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A review on microbial contamination of Cereal grains

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Abstract
Cereal grains are the most important staple foods for mankind worldwide. The constantly increasing annual production and yield is matched by demand for cereals, which is expected to increase drastically along with the global population growth. A critical food safety and quality issue is to minimize the microbiological contamination of grains as it affects cereals both quantitatively and qualitatively. Microorganisms present in cereals can affect the safety, quality, and functional properties of grains. Therefore, it is essential to reduce cereal grain contamination to the minimum to ensure safety both for human and animal consumption. Current production of cereals relies heavily on pesticides input; however, numerous harmful effects on human health and on the environment highlight the need for more sustainable pest management and agricultural methods.

Keywords: Cereal grains, food safety, microorganisms, mycotoxin, human health.

Introduction

Cereals are one of the most important agricultural products in the world, both as human foods and as the main constituent of animal feed. Development of agriculture in prehistoric times was heavily associated with domestication of cereal grains and since their first cultivation most civilizations have become dependent upon cereals for the majority of its food supply (Cordain, 1999) [5]. Cereal grains are the most commonly consumed food group worldwide and they are grown on about 60% of the cultivated land in the world (Koehler and Wieser, 2013) [14]. In order to meet the requirements of a growing world population, worldwide production and yield of cereals has been increased for the last 50 years. Major types of cereal grains include maize, rice, wheat, barley, sorghum, millet, oats, and rye (FAO, 2017) [8].

The potential sources for the contamination of grains are mostly environmentally based and include air, dust, soil, water, insects, rodents, birds, animals, microbes, humans, storage and shipping containers, and handling and processing equipment. Most contamination is of a microbiological nature but heavy metals and process contaminants play a role, too. The secondary metabolites produced by fungi which can grow on grain (or mycotoxins) belong to the most toxic contaminants occurring in a wide range of food commodities (Bennett and Klich, 2003) [2]. Some molds can potentially produce harmful mycotoxins and pose a serious health risk for consumers. Losses of cereal grains during storage are estimated between 5 and 30% due to molds and mycotoxins, 5% for insects and 2% for rodents, with an average yield loss of 1% for developed and 10% to 30% for developing countries. Depending on climatic conditions during growth, grains carry a microbial load with a high diversity of potential spoilage organisms when harvested. In addition, post-harvest contamination during transport is possible. This microbial load consists of bacteria, yeasts, and filamentous fungi belonging to many different genera. The activity of these micro-organisms during storage and, accordingly, the shelf life of the crop is dependent on a range of factors. Amongst the most influential parameters are moisture content and water availability during storage. As a result, grains are usually stored at low moisture contents of 12–13% and a water activity of <0.70.

Sources of microbial contamination of cereal grains

Microbial contamination of cereal grains occurs during crop growth, harvesting and postharvest drying and storage (Magan and Aldred, 2006) [19] and it derives from several sources, including air, dust, water, soil, insects, birds and rodents feces as well as contaminated equipment and unsanitary handling. The type of microbial contamination varies according to the growing region and is heavily influenced by environmental conditions such as drought, rainfall, temperature, and sunlight, as well as unsanitary handling, harvesting and processing equipment, and poor storage conditions (Bullerman and Bianchini, 2009) [3]. High rainfall just before harvest is a factor inducing extensive colonization of the grain ears by *Alternaria* spp., causing black fungi discoloration, that can be observable both on the surface of the kernels and as beneath the pericarp.

Table 1: Sources of microbial contamination of cereal grains

Type of microorganisms	Name of microorganisms	References
Bacteria	Salmonella, Escherichia coli, Bacillus cereus, Erwinia herbicola, Xanthomonas campestris, Azotobacter, Pseudomonas, Micrococcus, Lactobacillus	Laca *et al*., 2006 [15]; Harris *et al*., 2013 [11]
Filamentous fungi and yeasts	Eurotium, Aspergillus, Penicillium, Rhizopus, Mucor, Alternaria, Cladosporium, Fusarium, Helminthosporium, Sporobolomyces Rhodotorula, Hansenula, Torulopsis, Candida, and Saccharomyces	Harris *et al*., 2013 [11]; Pitt and Hocking, 2009 [21]; Bullerman and Bianchini, 2009 [3]

Table 2: Mycotoxins in cereal grains

Mycotoxin	Fungal source(s)	Effects of ingestion for humans	Commodity
Deoxynivalenol/nivalenol	*Fusarium graminearum, Fusarium crookwellense, Fusarium culmorum*	Human toxicoses e.g. nausea, vomiting, diarrhoea, headache, fever	Wheat, maize, barley
Zearalenone	*Fusarium graminearum, Fusarium crookwellense, Fusarium culmorum*	Identified by the International Agency for Research on Cancer (IARC 1994) as a possible human carcinogen	Maize, wheat
Ochratoxin A	*Aspergillus ochraceus, Penicillium verrucosum*	Suspected by IARC as human carcinogen	Barley, wheat, and many other commodities
Fumonisin B1	*Fusarium moniliforme* plus several less common species	Suspected by IARC as human carcinogen	Maize

Techniques for control of microbial spoilage of cereal grains

Certain technologies applied to control microbial spoilage of cereals successfully reduce the microbial load.

Table 3: Current methods and technologies used for cereal grains preservation

Method/Technology	Description	Limitations	References
Pesticides	Chemicals designed to prevent and control the occurrence of pests causing harm to crops - molds (fungicides), weeds (herbicides) and insects (insecticides)	High environmental impacts Direct negative impact on human health Increasing resistance against pesticides	Liu *et al.* (2015) [16]; Jess *et al.* (2014) [12]
Drying	Grains are dried to a low moisture content	Lack of uniformity of the process Over-drying may damage the grains and cause economic losses as well as increase mycotoxin contamination	Varga *et al.* (2010) [25]; Magan and Aldred, 2006 [19]
Debranning	Process during which the bran layers are removed from the endosperm by friction and abrasion	Not completely suitable for wheat due to the crease on the wheat kernels Whole-grain demand in the market	Laca *et al.* (2006) [15]
Chlorine and hypochlorite	Due to their oxidizing capacity, chlorine and hypochlorite treatments are one of the most widely used processes for microbial control	Low inactivation of fungal spores on cereal grains and generation of toxic by-products after the treatment	Delaquis and Bach (2012) [6]; Virto *et al.* (2005) [26]; Andrews *et al.* (1997) [1]
Irradiation	Exposing food to a certain amount of ionizing radiation	Can negatively modify the quality and technological properties of cereals and cereal products	Lung *et al.* (2015) [17]; Farkas *et al.* (2014) [9]
Ozone	Triatomic oxygen formed by addition of a free radical of oxygen to molecular oxygen	The cost of treatment can be relatively high due to complex technology	Greene *et al.* (2012) [10]; Environmental Protection Agency [EPA] (1999) [7]

Future trends for decontamination of cereal grains

Table 4: Potential methods and technologies for cereal grains preservation

Method/ Technology	Description	Limitations	References
Microwave (MW) treatment	Electromagnetic waves with frequency within 300 MHz to 300 GHz; microbial inactivation based mainly on thermal effect	Seed viability and seedling vigour can be decreased after the treatment Higher microbial reduction levels in presence of other stresses, such as acidic pH or increased temperature	Chandrasekaran *et al.* (2013) [4]; Reddy *et al.* (1998) [22];
Pulsed UV light	Short-duration, high-power pulses of a broad spectrum of white light from the UV (50% of the spectrum), to the near infrared region	Low ability to penetrate grains because of their irregular and complex surface Can decrease germination rate of the seeds	Maftei *et al.* (2013) [18]; Keklik *et al.* (2012) [13]

Non-thermal (cold) plasma	Partially ionized gas consisting of highly reactive chemical species	Efficiency of the method depends on the specific properties of the food product and its surface	Niemira (2012) [20]; Schluter *et al.* (2013) [24]
Organic acids	Antimicrobial agents due to the reduction of the environmental pH	Can increase moisture content and penetrate into the endosperm of grains	Sabillon *et al.* (2017) [23]

Conclusion

At a time of rapid growth in global populations, sufficient nutritional supply to humanity has become increasingly challenging. On the basis of their long tradition as global staples of the human diet and livestock feed, agricultural crops such as cereals will have a key role in satisfying this growing nutritional need. However, global agricultural area is limited, making it difficult to expand cereal production. Considering that approximately 15% of all cereals worldwide are lost due to microbial pests, the most sensible approach to combat this issue is to increase both food safety and sustainability to reduce economic losses. Pre- and post-harvest microbial spoilage counts as one of the predominant factors in crop loss all over the world. Various strategies to prevent microbial contamination in the field have been investigated and reviewed. However, even the best management practices cannot completely eliminate the risk of contamination. Because of the permanent and ubiquitous presence of microorganisms and fungal spores in the environment, cereals always carry a certain microbial load when harvested. Additionally, climatic conditions, such as temperature and humidity that are not under human control may be crucial for contamination with moulds. Therefore, appropriate post-harvest crop treatment, before and during storage, is as important as pre-harvest strategies in the prevention of microbial spoilage.

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