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Review

# A comprehensive review on the application of active packaging technologies to muscle foods

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ABSTRACT

Since the beginning of the current millennium, innovations in food packaging systems have evolved as response to the continuous changes in market trends and consumer's preferences for convenient, safe, healthy and quality food products. Active packaging (AP) system provides such functionalities to facilitate these demands and offers role beyond the traditional protection and inert barrier to the external environment. Various AP components such as antimicrobials, antioxidants, $O_2$ scavengers, $CO_2$ emitters/absorbers, moisture regulators, flavor releasers, and absorbers have been deliberately included in the package system for augmenting packaging performance. These constituents delay or stop chemical, microbial, enzymatic and oxidative spoilage, control weight loss, retain color and integrity of meat based products. Currently, the use of edible or biodegradable materials, plant extracts and nanomaterials are expected to substitute synthetic additives due to their packaging and waste management notions. This article reviews the principles and technological advances as well as the global patents and future research trends in AP sector with their applications focused on meat products.


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## 1. Introduction

The food packaging technologies are improving consistently in response to the demands of modern society, as well as the industrial production trends toward fresh, mildly preserved, convenient, delicious, safe, wholesome and quality food products with a longer shelf life (Kerry, 2014; Realini & Marcos, 2014). Recently, the passive role of food packaging has changed from simple preservation and containment methods to include such aspects as safety, convenience, point of purchase marketing, material reduction, environmental concerns and tamper-proofing (Han, 2014). Emerging concepts of active and smart packaging technologies provide all these functionalities and numerous other innovative solutions for prolonging the shelf life and improving the quality and safety of food products (Realini & Marcos, 2014).

Subsidiary constituents such as antimicrobial releasing systems, gas scavengers or emitters, gas flushers, moisture absorbents and antioxidants have been included deliberately in or on either the packaging material or the package headspace to augment the performance of packaging system (Dobrucka & Cierpiszewski, 2014; Realini & Marcos, 2014). Changes in retail and distribution practices (i.e., internet shopping), consumers life-styles and market globalization resulted breakthrough in AP (Dainelli, Gontard, Spyropoulos, Zondervan-van den Beuken, & Tobback, 2008; Mohan, Ravishankar, & Gopal, 2010). Extensive research schemes and developments are ongoing with the purpose of attaining competitive benefits and market shares.

Meat, poultry and seafood are among the highly perishable foods, which rapidly deteriorate unless properly processed, packaged and stored. The deteriorations and degradations are mainly because of the high contents of fat and moisture and are therefore vulnerable to biological reactions such as protein degradation, lipid oxidation, or putrefactions interceded by microbial and endogenous enzymes, resulting in a shorter life span (Alparslan & Baygar, 2017; Hosseini, Rezaei, Zandi, & Farahmandghavi, 2015, 2016a). These reactions lead to the buildup of detrimental compounds, and discoloration (melanosis) caused by the phenols polymerization into insoluble dark pigments (melanins), subsequently degrade the quality (Nirmal & Benjakul, 2011).

Other intrinsic factors such as water activity and pH of fresh meat also accelerate spoilage. Generally, fresh meat has over 0.85 water activity level and a favorable pH range more suited for spoilage microbes (Dave & Ghaly, 2011; Mariutti, Nogueira, & Bragagnolo, 2011). Several microorganisms, molds and yeasts are involved in the spoilage of meat and aquatic products (Table 1). In consequence, food-borne diseases have risen as a menace in many part of the world over the past few decades among all age groups. It has substantially influenced the environment and human health, and causes economic loss (Jayasena & Jo, 2013; Tauxe, Doyle, Kuchenmuller, Schlundt, & Stein, 2010).

Active packaging system is used to delay or stop microbial, enzymatic and oxidative spoilage, minimize contamination, weight loss and to ensure the color and integrity of the products during storage (Chong, Lai, & Yang, 2015; Kerry, O'Grady, & Hogan, 2006; Vital et al., 2016). The purpose of AP technologies for use in meat, poultry and fish industries are therefore to provide the aforementioned functionalities. Recently, a wide range of successful works have been done on the exploitation of AP systems for meat and meat products packaging (Barbosa-Pereira, Aurrekoetxea, Angulo, Paseiro-Losada, & Cruz, 2014; Bolumar, LaPeña, Skibsted, & Orlien, 2016; Dobrucka & Cierpiszewski, 2014; Mohebi & Marquez, 2015). Therefore, the focus of this paper is to overview the potential applications and research trends in AP of meat, poultry and aquatic products, with special emphasis on antimicrobial packaging (AMP).

**Table 1**
Common pathogenic and spoilage microorganisms involved with the deterioration of muscle foods (Adapted from: Lucera, Costa, Conte, & Nobile, 2012; Karabagias, Badeka, & Kontominas, 2011; Dave & Ghaly, 2011; Fratianni et al., 2010; Mor-Mur & Yuste, 2010; Rydlo, Miltz, & Mor, 2006; Borch, Kant-Muermans, & Blixt, 1996).

| Microorganisms | Genera/Species |
|---|---|
| Pathogenic microorganisms | *Salmonella* spp. |
| | *Mycobacterium* spp. |
| | *Staphylococcus aureus* |
| | *Arcobacter butzleri* |
| | *Listeria monocytogenes* |
| | *Bacillus cereus* |
| | *Clostridium botulinum* |
| | *Clostridium perfringens* |
| | *Yersinia enterocolitica* |
| | *Escherichia coli O157:H7* |
| | *Aeromonas hydrophilla* |
| | Enterohemorrhagic *E. coli (EHEC)* |
| | *Camplylobacter* spp. |
| Spoilage microorganisms Bacteria | *Acinetobacter* |
| | *Pseudomonas* |
| | *Corynebacterium* |
| | *Flavobacterium* |
| | *Alcaligenes* |
| | *Brochothrix thermosphacta* |
| | *Moraxella* |
| | *Klebsiella* |
| | *Enterobacter* |
| | *Proteus* spp. |
| | *Leuconostoc* spp. |
| | *Lactobacillus* spp. |
| Molds | *Rhizopus* |
| | *Aspergillus* |
| | *Sporotrichum* |
| | *Monilia* |
| | *Fusarium* |
| Yeasts | *Torulopsis* |
| | *Candida* |

## 2. Active packaging of muscle food

Active packaging is a system in which the package, packaging environment and the product interact positively in order to improve product safety and to accomplish some other desired characteristics (Ahvenainen, 2003; Biji, Ravishankar, & Mohan, 2015). Based on the European Union Guidance to the Commission Regulation No 450/2009 (EU, 2009), packaging is termed active when it provides functions beyond the traditional protection and inert barrier to the outside environment. Muscle food industries are displaying continuing fascination in the progress associated with technological advances to prolong the shelf life and encourage the consumer acceptance of the meat-based products by enhancing nutritional quality and safety (Chiavaro, Zanardi, Bottari, & Ianieri, 2008).

AP system associates the preservative role of antimicrobials and other components with the pre-existing packaging concepts to the meat industry (Mauriello, Ercolini, La Storia, Casaburi, & Villani, 2004; Scannell et al., 2000). The packaging releases substances into the food or the environment surrounding the food or it absorbs food-derived chemicals from the food or the environment with the packaging surrounding the food (Fig. 1). The interior environment of the packaging can be altered by the incorporation of active substances into the package via pad, tablet or sachet and permitting mechanisms such as evaporation and absorption processes to hinder the microbial proliferation and other degradation processes (Lee, 2010). The quality attributes of the actively packaged food products at the time of consumption is far better than the same food preserved conventionally. The various AP concepts pertained to meat based products are presented in Fig. 2.