Microbes in Food and Beverage Industry

15

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Abstract

Microorganisms play a crucial role in food spoilage and degradation. The unpleasant taste, odor and texture are the characteristics of spoiled food. However, despite being pathogenic, microorganisms play an important role in the production of many fermented food and beverages in household and food industries. Microbes are used in the fermentation of dairy products and development of alcoholic beverages. Yogurt, curd, sour cream, buttermilk, bread, and cheese are the basic examples of dairy products where microbes act as indispensable material for their production. Vegetables are also fermented to increase their shelf life and flavor. Pickles (cucumbers), sauerkraut (cabbage), soy sauce (soybeans), kimchi (Chinese cabbage), olives (green olives), etc. are examples of fermented vegetables. However, species of *Saccharomyces* play an inevitable role in the production of wine, beer, brews, champagne, etc. Today the demand for fermented food, probiotics and alcoholic beverages is increasing due to their taste and health benefits. This chapter reviews the different microorganisms which are involved in the production of food and beverages at industrial scale, and it also highlights the advantages of using the following microorganisms in food and beverage sector.

Keywords

Microbes · Food industry · Beverage industry · Yeast · Bacteria · Mold

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15.1 Introduction

Microorganisms in food vary from bacteria to fungi. They survive by consuming the food constituents, i.e., carbohydrates, and utilize them in their metabolic pathways. These organisms can be divided as those that can cause spoilage and decrease food and beverage quality and those that aid in the processing of the foods and beverages and aid in preservation. Spoilage microorganisms are introduced into food from raw materials or from the industrial environment (Rawat 2015). These microorganisms contribute to major food loss in various food industries. These microorganisms are present in the environment and also on the surface of various vegetables and food. The major reason of the loss is mishandling during post-harvesting period. The growth of these microorganisms is favored by intrinsic and extrinsic factors. The intrinsic factors that favor their growth include water activity of the food material, pH, moisture, and nutrient content, while the extrinsic factors include temperature, relative humidity, and presence of gases or oxygen (Rawat 2015). The microbes also play a vital role in the assessment and maintenance of food safety and its quality in the industries (Martorell 2005).

Microbes play the most important role in the fermentation process, where they convert simple sugars to ethanol, acid, and carbon dioxide, such as in beer and wine industry or in yogurt and cheese industry. They are also used in the bakery industry to produce bread (Beresford et al. 2001). Microorganisms play an essential role in the processing of a range of foodstuffs in the industrial food products sector.

For the prevention of diseases in humans, antibiotics play a vital role. *Penicillium notatum*, a bacterium which produces penicillin, is such an example for the industries which use bacteria to develop antibiotic. *Saccharomyces cerevisiae* produce and retain beverages such as brandy, rum, whiskey, and beer. Enzymes such as lipase are also manufactured by microorganisms. *Saccharomyces cerevisiae* manufactures ethanol as one of the most essential industrial chemicals. The fungus *Trichoderma* prepares immunosuppressive agents such as cyclosporine. To preserve packed foods in food processing technology, a few microorganisms are used. The food usually consist lots of bacteria that may be useful to some including that which preserve food via fermentation products and others that cause human disease or spoilage of food.

The most important groups of microorganisms in food production include lactic acid bacteria, largely those of the genera *Pediococcus*, *Vagococcus*, *Leuconostoc*, *Oenococcus*, *Carnobacterium*, *Lactobacillus*, *Enterococcus, Lactococcus*, and *Streptococcus*. Carbohydrate fermentation combined with substrate-level phosphorylation is an important characteristic of lactic acid bacteria. The LAB is a source of growth inhibitors (bacteriocins) and large amounts of lactic acid, helping the flavor and texture of fermented products and inhibiting food spoilage. These bacteriocins are peptides which are ribosomically formed and extracellularly set free by bacteria. A variety of LAB are beneficial to people and animal, while others ruin beer, wine, and meats. For thousands of years, fermented milk products have been produced, but the microbiological basis of these fermentations has only been clarified last year (Beresford et al. 2001). Food microorganisms such as lactic acid bacteria are

Table 15.1 List of main microbes involved in food and beverage industries

S. no.	Microorganisms	Types of microorganisms	Food or beverage
1.	*Acetobacter aceti*	Bacteria	Chocolate and vinegar
2.	*Acetobacter cerevisiae*	Bacterium	Beer
3.	*Candida colliculosa*	Fungus	Cheese, kefir
4.	*Streptococcus*, *Leuconostoc*, *Lactobacillus*	Bacteria	Buttermilk
5.	*Streptococcus thermophiles*, *Lactobacillus bulgaricus*	Bacteria	Yogurt
6.	*Penicillium camemberti*	Fungus	Camembert cheese
7.	*Leuconostoc*, *Lactobacillus* species	Bacteria	Sauerkraut
8.	*Saccharomyces cerevisiae*	Yeast	Bread
9.	*Aspergillus niger*	Fungus	Citric acid
10.	*Acetobacter acute*	Bacteria	Acetic acid
11.	*Saccharomyces cerevisiae*	Yeast	Ethanol (green petrol)
12.	*Aspergillus oryzae*	Fungus	Soy sauce
13.	*Lactobacillus kimchii*	Bacteria	Kimchi
14.	*Mucor hiemalis*	Fungus	Soybean curd
15.	*Zymomonas mobilis*	Bacteria	Palm wine

predominant starter cultures that are used in processing fermented foodstuffs to get texture, flavor, and appearance. Current examples of fermented foods are milk products such as cheese, sour cream, and yogurt, meat products, and vegetable products (pickles, sauerkraut, olives) for which the commercial starter cultures are used. In order to be effective during the fermentation process, starting cultures should be controlled by microflora that is normal and produces the desired fermentation end products. A wide variety of activities such as lactose metabolism, proteinase activity, transport of oligopeptides, bacteriophage resistance mechanisms, production and immunity of bacteriocin, resistance of bacteria, manufacture of exopolysacchrides, and use of citrate are carried by plasmids containing a bacterial content of lactic acid. Progress in molecular technology has allowed superior strains of starter culture to be constructed with respect to food fermentation. Such strains have improved their immunity to bacteriophage and genetic stability and decreased variability, and performance is unpredictable. The incorporation of probiotic microorganisms to provide consumers with health benefits is yet another use of beneficial microorganisms in foods. The use of fermented foodstuffs has risen dramatically over the past two decades. Fermenting microorganisms (starter culture) used for food processing have been produced and available to meet this demand. This involves the creation of new and improved genetic engineering strains (Ali 2010) (Table 15.1).

15.2 Microorganisms Involved in Food and Beverage Industries

15.2.1 Molds

Mold generally refers to fungus that grows in the form of multicellular filaments called hyphae, and whole mass of these hyphae is known as mycelium. Fungi are eukaryotic and heterotrophs, who get nutrition from external environment or sources through absorption. However, the single-celled fungi are referred to as yeasts. The fungi are quite fuzzy or cottony in appearance. Molds are easily distinguishable from bacteria. They require less moisture as compared to bacteria and yeast. The minimum water activity for germination of spores has been deduced to be in between 0.62 and 0.93. The reduction in water activity can result in decrease in growth rate. Majority of the molds are considered to be mesophilic. The optimum temperature for molds is 25–30 °C. Although some molds are capable to grow at freezing temperature too. The reason why molds grow on the surface of spoiled food is that they require or need free oxygen for growth. Molds are able to grow over a wide range of pH. Molds have significant use in industries in manufacture of different foods. Molds majorly play part in cheese production (e.g., Roquefort, Camembert). They also play important part in the production of bread, Quorn, soy sauce, etc. Molds are widely used in pharmaceutical industry (Barnett 2003; Dagnas and Membre 2013).

Molds usually found on meat and poultry are *Aspergillus*, *Botrytis*, *Cladosporium*, *Fusarium*, *Geotrichum*, *Monilia*, *Mortierella*, *Mucor*, *Neurospora*, *Oidium*, *Oospora*, *Penicillium*, *Rhizopus*, *and Thamnidium*. These molds are easily detectable on other food components also. Molds being a spoilage microorganism also aid food and beverage industries at various levels (Dagnas and Membre 2013).

Molds have remarkable use at industrial scale in the production of different kinds of cheese. Blue-veined cheese is produced by the introduction of *Penicillium roqueforti.* Fungi participate in ripening and in enhancement of flavor and color of food. *P. nalgiovense* is used as starter culture for cured and fermented meat products. This species of mold promotes notably flavor of product, controls moisture loss, and arrests the development of mycotoxigenic fungal species. However, *P. camemberti* produces enzymes, some of which are associated with casein hydrolysis during cheese ripening, which aids in the development of flavor and texture of Camembert and Brie cheeses (Lasztity 2011; Smit et al. 2005). *Aspergillus flavus* is used in the production of various cheeses and soy sauce. *Rhizopus* is able to metabolize starch into glucose and then directly converts it into alcohol. *Mucor indicus* has a great possibility to be used as a nutritional rich source, e.g., fish feed. *Aspergillus niger* aids in the production of citric acid at industrial scale (Saxena 2015). Many fermentations also include species from *Neurospora*, *Monascus*, and *Actinomucor*. Typical products from temperate areas (cheese or soy sauce) are species of *Aspergillus* and *Penicillium*, while *Rhizopus, Amylomyces*, and *Mucor* are typical products from mainly tropical areas (tempe, tape). The foods developed by mold fermentation range from mold-rich cheeses and meats; delicious staples, such as tempe; flavoring foods including soy sauce; and sweet foods like candy and brem cake is important (Smit et al. 2005).

15.2.2 Yeasts

Yeasts are unicellular fungi that dwell in wide habitats. They are mostly found on the leaves and flowers of plants, soil, and water. They are also found on the skin of animals and sometimes in the intestinal tract as parasitic organisms or symbiotic organisms (Sláviková and Vadkertiová 2003). These organisms divide asexually or sexually, asexually by budding, i.e., in *Saccharomyces*; direct division (fission), i.e., in *Schizosaccharomyces*; or growing as filaments (mycelium). Sexual reproduction is in the form of asci that contain eight haploid ascospores. The ascospores fuse with neighboring nuclei and divide by vegetative division or some fuse with other ascospores (Heslot and Gaillardin 1992).

Yeast was used in 6000 BC to make beer, wine, and bread by the Egyptians and later adopted by the Romans. This is how yeast is being currently used in the industry for alcoholic fermentation and baking. Their limitless capacity to break down simple sugars to produce alcohol, fats, enzymes, and heterologous proteins allows its application in the industry (Halasz and Lásztity 1991).

In baking, the most common yeast used is *Saccharomyces cerevisiae.* It is used as a leaving or raising agent. This occurs when the organisms break down the sugars present in the dough producing carbon dioxide gas that causes bubble formation in the dough causing it to rise. In brewing, several yeast species are used to brew beer. It is a very good protein source and a nutrient source rich in vitamin B. The products of brewer's yeast are normally found in liquid form, in powders, or in tablets. This is made from mainly cereals, i.e., barley, and they ferment the carbohydrates (sugar) to produce alcohol. In wine making, it is formed by the action of the yeast by fermentation on the sugars present in grape juice producing carbon dioxide as its by-product. Mostly, the yeast can be found on the grape skin, and it is sufficient to allow for the fermentation to occur. Other fermentative processes where yeast can be used are in soy sauce production (Otero et al. 1998; Corran 1975).

In dairy products, yeast is mainly used to enhance flavor and texture in manufacture of fermented milks, i.e., kefir and koumiss, and also in cheese production. They are being applied as secondary starter cultures in enriching the growth of lactic acid bacteria and boosting aroma of food substances. The mostly used species are *S. cerevisiae*, *D. hansenii*, and *K. marxianus* among others (Tofalo and Suzzi 2016). Starter culture includes yeasts for the production of certain kinds of fermented products such as cheese, bread, vegetable products, vinegar, etc. As alternative protein sources that meet requirements in a world of low production and rapidly developing populations, the importance of yeasts in food technology and human nutrition renders the development of food yeasts. There are also remarkable advantages of single cell protein (SCP) microorganisms relative to traditional protein sources (soya or meat). The advantages are well established. The high levels of protein in microorganisms are low contributing to the quick development of biomass, which can continue and is independent of environmental conditions. Yeasts can grow with or without oxygen as an optional anaerobe. Industrial alcohol and spirit such as brandy, rum, and tequila are processed by distillery yeast. Probiotic properties of yeasts have been documented and shown in the way of survival by

gastrointestinal pathogens including *E. coli*, *Salmonella*, and *Shigella*. More precisely *S. boulardii* is a thermophilic nonpathogenic yeast used as a probiotic supplement for a wide range of gut disorders, such as diarrhea for over 50 years. The torula yeast is produced in sugar and mineral blends generally comprising molasses, celluloses, or brewing by-products. In the food industry, table olive is a major fermenting product. It cannot be ingested directly and must be processed depending on some special features such as the oleuropein bitter component, low sugar content, or high oil levels. Microorganisms such as lactic acid bacteria and yeast play significant roles in the production of table olives.

15.2.3 Bacteria

Bacteria are prokaryotic microorganisms present widely in natural environment. Bacteria divide at very high rate. Some of the bacteria can sustain themselves in extreme conditions. The minimum water activity for multiplication of bacteria is 0, and the optimal temperature for bacterial growth is 37 °C. Some species of bacteria are pathogenic or disease causing in nature, whereas some are involved in food spoilage. *Clostridium botulinum*, *C. perfringens*, and *Bacillus cereus* are known to cause food intoxications (Kirkland and Fierer 1996).

Bacteria play a vital role in the production of food and beverages in food industries as well as in household. Lactic acid bacteria play chief role in a variety of fermented drinks and products. This group of bacteria is able to break down carbohydrates and produce lactic acid, is involved in the degradation of proteins and lipids and manufacturing alcoholic beverages, and helps in the development of curd, yogurt, and fermented milk and is also involved in the processing of fermented fish, meat, vegetables, etc. Besides, they also help in enhancing the flavor, texture, and nutritional value of the fermented food (sauerkraut, kimchi). *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *and Streptococcus* are the major LAB genera that are involved in food and beverage production.

However, in the production of wine (malolactic fermentation) and rice wine, *O. oeni* and *Lb. sakei* bacteria are involved (Saxena 2015). Many microorganisms have characteristics that can support food production and transformation. A variety of fermenting foods from crude animals and plants are produced by many food microorganisms. The fermentation of these microorganisms is the result of the acidic and partially organoleptic properties of fermentation products. The foods such as ripened cheeses, fermented sausage, sauerkraut, and pickles have not only a considerably longer life span than their raw materials but also the flavor and aroma characteristics that fermented organisms contribute directly or indirectly. LAB are the main entities engaged in dairy fermentation. Milk fermentations depended naturally on the LAB in raw milk before the availability of starter cultures.

15.3 Health Benefits of Microbes in Food

Benefits of microbial fermentations:

– **Microbial fermentation**

Various strains of bacteria and fungi are being used during food fermentation that yields various sorts of cultured products with enhanced flavor, taste, and aroma.

The following are examples of fermented products:

1. In dairy products, fermented milk products. During milk coagulation, various types of cheese are produced, e.g., soft unripened and ripened and various hard types. Mostly lactic acid–fermenting bacteria are used.
2. Vegetable, e.g., sauerkraut, pickles, and olive production.
3. Meat products, e.g., fermented sausage preparation.
4. Bread and alcoholic beverages, e.g., wine, beer, cider, and vinegar. During alcoholic beverage production, different yeast strains are used by fermentation of cereals and grains. Wines can be produced by action of molds on rotting grapes.

These microorganisms are used differently among various food industries, i.e., various fermentation industries, for example, breweries and vinegar manufacturers culture their own strains and inocula. In the dairy industry, meat industry, and bakeries, cultures are mostly obtained from suppliers that produce high-quality food ingredients (Hansen, 2004; Mogensen et al. 2002).

– **Food additives from microorganisms**

Some microorganisms are used for the production of processing aids that are used in the food industry, i.e., lactase prepared from strains of *Aspergillus niger*, *Aspergillus oryzae*, and *Kluyveromyces lactis*. It is mainly used in the preparation of low-lactose or lactose-free foods for lactose-intolerant individuals. In lactase-treated milk, its advantage is that there is increased sweetness of the milk and hence sugar addition can be avoided in flavored milk manufacture. Lactase can also be used in ice cream, yogurt, and frozen dessert industries to enhance sweetness, creaminess, and digestibility. Studies also revealed that cheese prepared from hydrolyzed milk ripens faster than that prepared from normal milk (Neelakantan et al. 1999). Other food additives include alkaline phosphates, microbial lipases, and flavor enhancement, i.e., after fermentation.

– **Preservation**

Microorganisms can also be used in the preservation of the food products, i.e., enhancing the shelf life of food and beverage products (Chen and Hoover 2003). The production of antimicrobial products from microorganisms, i.e., lactic acid-producing bacteria, enhances the shelf-life such as bacteriocins, organic acids, hydrogen peroxides, carbon dioxide, and diacetyls.

– **Probiotic and functional food production**

These types of products allow the consumer to eat or drink healthy foods or drinks without bringing a change in their diet. Probiotics have been defined as "live microorganisms which when administered in adequate amounts confer a health benefit on the host" (FAO/WHO 2002). These organisms should have the ability to survive the gut passage, i.e., acid tolerant and resistance to bile. These microorganisms must be safe and effective and also maintain effectiveness and potency for the time period of the product's shelf-life (FAO/WHO 2002; Saad et al. 2013).

Various genera of microorganisms are utilized as probiotics. The frequently used strains are lactic acid bacteria, e.g., *Lactobacillus* and *Enterococcus* and from the genus of *Bifidobacterium* (Ouwehand et al. 2002; Saad et al. 2013; Bintsis 2018). Currently, probiotics main applications are in dairy product production, e.g., cheese, yogurt, and ice cream. Probiotics oldest source is from fermented dairy products and has strains of *Lactobacillus* and currently has been added to cooked pork meat, fruit juices, chocolate, and chewing gum (Bernardeau et al. 2006; Ouwehand et al. 2002; Ranadheera et al. 2010).

15.4 Drawbacks of Using Microbes in Food and Beverage Industries

Although microorganisms play a vital role in the production of many edible products in food and beverage industries, some of the researches have concluded the harmful impacts by consumption of fermented products. During fermentation of some non-alcoholic food, the microorganisms produce alcohol as by-product. Soy sauce is a fermented food which contains alcohol in small quantity. Lactic acid and ammonia are other products of fermentation, which are considered to affect human health. The processed food possesses fewer nutrients as compared to the food which is consumed in their natural, fresh, and unprocessed state. According to the research, the fermented food usually contains less vitamin B12 (Kharobe 2018).

Few microorganisms are capable of releasing toxins such as biogenic amines and aflatoxins. Dairy products are perishable commodities and highly vulnerable to be contaminated by pathogens. Sometimes proliferation occurs during manufacturing which in turn causes sporadic cases or outbreaks of disease (Fernández et al. 2015).

Bifidobacteria is a vital group of nonstarter microorganisms that are included in manufacturing of some dairy products, such as fermented milks; their proliferation will add up to increase in the level of lactate and acetate in final products (Cremonesi et al. 2012).

Microorganisms majorly produce beneficial compounds during dairy fermentation, but in some cases metabolic activities result in the discharge of toxic substances. Mycotoxins produced by some fungi and biogenic amines mainly due to the metabolic activity of some *Lactobacillus* bacteria are the two types of toxic compounds that have been found in dairy products. *Aspergillus*, *Fusarium*, and

Penicillium are the three genera of filamentous fungi involved in releasing mycotoxins (Delavenne et al. 2011).

15.5 Conclusion

Microbes in the food and beverage industry can be monitored to produce a modified product, i.e., fermented food and beverages, or if not checked, then they can be a leading cause of food deterioration after processing. Raw food materials before processing should be decontaminated to reduce risk of spoilage and contamination. During processing, the microbes used for production of food should be monitored and given optimum conditions, and contamination from outer sources should be reduced. There are various methods that can be used to get rid of spoilage-causing microorganisms, i.e., application of high temperature, pH, or aseptic conditions (Martorell 2005). Different strains of useful microbes are used for various purposes, and these microbes should be handled separately.

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