Food Research International 83 (2016) 60–73

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Review

Trends in antimicrobial food packaging systems: Emitting sachets and absorbent pads

Caio G. Otoni [a,b,*], Paula J.P. Espitia [c,d], Roberto J. Avena-Bustillos [e], Tara H. McHugh [e]

[a] PPG-CEM, Dept. of Materials Engineering, Federal University of São Carlos, Rod. Washington Luís, km 235, São Carlos, SP 13565-905, Brazil
[b] National Nanotechnology Laboratory for Agribusiness, Embrapa Instrumentação, Rua XV de Novembro, 1452, São Carlos, SP 13560-979, Brazil
[c] Food Research Division, Observatorio del Caribe Colombiano Research Institute, Getsemaní, Calle del Guerrero #29-02, Cartagena de Indias, Colombia
[d] Food Science Laboratory, Nutrition and Dietetics School, University of Sinú, Cartagena de Indias, Colombia
[e] Healthy Processed Foods Research, Western Regional Research Center, Agricultural Research Service, United States Department of Agriculture, 800 Buchanan St., Albany, CA 94710, USA

ARTICLE INFO

Article history:
Received 11 December 2015
Received in revised form 19 February 2016
Accepted 20 February 2016
Available online 23 February 2016

Keywords:
Active packaging
Antimicrobial sachets
Absorbent pads
Volatile antimicrobials
Antimicrobial nanoparticles

ABSTRACT

Active antimicrobial packaging interacts with packaged food and headspace to reduce, retard, or even inhibit the growth of spoilage and pathogenic microorganisms. Sachets and pads are one of the most successful applications of active food packaging. This review discusses recent developments of antimicrobial active packaging focused exclusively on emitting sachets and absorbent pads, including elaboration techniques, characterization methods, and applications for food preservation purposes. Advantages, drawbacks, and future trends are also discussed, as well as the antimicrobial compounds incorporated in emitting sachets and absorbent pads, including ethanol, chlorine dioxide, a variety of plant essential oils and their main active compounds, and nanoparticles.

Contents

Abbreviations: AF4, asymmetric flow field-flow fractionation; AgNP, silver nanoparticle; AITC, allyl isothiocyanate; CFU, colony-forming units; CuNP, copper nanoparticle; EO, essential oil; GRAS, generally recognized as safe; ICP-MS, inductively coupled plasma mass spectrometry; LAB, lactic acid bacteria; LDPE, low-density polyethylene; MALLS, multi-angle laser light-scattering; MIC, minimal inhibitory concentrations; PE, polyethylene; RH, relative humidity; TAB, total aerobic bacteria; TAM, total aerobic mesophilics; UV, ultraviolet.

* Corresponding author at: National Nanotechnology Laboratory for Agribusiness, Embrapa Instrumentation, Rua XV de Novembro, 1452, São Carlos, SP 13560-979, Brazil.
E-mail addresses: caiogomide@gmail.com (C.G. Otoni), perez.espitia@gmail.com (P.J.P. Espitia), roberto.avena@ars.usda.gov (R.J. Avena-Bustillos), tara.mchugh@ars.usda.gov (T.H. McHugh).

http://dx.doi.org/10.1016/j.foodres.2016.02.018
0963-9969/

1. Introduction

Food losses constitute a remarkable economic concern for the food industry, whereas foodborne outbreaks denote a major threat to public health. The presence of spoilage microorganisms on raw materials and on processed foodstuffs due to cross contamination may be pointed out as a major reason for food loss. This results in alterations of nutritional and sensory characteristics of food, such as oxidation, production of off-flavors and off-odors as well as undesirable changes in texture and color. According to Gustavsson, Cederberg, Sonesson, van Otterdijk, and Meybeck (2011), as much as 1.3 billion tons of foods are wasted every year. Additionally, human diseases caused by the consumption of contaminated food result in heavy expenses in medical care and reduced productivity, which, among other inconveniences, account for more than $77.1 billion annually, only in the USA (Scharff, 2012).

As a result, new technologies have been studied in order to provide safer food products. Among these, active packaging stands out as an emerging technology, in which the packaging material interacts with the packaged food in a desirable way, overcoming the passive role of advertising and protecting food products from the outside environment (Soares, Pires, et al., 2009). There are different concepts of active food packaging, including oxygen scavengers, moisture absorbers, ultraviolet (UV) barriers, and other mechanisms delivering antioxidant, flavoring or antimicrobial activity.

Antimicrobial packaging, particularly, interacts with the packaged food or the package headspace in order to reduce, retard or even inhibit the growth of spoilage and pathogenic microorganisms (Soares, Silva, et al., 2009). Appendini and Hotchkiss (2002) indicated that antimicrobial active packaging can take several forms including direct incorporation of the active compound into the polymer matrix, coating it onto the packaging surface, or immobilizing it in sachets. Sachets or pouches and pads placed inside the packaging are one kind of active food packaging. The antioxidant (Gómez-Estaca, López-de-Dicastillo, Hernández-Muñoz, Catalá, & Gravara, 2014) and antimicrobial actions (Malhotra, Keshwani, & Kharkwal, 2015) of these systems denote their main active roles. Recent developments on active food packaging can take the form of biodegradable and/or edible films (Mellinas et al., 2015), metallic-based micro and nanocomposites (Llorens, Lloret, Picouet, Trbojevich, & Fernandez, 2012), and modified atmosphere packaging (Lee, Lee, Choi, & Hur, 2015). However, sachets or pouches and pads still play a remarkable role in food preservation, especially at commercial level (Gómez-Estaca et al., 2014).

One of the first developed sachets was Ageless®, an oxygen scavenger marketed by Japan's Mitsubishi Gas Chemical Company during the 70's (Brody, Strupinsky, & Kline, 2001). Later, several international companies developed similar oxygen scavenging sachets, consisting basically in the removal of oxygen inside the packaging by means of oxidation of a confined ferrous compound. Catechol, ascorbic acid, and oxidative enzymes (e.g., glucose oxidase) have also been used with this purpose (Brody et al., 2001). The application of sachets as oxygen scavengers has already been reviewed elsewhere (Cichello, 2015; Cruz, Camilloto, & Pires, 2012).

The use of sachets was recently expanded to other functions, such as antimicrobial, through the incorporation and subsequent release of volatile compounds with well-known antimicrobial activities against foodborne microorganisms. Antimicrobial compounds incorporated in sachets include ethanol, chlorine dioxide (ClO_2), and a variety of plant essential oils (EOs) and their main active constituents. Similar to sachets, absorbent pads have been recently developed to combine the antimicrobial activity of active compounds (including nanoparticles) with the convenience of an absorbent material inside the packaging. Absorbent pads have been used commercially for soaking up excess moisture, acting as a purge, especially in meat products. They are intended to remove moisture (arising from respiration, exudate generation, or water vapor permeation) from the packaged food in an effort to slow down microbial growth, which is strongly dependent on high water activity levels (Azeredo, 2013).

Although several reports have been published regarding antimicrobial active food packaging (Sung et al., 2013; Vermeiren, Devlieghere, van Beest, De Kruijf, & Debevere, 1999), as far as we know, literature devoted solely to review antimicrobial sachets and antimicrobial absorbent pads is limited, with no review paper exclusively based on this subject. Therefore, this review aims to analyze recent developments of food packaging systems focused on sachets and absorbent pads with antimicrobial properties, their elaboration techniques, characterization methods, and application as part of active systems for food preservation. The advantages and drawbacks of these concepts are also weighed. As a final point, future trends related to the use of emitting sachets and absorbent pads are presented.

2. Elaboration of antimicrobial sachets

2.1. Types of emitting sachets

The production of antimicrobial-releasing sachets has two approaches: sachets that generate antimicrobial compounds in situ and release it; and sachets that carry and release antimicrobials.

2.1.1. Sachets that generate and release antimicrobials

These sachets are produced in two steps: addition of the system that generates the antimicrobial compound inside the sachet and the sachet sealing. Ma (2012) developed a system that enzymatically generated allyl isothiocyanate (AITC) vapor via sinigrin–myrosinase reaction and released it in situ. Other example is the production of ClO_2 in situ. In this context, ClO_2 is an unstable gas and its compression and storage is not possible due to the risk of explosion, thus it must be generated in situ (Gómez-López, Rajkovic, Ragaert, Smigic, & Devlieghere, 2009). This is commercially accomplished by mixing two dry precursors (sodium chlorite and an acid) for ClO_2 generation within gas permeable sachets, according to the following reaction (Keskinen & Annous, 2010):

$$4H^+ + 5NaClO_2 \rightarrow 4ClO_2 + NaCl + 4Na^+ + 2H_2O$$

2.1.2. Sachets that carry and release antimicrobials

This procedure comprises three steps: antimicrobial agent incorporation into a carrier, carrier addition inside the sachet, and sachet sealing. Soares, Pires, and Camilloto (2008) developed antimicrobial sachets by incorporating liquid AITC into a porous high-density polyethylene resin (carrier). The carrier polymer was then placed inside a nonwoven fabric (sachet material), which was heat sealed to form the antimicrobial sachet.