Trends in Food Science & Technology 51 (2016) 1–11

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: http://www.journals.elsevier.com/trends-in-food-science-and-technology

Review

An overview of the intelligent packaging technologies in the food sector

Masoud Ghaani, Carlo A. Cozzolino, Giulia Castelli, Stefano Farris*

DeFENS, Department of Food, Environmental and Nutritional Sciences, Packaging Division, University of Milan, via Celoria 2, 20133 Milan, Italy

ARTICLE INFO

Article history:
Received 15 October 2015
Received in revised form
25 February 2016
Accepted 26 February 2016
Available online 2 March 2016

Keywords:
Barcode
Consumer perception
Indicator
Legislation
Sensor
RFID

ABSTRACT

Background: Intelligent packaging is the newest technology within the food packaging field. Even though this technology is still growing and not fully commercially viable, it has enormous potential to improve the safety, quality, and traceability of food products, as well as its convenience for consumers.
Scope and approach: This paper first describes both the technical aspects and commercial applications of the most representative intelligent technologies—indicators, data carriers, and sensors—with special focus on systems and devices that are directly integrated into the package. Secondly, to provide useful guidelines for future research in the field, the paper discusses some important aspects that still hinder the full exploitation of intelligent technology within the food packaging industry.
Key findings and conclusions: Future research needs to consider some important aspects in order to make intelligent systems commercially viable, such as cost, consumers' acceptance and confidence, regulatory aspects (e.g., labeling), and multifunctionality.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Packaging is one of the main processes to preserve the quality of food products for transportation, storage, and end use. It slows quality decay and makes distribution and marketing more efficient. Packaging has four basic functions: protection, communication, convenience, and containment (Han, 2005). Packages protect products from the external environment; communicate with the customer through written texts, brand logo, and graphics; accommodate the lifestyle of the customer, for example saving time (ready-to-eat and heat-and-eat meals) or making the manipulation and handling of packaged food easier for the customer (examples of convenient features are easy opening, resealability, and microwavability); and act as containers for differently shaped and sized products, with the goal of optimizing logistic efficiency (Yam & Lee, 2012). Secure delivery and the preservation of packaged foods before consumption are the main goals throughout the food supply chain. However, loss of food quality attributes occurs during distribution and storage due to biological, chemical, and physical degradation (Han, 2013).

Food quality preservation is an important research target because it is intimately linked to the more global goal of enhancing the quality of our lives (Sandulescu, Cristea, Harceaga, & Bodoki, 2011). Food quality control is necessary, both to better protect consumers against foodborne illness and to maximize the efficiency of the food industries, e.g., by reducing losses due to the microbial spoilage of perishable foods. At the company level, food quality is usually assessed by periodic microbiological and chemical analyses underlying routine tests (Viswanathan & Radecki, 2008).

Of late, two new concepts have greatly contributed to achieving an advanced concept of packaging for safer and healthier food: the active packaging and intelligent packaging concepts. Active packaging materials are "materials and articles that are intended to extend the shelf-life or to maintain or improve the condition of packaged food. They are designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food" (European Commission, 2004). To improve the functionality of food packages and give them additional functions, different active substances can be incorporated into the packaging material (Singh, Abas Wani, & Saengerlaub, 2011). Several active packaging systems have been widely reported, such as O_2 and ethylene scavengers, moisture regulators, CO_2 scavengers and emitters, antioxidant and antimicrobial controlled-release packages, and devices to control the release or adsorption of flavors and odors (Vermeiren, Devlieghere, van Beest, de Kruijf, & Debevere, 1999).

* Corresponding author.
E-mail address: stefano.farris@unimi.it (S. Farris).

http://dx.doi.org/10.1016/j.tifs.2016.02.008
0924-2244/© 2016 Elsevier Ltd. All rights reserved.

Intelligent packaging materials are "materials and articles that monitor the condition of packaged food or the environment surrounding the food" (European Commission, 2004). In a broader meaning, intelligent packaging is defined as science and technology that use the packaging system's communication function to facilitate decision making by monitoring changes in the internal and external environments and communicating the conditions of the packaged food product (Yam, 2012). Differently from active packaging systems, intelligent packaging does not directly act to extend the shelf life of foods. Rather, intelligent packaging aims to convey information to the stakeholders of the food supply chains (e.g., manufacturers, retailers, and consumers) related to the food's quality (Restuccia et al., 2010). For example, an intelligent packaging system can show when the food product is fresh or whether its shelf life has expired; it can show the food's temperature using thermochromic inks or microwave doneness indicators (MDIs); and it can display the food's temperature history using time-temperature indicators (TTIs) (Robertson, 2012). Additionally, intelligent packaging can be used to check the effectiveness of active packaging systems (Kerry, O'Grady, & Hogan, 2006). In other words, active packaging is the component that takes some action, while intelligent packaging is the component that senses and shares the information (Yam, Takhistov, & Miltz, 2005). Intelligent packaging and active packaging can work synergistically to yield what is defined as "smart" packaging, i.e., a total packaging concept that combines the benefits arising from active and intelligent technology (Vanderroost, Ragaert, Devlieghere, & De Meulenaer, 2014).

Over the last decade, the research interest in intelligent packaging lagged far behind the interest in active packaging, as demonstrated by the number of related publications (Fig. 1). An explanation for this trend can be twofold. On one hand, researchers first focused on new tools to improve the quality and safety of foods through new, "active" functions, in contrast to the original "passive" attributes, such as mechanical strength, barrier performance, and thermal stability. Intelligent packaging systems have come to the forefront because of the growing usage of active components in food packaging, which requires a means of monitoring both the active device's performance and the overall packaging conditions. On the other hand, the higher complexity needed to achieve a sophisticated, intelligent system that is simultaneously reliable, efficient, and cost effective represented a hurdle to the development of intelligent devices. Moreover, the development of such devices requires different technical skills and backgrounds to be merged, e.g., food science, materials science, and chemical and electrochemical engineering, which makes the overall design and development process more complex.

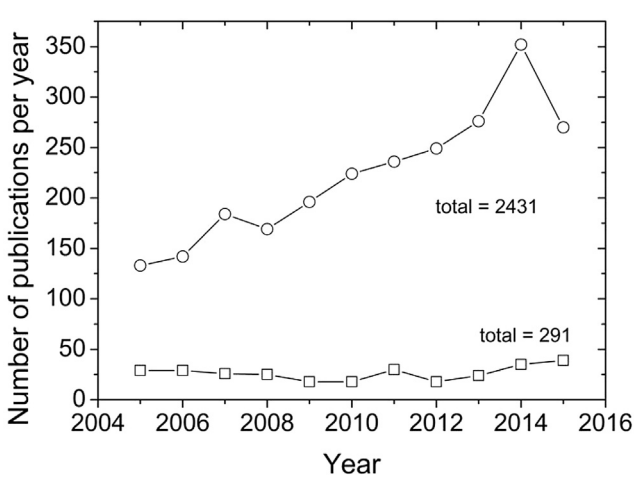

Fig. 1. Publication trends (research articles and review papers) on active packaging (–○–) and intelligent packaging (–□–) in the period 2005–2015. The total number is the cumulative sum of publications at the date of the last access to the web (December 2015).
Source: www.scopus.com.

Due to the increasing interest in intelligent developments, which have been forecast as the main food packaging innovations in the next years (Kuswandi et al., 2011; Vanderroost et al., 2014), this paper summarizes the intelligent packaging applications in the food sector, with special reference to the applications designed to integrate intelligent devices into packages. Therefore, instruments developed based on an intelligent technology (e.g., nose and tongue systems), as well as Internet-based technologies (e.g., *Internet of everything,* IoE), are out of the scope of this review. The focus is on the technical aspects and market applications of three main categories of intelligent systems, namely indicators, data carriers, and sensors. The last part of the work provides guidance for tomorrow's research in the field, with the goal of covering some important aspects that still hinder the full exploitation of intelligent systems for food quality and safety.

2. Intelligent systems in food packaging

The term "intelligent" involves an "ON/OFF" switching function on the package in response to changing external/internal stimuli, in order to communicate the product's status to its consumers or end users (Yam et al. 2005). In practice, an intelligent packaging system is manufactured by incorporating an external, discrete component in the final package, e.g., two-dimensional films or three-dimensional objects. It is widely accepted that intelligent packaging systems can be realized by three main technologies: (i) indicators, which aim to provide more convenience and/or to inform consumers about the food quality; (ii) data carriers, such as barcodes and radiofrequency identification tags (RFID), which are specifically intended for storage, distribution, and traceability purposes; and (iii) sensors, which allow for a rapid and definite quantification of the analytes in foods (Kerry et al., 2006).

2.1. Indicators

Indicators convey information to the consumer that is linked to the presence or absence of a substance, the extent of a reaction between two or more substances, or the concentration of a specific substance or class of substances. Most often, such information is displayed by immediate visual changes, e.g., different color intensities or the diffusion of a dye along the indicator geometry (O'Grady & Kerry, 2008). A distinct feature of indicators is the type of information involved, which is qualitative or semi-quantitative in nature. Despite the large varieties of indicators, all of them can be reasonably included within three categories: time-temperature indicators, freshness indicators, and gas indicators (Hogan & Kerry, 2008). All of them fall within the main category of "product quality and value-improving systems," which are undoubtedly the most widely used devices for food packaging applications (Robertson, 2012).

2.1.1. Temperature indicators

There are two types of temperature indicators: simple temperature indicators and time–temperature integrators (TTIs) (Ahvenainen & Hurme, 1997). Temperature indicators show whether products have been heated above or cooled below a reference (critical) temperature, warning consumers about the potential survival of micro-organisms and protein denaturation during, for example, freezing or defrosting processes (Pault, 1995).

Download English Version:

https://daneshyari.com/en/article/2098518

Download Persian Version:

https://daneshyari.com/article/2098518

Daneshyari.com