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Microbes and Their Role in Food Sciences

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ABSTRACT

Microbes are crucial to food science because they have an impact on numerous characteristics of food manufacturing, preservation and safety. In order to produce a varied choice of food products, including bread, dairy, pickled foods and alcohol, the fermentation and other processes require the help of beneficial microbes like yeast, bacteria and molds. These microorganisms also affect the development of food's flavors, textures and nutritional value. Bacteria also help in food preservation by extending their shelf life, maintaining food safety and preventing the development of harmful diseases. While the presence of harmful microorganisms such as molds and pathogenic bacteria can lead to contamination, spoiling and foodborne illnesses, advances in genetic engineering and biotechnology have improved product quality and safety by providing more precise control over microbial activity in food production. Despite these benefits, concerns about microbial resistance, environmental impacts and the ethics of altering microbial ecosystems persist. Microorganisms are abundant in soil, water, air, food, and the digestive tracts of humans and animals. They play a vital role in food production, safety, storage, preservation, and processing. Microbes such as bacteria, yeasts, and molds are used to produce foods like wine, dairy, and baked goods. However, contamination can occur at any stage—growing, harvesting, transport, storage, or preparation. Uncontrolled microbial growth in food can lead to visible spoilage signs, including color changes, powdery growths, altered taste and smell, and surface effervescence, compromising the food's quality and safety. Thus, microbial control is essential in the food industry.

INTRODUCTION

Each meal has a unique microbiota that could reveal information about a particular manufacturing stage or storage circumstances. Whether food is grown on a farm, in a garden, a lake, a pond, a river, or the ocean, it is always subject to microbe. At one time or another, microbe have been present in or come into contact with food storage facilities, industrial processing equipment, supermarkets, warehouses, brewery holdings, restaurants, lodging facilities and public dining venues (Schwarz, 2023). The microbiota of processed foods includes all types of microbes that contaminated the product during handling and processing as well as germs from the raw ingredients that made it through the processing, preservation and storage conditions. The predominant microbiota of raw foods will change based on their properties how they are handled the surrounding conditions and farming methods (De la Cal et al., 2005). Food production and then its preservation has been crucial to human survival since ancient times because it makes a wide range of foods more stable and safer. Traditional techniques of food preservation are like heating most common one, fermentation, deep-drying and salting are still used in the contemporary food sector. Since then, losses from food contamination and spoiling have decreased and our thoughtful of the main and important causes of food spoilage has grown considerably (Gram et al., 2002). Food preservation has been vital to human existence since ancient times because it improves the stability and safety of a wide range of foods. Traditional food preservation techniques like heating, fermenting, drying and salting are still used in the contemporary food sector. Since then, there has been a decrease in food contamination and spoilage losses and we now know more about the primary causes of deterioration (Stavropoulou & Bezirtzoglou, 2019).

Food deterioration is caused by activity of microorganisms in a variety of intricate ways, such as the loss of sensory attributes and consumer rejection. Unusual scents and aromas, as well as visible development in the form of slime and colonies that change texture due to the breakdown of proteins, carbohydrates and lipids, may indicate that microorganisms (such bacteria and molds) have ruined the meal (Amit et al., 2017). Food contamination and deterioration cause financial loss, damage to the food industry's reputation and legal repercussions for both customers and the industry. According to this scenario, the colonization of spoilage causing and pathogenic microorganisms in foodstuffs can be inhibited and delayed with the appropriate use of technology (such as pasteurization and sterilization), hygienic strategies (such as good hygiene and manufacturing practices) and traceability (prevent and reduce the distribution of unsafe and poor quality food) (Iulietto et al., 2015). Nonetheless, throughout the food chain, retail establishments, dining establishments and the consumer's home, food is still vulnerable to deterioration and contamination by harmful microbes (Aung & Chang, 2014).

Toxin synthesis, cross-contamination and generation by pathogenic microbes' risk of food safety and endanger the health of consumers. The intake and colonization of pathogen microorganisms in the human digestive tract is usually the cause of gastroenteritis, a condition characterized by diarrhea, intestinal cramps, nausea, vomiting and fever (McKillip & Drake, 2004). Although estimating the global incidence of foodborne infections is difficult, international, national and local initiatives have been made. Bacteria are the main cause of gastroenteritis, despite the fact that parasites, viruses, yeasts and molds are unappreciated causes of the illness that have become more common during the past ten years (Dorny et al., 2009).

Classification of Microbes in Food Science

Beneficial Microbes

In addition to acidifying milk, lactic fermentation is utilized to produce fermented dairy products such as sour cream, cheese, butter and yogurts. Vegetable silage and sourdough are produced and stabilized by this technique which is also utilized for cold cut maturation. (El-Nezami et al., 1998). Both homofermentative and heterofermentative lactic acid bacteria are used in fermentation. Bacteria belonging to the genera *Lactococus, Streptococcus, Lactobacillus, Leuconostoc, Pediococcus, Weisella* and *Bifidobacterium* are the most often utilized cultures in lactic fermentation procedures. Lactic acid bacteria and yeasts are two examples of beneficial microbes that are necessary for food production. Bread, cheese and yogurt are among the fermented items they produce (Luz et al., 2018). These bacteria enhance the taste, consistency and nutritional value of these foods. Some lactic acid bacteria strains convert disaccharides into nearly pure lactic acid through a process known as homo-fermentation, which is a slightly different method of breaking down lactose to produce lactic acid, ethyl alcohol, carbon dioxide, hydrogen peroxide, diacetyl, acetoin and acetic aldehyde. Lactic fermentation is the simplest method to us and because lactic acid bacteria is so widespread, its natural pH drop below 4.0 has no detrimental effects on the effectiveness of biochemistry (Barukčić et al., 2018). The presence or absence of capsules, the size and shape of the yeast cells the process of producing daughter cells (conidiogenesis), the development of pseudohyphae and real hyphae and the presence of sexual spores are additional characteristics that distinguish yeast taxa in addition to physiological data. While species are characterized by their morphology in conjunction with their ability to use nitrate as a nitrogen source and absorb and ferment different carbon sources, yeasts are primarily classified by their morphology at the genus level (Arevalo-Villena et al., 2017). As per the latest edition of Yeasts: A Taxonomic Research, there are now around 1500 species of yeast known to exist. The estimated amount of 150,000 fungal species represents about 5–10% of the total. While 70–80 of these yeast species have been used in experimental settings and could be useful in biotechnology, only about 12 are used on an industrial basis (Yépez et al., 2017). In this regard, the role of *Saccharomyces cerevisiae* in food production is widely recognized. It is present in wine, beer and distilled beverages and is a crucial stage in the fermentation process that converts sugar to alcohol. Additionally, yeast is utilized as a leavening ingredient in baking, releasing gas into the air during baking to give cakes and breads their spongy feel (Vilela, 2019). The yeasts *Kluyveromyces, Galactomyces, Hyphopichia, Pichia, Saccharomycodes, Rhodotorula, Metschnikowia, Saccharomycopsis, Yarrowia, Cryptococcus, Brettanomyces, Debaryomyces, Hansenula, Schizosaccharomyces, Hanseni aspora, Trichosporon, Torulopsis, Geotrichum, Zygosaccharomyces* and *Candida* are common fermented foods and beverages, such as breads and bakery goods, as well as dairy products (kefir, yoghurt, fermented milk, etc.) (Fell & Kurtzman, 2000).

Spoilage Microbes

Food rotting occurs in the loss of edible commodities in addition to financial loss.

Food that deteriorates past a certain point is not regarded as a serious issue in nations that produce and import food from numerous locations far more frequently than is necessary. However, food rotting can negatively impact food availability in many nations with inefficient food production. In light of the growing global population, particular attention needs to be paid to boosting food production while lowering food spoilage, which in some nations can reach 25% or more (Kilcher et al., 2010). Unwanted chemical and physical reactions, rodent and insect infestation and microbiological growth can all reduce the attractiveness of a food. Either microbial growth in a food or the action of particular microbial enzymes in the meal can result in microbiological rotting. The microbiological makeup of ruined food differs significantly from that of undamaged and nonsterile food (Wang et al., 2017). In the first instance, there are typically multiple microorganisms from various genera, possibly even multiple strains from the same species and even multiple species from the same genus. Other members of the main groups of microorganisms include bacteria, molds, yeasts and viruses. One or two categories are usually present when a meal spoils, though and they might not even be present in the maximum proportions in the original, fresh product (Emborg et al., 2002). Of the numerous species that are originally present and capable of developing in a given meal, only the species with the shortest development period under storage circumstances soon amass in numbers and cause deterioration. Food spoilage can be caused by any germ, including bacteria and pathogens used in food fermentation, that can grow in food to a high level (spoilage detection level) (Priest et al., 1987). However, in practice, the deterioration of the majority of foods has been more firmly linked to a very small number of bacterial taxa. Leuconostoc, Pediococcus, Stretococcus, *Kurthia zopfii*, Carnobacterium species, Lactobacillus species, Lactococcus species, *Kurthia thermosphacta* and Weisella species are the main bacteria linked to deterioration. Discolorations, slime creation, gas production, off-odors and off-flavors and pH decreases are the primary food defects caused by these bacteria (Beuchat et al., 2001).

Figure 1

Microbe Classification in Food Science.

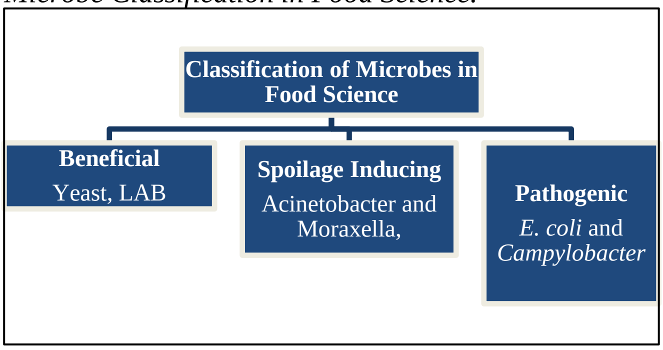


Table 1

Microbes and their food preference of spoilage.

Bacterial Specie	Food Preference
B. thermosphacta	Pork, lamb and fish.
Carnobacterium maltaromaticum	Meat (beef, pork, and poultry), seafood (fish and shrimps) and dairy (raw milk and cheese) food products.
Lactobacillus casei	Dairy products.
Lactobacillus curvatus	Raw sausage, milk, grapes and plant material coming into the winery.
Pediococcus damnosus	Wine and beer.
S. thermophiles	Fermented milk products.
Kurthia zopfiienus	Cured and fresh meat and meat related products.
Weissella minor	Milk and vegetables.

Pathogenic Microbes

Many harmful bacteria that do not produce spores have been connected to the majority of food contamination incidents in the past ten years, despite the fact that sporogenesis is thought to be a crucial mechanism for bacterial environmental survival and food contamination. *Salmonella, Yersinia, Listeria, Brucella, Campylobacter* and *Escherichia coli* are the most significant bacterial species in this group and are in charge of the majority of the 4362 foodborne outbreaks (McMeekin et al., 2008). The continuous invention, adaption and exploitation of novel vehicles brought about by new retail store and food marketing trends, changes in food consumption patterns and modern technologies all make it more difficult to control these hazardous germs. To increase our knowledge and offer innovative strategies for the treatment and prevention of food-related illnesses, it is crucial in this case to constantly track the routes of transmission, outbreaks, clinical symptoms and recently identified strains of well-known food pathogens (Augustin, 2011). Numerous diseases in humans, animals and plants are brought on by viruses, which are essential intracellular parasites. In order to reproduce by taking advantage of the metabolic processes that occur inside the cell, viruses, being mandatory parasites, must constantly search for new host cells and individuals. Foods that can only passively spread illnesses will therefore be unable to encourage the growth of viruses (Remize & De Santis, 2025). The most important food-borne infections were those that impacted the cells lining the intestinal system and spread by shedding into the feces or by producing emesis, however they can spread in many different ways. Multiple viruses may produce a single disease, or one virus may cause a different disease due to its interactions with the body, depending on the tissue or organ affected (Rosenthal, 2021). Only a small percentage of the many viruses found in the human gut are generally recognized as serious foodborne pathogens. Based on the illnesses they produce viruses can be divided into three groups. There are only a few parasitic diseases that are representative of the primary parasitic organism groups that are present in food. Numerous parasites, including helminths and protozoa can be transmitted by food. The most common food-borne parasite transmission in underdeveloped countries occurs through the consumption of raw aquatic plants such as watercress, undercooked fish, crabs, mollusks, pork and raw vegetables contaminated with human or animal waste (Robertson, 2018). Depending on the type of parasite, a foodborne parasite infection might present with a wide range of symptoms. Depending on the specific organism and infection burden, helminthic infections can produce a wide range of symptoms, including coughing, skin sores, diarrhea, abdominal pain, muscular sores, malnourishment, weight loss, neurological issues and many more. Diarrhea and associated gastrointestinal symptoms are most frequently caused by protozoa, including *Giardia intestina*, *Cyclospora cayetanensis* and Cryptosporidium spp. (Hazards et al., 2018).

Table 2
Microbes and Their Health Consequences.

Specie	Disease
B. abortus, B. melitensis, B. suis, B. ovis, B. canis	Causes brucellosis in caprine and ovine
C. jejuni, C. col, and *C. lari*	Gastrointestinal infection
S. enterica	Enteric fever, enterocolitis with diarrhea, bacteremia
Y. pseudotuberculosis	Intermittent fever, abdominal pain and diarrhea.
L. monocytogenes and *L. ivanovii*	Headache, nausea, vomiting, fever, myalgia and general malaise
Norovirus	Stomach pain, nausea and diarrhea
Picornavirus	Hepatitits
Aichivirus	Gastroenteritis
Astrovirus	Gastroenteritis
Rotavirus	Vomiting, fever and abdominal pain.
Trichinella spiralis	Tissue pain, swelling and fever.
T. asiatica	Increased appetite, headache, constipation and dizziness
G. muris, G. lambia, G. agilis	Flatulence, abdominal cramps, bloating, nausea, anorexia and weight loss

Beneficial Effects, The Pros

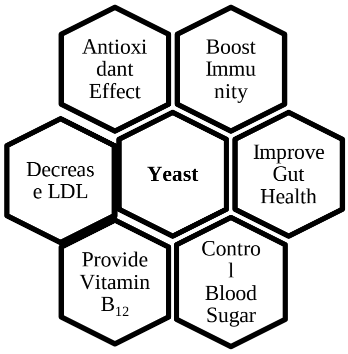
Fermentation and Food Production

In addition to providing nutritional diversity, fermentation preserves food, increases flavor and improves texture in a wide range of foods and drinks, including vinegar, wine, beer, bread, cheese, yogurt, kimchi, sauerkraut and soy sauce. A metabolic process known as "microbial fermentation" converts carbohydrates—such as sugars, grains or any food composed of the same carbohydrates—into acids, gasses or alcohols without the presence of oxygen (Tamang et al., 2016). In the food and beverage business, natural and minimally processed products are growing in importance in tandem with this trend. These compounds stop harmful microorganisms from growing in the food being processed by creating inhibitory molecules such bacteriocins, carbon dioxide, organic acids and alcohols among others (Caplice & Fitzgerald, 1999). Lactic acid bacteria species reduce pH and act as a natural barrier against dangerous and deteriorating microorganisms by fermenting carbohydrates with lactic acid. The levels of carbon dioxide and ethanol produced during yeast fermentation create an anaerobic and antibacterial environment. Lactic acid bacteria serve as efficient biological agents that produce bacteriocin throughout this bio-preservation process. Microbial activity during fermentation can result in the production of a wide range of metabolites, such as organic acids, aldehydes, alcohols and esters. In fermented foods, these metabolites combine to produce a variety of aromas (Smid & Lacroix, 2013). Ester-forming yeast and bacteria are found in wine and beer, whereas amino acid conversion provides the savory flavor in the ripening of cheese and the brewing of soy sauce. The digestive process breaks down lipids, proteins and gases. This occurs as a result of chemical reactions that change food's texture and mouthfeel by turning it from solid to jelly and liquid to solid (Liu, 2003).

Yeast

It should be mentioned, nonetheless, that because of their metabolic abilities, some yeasts and fungi are helpful for food production. For instance, sourdough, kombucha and kefir are examples of fermented foods made with the yeast strain *Candida miller*, while wine, cider, sake, kefir, beer and bread are made with the yeast strain *Saccharomyces cerevisiae* (Steensels et al., 2014). Furthermore, the role that *Aspergillus oryzae* plays in the production of koji, miso, sake, rice vinegar and soy sauce cannot be overlooked. *Penicillium camemberti* is used to make soft cheeses like camembert and brie which are crucial (Marsh et al., 2014). Rhizopus species, particularly *Rhizopus oryzae* are used to make traditional fermented foods like tempeh. Soy sauce, sake and miso are made from koji, a mold known as *Neurospora crassa*. Lastly, *Monascus purpureus* is the strain that produces crimson yeast rice, which is used in many Chinese dishes. Molds are vital components for the significant processes of food manufacturing and preservation. *Aspergillus oryzae* is the main fungus used to produce rice vinegar, miso, sake, soy sauce and koji. While *P. roqueforti* is the primary contributor to the creation of blue-veined cheeses such as roquefort, stilton and gorgonzola, *P. camemberti* is essential to the development of the distinctive texture and flavor of camembert or brie cheeses (Machida et al., 2008).

Figure 2
Beneficial Effects of Yeast.



Bacteria

Lactic acid bacteria and acetic acid bacteria are two types of bacteria that are vital to food fermentation and produce foods like yogurt, cheese, sauerkraut, kimchi, pickles and vinegar (Battcock & Azam-Ali, 1998). The most often cultivated bacterial genera include *Lactobacillus*, *Streptococcus*, *Lactococcus*, *Propionibacterium*, *Acetobacter* and *Leuconostoc*. Fermentation processes that produce yogurt, cheeses, sauerkraut, kimchi, pickles and fermented vegetables are facilitated by beneficial Lactobacillus species, such as *L. acidophilus*, *L. delbrueckii* and *L. plantarum* (Wang et al., 2021). Another significant bacterium found in yogurt and cheese starter cultures is *Streptococcus thermophilus*. Important strains of *Lactococcus lactis* subsp. lactis and cremoris are responsible for the production of sour cream, cheese and buttermilk. Foods like Emmental and Gruyère which are mostly composed of milk and butter, depend on *P. freundenreichii* and *P. acidipropionici* for their production (Thierry & Maillard, 2002). Vinegar and kombucha beverages are made from members of the Acetobacter spp., *A. aceti* and *A. pasteurianus*. Lastly, *Leuconostoc mesenteroides* and *Lactobacillus lactis* are employed in seed culture for the fermentation of vegetables, including kimchi, sauerkraut and pickles. On the one hand, the regulated application of such a wide range of desired bacteria improves flavors, textures, and nutritional value; on the other hand, it creates new options for food preservation (El-Sayed et al., 2022).

Table 3
Bacterial and Fungal Species in Fermentation.

Specie	Fermented food
Lactobacillus bulgaricus, Streptococcus thermophilus	Yogurt
Lactobacillus and *Penicillium*	Cheese
Saccharomyces cerevisiae	Beer and wine
Spirulina platensis and *Chlorella vulgaris*	Milk
Leuconostoc mesenteroides	Sauerkraut
Rhizopus oligosporus	Tempeh

Natural Preservation

Using natural food preservatives is extremely safe. The most common sources of natural food preservatives are bacteria, plants and animals. Natural preservatives are mostly used in the food business to stop the growth of unwanted microbes. Plant antimicrobials can be incorporated into product formulations, applied to food surfaces or added to packaging materials (Inetianbor et al., 2015). Numerous food industries have made use of organic acids, bacteriocins from microbes, animal enzymes, essential oils from plants, and naturally occurring polymers like chitosan. The propagation of food-borne viruses in food products cannot be stopped by traditional food preservation techniques. The use of antimicrobials in the food industry has been made possible by consumers' increasing demand for food free of chemicals (Arshad & Batool, 2017). The food industry use antimicrobials, a state-of-the-art technology, to address quality and safety concerns and extend the shelf life of food.

Plant Based Antimicrobials

Natural antimicrobials can be found in raw fruits, vegetables, herbs and spices. Fruits and vegetables (garlic, pepper, onion, cabbage, and guava), seeds and leaves (olive leaves, parsley, caraway, nutmeg, fennel, and grape seeds), and herbs and spices (garlic, pepper, oregano, rosemary, thyme, sage, clove, and cardamom) are all natural sources of chemicals derived from plants (Tajkarimi et al., 2010). Plant-based extracts and essential oils have long been used as food additives to enhance flavor and taste while increasing food shelf life by preventing rancidity and reducing microbiological contamination. Indeed, due to their high concentration of secondary metabolites, mainly phenolic compounds, iso-flavonoids, terpenes, ketones, aliphatic alcohols, acids and aldehydes, these substances may restrict or hinder the growth of dangerous bacteria. The kind of microbe, inoculum size, culture medium, extraction technique and antimicrobial activity testing method are the primary determinants of the antibacterial activity of chemicals obtained from plants (Singh, 2018). Alkaloids, terpenes and polyphenols are examples of naturally occurring plant-based chemicals. Plants have a wide range of secondary compounds that shield them against predators and microbiological diseases by acting as biocide against bacteria or repelling herbivores. Among the important types included in secondary metabolite compounds are phenolic and polyphenolic groups (Nestor Bassolé & Juliani, 2012).

Microbial Based Antimicrobials

Numerous compounds produced by mold, fungus and bacteria have the ability to destroy other microorganisms. Numerous compounds that bacteria create help them repel other bacteria. Food-deteriorating bacteria can be stopped in their tracks by those active bacteria (Singh et al., 2003). One essential element that can act as an antibacterial agent against microbial infections or decaying is the protein molecule bacteriocin. Both Gram-positive and Gram-negative bacteria create bacteriocins, which are proteinaceous molecules that puncture the cytoplasmic membrane and allow intracellular metabolites to flow out. Bacteriocins can cause membrane depletion (Singh, 2018). Some active bacteria, including reuterin and pediocin, can effectively stop the growth of spoilage germs, while bacteriocins can stop food-borne pathogens like *Clostridium botulinum*, *Enterococcus faecalis* and *Listeria monocytogenes*. Bacteriocins are protease-degradable, making them safe to use in biopreservatives. In the US and Europe, the FDA frequently mentions the well-known bacteriocin nisin as a food ingredient. Cheese and sausage are frequently made with nisin (Abebe et al., 2020). Nisin, which is composed of amino acids such lanthionine, dehydroalanine, and aminobutyric acid, is produced by *Lactococcus lactis*. Numerous Gram-positive bacteria are inhibited by nisin. The ionic interaction with the C-terminus will cause a pore to form, causing nisin to stick to the microbe's cell membrane. When using chelators like ethylene diamine tetra-acetic acid (EDTA), for instance, nisin should be employed. Since nisin suppresses the *Staphylococcus aureus* bacterium present in raw milk, it is used to create cheese (Sadeghi et al., 2022).

Harmful Effects, The Cons

Contamination and Food Spoilage

Food production, safety, storage, preservation and processing are all significantly impacted by microbes. Microbes like bacteria, molds, and yeasts are used to make food ingredients and foods (wine, beer, dairy products, bakery goods, etc.). Millions of distinct kinds of microorganisms can be found in the air, soil and water, as well as on food and in both human and animal digestive tracts (Azad et al., 2019). However, food can become contaminated by microorganisms at any stage of the manufacturing process, including growing, harvesting, transportation, storage and final preparation. Thus, microbial development in food can also result in outward manifestations including color changes, the buildup of powdery growth, the loss of the meal's organoleptic qualities and surface effervescences. Because microbial habitats are varied and subject to change, it is challenging to find, identify and track the sources of these bacteria during fermentation process production (Karanth et al., 2023). Even so, it is routine practice to prevent occasional contamination cases. At various points in the food supply chain, spoilage microbial species invade and flourish in certain food items based on inherent bacterial traits and other external factors. This leads to food loss and waste. (i) The physical and chemical characteristics of the meal, such as its pH, water activity and nutritional availability, are considered intrinsic factors. (ii) Environmental elements that affect food storage, such as temperature, humidity and oxygen availability, are examples of extrinsic features. The primary cause of chicken rotting is microbes, while molds and yeasts can also play a significant role. The most common bacteria that cause chicken to spoil are Pseudomonas species, which include both fluorescent and non-fluorescent strains (Bruton et al., 1991). Unexpectedly, a common cause of poultry rotting is *Shewanella putrefaciens*, which is typically thought of as a marine bacterium. The main characteristics of poultry rotting are undesirable off-odors brought on by amino acid metabolism and the consequent formation of surface slime (Russell et al., 1995). When fresh and fresh-cut produce that has had minimal processing (without changing its "fresh" quality) becomes naturally polluted, the danger of microbial degradation increases. Bacterial soft rot, primarily caused by fluorescent Pseudomonas species and *Erwinia carotovora*, can degrade fresh and fresh-cut vegetables. Fresh and fresh-cut vegetables can decay due to a variety of fungal causes, including sour rot from *Geotrichum candidum*, soft rot from Rhizopus, and gray rot from Botrytis cinerea (Deshi et al., 2014).

Toxins Production

While fermented foods are generally safe to eat, there are some potential health risks associated with toxins. A variety of factors, including the use of tainted raw materials, inappropriate storage conditions, an inappropriate starter culture and inadequate hygiene, can result in the presence of toxins in fermented foods.

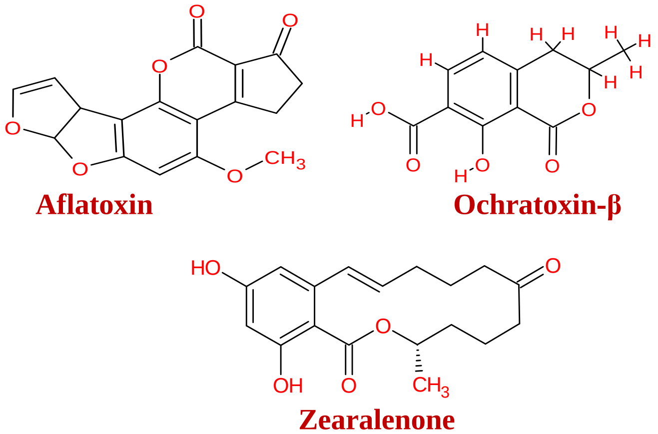
Table 4

Toxic Producing Species Their Respective Toxins and Health Hazards.

Microbe	Toxin	Health Consequence
Aspergillus spp	Aflatoxins	Neurotoxicity,
Penicillium	Zearalenone	Nephrotoxicity
Rhizopus spp., *E-coli*	Ochratoxin	Hemolytic uremic syndrome
Aspergillus flavus	Aflatoxin B1	Cytotoxicity
Rhizopus spp	Endotoxins	Immunosuppression

Figure 3

Chemical Structure of Toxins



Food Safety

With over 2.4 million cases annually, campylobacter is the leading cause of foodborne infections in the United States, surpassing salmonellosis. The most frequent cause of Guillain-Barré Syndrome (GBS), an acute immune-mediated disease that affects the peripheral nerve system, is caused by Campylobacter. After polio, GBS is the most common type of acute flaccid paralysis and is brought on by host factors, autoimmune diseases and Campylobacter (Nachamkin, 2002). Foodborne infections have emerged as a major global public health concern in the last ten years. The rise of new pathogens, advancements in food production, processing and distribution technologies and shifting lifestyles—such as less time spent on food preparation, convenience meals and more adventurous eating—have all contributed to changes in the epidemiology of microbiological foodborne infections. The following topics are discussed: The chronic effects of campylobacterosis, bacterial antibiotic resistance, microbial survival and growth on fresh fruits and vegetables (Meng & Doyle, 1998). Over the past ten years, foodborne illnesses like *Salmonella*, *Campylobacter*, *Escherichia coli* that produces Shiga toxin, *Listeria monocytogenes* and *Yersinia enterocolitica* have grown more resistant to antibiotics (Threlfall et al., 2000). Inactivating foodborne pathogenic germs is the final defense against foodborne disease. For millennia, the food industry has used thermal pasteurization and sterilization extensively. These technologies may cause unfavorable sensory changes and nutritional loss if they apply excessive heat treatment. It may be possible to enhance product quality by using preservation technology to inactivate bacteria in food without or with less heat (Beuchat, 1996).

DISCUSSION

Microbes like bacteria, yeast and molds are crucial to food science because they aid in fermentation, food preservation and nutritional enhancement. They aid in the development of the flavors, textures and digestibility of foods including cheese, yogurt and beer. However, harmful bacteria that cause contamination and foodborne illnesses, such as Salmonella and *E. coli*, pose significant risks. Food waste and monetary losses can also result from microbial degradation. Abuse of antibiotics causes microbial resistance and the rise of "superbugs." The genetic modification of microorganisms raises ethical and environmental concerns. Strict quality control is required in large-scale production to prevent contamination. Although microbes have numerous benefits, there are risks that should be carefully evaluated. Advances in biotechnology provide the way for safer and more sustainable food systems. Ultimately, balancing the usage of bacteria in food science ensures food safety and quality. Microbial control in food safety refers to identifying hazards, developing testing protocols and implementing control measures to reduce contamination. Techniques include monitoring infections, ensuring adherence to regulations and creating detection tools. Researchers focus on mycotoxins, antimicrobial resistance and innovative packaging to improve food safety. Training, consumer education and sustainable practices all contribute to lowering risks and ensuring the production of safe food.

CONCLUSION

The soil, water, air, food, and the digestive tracts of both people and animals are home to millions of different kinds of bacteria. Microbes have a significant impact on food production, safety, storage, preservation and processing. Foods (wine, beer, dairy products, bakery goods, etc.) and food ingredients are produced using microbes such as bacteria, molds and yeasts. However, food can become contaminated by microorganisms at any stage of the manufacturing process, including growing, harvesting, transportation, storage and final preparation. Thus, microbial development in food can also result in outward manifestations including color changes, the buildup of powdery growth, the loss of the meal's organoleptic qualities, and surface effervescences.

REFERENCES

1. Abebe, E., Gugsa, G., & Ahmed, M. (2020). Review on major food-borne zoonotic bacterial pathogens. *Journal of tropical medicine*, *2020*(1), 4674235. https://doi.org/10.1155/2020/4674235
2. Amit, S. K., Uddin, M. M., Rahman, R., Islam, S. R., & Khan, M. S. (2017). A review on mechanisms and commercial aspects of food preservation and processing. *Agriculture & Food Security*, *6*, 1-22. https://doi.org/10.1186/s40066-017-0130-8
3. Arevalo-Villena, M., Briones-Perez, A., Corbo, M. R., Sinigaglia, M., & Bevilacqua, A. (2017). Biotechnological application of yeasts in food science: starter cultures, probiotics and enzyme production. *Journal of applied microbiology*, *123*(6), 1360-1372. https://doi.org/10.1111/jam.13548
4. Arshad, M. S., & Batool, S. A. (2017). Natural antimicrobials, their sources and food safety. *Food additives*, *87*(1). https://doi.org/10.5772/intechopen.70197
5. Augustin, J.-C. (2011). Challenges in risk assessment and predictive microbiology of foodborne spore-forming bacteria. *Food*

Microbiology, *28*(2), 209-213. https://doi.org/10.1016/j.fm.2010.05.003
6. Aung, M. M., & Chang, Y. S. (2014). Traceability in a food supply chain: Safety and quality perspectives. *Food control*, *39*, 172-184. https://doi.org/10.1016/j.foodcont.2013.11.007
7. Azad, Z. A. A., Ahmad, M. F., & Siddiqui, W. A. (2019). Food spoilage and food contamination. *Health and safety aspects of food processing technologies*, 9-28. https://doi.org/10.1007/978-3-030-24903-8_2
8. Barukčić, I., Bilandžić, N., Markov, K., Jakopović, K. L., & Božanić, R. (2018). Reduction in aflatoxin M1 concentration during production and storage of selected fermented milks. *International journal of dairy technology*, *71*(3), 734-740. https://doi.org/10.1111/1471-0307.12490
9. Battcock, M., & Azam-Ali, S. (1998). *Fermented fruits and vegetables: a global perspective*. Food & Agriculture Org.
10. Beuchat, L. R. (1996). Pathogenic microorganisms associated with fresh produce. *Journal of food protection*, *59*(2), 204-216. https://doi.org/10.4315/0362-028x-59.2.204
11. Beuchat, L. R., Doyle, M. P., & Montville, T. J. (2001). *Food microbiology: fundamentals and frontiers*. ASM press.
12. Bruton, B., Wells, J., Lester, G., & Patterson, C. (1991). Pathogenicity and characterization of Erwinia ananas causing a postharvest disease of cantaloup fruit. https://doi.org/10.1094/pd-75-0180
13. Caplice, E., & Fitzgerald, G. F. (1999). Food fermentations: role of microorganisms in food production and preservation. *International journal of food microbiology*, *50*(1-2), 131-149. https://doi.org/10.1016/s0168-1605(99)00082-3
14. De la Cal, M., Cerdà, E., Abella, A., & Garcia-Hierro, P. (2005). Classification of micro-organisms according to their pathogenicity. *Infection Control in the Intensive Care Unit*, 49-60. https://doi.org/10.1007/88-470-0361-x_4
15. Deshi, S., Wonang, D., & Dafur, B. (2014). Control of rots and spoilage of agricultural products: a review. *International Letters of Natural Sciences*, *13*(2). https://doi.org/10.56431/p-o2e232
16. Dorny, P., Praet, N., Deckers, N., & Gabriël, S. (2009). Emerging food-borne parasites. *Veterinary parasitology*, *163*(3), 196-206. https://doi.org/10.1016/j.vetpar.2009.05.026
17. El-Nezami, H., Kankaanpaa, P., Salminen, S., & Ahokas, J. (1998). Ability of dairy strains of lactic acid bacteria to bind a common food carcinogen, aflatoxin B1. *Food and chemical toxicology*, *36*(4), 321-326. https://doi.org/10.1016/s0278-6915(97)00160-9
18. El-Sayed, A. I., El-Borai, A. M., Akl, S. H., El-Aassar, S. A., & Abdel-Latif, M. S. (2022). Identification of Lactobacillus strains from human mother milk and cottage cheese revealed potential probiotic properties with enzymatic activity. *Scientific Reports*, *12*(1), 22522. https://doi.org/10.1038/s41598-022-27003-2
19. Emborg, J., Laursen, B., Rathjen, T., & Dalgaard, P. (2002). Microbial spoilage and formation of biogenic amines in fresh and thawed modified atmosphere-packed salmon (Salmo salar) at 2° C. *Journal of Applied Microbiology*, *92*(4), 790-799. https://doi.org/10.1046/j.1365-2672.2002.01588.x
20. Fell, J. W., & Kurtzman, C. P. (2000). *The yeasts: a taxonomic study*. Elsevier.
21. Gram, L., Ravn, L., Rasch, M., Bruhn, J. B., Christensen, A. B., & Givskov, M. (2002). Food spoilage—interactions between food spoilage bacteria. *International journal of food microbiology*, *78*(1-2), 79-97. https://doi.org/10.1016/s0168-1605(02)00233-7
22. Hazards, E. P. o. B., Koutsoumanis, K., Allende, A., Alvarez-Ordóñez, A., Bolton, D., Bover-Cid, S., Chemaly, M., Davies, R., De Cesare, A., & Herman, L. (2018). Public health risks associated with food-borne parasites. *EFSA journal*, *16*(12), e05495. https://doi.org/10.2903/j.efsa.2018.5495
23. Inetianbor, J., Yakubu, J., & Ezeonu, S. (2015). Effects of food additives and preservatives on man-a review. *Asian Journal of Science and Technology*, *6*(2), 1118-1135.
24. Iulietto, M. F., Sechi, P., Borgogni, E., & Cenci-Goga, B. T. (2015). Meat spoilage: A critical review of a neglected alteration due to ropy slime producing bacteria. *Italian Journal of Animal Science*, *14*(3), 4011. https://doi.org/10.4081/ijas.2015.4011
25. Karanth, S., Feng, S., Patra, D., & Pradhan, A. K. (2023). Linking microbial contamination to food spoilage and food waste: The role of smart packaging, spoilage risk assessments, and date labeling. *Frontiers in Microbiology*, *14*, 1198124. https://doi.org/10.3389/fmicb.2023.1198124
26. Kilcher, S., Loessner, M. J., & Klumpp, J. (2010). Brochothrix thermosphacta bacteriophages feature heterogeneous and highly mosaic genomes and utilize unique prophage insertion sites. *Journal of bacteriology*, *192*(20), 5441-5453. https://doi.org/10.1128/jb.00709-10
27. Liu, S.-Q. (2003). Practical implications of lactate and pyruvate metabolism by lactic acid bacteria in food and beverage fermentations. *International journal of food microbiology*, *83*(2), 115-131. https://doi.org/10.1016/s0168-1605(02)00366-5
28. Luz, C., Ferrer, J., Mañes, J., & Meca, G. (2018). Toxicity reduction of ochratoxin A by lactic acid

bacteria. *Food and chemical toxicology*, *112*, 60-66. https://doi.org/10.1016/j.fct.2017.12.030
29. Machida, M., Yamada, O., & Gomi, K. (2008). Genomics of Aspergillus oryzae: learning from the history of Koji mold and exploration of its future. *DNA research*, *15*(4), 173-183. https://doi.org/10.1093/dnares/dsn020
30. Marsh, A. J., O'Sullivan, O., Hill, C., Ross, R. P., & Cotter, P. D. (2014). Sequence-based analysis of the bacterial and fungal compositions of multiple kombucha (tea fungus) samples. *Food microbiology*, *38*, 171-178. https://doi.org/10.1016/j.fm.2013.09.003
31. McKillip, J. L., & Drake, M. (2004). Real-time nucleic acid–based detection methods for pathogenic bacteria in food. *Journal of food protection*, *67*(4), 823-832. https://doi.org/10.4315/0362-028x-67.4.823
32. McMeekin, T., Bowman, J., McQuestin, O., Mellefont, L., Ross, T., & Tamplin, M. (2008). The future of predictive microbiology: strategic research, innovative applications and great expectations. *International Journal of Food Microbiology*, *128*(1), 2-9. https://doi.org/10.1016/j.ijfoodmicro.2008.06.026
33. Meng, J., & Doyle, M. (1998). Emerging and evolving microbial foodborne pathogens. *Bulletin de l'Institut Pasteur*, *96*(3), 151-163. https://doi.org/10.1016/s0020-2452(98)80010-9
34. Nachamkin, I. (2002). Chronic effects of Campylobacter infection. *Microbes and infection*, *4*(4), 399-403. https://doi.org/10.1016/s1286-4579(02)01553-8
35. Nestor Bassolé, I. H., & Juliani, H. R. (2012). Essential Oils in Combination and Their Antimicrobial Properties. *Molecules*, *17*(4). https://doi.org/10.3390/molecules17043989
36. Priest, F., Goodfellow, M., Shute, L., & Berkeley, R. (1987). Bacillus amyloliquefaciens sp. nov., nom. rev. *International journal of systematic and evolutionary microbiology*, *37*(1), 69-71. https://doi.org/10.1099/00207713-37-1-69
37. Remize, F., & De Santis, A. (2025). Spore-forming bacteria. In *The microbiological quality of food* (pp. 157-174). Elsevier.
38. Robertson, L. J. (2018). Parasites in food: from a neglected position to an emerging issue. *Advances in food and nutrition research*, *86*, 71-113. https://doi.org/10.1016/bs.afnr.2018.04.003
39. Rosenthal, K. S. (2021). Introduction to virology. In *Practical Handbook of Microbiology* (pp. 703-722). CRC Press.
40. Russell, S., Fletcher, D., & Cox, N. (1995). Spoilage bacteria of fresh broiler chicken carcasses. *Poultry Science*, *74*(12), 2041-2047. https://doi.org/10.3382/ps.0742041
41. Sadeghi, M., Panahi, B., Mazlumi, A., Hejazi, M. A., Komi, D. E. A., & Nami, Y. (2022). Screening of potential probiotic lactic acid bacteria with antimicrobial properties and selection of superior bacteria for application as biocontrol using machine learning models. *Lwt*, *162*, 113471. https://doi.org/10.1016/j.lwt.2022.113471
42. Schwarz, V. (2023). A gardenful of microbes. *Yale University* https://teachers.yale.edu/pdfs/curriculum_pdfs/14, 6(04).
43. Singh, A., Singh, R., Bhunia, A., & Singh, N. (2003). Efficacy of plant essential oils as antimicrobial agents against Listeria monocytogenes in hotdogs. *LWT-Food Science and Technology*, *36*(8), 787-794. https://doi.org/10.1016/s0023-6438(03)00112-9
44. Singh, V. P. (2018). Recent approaches in food bio-preservation-a review. *Open veterinary journal*, *8*(1), 104-111. https://doi.org/10.4314/ovj.v8i1.16
45. Smid, E. J., & Lacroix, C. (2013). Microbe–microbe interactions in mixed culture food fermentations. *Current opinion in biotechnology*, *24*(2), 148-154. https://doi.org/10.1016/j.copbio.2012.11.007
46. Stavropoulou, E., & Bezirtzoglou, E. (2019). Predictive modeling of microbial behavior in food. *Foods*, *8*(12), 654. https://doi.org/10.3390/foods8120654
47. Steensels, J., Snoek, T., Meersman, E., Nicolino, M. P., Voordeckers, K., & Verstrepen, K. J. (2014). Improving industrial yeast strains: exploiting natural and artificial diversity. *FEMS microbiology reviews*, *38*(5), 947-995. https://doi.org/10.1111/1574-6976.12073
48. Tajkarimi, M., Ibrahim, S. A., & Cliver, D. (2010). Antimicrobial herb and spice compounds in food. *Food control*, *21*(9), 1199-1218. https://doi.org/10.1016/j.foodcont.2010.02.003
49. Tamang, J. P., Watanabe, K., & Holzapfel, W. H. (2016). Diversity of microorganisms in global fermented foods and beverages. *Frontiers in microbiology*, *7*, 377. https://doi.org/10.3389/fmicb.2016.00377
50. Thierry, A., & Maillard, M.-B. (2002). Production of cheese flavour compounds derived from amino acid catabolism by Propionibacterium freudenreichii. *Le Lait*, *82*(1), 17-32. https://doi.org/10.1051/lait:2001002
51. Threlfall, E. J., Ward, L. R., Frost, J. A., & Willshaw, G. A. (2000). The emergence and spread of antibiotic resistance in food-borne bacteria. *International journal of food microbiology*, *62*(1-2), 1-5. https://doi.org/10.1016/s0168-1605(00)00351-2
52. Vilela, A. (2019). The importance of yeasts on fermentation quality and human health-promoting

compounds. *Fermentation*, *5*(2), 46. https://doi.org/10.3390/fermentation5020046

53. Wang, Y., Wu, J., Lv, M., Shao, Z., Hungwe, M., Wang, J., Bai, X., Xie, J., Wang, Y., & Geng, W. (2021). Metabolism characteristics of lactic acid bacteria and the expanding applications in food industry. *Frontiers in bioengineering and biotechnology*, *9*, 612285. https://doi.org/10.3389/fbioe.2021.612285
54. Wang, Y., Zhang, W., & Fu, L. (2017). *Food spoilage microorganisms: ecology and control*. CRC Press. https://doi.org/10.4324/9781315368887
55. Yépez, A., Luz, C., Meca, G., Vignolo, G., Manes, J., & Aznar, R. (2017). Biopreservation potential of lactic acid bacteria from Andean fermented food of vegetal origin. *Food Control*, *78*, 393-400. https://doi.org/10.1016/j.foodcont.2017.03.009