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Air quality and impact on food safety

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Abstract. Air is an important potential source of contamination in different areas of human endeavor (medicine, pharmaceuticals, agriculture, food industry etc.). During the various technological procedures of producing and processing food, its contamination by polluting substances contained in air, such as suspended particles (physical contamination), combustion products and volatile organic substances (chemical contamination) and biological pollutants (bacteria, viruses, molds and mites) very often occurs. Although the sources of air contamination are numerous (poor construction aspects of the building, improper air conditioning and ventilation, etc.), basic and common sources are people and their activities in food production plants. The task of responsible food production is to adequately and continuously implement good production practices, and thereby, prevent potentially harmful practices, to ensure environmental health and safety for the life and work of the staff in that environment, and to create conditions for safe food production, while protecting the environment.

1. The most common air pollutants

Cleaning and sanitation of that food contact surfaces is an integral part of mandatory sanitary procedure in the food industry. However, is the same level of concern aimed at preventing the occurrence of air contamination or at air contamination control during the food production process? The real answer is no, or not enough.

According to the World Health Organization [1], air-polluting substances are considered to be materials, the presence of which in specific concentrations can have direct or indirect negative consequences for human health and the environment. The data suggest that polluted air, on an annual basis, is responsible for 7 million premature deaths around the world, placing it as one of the eight most important etiological death factors.

Primary air pollutants in the food industry are marked, being, in addition to microorganisms, suspended particles, combustion products (nitrogen oxide, carbon monoxide, carbon dioxide, sulfur oxide) and volatile organic substances. Bacteria can be found individually in the air, but also occur as agglomerates on solid (e.g. dust) or liquid (e.g. condensed water) microscopic particles scattered in the air [2]. In addition to bacteria occurring in specific *bioaerosols* (synonym, organic dust), these particles can contain bacterial spores, fungi and/or their spores or hyphae, viruses, different types of antigens, pollen grains, toxins, fecal material or their combinations [3, 4]. Metabolites and secretions are also included in this context [5]. The size of aerosol particles is generally in the range 0.5-50 µm



[6]. It was long thought the size of particles of microorganisms in the air was the same as the microorganisms themselves. However, very often this is not the case, so the sizes of particles containing microorganisms in the air are frequently much larger than the microorganisms. For example, a bacterial cell with a diameter of $\sim 1 \mu\text{m}$, on being bioaerosolized in water, produces a water droplet with diameter of 15-25 μm . Skin particles, according to Noble [7], have a mean equivalent diameter of 13.5 μm and fewer than 30% of the particles carrying staphylococci were less than 10 μm in equivalent diameter.

Different aspects of the technological process of food production, starting from manipulation of raw materials, processing stages (measuring, grinding, mixing, etc.), storage, transport, and sales of finished product to the consumer are risk phases in which the air is a significant source of microbiological contamination. That is what, more than one and a half centuries ago (1861), in *Annales des Sciences Naturelles*, Louis Pasteur [8] wrote about when presenting his first research on the presence of microorganisms in air.

The most common means of spreading microorganisms in food production plants is through various construction openings (doors, drains, etc.), disinfectant tunnels, during cleaning processes, washing and packaging, due to poorly designed and poorly maintained ventilation and air conditioning systems, and poorly constructed interior and roof structures (drainage, leakage) etc. [9]. However, the basic and most dangerous sources are people and their activities in food production plants [10]. The microorganisms are, in this case, suspended on particles of dust, hair, shoes or clothes originating from the workers, as well as in the droplets that are formed during talking, coughing or sneezing [11]. Also, all manipulative actions that aerosolize contaminants lead to unacceptable levels of microbial pollution in food production plants [12], so it is desirable to maintain dry conditions.

In Table 1, an overview of the most common sources of microbiological contamination of air in the food industry, the principles of their transfer, and their consequential level of risk on product is given.

Table 1. Influence of sources of contamination and air ventilation system producing risk to product safety [12]

Source of contamination	Transmission mechanism	Ventilation system effect	Risk for product safety
Material (packaging, etc.)	Material surface	Low	Medium to high
Workforce	Clothes, footwear, and enhanced due to poor personal hygiene	Low	Medium to high
Internal transport	Manipulation by transport assets	Low	Medium to high
Air inside facilities	Fresh air	High	Medium
	Dust or powder	High	Medium
	Spray aerosolation	Medium	High
Condensation	Pneumatic transport, crimping	High	High
	Contact	High	High
Equipment surface	Contact with materials	Low	High
Cleaning operations	Spray-splash, washing, vacuolation	High	High
Equipment and machines	Pneumatic gas exhaust systems, compressed air	High	Medium to high
Building appearance	Building construction, poor ventilation via windows and	Low	Medium to high

doors, poor building design and construction

Temperature, relative humidity, sources of nutrients, and air movement affect the growth and dissemination of airborne contaminants. In other words, unless favorable nutritional conditions are present, the air is not a natural environment for growth and reproduction of microorganisms [2]. On the other hand, if there are adequate conditions for survival and multiplication of microorganisms, there is a potential risk that contaminated air in food production environments will lead to public health burdens on the staff, but also to the possibilities of food contamination or reduced quality and/or shelf-life of the food product [13, 14].

2. Most common microorganisms involved in air contamination in the food industry

Although pathogenic and spoilage microorganisms can come in contact with a finished food product in different ways [15], the air is often cited as a significant source of microbiological contamination, especially in plants processing milk and dairy products [16], pork [17], poultry [18], and beef meat [19]. The microbiological air quality, from the aspect of acceptable level of contamination, in food industry facilities, is proportional to the level of product risk. Therefore, for a low-risk food, such as packaged, canned products, low-value products that are stable at room temperature, or products that are required to undergo thermal processing by consumers, the air system can be permitted less challenging performance requirements. On the other hand, when producing high-risk foods, such as ready-to-eat foods, the air quality level must be high. Thus, factories producing medium or high risk foods very often utilize physical separation of the production units [20].

The interconnection between microbiological contamination of food products and the spread of microorganisms in the air environment is presented in Table 2.

Table 2. Microbiological contamination of air that comes into contact with food products [21]

Air contamination	Processes/Rooms	Total microorganisms, CFU ^a /m ³	Yeasts and molds, CFU/m ³	Relative humidity, %
Low	Packaging milk products	100-40	10-40	50-70
	Preserving meat products	150-300	30-120	45-60
	/laboratory control			
Medium	Fresh meat delivery	300-600	100-500	45-60
	Meat processing	800-1800	250-500	70-80
	Meat shops	400-900	150-500	50-60
	Gastronomic food	500-1100	200-600	55-65
	Bars	600-1000	150-450	50-60
High	Slaughterhouses	1500-6500	600-1900	55-65
	Sausage production	1500-3500	2000-10000	70-80
	Internal organ processing	4000-6000	700-3500	55-70
	Market	1500-7000	500-5000	50-70

^a CFU – colony-forming unit

The contamination of food products is dependent on air's microbial load, and on the duration of exposure to the air, whether during specific technological processing stages (e.g. cooling) or during storage [22]. For example, the rate of food contamination is increased by 120% after 48 h of air exposure at 32°C, compared to the same conditions with 24 h exposure [2].

Microbiological contamination is higher given greater air humidity, in which conditions, 80-95% of isolated microorganisms are Gram-positive bacteria. The air in slaughterhouses is contaminated mostly with Gram-negative airborne bacteria belonging to the families *Enterobacteriaceae* and

Pseudomonadaceae, while the Gram-positive airborne bacteria present belong to the genera *Staphylococcus*, *Microbacterium*, *Bacillus* and *Micrococcus* [23]. The most significant species are *Bacillus megaterium*, *Bacillus brevis*, *Micrococcus luteus* and *Micrococcus varians*.

Gram-negative bacteria that produce endotoxins were determined in the air of poultry slaughterhouses, and they are the consequence of air being contaminated with feces from slaughtered poultry [24, 25]. To reinforce this point, high numbers of bacteria, especially *Staphylococcus* and *Corynebacteria*, were also determined in the air of broiler farms [26].

A large number of molds (11 orders and 32 species) were determined in cheese ripening facilities [27]. Most species (45.16%) belonged to the genera *Penicillium* (the most dominant species was *Penicillium verrucosum* var. *cyclopium*) and *Aspergillus*. Air quality is particularly important in facilities for production and packaging of butter, if this is manufactured in open-type mixers, since these devices can also incorporate up to 5% of the surrounding air into the product [28]. In terms of storage of cooled butter products, i.e., in refrigerators or other cooling chambers, the predominant molds belonged to the genera *Penicillium*, *Aspergillus*, *Mucor* and *Cladosporium* [29, 30].

3. Conclusions

This summary of existing information on the bioaerosol contamination in food processing plants concludes that existing data in Serbia, however, are limited, mainly because of the lack of appropriate equipment for sampling, and lack of expertise in procedures for bioaerosol examination, but partly because of fear that the outcomes of such studies would negatively affect food producers. On the other hand, consumer demand for microbiologically healthy food is increasing, and this is also an expressed imperative of food producers. Therefore, regardless of whether bioaerosols constitute a small or high risk for food contamination, it is necessary to implement permanent air control while taking appropriate measures to comply with minimal quality standards, and thereby, limit and/or prevent the possibility of microbiological contamination of food.

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