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Review

A review of the state-of-the-art in air filtration technologies as may be applied to cold storage warehouses

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ABSTRACT

Background: Storage of fruit, vegetables and other products is used worldwide with a wide variety of foods. In many cases, though environmental conditions such as air humidity and temperature are taken into consideration, air filters are not employed even though such filters could potentially reduce the perishing of product during storage.
Scope and approach: The purpose of this review is to list and evaluate currently available air filtration technologies, in order to determine their suitability for use inside food storage warehouses. Factors such as pressure drop, running costs, and the environmental conditions which the filters will be operating in need to be taken into consideration.
Key findings and conclusions: A number of physical filters, i.e., HEPA, glass fiber, PTFE and cellulose filters as well as polyurethane foams and nanofiber mats are presented first. These are filters which function by providing a physical barrier which particles cannot pass through, or which particles stick to. These are followed by a discussion of other, non-physical methods, such as electrostatic precipitation, cold plasma, wet scrubbing, cyclonic air filtration, UV radiation (and coatings), fumigation, nanoparticles bound on filter media, which are either commonly employed in industry, or are interesting emerging technologies.

1. Introduction

Control of particulate matter in the air is essential in the healthcare industry (Leung & Chan, 2006). It is also regularly applied to food processing and packaging plants, with specific guidelines and legislation being available to cover these scenarios (EHEDG 2006; Wirtanen, Miettinen, Pahkala, Enbom, & Vanne, 2012). Air filtration is applied, for instance, to clean rooms inside milk packaging facilities (Aires 2010), meat production and packaging lines (Burfoot, Whyte, Tinker, Hall, & Allen, 2007), in the production of soft cheese (Todt, 1990) and a large number of other scenarios (López-Gómez, Castaño-Villar, Palop, & Marín-Iniesta, 2013). However, while fruit and vegetable storage warehouses go through great lengths to control the environmental conditions within them (Hardenburg, Watada, & Yang, 1990), there is often next to no attention paid to the quality of the air in terms of circulating particulate matter, even though it has been shown that the presence of spores in the air inside these facilities affects the quality of the product negatively (Ocón et al., 2011). The purpose of this review is to list and evaluate currently available air filtration technologies, in order to determine their suitability for use inside food storage warehouses. Special care will be taken to assess the suitability of the filters to the particular circumstances which they would be operating in. In particular:

- The pressure drop across the filter should be low, in order to minimize operational cost.
- An eventual filter would primarily need to remove spores from the air. This implies that the particles which need to be removed from the air have a relatively constant size of a few μm (see Fig. 1) (Reponen, Hyvärinen, Ruuskanen, Raunemaa, & Nevalainen, 1994; Riley, McKone, Lai, & Nazaroff, 2002; Yamamoto et al., 2012)
- The setup cost of the filter, as well as any running costs, need to be taken into consideration

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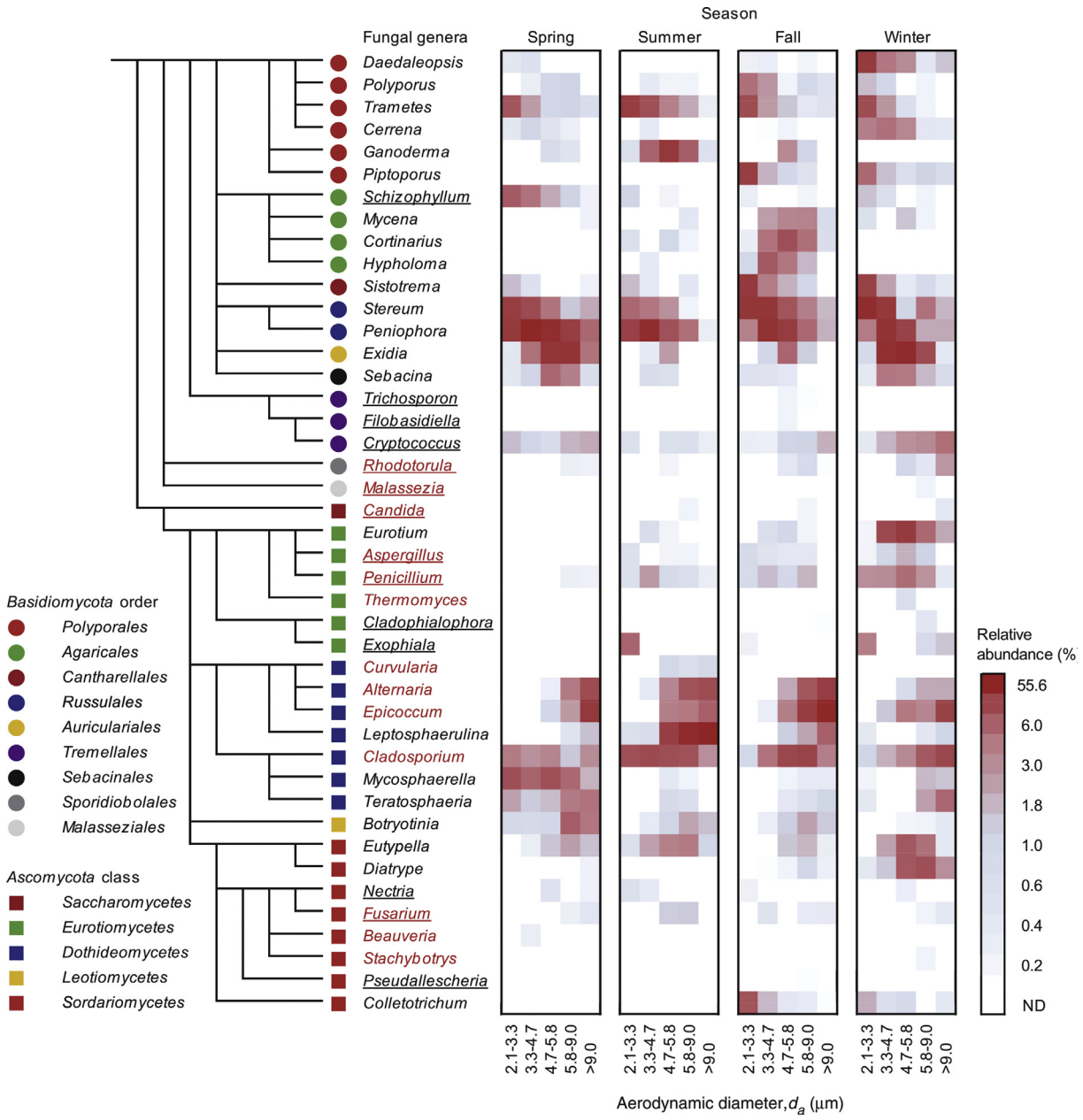

Fig. 1. From (Yamamoto et al., 2012). Aerodynamic diameter of spores of different fungal species. All spores are within the micrometer range.

This review will first present a number of physical filters. These are filters which function by providing a physical barrier which particles cannot pass through, or which particles stick to, and are the most common way of clearing the air of contaminants (EHEDG, 2006). This will be followed by a discussion of other, non-physical methods which are commonly employed in industry, or are interesting emerging technologies. In each case, some specific examples where these technologies are used will be given, such that they can serve as examples for other industries to start implementing these technologies.

2. HEPA filters

HEPA (High Efficiency Particle Arresting) filters are known to be amongst the most efficient filters available for trapping particles of different diameter. They are designed to be over 99.99% efficient, and are routinely used for air filtering in locations such as hospital operating theatres, respirators, vehicles etc. HEPA filters are the food industry standard for producing clean indoor air, and are regulated by the European standard EN 1822.

2.1. Mechanism of air filtration

HEPA filters essentially consist of a pleated sheet of fiber with a very high surface area. Particles being forced through this sheet are trapped through three major mechanisms called diffusion, interception and inertia (or impaction), each of which becomes more or less important at different particle sizes. When combined, these three mechanisms generate a very high air filtration efficiency across a very wide range of particle sizes (First, 1998).

The material which is trapped by the filter forms a 'cake'. As the thickness of the cake increases, the path that particles in the air