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REVIEW

MICROBIAL SPOILAGE IN FOOD AND ITS AGENTS, COLD CHAIN AND MEASURES TO PROLONG MICROBIAL SPOILAGE

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ABSTRACT

Today, many different methods are applied for the correct use of foods and to prevent their deterioration. Ensuring healthy conditions for people in food consumption and consumption of healthy foods is very important for human welfare. In this study, food spoilage, the factors that cause food spoilage, its effects on a global basis, food transport systems (cold chain) and measures that prevent or delay food spoilage are discussed.

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1. INTRODUCTION

Throughout the beginning of human history, food has ranked high among fundamental requirements. Being healthy is an important consideration when choosing what to eat. Because of this degeneration, it is just as crucial as the proper application of food and its storage. Food rotting can lead to issues with health, money, and credibility. The metabolic breakdown that occurs when food spoils makes it unfit for human ingestion. There are a few key factors to consider while investigating the causes of food rotting. This is mostly due to degradation on a microscopic, chemical, and physical level, as well as food decay and other animal variables. (Di Renzo *et al*. 2015; Anwer *et al*. 2017; Sevindik and Uysal, 2021).

2. ABOUT MICROBIAL SPOILAGE

Biologically speaking, microbes are one of the most noticeable causes of food spoilage. Growth of bacteria that generate by-products and create enzymes is a major contributor to food spoilage, according to microbiologists. When it comes to the rotting of protein-rich foods like meat, poultry, fish, shellfish, milk, and some dairy products, bacteria are typically the most problematic pathogens. To a lesser extent than bacteria, yeasts and moulds contribute to the degradation of items in this category. The ecological balance and tolerance ranges of yeasts and moulds rely on it, and despite its sluggish effects, it is among the causes of microbial degradation. Furthermore, it is ecologically significant in the microbial state of potentially perishable items, such as fruits and vegetables. To a greater extent than ever before, the microbiological condition in fruit and vegetable rotting is accelerated by the interplay of soil, air, irrigation water, insects, and animals. Microorganisms; they are always in motion, moving from one food item to another through cross-contamination with other foods, equipment, or humans. (Gram *et al*. 2002; Martínez *et al*. 2011; Kreyenschmidt and Ibald, 2012; Moreira *et al*. 2016; Ibrahim *et al*. 2021; Sevindik and Uysal, 2021).

3. THE GLOBAL PROBLEM IN FOOD SPOILAGE

In addition to the obvious health risks, food rotting also has a significant financial impact on the food industry, as well as on customers and merchants throughout the world. The actual monetary cost of economic losses is murky at best, but the damage they do is constantly a topic of discussion. FAO calculates annual product loss at around 1.3 billion tonnes. In terms of percentages, the most wasteful items are fresh produce (19.6%), liquid milk (18.1%), cereal products (15.2%), and sweeteners (12.4%), mostly sugar and high fructose corn syrup. Spoilage brought on by microorganisms accounts for a sizable portion of the waste (Luo *et al*. 2012; Cichello, 2015; Mageswari *et al*. 2015; Van Long *et al*. 2016; Snyder and Worobo, 2018; Odeyemi *et al*. 2018). As we consider health issues, we find that this one persists everywhere, while its prevalence is greatest in less developed nations. The Reference Group on the Epidemiology of the Foodborne Disease Burden at the World Health Organization estimates 582 million instances of foodborne disease and 351,000 deaths globally in 2010. Those with weakened immune systems, infants and young children, and the elderly are at greater risk of becoming unwell from consuming contaminated food. Food rotting is a worldwide issue that has not been solved despite advances in food science and technology (Redmond and Griffith, 2006; Wills *et al*. 2015; Biranjia-Hurdoyal and Latouche, 2016).

4. MICROBIAL SPOILAGE

When looking at the literature studies for microorganisms that play a role in microbial spoilage in foods; Bacteria, yeast and molds are the main microorganisms.

Bacteria

Bacteria that cause microbial spoilage in foods are usually spore-forming bacteria. Among these bacterial groups, generally pathogenic microorganisms, *Enterobacter* sp., heterofermentative lactic acid bacteria, *Propionibacterium cyclohexanicum*, *Pseudomonas* spp., *Erwinia* spp., acetic acid bacteria, *Clostridium* spp., *Alicyclobacillus acidoterrestris* and *Bacillus* spp. (Raybaudi-Massilia *et al*. 2009; Bevilacqua *et al*. 2011; Sevindik and Uysal, 2021). If we examine the status of some of these microorganisms, lactic acid bacteria are gram positive, rod-shaped and catalase negative. Heterofermentative lactic acid bacteria are especially involved in the deterioration of fruit juices between foods. Acetic acid bacteria are involved in microbial spoilage due to their ability to grow at low pH and low nutrient levels. *Alicyclobacillus* spp., is an endospore producing microorganism. Especially; It causes deterioration in areas such as canning, bakery, beverage industry, dairy. *Propionibacterium cyclohexanicum*, as the genus *Alicyclobacillus* spp.,, contains -cyclohexyl undecanoic acid in the cell membrane but lacks endospore production. This live is included in the sources where it comes out alive even from pasteurization processes. *B. polymyx*, *B. marcesens* and *B. coagulans*, which are especially included in *Bacillus* spp. cause microbial spoilage in some vegetables and fruits. Microorganisms in *Clostridium* spp. are organisms that are involved in the degradation of gram-positive and anaerobic endospores. Among the pathogenic microorganisms, especially *Yersinia* spp., *Cronobacter* spp., *Shigella* spp., *Vibrio* spp., *Salmonella* spp., and *Escherichia coli* have been reported (Kusano *et al*. 1997; ICMSF, 1998; Stratford *et al*. 2000; Walls, 2000; Silva and Gibbs, 2004; Worobo and Splittstoesser, 2005; Walker and Phillips, 2008; Smit *et al*. 2011; Steyn *et al*. 2011; Daryaei and Balasubramaniam, 2013; Sevindik and Uysal, 2021).

Molds

Molds are aerobic organisms that usually thrive at low pH and high sugar concentrations. Generally, the spreading areas are very large. They usually produce spores that are carried in the air and need oxygen for their metabolic processes. Molds play a role in the microbial spoilage process, especially in products such as vegetables, fruits, bread and beverages. Microbial spoilage of molds is high in all areas from the first processing of the food to the last processing. Among the microbial deterioration conditions, quality loss in the product usually comes first. Among the molds, the most notable genera are *Aspergillus* spp., *Wallemia* spp., *Mucor* spp., *Endomyces* spp., *Geotrichum* spp., *Cladosporium* spp., *Botrytis* spp., *Fusarium* spp., *Rhizopus* spp., *Penicillium* spp., *Hyphopichia* spp., and *Chrysonilia* spp. known as. In addition, some of these molds produce mycotoxins that threaten human health to a great extent (Delage *et al*. 2003; Moss, 2008; Wareing, 2016; Garcia and Copetti, 2019; Sevindik and Uysal, 2021).

Yeasts

Yeasts are a subset of a large group of organisms called fungi, which also includes molds and fungi. Yeasts can grow with or without oxygen. In most of the literature, yeasts are mentioned as beneficial in terms of fermentation (bread making, beverage and other conditions). However, there are cases of microbial deterioration. For the development of yeast, the water activity must be low, the pH value must be low and the sugar concentration must be high. More than 110 yeast species are associated with food and

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food products. The deficiencies in the sanitation process are at the root of the deterioration of the yeasts. Among the yeasts that cause spoilage; *Dekkera/Brettanomyces*, *Zygosaccharomyces*, *Saccharomyces* spp., *Rhodotorula* spp., *Candida* spp. and *Pichia* spp. (Lenovich *et al.* 1988; Fleet, 1992; Loureiro and Malfeito-Ferreira, 2003; Stratford, 2006).

5. MICROBIAL SPOILAGE FACTORS

Water Activity

Water activity is expressed with "AW". Water activity is defined as the ratio of the vapor pressure of the food to the vapor pressure of pure water. The optimum water activity is between 0.995 and 0.980. Water activity is the basis of microbial growth in foods. This can be avoided with the help of hardening, adding sugar or salt and drying processes. However, if the optimal water activity range is changed or other factors that will make the activity suitable are not applied, microbial spoilage in foods may accelerate (Abbas *et al.* 2009; Kreyenschmidt and Ibald, 2012; Baron and Gautier, 2016; Sevindik and Uysal, 2021).

pH

The pH value of foods is very important for microbial spoilage. Generally, pH-neutral values provide optimal conditions for microbial organisms. But there are also microorganisms that can tolerate a pH outside these ranges. Example; *Lactobacillus* 3.0-4.4, *Acetobacter* 2.8, Neutrophils 5-8, Acidophiles 5.5, Alkaliphiles 8.5 and yeasts 4.5-7. pH changes in foods can trigger microbial spoilage (Koutsoumanis *et al.* 2006; Rousk *et al.* 2009; Baron and Gautier, 2016; Sevindik and Uysal, 2021).

Temperature

When it comes to deterioration from microorganisms, temperature is a crucial factor. For the simple reason that food spoils in direct proportion to the temperature at which it was prepared, transported, and stored. Each psychrophile, mesophile, and thermophile prefers a slightly different temperature range. Most food spoilage bacteria and diseases in humans and animals belong to the mesophile group. Psychrophiles thrive between 20 and 30 degrees Celsius. Important food-borne diseases such as Yersinia enterocolitica and Listeria monocytogenes, as well as spoiling bacteria such as *Pseudomonas* spp., are all psychrophiles. For mesophiles, the ideal range is between 30 and 45 degrees Celsius. *E. coli*, *Salmonella* spp., *Clostridium botulinum*, and *Staphylococcus aureus* are examples of prominent mesophiles. For thermophiles, the sweet spot is between 55 and 75 degrees Celsius. Among the most significant thermophiles are *Geobacillus stearothermophilus* and *Clostridium thermosaccharolyticum* (Sautour *et al*. 2002; Davidson and Critzer, 2011; Oliveira *et al*. 2015; Sevindik and Uysal, 2021).

Property of Food

Some food products such as egg shells, nut shells, fruit shells and bran are not easily degraded by microbial organisms without processing. If deterioration conditions are observed, these deteriorations are usually from the surface part. However, when these foods are put into practice according to their usage areas, the microbial spoilage process can be observed earlier than the specified times. Apart from these foods; Foods such as meat products, fruit drinks, liquid meals, and animal-based beverages tend to deteriorate more quickly than other foods (Pin *et al*. 1999; Modi, 2009; Speranza *et al*. 2010; Baron and Gautier, 2016).

Food Content

Substances such as protein, carbohydrates and fat in the content of foods are targeted and affected in the case of microbial

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deterioration. Eggs, fish, meat, and many other plant and animal products are rich in protein. Many of these products are targeted by proteolytic organisms and are near-perishable food products. Of the carbohydrate products, those that are prone to fermentation are a clear target for microbial microorganisms. Jam types, pasta types and bread types can be given as examples for this situation. Fats, on the other hand, are prone to microbial degradation by lipolytic organisms. Sour and unpleasant aromas occur as a result of microbial degradation of oils (Singh and Anderson, 2004; Modi, 2009; Nobmann *et al*. 2009; Howell, 2015).

Other Triggers

When looking at other triggering conditions in microbial spoilage; Since the deterioration process in seafood and animal foods is seen quickly, as a result of the deterioration of these products, other foods around these products also go through the microbial deterioration process. Dirty water that comes into contact with food also causes microbial spoilage. In order to prevent this situation, clean water should be preferred. It helps to occur microbial spoilage in most equipment used for food when non-sterile. It is also effective in terms of direct contact with foods and contaminating other foods around these foods. Another factor that triggers microbial spoilage is the environment in which the food is found. If food is close to garbage or other waste products, then it promotes microbial spoilage (Collins, 1997; Kaferstein et al. 1997; Wheeler et al. 1999; Uysal and Lekesiz, 2022).

6. COLD CHAIN

Food safety is the system cycle that will prevent biological, chemical and microbiological factors that may cause diseases caused by food spoilage during the processing, preparation, storage and supply stages of food from field to consumption. Compliance with hygiene rules in the production of foodstuffs and reaching the consumer without spoiling during the supply chain are among the critical control points (Barrett, 2010).

In the food sector, spoilage and growth of germs are typically avoided thanks to the cold chain. At specific temperatures, the chemical structure of various components in the structure of pharmaceuticals degrades, hence it is important to maintain these low temperatures in the pharmaceutical sector (Selamoglu, 2021). In order to keep food goods in compliance and qualities with "food safety" standards at all phases from manufacture to consumption, including shipment, storage, and display, "obligatory" cold storage, cold transportation, and similar techniques must be performed. Its goal is to make sure that people who buy food from stores aren't putting themselves in harm's way (Likar and Jevsnik, 2006). Manufacturers of food products have certain obligations that are spelt out in law. Manufacturers are liable for ensuring that food items remain at the required temperature throughout the supply chain, from initial shipment to final consumption. Foods that must be refrigerated in order to keep for longer periods of time are required by law to follow a protocol known as the "cold chain" (Montanari, 2008).

Food deterioration is caused by microorganisms that may proliferate at a variety of temperatures. As a result, the items must be kept at the appropriate temperatures as indicated on the box. Food deterioration is caused by microorganisms that have varying reproduction temperatures (Lin *et al*. 2020). As a result, the items must be kept at the appropriate temperatures as indicated on the box. Materials that are easily damaged by changes in temperature and humidity require extra care when being transported. If these precautions are not taken and proper air conditioning conditions are not

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provided, the products may be seriously damaged. For example; Cold chain food logistics is very important for the safe transportation of food materials that are at risk of deterioration. By ensuring that the temperature and humidity values at which the products will be stored are preserved until the delivery time, they preserve their freshness and ensure that they are delivered to consumers (Keenan *et al*. 2001). In addition, cold chain transportation is very important in terms of accessing the transported food materials. Medicines and vaccines are transported in this way, as well as basic food supplies. In other words, the cold chain has important functions in terms of the activities of the health sector (Cole *et al*. 2018).

Cold chain logistics companies have knowledge and experience about the transportation conditions of perishable products. Working in an integrated way in the supply chain and constantly controlling the products is the most important key of the cold chain. Depending on the type of perishable product being transported, safety, temperature, humidity, packaging and labeling conditions vary; Therefore, it is necessary to work meticulously. Logistics companies also benefit from technology in this regard. Data science also helps companies in this area (Wakeland et al. 2012). It provides information about the storage conditions and shipping routes of perishable products together. Thanks to this information, companies can make more accurate decisions about the vehicle, timing, transportation and equipment selection to be used. Cold chain technologies are used to reduce possible risks and a safe environment is created for perishable products. As a result, the products are delivered to the delivery points in an appropriate and healthy way, keeping their freshness on the first day (Wheeler and Von Braun, 2013).

The cold chain is used to convey perishable commodities. Foodstuffs, flowers, plants, eggs, fish, live animals, medications, and vaccinations are all examples of perishables. Seafood, meat, and frozen goods are particularly vulnerable to cooking temperatures (Korucuk, 2018). Food safety includes meeting the standards necessary for transporting these items to restaurants, distributors, or consumers. Little disruptions and errors in cold chain management can pose a significant risk to food quality and safety. Due to the gravity of the situation, it is crucial to employ appropriate technological means and provide prompt, adaptable responses to any difficulties that may arise (Zulkefly *et al*. 2021). Products carried along the cold chain must meet the requirements set for them. In the absence of proper storage, the items' quality and performance may degrade. The following categorization is possible depending on the level of travel involved: (İpekçi and Tanyaş, 2021):

- Dull (-18 to -25 degrees)
- Cold (+2 to +8 degrees)
- Cool (+8 to +15 degrees)
- General (+15 to +25 degrees)

Cold chain logistics, which is the ideal method for the transportation of perishable cargo products, has many advantages. With perishable cargo transportation, you can transport your goods such as food products, medicines, flowers in a quality and healthy way. It also provides safe transportation of perishable products to any point in the world. In this way, the products maintain their freshness when they reach their destination, ensure the import and export transactions of sensitive products and minimize possible risks during transportation (Ji and Guo, 2009). It offers the ideal temperature for perishable products that need to be transported at different temperatures. Maximum speed and safety can be achieved with cold chain transportation (Yu *et al*. 2021).

As a result, cold chain transportation is a special transportation method that aims to distribute products that are at risk of deterioration by using advanced technologies with air conditioning. It has an important place in the transportation of perishable products, especially in the food sector. Thanks to its air-conditioning feature, it protects products that are at risk of deterioration from environmental factors and ensures that they are delivered fresh and safely even to very long distances (Shashi *et al.* 2018). It can be integrated into different transportation modes with solutions developed for vehicles used in air, road and sea transportation. Cold chain logistics is frequently preferred with the solutions it offers for special heat and humidity conditions for perishable products. Logistics companies that carry out cold chain transportation are knowledgeable in the regulation of appropriate storage conditions and the transportation of heat-sensitive products. The key to this technology is integrating and controlling various elements of the supply chain. This control requires both information and food safety data. These data are also shaped by food types and constantly change (Taoukis *et al*. 2016). For this reason, cold chain logistics companies benefit from smart technologies and data science. It also meaningfully brings together data science, shipping networks, and preservation instructions of food conditions. The aggregated data provides logistics companies' transportation planners with the ability to make dynamic, rational decisions about timing, choosing the right equipment, and transportation methods. As a result, planners use new technologies to reduce risks on cold chain logistics and deliver food to suppliers and consumers with maximum safety and appropriate conditions (Castiaux, 2010).

7. PRECACAUTION OF MICROBIAL SPOILAGE

In many cases, food deterioration is caused by microorganisms. Because of this, there are measures that must be taken at every stage of the food chain, beginning in the house and ending at the supermarket. Reason being that fighting off germs that cause food to go bad or become dangerous is an ongoing battle for the food preservation industry. Avoiding spoiling during processing, storage, and distribution relies heavily on preservation techniques. Food poisoning also occurs as a result of microbial spoilage in foods. Various protection systems such as antimicrobial compounds, heating and cooling are preferred in the fight against food poisoning outbreaks. However, these methods of protection may also be insufficient in some cases. This lack of adequacy is grounded in the fact that consumers are increasingly interested in convenient and all-natural food options for their dietary needs. The most fundamental compounds used to prevent microbial spoilage are weak acids like lactic acid, sorbic acid, acetic acid, and benzoic acid. It is known that these weak acids used have the ability to inhibit fungal and bacterial growth. Innovative preservation methods have also been developed, as consumers prefer foods without preservatives. Adding salt, adjusting the pH range, taking into account the humidity situation and other applications (high salt concentration in serum emulsion in butter lipid) can be given as examples of innovative preservation methods. By adding 44% sucrose or glucose to milk, which is an animal product, it can be protected from microbial conditions by reducing the water activity below a certain level, or protection occurs when evaporated milk or sweetened condensed milk is canned (Arneborg *et al*. 2000; Lindow and Brandl, 2003; Mani-López *et al*. 2018).

Chemical preservatives are widely used because of their ability to prevent the growth of rotting bacteria and yeasts.

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Sodium benzoate is used to kill yeasts and may be preferable in some beverages; hydrogen sulphide is used to kill mould; potassium metabisulfate is used to preserve fruit; and so on (Gram *et al*. 2002; Rawat, 2015).

8. CONCLUSION

In this study, food spoilage, factors in food spoilage, safe transportation of food, precautions to be taken to prevent or delay food spoilage are stated. As a result, the factors that cause food spoilage are stated and the measures to be taken against them are mentioned. In addition, information about safe food transportation is given.

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