REVIEW ARTICLE

ROLE OF MICROORGANISMS IN POST-HARVEST LOSS OF AGRICULTURAL PRODUCTS: A REVIEW

Naresh Singh Bist*, Pratibha Bist

Agriculture And Forestry University Rampur, Chitwan, Nepal.

*Corresponding Author Email: nracebist54@gmail.com

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ABSTRACT

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The measurable quantitative (weight or volume) and qualitative (changed physical condition or characteristics) loss of agricultural products after harvest is considered as a post-harvest loss. Microbiological postharvest loss is one of the major types of postharvest loss and it refers to losses caused by microorganisms like moulds, yeasts, and bacteria. Microorganisms have a cosmopolitan distribution in the terrestrial ecosystem and are responsible for the contamination of agricultural products. Poor post-harvest management of agricultural products makes them susceptible to microbial contamination. Different genera of fungi, bacteria, protista even viruses are responsible for spoilage of food agricultural products rendering them unsuitable for consumption. Some microorganisms like *Aspergillus*, *Penicillium*, and *Fusarium* expel or produce mycotoxins on food material which is detrimental to human health. Thus, appropriate control measures should be applied to minimize microbial post-harvest loss for not only reducing risk to human health but also obtaining sustainable food security.

KEYWORDS

Fungus, Bacteria, Spoilage, Contamination.

1. INTRODUCTION

The postharvest handling is the stage of crop production that starts immediately after the harvest of crops and includes cleaning, sorting, cooling, processing, packing, marketing, food preparation, to the final decision by the consumer to consume or discard the food. The process of deterioration starts soon after the crop is removed from the ground or separated from its parent plant (Wikipedia, 2005). If the food is consumed by people then it is not lost but if it is not consumed by people for any reason then it is considered as a post-harvest loss. In Nepal, different studies have estimated the postharvest losses from 20 to 30% for fresh fruits and vegetables which could exceed up to 50% under adverse conditions (Bhattarai, 2018). After harvest, the product undergoes a series of operations causing possible quantitative and qualitative losses. For example, insufficient drying of grain and pulse can cause losses from the development of moulds and insects.

An organism that is microscopic in nature (i.e. cannot be seen with the naked eye) is known as a microorganism. Microorganisms may be free-living or parasitic based on their habitat. Most of the micro-organisms are unicellular organisms while some are multicellular and include bacteria, fungi, archaea, protista and viruses (Wikipedia, 2006). Agricultural products which are to be stored for a period of time are subjected to a wide variety of microorganism causing degradation of the food product either directly by rot or reducing its palatability by inducing offensive taste. Microorganisms include prokaryotes (bacteria), which are single-celled organisms that lack defined nuclei and other organelles, and eukaryotes, which may be single-celled (yeasts) or multicellular (moulds) organisms with nuclei and other organelles.

Some microorganisms are commonly found in many types of spoiled foods

i.e. many species are often identified in a single spoiled food item but there may be only one specific spoilage species which is primarily responsible for the production of the compounds causing off-odours and flavors, while others are more selective in the foods they consume. Some microbes inhibit the competitors by secreting compounds (Gram, et al., 2002). Some microorganisms like *Aspergillus*, *Penicillium*, and *Fusarium* expel or produce mycotoxins on food material which is capable of causing disease and death in both humans and other animals and thus make the food unsafe for consumption (Law and Cooper, 2001)

There are mainly four groups of spoilage yeasts:-

- *Zygosaccharomyces* and related genera are the common spoilage organisms in foods such as honey, dried fruit, jams, and soy sauce and can tolerate high sugar and salt concentration (Rawat, 2015).
- *Debaryomyces hansenii* can grow at salt concentrations up to 24%, causing spoilage of cured meats, cheeses, and olives in salt brine. This group also includes the most important spoilage organisms in salad dressings (Mandrell et al., 2006).
- Some strains of *Saccharomyces spp.* spoil alcoholic beverages including wine by causing turbidity, gassiness, and off-flavors. Some species of this group can also grow on fruits, including yogurt containing fruit, and some are resistant to heat processing (Elez-Martinez et al., 2004).
- *Dekkera/Brettanomyces* are principally involved in spoilage of fermented foods, including alcoholic beverages and dairy products including milk. They produce volatile phenolic compounds responsible for off-odour and unpleasant flavor resulting in heavy loss in winery business (Couto et al., 2005).

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Table 1: Some Organisms that are Negatively Correlated with Product Quality

Microorganisms	Products
<i>Acetobacter spp.</i>	Fresh cider
<i>Bacillus spp.</i>	Bread dough
<i>Byssoschlamys spp.</i>	Canned fruits
<i>Clostridium spp.</i>	Hard cheeses
Flat-sour spores	Canned vegetables
<i>Geotrichum spp</i>	Fruit cannery sanitation
Lactic acid bacteria	Lactic acid bacteria
<i>Leuconostoc mesenteroides</i>	Sugar (during refinery)
Yeasts	Fruit juice concentrates
<i>Lactococcus lactis</i>	Raw milk (refrigerated)
<i>Zygosaccharomyces bailii</i> <i>Mayonnaise</i>	salad dressing

Source: (Jay et al., 2005)

2. ROLE OF MICROORGANISMS IN POST-HARVEST LOSS OF FRUITS AND VEGETABLES

Because of high moisture and nutrient content, fruits and vegetables are highly susceptible to microbial spoilage caused by fungi, bacteria, yeast and moulds. Fungal and bacterial diseases cause heavy loss of fruits and vegetables during the post-harvest period (Yahaya and Mardiyya, 2019). Pathogens cause rots and render them unfit for consumption by production of mycotoxin (Naureen et al., 2009). Species of *Alternaria*, *Fusarium*, *Penicillium*, *Aspergillus*, *Geotrichum*, *Phytophthora* as well as *Botrytis* have been reported as common pathogens implicated with postharvest diseases of tomato fruits; responsible for as much as 10-30% reduction in the yield of major tomato crops (Etebu et al., 2013). *Penicillium expansum* is one of the major and most important post-harvest pathogens of stored pear fruit which causes the blue mould rot, a decay that can lead to significant economic losses during postharvest (Amin et al., 2017).

Table 2: Post-harvest Diseases of Papaya

Post-harvest Diseases in Papaya	Causal Agent
Anthraxnose and Chocolate spot	<i>Glomerella cingulata</i>
Dry rot	<i>Mycosphaerella caricae</i>
Wet rot	<i>Phomopsis</i>
Alternaria fruit spot	<i>A. alternata</i>
Stemphylium fruit spot	<i>S. lycopersici</i>
Fusarium rot	<i>F. solani</i>
Internal fruit infections	<i>Cladosporium sp.</i>

Source: (Alvarez and Nishijima, 1987)

3. ROLE OF MICROORGANISMS IN POST-HARVEST LOSS OF GRAIN

Microbial spoilage of grains is majorly caused by filamentous fungi. The extent of spoilage is determined by microbial density, diversity, moisture content, percentage of damaged grain, the gas composition of storage, time span, etc. Microbial damage causes a reduction in nutritive value, off-odour, abnormal coloration, deterioration in milling and baking property (Schmidt et al., 2018). *Fusarium moniliforme* is a common fungal contaminant of corn which produce mycotoxin has been correlated with the risk of human esophageal cancer in Transkei (Sydenham et al., 1990). Similarly, fungi of *Aspergillus*, *Penicillium*, *Alternaria* and *Fusarium*, genera are responsible for spoilage of rice and wheat grains.

4. ROLE OF MICROORGANISMS IN POST-HARVEST LOSS OF MEAT PRODUCTS

Meats are subjected to spoilage by a wide range of microbes (Jay et al., 2005). Meat spoilage organisms primarily belong to the genus *Pseudomonas* which is gram negative bacteria. The other major members of the spoilage flora of meat in aerobic condition include *Psychrobacter spp.*, *Moraxella spp.*, and *Acinetobacter spp.* (Ellis et al., 2002). A condition during packaging and storage creates environmental niches that favor a particular strain of microbes while inhibiting others (Castellano et al., 2008). As a result, even though initial population may also contain various levels of gram-positive genera, the gram-negative non-motile and motile aerobic rods and *Coccobacilli* usually dominate the contaminating population of meat (Ellis et al., 2002). The primary spoilage ground meat

(keema) is mainly composed of *Pseudomonads* and psychrotrophic *Enterobacteriaceae*. These bacteria are responsible for spoilage of fresh meat because they have the ability to metabolize the meat constituents, and grow well in the 5.5–7.0 pH range (Doyle et al., 2007). The spoilage of cured meat-packaged aerobically is caused, by the growth of yeasts and moulds. When the same cured product is packaged anaerobically in impermeable films, then spoilage is caused by the growth of lactic acid bacteria, which include *Enterococcus*, *Lactococcus*, *Lactobacillus*, *Leuconostoc*, *Pediococcus*, and *Weissella* (Seman et al., 2002).

5. ROLE OF MICROORGANISMS IN POST-HARVEST LOSS OF FLOWERS

In flower after harvest water relation interruption is mostly due to the growth of microorganism in vase solution and blockage in the xylem of the cut flower stem by microbe (Doorn et al., 1989). Stem blockage could take place by the microorganism or by extracellular polysaccharides and degradation products of dead cells, besides vessel blockage, bacteria secrete pectinases, toxic compounds, produce ethylene, and therefore accelerate senescence. It has been shown that besides vase life reduction, disruption of water relations in rose flowers causes lack of flower opening, improper opening and wilting of flowers (Jowkar et al., 2012). Bacterial strains found in rose stems were: *Pseudomonads* (more than 70 %), *Enterobacteria* (5-10%); and some other genera such as *Aeromonas*, *Acinetobacter*, *Alcaligenes*, *Citrobacter*, and *Flavobacterium* (Doorn et al., 1991).

6. ROLE OF MICROORGANISMS IN POST-HARVEST LOSS OF DAIRY PRODUCTS

Milk spoilage bacteria may originate on the farm environment or milking equipment or in processing plants and transfer from equipment, employees, or from the air to milk. Due to the production of lactic acid and other compounds, milk produces off-flavor when populations of microorganisms reach 10⁶ cfu/ml. Refrigeration can suppress the growth of lactic acid bacteria but psychrophilic bacteria (*Pseudomonas*, *Alcaligenes*, *Enterobacter*, and some spore-formers) can grow within a day and eventually produce rancid odours (Dogan and Boor, 2003). Pasteurization kills the psychrophiles and mesophilic bacteria (lactic acid bacteria), but heat-tolerant species (*Alcaligenes*, *Microbacterium*, *Bacillus* and *Clostridium*) can still survive and later cause spoilage in milk and other dairy products (Rawat, 2015). *Pseudomonas*, *Achromobacter*, *Alcaligenes*, *Flavobacterium*, and *Bacillus* can spoil soft cheese while *Clostridium sporogenes* spoils processed cheese. Yeasts and moulds are the main spoilage organisms found in cultured milk (yogurt, sour cream and buttermilk). The higher acidity in these products inhibits many other bacteria (Mayoral et al., 2005). *Pseudomonas*, yeasts and moulds can spoil light butter. Since the light butter has higher moisture content than other butter and it is more susceptible to microbial growth.

7. ROLE OF MICROORGANISMS IN POST-HARVEST LOSS OF EGG

The microorganisms that are primarily responsible for the spoilage of eggshells and liquid eggs are typically gram-negative microorganisms. Microbial contamination of egg is related to the moisture content of eggshells. Eggshell acts as a barrier between the external and internal environment of the egg. With poor storage and management, the moisture percentage of eggshell increases making it favorable for fungal (mould) growth resulting in spoilage of eggshell. With increasing fungal activity on the eggshell surface, the pore size of the shell increase and penetration through the shell becomes easier for microbes causing spoilage of liquid egg. The types of spoilage or rots can be sometimes characterized by the color of the eggs (Erkmen and Bozoglu, 2016).

Table 3: Bacteria Associated with Various Types of Egg Spoilage or Rot

Spoilage bacteria	Type of spoilage or rot (color)
<i>Proteus spp.</i>	Black
<i>Aeromonas liquefaciens</i>	Black
<i>Serratia marcescens</i>	Red
<i>Enterobacter spp.</i>	Custard
<i>Pseudomonas maltophilia</i>	Green
<i>Pseudomonas fluorescens</i>	Pink
<i>Flavobacterium cytophaga</i>	Yellow
Other	Colorless
<i>Enterobacter</i> and <i>Alcaligenes spp.</i>	

Source: (Board and Tranter, 1995)

8. CONTROLLING MEASURES OF MICROBIAL POST-HARVEST LOSS OF AGRICULTURAL PRODUCT

Pathogenic infections in many horticultural commodities can be prevented by microbial volatile organic compounds. Gaseous treatments, a process defined as 'biofumigation', can be potentially employed with success for this. Different plant-produced volatiles have been recognized as potential substances for biofumigation (Marta et al., 2016). In order to prevent microbial proliferation in vase solutions of cut flowers, various compounds, and chemicals, namely, silver nitrate, silver thiosulphate, aluminum sulfate, and sodium hypochlorite, can be used (Liao et al., 2000). Yeasts and yeast-like organisms, such as *Pichia guilliermondii* can be used for control of postharvest rots of citrus and other fruits. Similarly, *Acremonium breve* and several species of *Cryptococcus* can be used for control of postharvest rots of apple (*Malus domestica* Borkh.) and pear (*Pyrus communis* L.) (Sharma et al., 2009). Safe anti-microbial additives such as acetic, sorbic, and benzoic acids, also have wide application as preservatives in foods and beverages (Garg and Kumar, 2015). The most common preservative agents are acetic, lactic, benzoic, and sorbic acid which is capable of inhibiting the outgrowth of both bacterial and fungal cells. Sorbic acid can also be used to inhibit the germination and outgrowth of bacterial spores (Rawat, 2015). Grains can be preserved by treatment with pesticides, drying, debranning, irradiation, and ozone treatment and by treatment with chlorine and hypochlorite (Los et al., 2018). Spoilage of milk can be controlled by pasteurization, sterilization and dehydration of milk. Antimicrobial agents and GRAS substances which act as food additives, food stabilizers and emulsifiers can also be added for the preservation of dairy products (Verma et al., 2017). Microbial contamination of eggs can be avoided by maintaining the aseptic condition at the time of storage. Microbes can also be removed by washing and disinfecting eggs with hypochlorite solution, pasteurization of eggs or heat treatment, low-temperature treatment (conceal growth of microbes) (Erkmen and Bozoglu, 2016).

9. CONCLUSION

Microorganisms play a crucial role in causing the deterioration of agricultural products starting soon after their harvest. Appropriate control measures should be applied to minimize microbial post-harvest loss enabling more availability of edible food products and thus obtaining sustainable food security.

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