



Review article

The digitization of a food package's life cycle: Existing and emerging computer systems in the logistics and post-logistics phase



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ARTICLE INFO

Article history:

Received 1 February 2016

Received in revised form 17 January 2017

Accepted 25 January 2017

Available online xxx

Keywords:

Food package

Cyber-physical system

Logistics

Augmented reality

Reuse and recycle

HACCP

ABSTRACT

At present, the food and food packaging industry is increasingly confronted with and gently forced by consumers and governmental organizations to resolve issues related to food fraud, counterfeit, theft, food quality and safety, and package reuse and recycling. This requires the development and/or integration of new or existing technologies such as intelligent food packages or wireless sensor networks to improve monitoring capabilities during logistics and sales and consumption, allow interaction with consumers, and improve the reuse or recycling of food packages. In this review paper, an extensive overview is provided of computer systems that are used in the logistics and post-logistics phase of a food package's life cycle and that to a certain extent integrate the aforementioned technologies. These systems offer the perspective to improve the efficiency of logistics operations on food packages to reduce food loss, better inform consumers through food packages, and support package reuse and recycling. The main purpose of this review paper is to encourage the academia and engineers to tackle existing research challenges and resolve technical issues related to the development of new integrated computer systems.

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1. Introduction

The ultimate goal of every food company is to ensure that its food products are available at the right place at the right time at the lowest possible cost, of the best quality and in a transparent and reliable way. To achieve this, all actors in the food supply chain need to take into account increasingly stringent food safety regulations [1] and reflect about what will or can happen with food¹ packages² and packaging during logistics or during and after consumption. This means that the food industry needs to resolve issues about

- brand security and food authenticity, origin, traceability, fraude, counterfeit and theft;
- package integrity and food quality and safety;
- void fill, food spoilage, food loss, package reuse and recycling.

This is quite a challenge for two reasons. On the one hand, the current evaluation of food quality, origin and authenticity is performed through destructive and time-consuming analytical methods [2,3]. On the other hand, due to the emergence of e-commerce and the omnichannel paradigm, food products and related packages travel along an increasing number of, sometimes unknown or difficult to predict, delivery pathways to reach a consumer. It therefore becomes increasingly difficult to monitor and control logistics activities related to food products and packages. This is a major issue, not only in terms of package integrity and food safety (many food products require a well-monitored cold chain and the related packages are particularly susceptible to external forces and other possible harmful environmental factors), but also in terms of food authenticity, origin, traceability, fraude, counterfeit and theft [4–7].

Some of the aforementioned issues could be resolved in the near future due to the emergence of the Internet of Everything (IoE) and Wireless Sensor Networks (WSN), and the extensive research that has been carried out since the beginning of this century within the domain of intelligent food packaging. An intelligent food package can be defined as a food package that is in some way provided with one or more intelligent devices (sensors, RFID tags, . . .) to identify or locate a food package, or monitor the condition of a food package, its contents or its environment. Such packages also offer the perspective to facilitate bidirectional interaction for consumers and retailers and/or food companies [8].

At present, a broad range of wireless communication technologies exists to connect many different entities (animals, persons, consumer products, vehicles, appliances, . . .) to the IoE. An extended overview of these technologies can be found in a paper of Atanasov [9]. Of particular interest for intelligent food packages are Low Power Wide Area (LPWA) communication technologies because they offer the perspective of extensive (both in time and space) data exchange with limited power consumption [10,11]. Connecting intelligent food packages to the IoE requires of course the development of new cyber-physical systems (CPS) that are to a certain extent able to read, store, analyze and manage various sources of data. Through such systems, information could then be extracted from the collected data and applied to

- control, automate, support or improve food logistics processes (see Fig. 1);
- better respond to new or changing trends and geographical differences in consumer preferences and/or needs, and related hereto, realize more targeted advertising campaigns or health advice;
- improve the manufacturing processes of food packages in the pre-logistics phase;
- guarantee the quality, authenticity, origin, and safety of food products;
- facilitate the reuse and recycling of food packages;

In this review paper, an extensive, general overview will be given of existing and emerging computer systems that can interact or communicate with (intelligent) food packages and are already being or possibly will be employed in the logistics and post-logistics phase of a food package's life cycle. The main purpose of this review paper is to expose the existing research challenges and technical issues that to a certain extent limit the efficiency of logistics operations on food packages, the interaction between the food industry and consumers through food packages, and the reuse or recycling of food packages.

2. Review methodology

For the discussion of computer systems applied during a food package's life cycle, the latter was roughly divided into a pre-logistics,³ logistics and post-logistics⁴ phase, largely based on the phases defined in a report of the National Institute of Standards

¹ In this review, food stands for food and beverages.

² In this review, the term "packaging" is used to denote packaging materials. The term "package" is used to denote a package as a whole.

³ The pre-logistics phase of a food package is defined as the phase encompassing all steps in the manufacturing process of a food package, i.e. the phase before its actual application.

⁴ The post-logistics phase of a food package's life cycle is defined as the phase encompassing sales, consumption, reuse & recycling.

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