Indian Journal of
Nutrition

Open Science Publications

Volume 11, Issue 1 - 2024

www.opensciencepublications.com

Role of Fungi in Revolutionizing the Food Sector

Review Article

Pandit A1*, Darshane P[1] and Dixit M[2]

[1]*Assistant Professor, Department of Ayurved and Yoga, Tilak Maharashtra Vidyapeeth, Pune, Maharashtra, India*

[2]*Senior Research Fellow, Department of Ayurved and Yoga, Tilak Maharashtra Vidyapeeth, Pune, Maharashtra, India*

***Corresponding author:** Avdhoot Pandit, Assistant Professor, Department of Ayurved and Yoga, Tilak Maharashtra Vidyapeeth, Pune, Maharashtra, India. E-mail Id- avdhootpandit8@gmail.com

Article Information: **Submission:** 08/03/2024; **Accepted:** 04/04/2024; **Published:** 08/04/2024

Abstract

Fungi play a crucial role in food production, processing, and preservation, yet their effects on food safety and quality are diverse and complex. This review aims to comprehensively analyze the multifaceted involvement of fungi in the food industry, emphasizing both their beneficial and harmful impacts. The literature review was conducted through an extensive search of databases including Pub-Med, Scopus, Web of Science, and Google Scholar, using keywords such as "fungi in food" and "mycotoxins" in order to meet the objective of the study. It was observed that fungi have multifaceted role in food sector contributing to various aspects in the field of dairy industry, bakery industry, post-harvest technology of fruits and vegetables, mycoprotein production, mycotoxin production and food spoilage. Various types of fungal cultures are incorporated into the food industry to enhance shelf stability, nutritional content and ensure food safety. Examining both the health benefits and risks associated with fungal consumption, this review underscores the need for proper management and understanding of fungi to ensure food safety, quality and innovation in the food industry.

Keywords: Fungi; Food Production; Fermentation; Fungal Enzymes; Mycotoxins; Novel Food Ingredients; Health Benefits; Food Safety

Introduction

Background

Fungi are a diverse group of microorganisms that have a significant impact on the production, processing, and preservation of various food products. They play a crucial role in shaping the sensory characteristics, nutritional composition, and safety of foods [1]. Fungi encompass a wide range of species, including yeasts and molds, each with unique properties and capabilities that make them valuable in the food industry [2]. Understanding the roles of fungi in food systems is essential for optimizing food production, improving product quality, and ensuring food safety [3]. Fungal involvement in foods is not a recent phenomenon but has been practiced for centuries. Traditional food fermentation processes, such as the production of cheese, bread, and alcoholic beverages, rely on the activities of specific fungal strains to achieve desired sensory and nutritional attributes [4]. In addition to their traditional applications, fungi have gained attention in modern food science and technology due to their versatile nature and potential for novel applications [5]. They are being explored for their ability to enhance flavor profiles, increase nutritional value, and contribute to the development of functional foods [6].

Objectives

The objective of this review is to provide a comprehensive overview of the role of fungi in various food categories as well as to address the challenges associated with fungal contamination, mycotoxin production, and food spoilage.

Role of Fungi in Dairy Industry

Fungi in cheese production

Cheese production is a traditional fermentation process that relies on the activities of various fungi, including yeasts and molds. These fungi contribute to the development of unique flavors, textures, and aromas in different types of cheese [7]. For instance, specific fungal strains, such as *Penicillium roqueforti* and *Penicillium camemberti*, are used in the production of blue and soft-ripened cheeses, respectively [8]. These fungi play a crucial role in the breakdown of proteins and lipids, resulting in the characteristic flavor and texture of cheese [9].

Yogurt and Fermented Milk Products

Fungi, particularly lactic acid bacteria and yeasts, play a significant role in the production of yogurt and other fermented milk products. The addition of specific fungal strains, such as *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus*, alongside yeasts

ISSN: 2395-2326

like *Saccharomyces cerevisiae*, allows for the conversion of lactose into lactic acid and the production of characteristic flavors and textures [10]. These fungi contribute to the acidity, aroma, and viscosity of fermented milk products.

Fungal Starter Cultures in Dairy Fermentations

Fungal starter cultures are widely used in dairy fermentations to initiate and control fermentation processes. These cultures consist of specific fungal strains selected for their ability to contribute to the sensory and textural properties of fermented dairy products. For example, *Geotrichum candidum* is a common fungal starter culture used in the production of soft cheese and contributes to the development of characteristic flavors and textures [5]. Fungal starter cultures also aid in the inhibition of undesirable microorganisms, thereby improving product safety and shelf life [12].

Role of Fungi in Cereal-based Products

Bread and Bakery Products

Fungi play a vital role in the production of bread and other bakery products. *Saccharomyces cerevisiae*, commonly known as baker's yeast, is used as a leavening agent in bread-making processes. It ferments sugars present in dough, producing carbon dioxide gas, which helps to leaven the dough and create a light and airy texture [13]. Additionally, filamentous fungi, such as *Aspergillus Niger*, are utilized in the production of enzymes, including amylases and xylanases, which improve dough handling and bread quality [14].

Fermented Cereals and Grains

Fermented cereals and grains are important food staples in many cultures, and fungi play a significant role in their fermentation processes. For instance, in the production of traditional African fermented foods like *ogi*, *kenkey*, and *injera*, filamentous fungi, including *Rhizopus* and *Aspergillus* species, are utilized as starter cultures. These fungi contribute to the break down of Complex carbohydrates, protein hydrolysis, and the development of characteristic flavors and textures in the final products [15 ,16].

Mycotoxins in Cereal-Based Foods

Mycotoxins are toxic compounds produced by certain fungi that can contaminate cereal- based foods, posing health risks to consumers. Some common mycotoxins include aflatoxins, produced by Aspergillus species, and deoxynivalenol, produced by *Fusarium* species. These mycotoxins can occur in grains and cereals and may persist through food processing steps, leading to potential human exposure. Stringent quality control measures and proper storage conditions are essential to minimize mycotoxin contamination and ensure food safety [17].

Role of Fungi in Fruits and Vegetables

Post-Harvest Diseases and Decay

Fungi are major contributors to post-harvest diseases and decay in fruits and vegetables. Various fungal species, such as *Botrytis* **cinerea,** *Colletotrichum spp.,* and *Penicillium spp.,* can cause significant losses during storage and transportation. These fungi invade plant tissues, leading to rotting, discoloration, and deterioration of the quality and shelf life of fresh produce [18,19]. Effective management strategies, including proper storage conditions, fungicide applications, and post-harvest treatments, are essential to control fungal diseases and preserve the quality of fruits and vegetables [20].

Edible Mushrooms

Fungi are extensively utilized in the cultivation and production of edible mushrooms. Species such as *Agaricusbisporus* (button mushrooms), *Pleurotusostreatus* (oyster mushrooms), and *Lentinulaedodes* (shiitake mushrooms) are commercially grown for their culinary and nutritional value. Fungi play a vital role in the degradation of lignocellulosic materials and the conversion of agricultural wastes into nutrient-rich substrates for mushroom cultivation. They also contribute to the formation of characteristic flavors, textures, and aromas in edible mushrooms [21,22].

Mycoprotein Production

Mycoprotein is a protein-rich food ingredient produced from filamentous fungi, specifically the species *Fusarium venenatum*. It serves as an alternative protein source for vegetarian and vegan diets. Fungi are cultivated on a substrate composed of carbohydrates, such as glucose or lactose, to promote fungal biomass production. The resulting mycoprotein is then harvested, processed, and used as a meat substitute in various food products. Mycoprotein production offers sustainable and efficient utilization of fungal biomass for human consumption [23].

Role of Fungi in Fermented Food Products

Traditional Fermented Foods

Fungi have long been utilized in the fermentation of various traditional foods. Fermented foods from different regions and cultures, such as *sauerkraut*, *kimchi*, *miso*, and *tempeh*, rely on fungal activity for the transformation of raw materials into flavorful and preserved products. Fungal strains, including *Aspergillus*, *Rhizopus*, and *Saccharomyces*, contribute to the fermentation process, imparting unique flavors, textures, and nutritional changes to the final products [24,25].

Fungi in Alcoholic Beverages

Fungi, particularly yeast species, are crucial in the production of alcoholic beverages. *Saccharomyces cerevisiae*, commonly known as brewer's yeast, is used in the fermentation of beer, wine, and other alcoholic beverages. Yeasts convert sugars into alcohol and carbon dioxide through the process of fermentation. Different strains of yeast contribute to the flavor, aroma, and alcohol content of the final beverages. In addition to *Saccharomyces cerevisiae*, other yeast species such as *Saccharomyces pastorianus* **and** *Brettanomyces bruxellensis* are also involved in specific types of alcoholic fermentations [26,27].

Fungi in Non-Alcoholic Beverages

Fungi also contribute to the production of non-alcoholic fermented beverages. For example, certain species of filamentous fungi, such as *Aspergillus oryzae* and *Rhizopus spp.,* are used in the fermentation of traditional Asian beverages like sake and rice wine. These fungi produce enzymes that break down starches and proteins,

Citation: Pandit A, Darshane P, Dixit M. Role of Fungi in Revolutionizing the Food Sector. Indian J Nutri. 2024;11(1): 290.

leading to the conversion of raw materials into flavorful and aromatic beverages [28]. Additionally, *kombucha*, a popular fermented tea drink, involves the symbiotic growth of yeasts and bacteria, including *Saccharomyces cerevisiae* **and** *Acetobacter* species, which contribute to the fermentation process and the development of characteristic flavors [29].

Beneficial Aspects of Fungal Involvement in Foods

Flavor Development

Fungi play a crucial role in the development of flavors in various food products. During fermentation processes, fungi produce a range of volatile compounds, including alcohols, esters, and organic acids, which contribute to the characteristic aromas and flavors of fermented foods. For example, the production of specific flavor compounds by yeast strains is essential in the production of bread, beer, wine, and cheese, enhancing the sensory profiles and overall consumer acceptance [30,31].

Nutritional Enhancement

Fungi can contribute to the nutritional enhancement of food products. Certain fungal species, such as filamentous fungi and yeasts, are capable of producing essential vitamins, including B vitamins, as well as minerals and other bioactive compounds. For instance, the fermentation of soybeans by *Aspergillus oryzae* in the production of soy sauce leads to the synthesis of vitamins and amino acids, improving the nutritional value of the final product [32]. Fungi can also enhance the bioavailability and digestibility of nutrients in food matrices, thereby increasing their nutritional benefits [33].

Probiotic Properties

Certain fungal species possess probiotic properties and can contribute to gut health when consumed. For example, species of the yeast *Saccharomyces* and filamentous fungi from the genus *Trichoderma* have been studied for their probiotic potential. These fungi can survive and prolife rate in the gastro intestinal tract, promoting beneficial effects such as the modulation of gut microbiota, improvement of intestinal barrier function, and enhancement of immune responses [34,35] . However, further research is needed to fully explore and understand the probiotic properties of fungi and their potential applications in food products.

Challenges Associated with Fungal Contamination and Spoilage

Food borne Fungal Pathogens

Although most fungi are harmless or even beneficial, certain fungal species can act as food borne pathogens and cause infections in humans. Examples include *Aspergillus flavus*, which produces aflatoxins in food and can lead to liver toxicity, and *Fusarium* species, which produce mycotoxins associated with various health effects. Adequate food safety measures, such as good manufacturing practices, proper storage conditions, and monitoring for fungal pathogens, are essential to prevent food borne illnesses caused by these fungi [36,37].

Mycotoxin Production

Mycotoxins are toxic secondary metabolites produced by fungi, primarily molds that can contaminate food and pose significant risks to human health. Common mycotoxins include aflatoxins, ochratoxins, and fumonisins, among others. These mycotoxins are known to have carcinogenic, mutagenic, and immunosuppressive effects. Preventing mycotoxin contamination requires appropriate storage conditions, monitoring of raw materials, and effective post-harvest management strategies [38].

Food Spoilage by Fungi

Fungi are responsible for a significant portion of food spoilage. Their ability to grow on various food matrices, especially under favorable environmental conditions, can lead to undesirable changes in color, texture, odor, and taste, rendering the food unpalatable and unsafe for consumption. Common spoilage fungi include species of *Penicillium*, *Aspergillus*, and *Rhizopus*. Proper sanitation, temperature control, and packaging techniques are essential to prevent fungal spoilage and maintain the quality and safety of food products [39].

Fungal Biotechnology and Future Prospects

Fungal Enzymes in Food Processing

Fungi produce a wide range of enzymes with diverse functionalities that can be utilized in food processing. Fungal enzymes, such as amylases, proteases, lipases, and celluloses, have applications in various food industries, including baking, brewing, dairy, and meat processing. These enzymes facilitate the break down of complex substrates, improve product quality, enhance Process efficiency, and enable the development of novel food products with desired attributes [40-41].

Single-Cell Protein and Fungal Biomass

Fungi offer the potential for the production of single-cell protein (SCP) and fungal biomass, which can serve as alternative protein sources. Certain fungal species, such as *Candidautilis* and *Fusarium venenatum*, are grown on various substrates to produce protein-rich biomass. This biomass can be incorporated into animal feed, human food products, and biofuels, providing sustainable and eco-friendly alternatives to conventional protein sources [42,43].

Emerging Trends in Fungal Fermentation

Fungal fermentation is a rapidly evolving field with emerging trends and novel applications. Recent advancements include the use of genetically modified fungi for enhanced production of specific compounds, the exploration of fungal consortia for complex fermentations, and the integration of omics technologies for better understanding and control of fermentation processes. Additionally, the application of fungal fermentation in the production of bioactive compounds, functional foods, and nutraceuticals is gaining momentum, opening up new avenues for innovation in the food industry [44,45].

Conclusion

In conclusion fungi are indispensable agents in food production, offering diverse benefits from flavor enhancement to nutritional enrichment. Despite their pivotal role, fungal contamination and mycotoxin risks necessitate stringent monitoring. Yet, fungal

Citation: Pandit A, Darshane P, Dixit M. Role of Fungi in Revolutionizing the Food Sector. Indian J Nutri. 2024;11(1): 290.

biotechnology offers promising solutions, leveraging enzymes and biomass for sustainable food alternatives. Understanding fungal dynamics is paramount for optimizing production and ensuring food safety. This review underscores significance of fungi in food sector, driving innovation and heralding a new era of fungal biotechnology in the food industry. Future research can be conducted on harnessing fungal biotechnology for sustainable food production and safety enhancement through advanced genetic modifications and omics technologies.

References

1. Nielsen DS, Teniola OD, Ban-Koffi L (2019) Fungal food spoilage. Food Spoilage Microorganisms. Woodhead Publishing.
2. Böhnlein C, Schlemmer D, Kohajdová Z (2018) Fungal biotechnology in the food and feed industries. Food Processing Technologies. Springer.
3. Pagnocca FC, Rosa LH, Cota BB, (2018) Fungal diversity in fermented foods. Fungi in Biogeochemical Cycles. Springer.
4. Fleet GH (2019) Yeast in the production of foods and beverages. Yeasts in Food and Beverages. Springer.
5. Tamang J, Watanabe K, Holzapfel W (2016) Review: Diversity of microorganisms in global fermented foods and beverages. Frontiers in Microbiology 7: 377.
6. Zheng XW, Yan Z, Nout MJ, Boekhout T (2014) Biotechnological advances in the production of functional compounds in food fermentations. Food Research International 64: 1-10.
7. Tamime, AY, Robinson RK (2007) Yeasts in dairy products. Yeasts in Food and Beverages. Springer.
8. Fox PF, McSweeney PLH, (2017) Cheese: An overview. Cheese. Academic Press.2017: 5-21.
9. McSweeney PL (2004) Biochemistry of Cheese Ripening. International Journal of Dairy Technology 57:127-144.
10. Tamime AY, Robinson RK (2007) Yeasts in dairy products. Yeasts in Food and Beverages. Springer.
11. Rezac A, Kok CR, Heermann M,Hutkins R (2019) Fermented foods as a dietary source of live organisms. Frontiers in Microbiology 10: 1785.
12. Leroy F, De Vuyst L (2004) Lactic acid bacteria as functional starter cultures for the food fermentation industry. Trends in Food Science and Technology 15: 67-78.
13. Corsetti A,Settanni L (2007) Lactic acid bacteria in sourdough fermentation. Food Research International 40: 539–558.
14. Nielsen DS, Teniola OD, Ban-Koffi L (2019) Fungal food spoilage. Food Spoilage Microorganisms. Woodhead Publishing.
15. Holzapfel WH, Schillinger U (2002) Introduction to pre- and probiotics. Food Research International 35: 109-116.
16. Rousta N, Hellwig C, Wainaina S, Lukitawesa L, Agnihotri S, et al. (2021). Filamentous Fungus Aspergillus oryzae for Food: From Submerged Cultivation to Fungal Burgers and Their Sensory Evaluation-A Pilot Study. Foods (Basel, Switzerland) 10: 2774.
17. Bhat R, Rai RV, Karim AA (2010) Mycotoxins in Food and Feed: Present Status and Future Concerns. Comprehensive reviews in food science and food safety, 9: 57-81.
18. Prusky D (1996) Pathogen quiescence in postharvest diseases. Annual review of phytopathology 34: 413-434.
19. Jain A, Sarsaiya S, Wu Q, Lu Y, Shi J (2019). A review of plant leaf fungal diseases and its environment speciation. Bioengineered, 10: 409-424.
20. Janisiewicz WJ, Korsten L (2002). Biological control of postharvest diseases of fruits. Annual Review of Phytopathology 40: 411-441.
21. Royse DJ (2014) Cultivation of mushrooms with lignocellulosic biomass. Mushroom biology and mushroom products. CRC Press.
22. Wasser SP (2002) Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides. Applied microbiology and biotechnology 60: 258-274.
23. Ahmed S, Mustafa G, Arshad M, Rajoka MI (2017) Fungal Biomass Protein Production from Trichoderma harzianum Using Rice Polishing Biomed Res Int 2017: 6232793.
24. Steinkraus K H (2002) Fermented vegetables. In Handbook of Fermented Functional Foods. CRC Press.
25. Thierry A, Madec MN, Chuat V, Bage A S, Picard O, et al. (2023). Microbial communities of a variety of 75 homemade fermented vegetables. Frontiers in microbiology 14: 1323424.
26. Fleet GH (2003) Yeasts in foods and beverages: Impact on product quality and safety. Current Opinion in Biotechnology 14: 170-175.
27. Sidari R, Ženišová K, Tobolková B, Belajová E, Cabicarová T, et al. (2021) Wine Yeasts Selection: Laboratory Characterization and Protocol Review. Microorganisms, 9: 2223.
28. Kwon YS, Lee S, Lee SH, Kim HJ, Lee CH (2019) Comparative Evaluation of Six Traditional Fermented Soybean Products in East Asia: A Metabolomics Approach. Metabolites, 9: 183.
29. Marsh AJ, O'Sullivan O, Hill C, Ross RP, Cotter PD (2014) Sequence-based analysis of the bacterial and fungal compositions of multiple kombucha (tea fungus) samples. Food Microbiology 38: 171-178.
30. Zheng X, Shi X., Wang B (2021) A Review on the General Cheese Processing Technology, Flavor Biochemical Pathways and the Influence of Yeasts in Cheese. Frontiers in microbiology 12: 703284.
31. Annett LE, Spaner D, Wismer WV (2007) Sensory profiles of bread made from paired samples of organic and conventionally grown wheat grain. Journal of food science, 72: S254-S260.
32. Dimidi E, Cox SR, Rossi M, Whelan K. (2019) Fermented Foods: Definitions and Characteristics, Impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease. Nutrients 11: 1806.
33. Bertsch A, Roy D, LaPointe G (2020) Fermentation of Wheat Bran and Whey Permeate by Mono-Cultures of Lacticaseibacillus rhamnosus Strains and Co-culture with Yeast Enhances Bioactive Properties. Frontiers in bioengineering and biotechnology 8: 956.
34. Wu Y, Hu S, Wu C, Gu F, Yang Y (2022) Probiotics: Potential Novel Therapeutics Against Fungal Infections. Frontiers in cellular and infection microbiology 11: 793419.
35. Svahn KS, Göransson U, El-Seedi H, Bohlin L, Larsson DG, et al. (2012) Antimicrobial activity of filamentous fungi isolated from highly antibiotic-contaminated river sediment. Infection ecology & epidemiology 10: 3402.
36. Medina, A. et al. (2014) Prevention of mycotoxin contamination in the food chain: A review. International Journal of Food Microbiology 189: 79-95.
37. Awuchi CG, Ondari EN, Ogbonna CU, Upadhyay AK, Baran K, et al. (2021) Mycotoxins Affecting Animals, Foods, Humans, and Plants: Types, Occurrence, Toxicities, Action Mechanisms, Prevention, and Detoxification Strategies-A Revisit. Foods (Basel, Switzerland), 10: 1279.
38. Pitt JI, Hocking AD (2009) Fungi and food spoilage (3rd Ed). Springer.
39. Beuchat LR (1996) Pathogenic microorganisms associated with fresh produce. Journal of Food Protection 59: 204-216.
40. Gummadi SN, Panda T (2003) Fungal enzymes. In Biotechnology of microbial enzymes. Academic Press.
41. Kapoor M, Gupta MN (2012) Lipase promiscuity and its biochemical applications. Process Biochemistry, 47: 555-569.
42. Pereira AG, Fraga-Corral M, Garcia-Oliveira P, Otero P, Soria-Lopez A, Cassani L,et al. (2022) Single-Cell Proteins Obtained by Circular Economy

Citation: Pandit A, Darshane P, Dixit M. Role of Fungi in Revolutionizing the Food Sector. Indian J Nutri. 2024;11(1): 290.

Intended as a Feed Ingredient in Aquaculture. Foods (Basel, Switzerland), 11: 2831.

43. Bratosin BC, Darjan S, Vodnar DC (2021) Single Cell Protein: A Potential Substitute in Human and Animal Nutrition. Sustainability 13: 9284.

44. El-Gendi H, Saleh AK, Badierah R, Redwan EM, El-Maradny YA, et al. (2021) A Comprehensive Insight into Fungal Enzymes: Structure, Classification, and Their Role in Mankind's Challenges. Journal of fungi (Basel, Switzerland), 8: 23.

45. Arora DK (2003) Fungal Biotechnology in Agricultural, Food, and Environmental Applications (1st Ed.) Taylors & Francis Group. CRC Press.

Citation: Pandit A, Darshane P, Dixit M. Role of Fungi in Revolutionizing the Food Sector. Indian J Nutri. 2024;11(1): 290.