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International Journal of Recent Innovations in Medicine and Clinical Research

Journal homepage: https://www.ijrimcr.com/

Review Article

A critical review of agricultural microorganism

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A R T I C L E I N F O

Article history:
Received 10-07-2024
Accepted 01-08-2024
Available online 30-08-2024

Keywords:
Agricultural microbiology
Advanced technique
Chocolate Microbes
Microbial-enhanced crop stress tolerance

A B S T R A C T

The field of agricultural microbiology remains dynamic, driven by the need for sustainable agricultural practices, climate change adaptation, and the quest for eco-friendly alternatives to traditional farming inputs. This review summarizes the current state of the art in the field of agriculture and food sciences, focusing on the fields of microbial research, crop stress tolerance, crop productivity, soil health, and overall agricultural sustainability. The development of a comprehensive understanding of plant-microbe interactions has led to the development of novel techniques for enhancing crop productivity and soil health. These techniques have the potential to sustain modern agriculture and mitigate the effects of climate change by using biotechnological methods for breeding crops resistant to biotic and abiotic challenges, such as cisgenesis, genome editing, RNA interference, and epigenome edits. Insect biotechnology has also emerged as a valuable tool with applications in agriculture, industry, and human welfare. These advances have been facilitated by advances in agriculture and biotechnology, which have supported the food industries and agriculture's sustainable growth.

Key points: 1. Recent advances in agricultural microbiology and biotechnology have led to significant progress in the field. 2. These advancements include the application of new methods in food production technology, such as modern methods of production and testing of food, as well as the sustainable development of agriculture and the food industry. 3. Insect biotechnology has also emerged as a valuable tool with applications in agriculture, industry, and human welfare. 4. These advancements in agricultural microbiology have the potential to address challenges in the industry and contribute to the development of more sustainable and efficient agricultural practices. 5. Microbes are widely used in the food industry for various purposes.

1. Introduction

Technological developments in food production have been facilitated by advances in agricultural microbiology and biotechnology, which have supported the food industries and agriculture's sustainable growth. Identifying insects, researching genetic relationships, and managing natural adversaries have all been accomplished through the application of insect biotechnology. It may be possible to maintain contemporary agriculture and lessen the consequences of climate change by using biotechnological methods for breeding crops resistant to biotic and abiotic challenges, such as cisgenesis, genome editing, RNA interference, and epigenome edits. Biotransformation, microbial biomass, metabolic manufacturing, and biofuels are just a few of the many uses of microbes in the food industry. It is now possible to generate commercially viable products in the food sector because of recent developments

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in protein engineering and metabolic engineering.

2. Role of Microorganisms in Agriculture

Recent advances in agricultural microbiology and biotechnology have led to significant progress in the field. These advancements include the application of new methods in food production technology, such as modern methods of production and testing of food, as well as the sustainable development of agriculture and the food industry.[1] Insect biotechnology has also emerged as a valuable tool with applications in agriculture, industry, and human welfare. It has been used for insect identification, genetic relationship studies, and the control of specific biotypes of natural enemies. Insect biotechnology has also contributed to the production of industrial enzymes, pharmaceuticals, microbial insecticides, and other substances.[2] Additionally, there have been developments in biotechnological approaches for breeding crops that are more tolerant to biotic and abiotic stresses. These approaches include cisgenesis, genome editing, RNA interference, and epigenome modifications. These techniques, combined with traditional breeding, have the potential to sustain modern agriculture and mitigate the effects of climate change.[1] These advancements in agricultural microbiology have the potential to address challenges in the industry and contribute to the development of more sustainable and efficient agricultural practices.

Microbes are widely used in the food industry for various purposes. Microbes also play a crucial role in the production of fermented food products and enzymes, as well as in the improvement of gut flora through the use of probiotics and prebiotics.[3] They have been used since ancient times in the production of yogurt, bread, wine, and other food products.[4] Microorganisms are utilized in the production of dairy products, fermented vegetables, fermented meats, and sourdough bread, as well as in the production of chocolate, food color, and probiotics.[5] Furthermore, recent advances in protein engineering and metabolic engineering have allowed for the development of microbial factories to produce commercially relevant products in the food industry.

3. Chocolate Microbes

Chocolate contains various microorganisms, including bacteria, yeasts, and molds, which can have both positive and negative effects on its quality and safety. Some studies have focused on enriching chocolate with probiotic bacteria, such as *Lactobacillus* strains, to create potentially probiotic chocolate.[6] Fermentation of cocoa beans during chocolate production involves a succession of microorganisms, including *Saccharomyces cerevisiae*, *Pichia kluivery*, and *Hanseniaspora uvarum*, which can influence the flavor and aroma of the resulting chocolate.[7] However, the presence of microorganisms in chocolate can also lead to spoilage and food safety issues, particularly if the chocolate is contaminated with pathogens like *Salmonella*.[8] To ensure the safety of chocolate, it is important to implement good manufacturing practices, including proper hygiene, control of water use, and supplier assurance programs for ingredients.[9] Microencapsulation of probiotics in chocolate has been shown to protect the bacteria during digestion and delivery to the colon, making it a promising method for probiotic delivery.[10]

4. Benefits of Microorganisms in Soil Health and Nutrient Cycling

4.1. *Impact of microorganisms on plant growth and productivity*

Refinement in the understanding of plant-microbe interactions may lead to more precise engineering of plant-associated microbial communities. Scientists might explore designing custom microbial consortia tailored to specific crop needs or environmental conditions.

Precision microbiome engineering involves the targeted manipulation of specific microbes or microbial functions within the microbiome to modulate host health and disease. Current approaches for microbiome manipulation often involve non-specific transfer of entire microbial communities, leading to potential unwanted side effects.[11] Precision prebiotics, which specifically modulate the abundance of individual microbes or microbial functions of interest, have been proposed as a solution to this limitation. Constraint-based metabolic modeling has been used to design precision prebiotics that can boost the abundance of beneficial microbes, such as *Pseudomonas lurida* MYb11, in a two-member C. elegans microbiome model community.[12] Supplementation with precision biotics has been shown to improve growth performance and modulate the microbiome in broiler chickens, leading to beneficial shifts in protein metabolism and increased short-chain fatty acid production.[13,14] Microbiome engineering strategies, including genetic engineering and complementary approaches such as encapsulation and diet engineering, show promise for treating dysbiosis and improving human health.[15] The future potential of microbiome engineering for precision agriculture is also being explored.

4.2. *Microbial-enhanced crop stress tolerance*

With the escalating challenges posed by climate change, there could be a focus on identifying and utilizing microbes that confer increased resilience to crops against various stressors like drought, heat, and soil salinity.

Crop plants are often exposed to different types of stress, which can limit their growth and reduce yield. Microbial-based approaches have shown promise in enhancing crop stress tolerance by reducing oxidative stress, modulating plant hormone levels, and improving metabolic ability. For example, inoculating plants with a combination of *Trichoderma* T42 and *Pseudomonas* has been shown to significantly improve metabolic ability during drought stress and lead to the overexpression of PAL, a gene responsible for combating drought stress. Inoculation has also been shown to improve characteristics such as growth limitation and metabolite content compared to uninoculated plants.[16] Furthermore, microbial biostimulants, such as those produced by microbiome engineering, can be selected for specific cultivars or crops under particular cultural situations by understanding microbial activities and interaction processes.[17] However, the effectiveness of microbial-based approaches varies depending on the plant species and the type of stress, and further studies are necessary to develop targeted products that can be successfully validated in field experiments.[18] Microorganisms associated with crops can stimulate the production of plant growth-promoting hormones, antioxidants, and other protective compounds that help plants cope with heavy metal stress. For instance, strains of *Pseudomonas fluorescence* and *Trichoderma* spp. isolated from heavy metal-contaminated soil have been shown to improve the growth and yield of chickpea by lowering Cd uptake.[19] Overall, microbial-based approaches offer a promising means of enhancing crop stress tolerance, and further research is necessary to understand and exploit plant-microbe interactions for sustainable agriculture in an eco-friendly manner.

4.3. Use of beneficial microorganisms for pest and disease management

Continued exploration of microbial biostimulants that enhance plant growth, nutrient uptake, and overall productivity might lead to the development of novel microbial formulations for sustainable agriculture.

Microbial biostimulants are natural substances that stimulate plant growth and enhance crop productivity. They can be obtained from naturally occurring microorganisms and their biochemical products, such as organic acids, proteins, enzymes, and hormones.[20] These biostimulants interact with the plant-soil continuum, improving the availability and uptake of essential nutrients, thereby increasing crop productivity and soil fertility.[21] Additionally, microbial biostimulants have plant growth-promoting effects with minimal environmental disturbances, making them environmentally friendly and sustainable.[22] They can enhance nutrient use efficiency, stimulate plant growth, and reduce fertilizer consumption.[23] Furthermore, microbial biostimulants can be used in the bioremediation of municipal solid waste, improving the conditions of sanitary landfills, compost quality, and the conversion of waste into energy and fertilizers.[24] Overall, microbial biostimulants offer advanced techniques for improving crop productivity, soil fertility, and waste management.

4.4. Current trends in agricultural microbiology: Omics technologies in microbial research

Advances in ’omics’ technologies (such as genomics, metagenomics, transcriptomics, and metabolomics) could provide deeper insights into microbial communities associated with plants. This could facilitate a more comprehensive understanding of their functions and interactions.

Omics technologies, which offer sophisticated methods for analysis and optimisation, have completely changed the field of microbial research. Comprehensive investigation of microbial metabolism, gene expression, and cellular responses is made possible by these technologies, which include metagenomics, transcriptomics, proteomics, and metabolomics.[25,26] Research on bioremediation can be aided by metagenomics, which enables the examination of genetic material directly extracted from environmental samples. This allows for the discovery of uncultivable microbial populations. With the quick development of transcriptomics tools, it is now possible to analyse gene expression at the sequence level and in many spatial contexts, including single cells and epigenetics. Understanding the proteins and metabolites that microorganisms produce using proteomics and metabolomics makes it easier to research how microbes interact with interfaces and identify archaic pathogens.

4.5. Potential for using microbiology to enhance food security and sustainability

Further development and refinement of regulations regarding the use of microbial products in agriculture are anticipated. Additionally, there might be an increase in the commercialization and adoption of microbial-based solutions by farmers as more products reach the market.

The regulatory frameworks for advanced therapy medicinal products (ATMPs) have been a topic of discussion in the literature. The ATMP Regulation in the EU provides a regulatory framework for the commercialization and use of regenerative medicine-based therapeutic products.[27] However, concerns have been raised about the appropriateness of the regulatory strategy in keeping up with evolving technologies.[28] Mobile medical apps have gained popularity, but their regulatory context and applicable prescriptions need to be identified if they have effects on user health.[29] The development of ATMPs requires a scientifically sound preclinical and clinical development plan, and specific requirements for the initial clinical trial involving ATMPs need to be addressed.[30] The manufacturing of individualized neoantigen-specific therapies requires a novel regulatory framework to accommodate rapid technological advancements and ensure continuous improvement.

4.6. Climate change and its effects on soil microbial communities

Improved formulations and application methods of microbial seed coatings and inoculants may emerge, aiming to optimize microbial delivery to plants while ensuring their efficacy.

The field of agricultural microbiology remains dynamic, driven by the need for sustainable agricultural practices, climate change adaptation, and the quest for eco-friendly alternatives to traditional farming inputs. Researchers and industry stakeholders continue to explore innovative ways to harness the potential of microbes for enhancing crop productivity, soil health, and overall agricultural sustainability.

4.7. Potential impact of agricultural microbiology on future food production and environmental sustainability

The implementation of novel techniques in food production technology and the creation of sustainable agricultural practices are just two examples of the notable advancements in the sector brought about by recent developments in agricultural microbiology and biotechnology. Precision microbiome engineering, microbially enhanced crop stress tolerance, microbial biostimulants, and omics technologies are areas of active study that show promise for the future of agriculture. Insect biotechnology has emerged as a key tool in this regard.

5. Source of Funding

None.

6. Conflict of Interest

None.

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Cite this article: Debnath M, Garani S, Debnath R. A critical review of agricultural microorganism. *Int J Recent Innov Med Clin Res* 2024;6(3):56-60.