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Review

Vegetable nanocellulose in food science: A review

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ABSTRACT

The use of nanocellulose as a food additive in 1983 was one of the first applications of this plant-derived biopolymer. However, at that time, the product was not commercialized owing to the high energetic cost of the isolation methods used. Currently, improvements in nanocellulose production allow its commercialization. The high surface area and aspect ratio, rheological behavior, water absorption and absence of cytotoxic and genotoxic properties of nanocellulose facilitate its use in food applications. In this review, three different applications were identified: (***i***) nanocellulose as a stabilizing agent, (***ii***) nanocellulose as a functional food ingredient and (***iii***) nanocellulose in food packaging. The last is the most common application of nanocellulose in the food industry. Aiming to demonstrate the potential of nanocellulose as a stabilizing and functional food ingredient, relevant publications on uses of nanocellulose in food are examined, focusing on applications of nanocellulose as a food additive and safety and regulatory issues. Nanocellulose has potential use as a stabilizing agent in food emulsions, as dietary fiber and to reduce the caloric value of food. Nevertheless, validated standards to characterize the produced nanostructure, quantify its properties and evaluate its toxicity are still required to answer safety and regulatory issues to achieve the incorporation of nanocellulose as a commercial product in the food industry.

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1. Introduction

Nanomaterial engineering technologies have the potential to revolutionize industrial food systems, addressing issues related to health concerns and sustainability (Szakal et al., 2014). According to the scientific report *"Inventory in nanotechnology applications in the*

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agricultural, feed and food sector", published by EFSA in 2014, silver, titanium dioxide and nanoencapsulates represent most of the nanoparticles used in the food industry in recent years (RIKILT and JRC, 2014). They are commonly used as food contact material (for instance, food packaging) and nanoencapsulated or nanosized food additives. According to the Food and Drug Administration FDA the term "food additive" refers to any substance that is reasonably expected to become a component of food (Food and Drug Administration, 2014). However, a comparison between current and future applications indicates a trend towards organic nanomaterials, such as vegetable and bacterial nanocellulose (RIKILT and JRC, 2014).

Vegetable nanocellulose is a nanomaterial extracted from wood, cotton, natural fibers and lignocellulosic materials. It was first developed by researchers at the ITT Rayonier Eastern Research Division Lab in Whippany, USA in 1977, but their work was not published until 1983 (Turbak, Snyder, & Sandberg, 1983a). Nanocellulose has received considerable attention in the following years, evidenced by the significant rise in the number of scientific articles and patents published. Most of the scientific articles and patents developed in recent years about nanocellulose are focused on applications with 83 and 69 publications in 2014 and 2015 respectively, or packaging with 99 and 77 publications in 2014 and 2015 respectively as can be observed in Fig. 1.

Patent applications on nanocellulose include composite materials (38%), non-woven absorbent webs (18%), paper and boards (16%), food products (13%), paper and board coatings (8%), cosmetics and toiletries (3%), and filter materials (4%) (Koskinen, Qvintus, Ritschkoff, Tammelin, & Pere, 2013; Tammelin et al., 2013). Nanocellulose in the food industry can be used to develop food packaging materials or food additives. However, most publications to date have been related to food packaging or additives to polymer matrices as observed in Fig. 1. The paper published by Turbak and co-workers in 1983 (Turbak et al., 1983a) was the first scientific consideration of nanocellulose as a food additive; however, the product was not marketed owing to the high energy consumption and production costs (Ström, Öhgren, & Ankerfors, 2013). Currently, the isolation methods to produce nanocellulose are more cost efficient, changing the perspectives on the industrial production of the nanopolymer (Ström et al., 2013). This development has enabled its availability as a commercial product, manufactured by various companies such as Daicel and Nippon paper in Japan, Rettenmaier in Germany and UPM Kymmene and CelluForce Co. in Canada (Charreau, Forestí, & Vazquez, 2013). Some research institutes such as VTT in Finland and Innventia AB in Sweden have also developed pilot plants to produce nanocellulose as a commercial product (Charreau et al., 2013).

This paper aims to review the impact, benefits and challenges of the use of vegetable nanocellulose in the food industry. Therefore, relevant publications on the potential of nanocellulose in various food applications were studied, focusing on publications about its use as a food additive and safety and regulatory issues (Andrade et al., 2015; Cunha, Mougel, Cathala, Berglund, & Capron, 2014; Pitkänen et al., 2010; Ström et al., 2013; Turbak et al., 1983a; Winuprasith & Suphantharika, 2013, 2015). Reviews of nanocellulose as an additive in plastics to develop food packaging (Li, Mascheroni, & Piergiovanni, 2015) or bacterial nanocellulose as a food additive (Shi, Zhang, Phillips, & Yang, 2014) were found in the literature. However, reviews of vegetable nanocellulose as food additive were not found in the literature.

The literature review revealed the applications of vegetable nanocellulose as a food stabilizer, functional food ingredient and new packaging material in the food industry. However, the literature reports few validated standards to characterize the

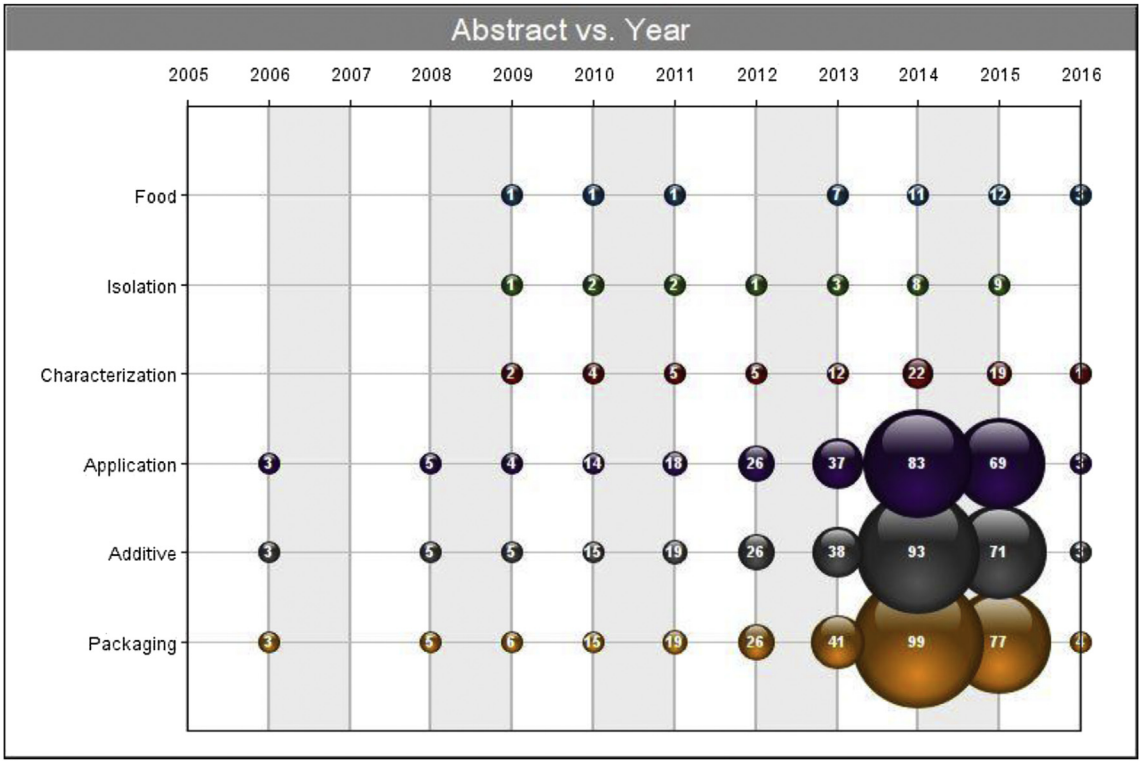

Fig. 1. Number of publications per topic of interest among 733 publications related to nanocellulose (2006–2015 (October)).
Source: Scopus, VantagePoint, 2015. Search criteria: The words mentioned in Fig. 1 were searched using Scopus and VantagePoint. Each word must not be separated by more than two words from the word "nanocellulose."