria. *Biotechnology: prospects and applications*, 127-141.

43. **Losteinkit C., Uchiyama K., Ochi S., Takaoka T., Nagahisa K., & Shioya S. 2001.** Characterization of bacteriocin N15 produced by *Enterococcus faecium* N15 and cloning of the related genes. *Journal of Bioscience and Bioengineering*, **91(4):** 390-395.

44. **Sepp S. K., Vasar M., Davison J., Oja J., Anslan S., Al-Quraishy S., ... & Zobel M. 2023.** Global diversity and distribution of nitrogen-fixing bacteria in the soil. *Frontiers in Plant Science*, **14:** 1100235.

45. **Kawaka F. 2022.** Characterization of symbiotic and nitrogen fixing bacteria. *AMB Express*, **12(1):** 99.

46. **Koshila Ravi R., Anusuya S., Balachandar M., & Muthukumar T. 2019.** Microbial interactions in soil formation and nutrient cycling. *Mycorrhizosphere and pedogenesis*, 363-382.

47. **Lambers H., Mougel C., Jaillard B., & Hinsinger P. 2009.** Plant-microbe-soil interactions in the rhizosphere: an evolutionary perspective.

48. **Woraruthai T., Kunno J., Pongsopon M., Yansakon K., Phoopraintra P., Chantiwas R., ... & Wongnate T. 2020.** Identification and cultivation of hydro genotrophic methanogens from palm oil mill effluent for high methane production. *International Journal of Energy Research*, **44(13):** 10058-10070.

49. **Zeikus J. G. 1977.** The biology of methanogenic bacteria. *Bacteriological reviews*, **41(2):** 514-541.

50. **Nair S., & Abraham J. 2019.** Coral reef microbiota and its role in marine ecosystem sustainability. *Microbial Interventions in Agriculture and Environment:Research Trends, Priorities and Prospects*, **1:** 453-478.

51. **Ray A. K., Ghosh K., & Ringø E. J. A. N. 2012.** Enzyme producing bacteria isolated from fish gut: a review. *Aquaculture Nutrition*, **18(5):** 465-492.

52. **Cheng T. H., Ismail N., Kamaruding N., Saidin J., & Danish-Daniel M. J. B. R. 2020.** Industrial enzymes-producing marine bacteria from marine resources. *Biotechnology Reports*, **27:** e00482.

53. **Kaushal J., Mehandia S., Singh G., Raina A. & Arya S. K. 2018.** Catalase enzyme: Application in bioremediation and food industry. *Biocatalysis and agricultural biotechnology*, **16:** 192-199.

54. **Sethi S., Datta A., Gupta B. L., & Gupta S. 2013.** Optimization of cellulase production from bacteria isolated from soil. *International Scholarly Research Notices*.

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