

Food packaging materials with polyphenols as active compounds

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Abstract

Packaging is the basis for good preservation of food quality and food safety. A relatively new type of packaging is active packaging, which attracts attention due to its many positive features. Especially interesting materials for active packaging are biodegradable materials. Not only can these materials play the role of the carrier of the active component, but they are also more rapidly degradable and edible, which gives additional positive properties. Natural compounds such as polyphenolic compounds can be added to the packaging materials as an active compound. Although the addition of polyphenols to the active packaging is in the research phase, it is evident from the results so far that such materials have the potential for commercial use in food packaging. The aim of this paper is to briefly describe the use of polyphenolic compounds as active ingredients in active packaging.

Keywords: polyphenols, biodegradable packaging, edible packaging, active packaging

Introduction

Packaging is an indispensable part of the food industry in today's world. It protects the product from the moment it is packed until the moment it is opened. Without packaging, the consumer society that we have today would be unthinkable. In order to meet today's needs of industry, consumers and society, some new packaging materials / technologies are being studied. They should contribute to the safety of packaged foods. Such packaging is active packaging.

Active packaging is a novel type of packaging that contains active compounds which give the package an additional role. Depending on the active compound added into the packaging material or inside of the package, active packaging can

prevent oxidation reactions in food or control carbon dioxide or humidity inside the package (Robertson, 2013). A special case of active packaging is antimicrobial packaging with an active component which increases the antimicrobial resistance of food and thus prolongs the shelflife of the food or increases its quality.

Another type of novel packaging is biodegradable packaging (Piscopo et al., 2019). It is made of materials that can degrade in nature faster than other traditional packaging materials. The development of biodegradable materials is important due to the growing tendency to reduce the use of materials made from nonrenewable sources (based on petroleum) and enhance the

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use of materials from renewable sources (Roberts, 2013). The materials used for biodegradable packaging are proteins or carbohydrates from different sources (animal or plant origin). Biodegradable packaging can also be an edible packaging.

Another novelty are active, biodegradable/edible materials. Namely, an active compound can be added into the biodegradable materials to enhance positive roles of biodegradable package which then makes an active, biodegradable/edible packaging.

Natural compounds such as polyphenols can be active components in the packaging. Polyphenols are secondary plant metabolites that have shown a number of potentially positive bioactivities. Some of those are anti-radical and anti-microbial activity (Silva et al., 2018; Denev et al., 2019). They are still intensively studied since the real mechanism of its bioactivities is still not completely understood. Due to positive bioactivities, especially their anti-radical and antimicrobial activity, polyphenols can be used as active compounds in food packaging materials. Earlier studies have shown the role of polyphenols as active compounds in packaging materials (Biao et al., 2019; Dou et al., 2018; Fabra et al., 2018; Lei et al., 2019; Riaz et al., 2018; Rollini et al., 2019; Sun et al., 2017; Wu et al., 2019).

The aim of this work is to briefly present the use of polyphenols as active components in food packaging materials, especially in active, biodegradable materials.

Active packaging

Traditional food packaging materials usually give a passive barrier to various environmental influences and thereby protect the food. But due to higher demands for food quality, active packaging has been developed (Fang et al., 2017). It was first reported as active packaging in 1987 (Robertson, 2013). According to European Union's Commission regulation number 450/2009, active packaging is a material with incorporated active compounds that can release substances into the food or absorb substances from the food or from the environment surrounding the food, which help to preserve the food quality. An active component can be incorporated into a small sachet which is then inserted into the traditional package. The other possibility is that the active

component is incorporated into the packaging material. The role of active components can be various. An active component can absorb oxygen, control carbon dioxide or humidity, absorb ethylene, emit ethanol, absorb moisture or flavour or have antimicrobial or antioxidant role (Robertson, 2013). These different types of active packaging are the subject of present studies, since their potential use can decrease the need for preservatives in the food.

Antimicrobial and antioxidant active packaging have received special attention because they can improve the preservation of quality of some foods important for the human diet which are otherwise sensitive to microbial and oxidant spoilage. Components with antimicrobial role are various chemicals and natural compounds (such as organic acids, enzymes, bacteriocins and silver) or some natural extracts from plants (Robertson, 2013). Due to public concern about chemical compounds or additives, there is an effort to find natural compounds or extracts from natural sources that possess antimicrobial activity. Furthermore, active packages with enhanced antioxidant activity can help preserve the quality of food in which oxidation reactions are the cause of food deterioration. In both types, antimicrobial and antioxidant active packaging, polyphenols as natural compounds are promising active components.

Polyphenols or polyphenol extracts as active component in packaging material

Polyphenolic compounds are a large group of natural compounds that can be found in fruits and vegetables. They can be divided into main categories like phenolic acids, flavonoids, lignans and stilbens (Quirós-Sauceda et al., 2014). Due to their antioxidant and antimicrobial activity (Denev et al., 2019; Silva et al., 2018) they can be used as the active components in active food packaging. Important sources of polyphenols can be various plant materials or by-products or waste products from the food industry that are rich in polyphenols.

Polyphenol extracts as antioxidants in food packaging materials

Polyphenols can be incorporated into biodegrad-

able and edible packaging materials made from biopolymers such as polysaccharides (alginates, chitosan, glucomannan or pectin) which gives these materials enhanced antioxidant properties and an active role. Earlier studies have shown that green tea extracts or grape seed extracts can be incorporated into alginate films (Fabra et al., 2018) or into calcium alginate films (Biao et al., 2019). Those studies showed that added polyphenolic compounds improved the antioxidant activity of films (Biao et al., 2019; Fabra et al., 2018). Edible films composed of pectin and konjac glucomannan were incorporated with tea polyphenols (Lei et al., 2019). In these films also, antioxidant activity was enhanced. Another example was the incorporation of apple peel polyphenols (Riaz et al., 2018) or young apple polyphenols (Sun et al., 2017) into edible chitosan films where they enhanced antioxidant activity of the chitosan film (Riaz et al., 2018; Sun et al., 2017). Polyphenol extracts can be incorporated into biodegradable and edible multilayer films as in the case of the gelatin-sodium alginate combination. Tea polyphenols were investigated as active substance in those materials (Dou et al., 2018) where they improved antioxidant activity. In addition, films based on pomelo peel flour incorporated with tea polyphenols (Wu et al., 2019) enhanced the antioxidant activity of the film (Wu et al., 2019).

A polyphenol extract can serve as an active antioxidant substance even in traditional packaging materials. Olive leaf extract was incorporated into poly(ethylene terephthalate) / polyethylene (PET/PE) multilayer film where polyphenols from the olive leaf extract delayed lipid oxidation in sunflower seeds (Cejudo Bastante et al., 2018). Tea polyphenols were incorporated into poly(vinyl alcohol)/clay nanocomposite films where they showed that the antioxidant activity of the films were enhanced (Chen et al., 2018).

Polyphenol extracts as antimicrobial agents in food packaging materials

Polyphenol extracts can serve as antimicrobial agents in biodegradable, edible packaging materials made from various polysaccharides (alginate, pectin, glucomannan or chitosan). Namely, green tea extracts and grape seed extracts in edible alginate films exhibit significant antiviral activity against the murine norovirus and the hepatitis A virus (Fabra et

al., 2018). Tea polyphenols were also studied as active components in calcium alginate films where they enhanced anti-inflammatory properties of the film (Biao et al., 2019). Pectin and glucomannan are other biodegradable, edible polysaccharides used as packaging materials. Tea polyphenols were incorporated into pectin and konjac glucomannan films (Lei et al., 2019) where the tea polyphenol significantly improved antimicrobial activity (Lei et al., 2019). Furthermore, apple peel extracts (Riaz et al., 2018) or young apple polyphenol extracts (Sun et al., 2017) incorporated into chitosan significantly enhanced the antimicrobial activity of the film. Tea polyphenols in films based on pomelo peel flour (Wu et al., 2019) showed antimicrobial activity. Propolis as a source of polyphenols and chitosan were incorporated into paper to make active propolis-chitosan paper (Rollini et al., 2019). Antimicrobial activity of that material was also demonstrated. Edible, biodegradable packaging material can be made of proteins like zein. Polyphenols can be incorporated into these films as well. It was shown that gallic acid in zein electrospun fiber mats enhanced the antibacterial activity of the film (Neo et al., 2013).

Polyphenols can be the active antimicrobial components in some traditional packaging materials. For example, tea polyphenols incorporated into poly(vinyl alcohol) films showed antimicrobial activity (Lan et al., 2019). The incorporation of tea polyphenols into more complex poly(vinyl alcohol)/clay nanocomposite films also showed enhanced antimicrobial activity (Chen et al., 2018).

Properties of materials with added polyphenols

Usually edible and biodegradable packaging materials are sensitive to water and degrade faster in the presence of water. Since both food and the outer atmosphere surrounding the package can contain water vapor, this can be a problem in edible materials because water vapor or water can cause the degradation of films while food is still packaged. That is why water-resistance properties of biodegradable/edible films need to be improved. Studies have shown that polyphenols added into edible films usually enhance water resistance properties or, in other words, decrease the water vapor permeability. It was shown that tea polyphenols incorporated into edible pectin and konjac glucomannan films increased water

resistant properties (Lei et al., 2019). The film made of chitosan incorporating apple peel polyphenols (Riaz et al., 2018) or film based on pomelo peel flour incorporating tea polyphenols (Wu et al., 2019) decreased water vapor permeability (Riaz et al., 2018). In addition, young apple polyphenols incorporated into chitosan films decreased water vapor permeability as well (Sun et al., 2017). But there are some studies that have shown the water permeability can be increased by the incorporation of polyphenols. This was shown in the study where the incorporation of tea polyphenols into calcium alginate film was studied and as a result, added polyphenols increased the water permeability of the film (Biao et al., 2019).

Biodegradable and edible films have to have certain physical and mechanical characteristics in order to be used for packaging. Studies have shown that polyphenols added to biodegradable/edible materials increase the properties of films. In particular, tea polyphenols as cross-linking agents in alginate based films enhanced the mechanical and physical properties of films (Biao et al., 2019). Low concentrations of young apple polyphenols in chitosan films caused slight changes in mechanical properties too (Sun et al., 2017). Tea polyphenols in poly(vinyl alcohol)/clay nanocomposite films (Chen et al., 2018), poly(vinyl alcohol) films (Lan et al., 2019), pectin and konjac glucomannan films (Lei et al., 2019), gelatin-sodium alginate films (Dou et al., 2018), or films based on pomelo peel flour (Wu et al., 2019) also improved the mechanical properties of films.

Active package for meat products

Active packaging for meat products include antimicrobial, antioxidant and carbon

dioxide emitting/generating package (Fang et al., 2017). Those packaging are described well in a review paper (Fang et al., 2017). Since this area is still under study, there are not so many papers describing polyphenols as active compounds in packaging for meat. But still, it was shown that polyphenols and polyphenol extracts can be active compounds in packaging material for meat and meat products. Propolis as a polyphenol source and chitosan were added into paper to obtain propolis – chitosan active paper. The antimicrobial activity of this material was confirmed on raw veal meat (Rollini et al., 2019). The quality of pork meat patties was examined wrapping the meat into chitosan-tea polyphenol composite films and then aerobically packaging them in low density polyethylene bags. The samples were stored at 4 °C for 12 days. The antioxidant and antimicrobial properties of the film helped to preserve the quality of pork meat during refrigerated storage for 12 days (Qin et al., 2013).

Conclusion

Active, biodegradable and edible packaging with polyphenols as active components is a novelty in the development of packaging materials and is still a subject of research. This type of packaging shows the potential to develop packaging with additional positive features for packaging various foods, including meat and meat products.

**Financiranje: ovaj rad je financirala Hrvatska zaklada za znanost projektom HRZZ-IP-2016-06-6777*

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Dostavljeno: 20.08.2019.

Prihvaćeno: 04.09.2019.

Ambalažni materijali s polifenolima kao aktivnim spojevima

Sažetak

Ambalaža je osnova dobrog očuvanja kvalitete i sigurnosti hrane. Relativno novija vrsta ambalaže je aktivna ambalaža koja privlači pažnju zbog brojnih pozitivnih značajki. Posebno zanimljivi materijali za izradu aktivne ambalaže su biorazgradivi materijali. Ovi materijali ne samo da mogu igrati ulogu nosača aktivne komponente u aktivnoj ambalaži, već su i brže razgradljivi i jestivi, što ovoj ambalaži daje dodatna pozitivna svojstva. Prirodni spojevi poput polifenolnih spojeva mogu se dodati u ambalažni materijal kao aktivni spojevi. Iako je dodavanje polifenola aktivnoj ambalaži u fazi istraživanja, iz dosadašnjih rezultata vidljivo je da takvi materijali imaju potencijal za komercijalnu upotrebu u pakiranju hrane. Cilj ovog rada je ukratko opisati uporabu polifenolnih spojeva kao aktivnih spojeva u aktivnoj ambalaži.

Ključne riječi: polifenoli, biorazgradiva ambalaža, jestiva ambalaža, aktivna ambalaža

Verpackungsmaterialien mit Polyphenolen als aktiven Verbindungen

Zusammenfassung

Die Verpackung ist die Grundlage für die Erhaltung der Qualität und der Sicherheit von Nahrung. Zu den verhältnismäßig neueren Verpackungen gehört die aktive Verpackung, die wegen ihrer zahlreichen positiven Eigenschaften große Aufmerksamkeit erweckt. Besonders interessante Werkstoffe für die Herstellung von aktiven Verpackungen sind biologisch abbaubare Werkstoffe. Diese Werkstoffe spielen nicht nur die Rolle des Trägers der aktiven Komponente in der aktiven Verpackung sondern können schneller abgebaut werden und sind essbar, wodurch diese Verpackung zusätzliche positive Eigenschaften erhält. Natürliche Verbindungen wie Polyphenolverbindungen können dem Verpackungsmaterial als aktive Stoffe zugesetzt werden. Obwohl sich die Zugabe von Polyphenolen zur aktiven Verpackung in der Untersuchungsphase befindet, geht aus den bisherigen Ergebnissen hervor, dass solche Werkstoffe für den gewerblichen Gebrauch bei der Lebensmittelverpackung verwendet werden könnten. Ziel dieser Arbeit ist es, die Verwendung von Polyphenolverbindungen als aktiven Verbindungen in aktiven Verpackungen zu beschreiben.

Schlüsselwörter: Polyphenole, biologisch abbaubare Verpackung, essbare Verpackung, aktive Verpackung

Materiales de embalaje con polifenoles como compuestos activos

Resumen

El embalaje es la base de la buena calidad y de la seguridad de comida. Un tipo de embalaje relativamente reciente es el empaque activo que llama atención por tener muchas características positivas. Materiales para la producción del empaque activo especialmente interesantes son materiales biodegradables. Estos materiales además de ser portadores de componentes activos en el empaque activo, también degradan rápidamente y son comestibles, lo que añade a las características positivas de este tipo de embalaje. Los compuestos naturales como polifenoles pueden ser añadidos al material de embalaje como compuestos activos. Aunque la añadidura de los polifenoles al empaque activo está en la fase de investigación, los resultados hasta ahora muestran que estos materiales tienen un potencial comercial para el uso en el envasado de alimentos. El fin de este trabajo es describir brevemente el uso de los polifenoles como compuestos activos en el empaque activo.

Palabras claves: polifenoles, embalaje biodegradable, embalaje comestible, empaque activo

Materiali da imballaggio con polifenoli come composti attivi

Riassunto

L'imballaggio è fondamentale per preservare la qualità e la sicurezza del cibo. C'è un tipo d'imballaggio relativamente nuovo che attira su di sé l'attenzione per i numerosi aspetti positivi che lo contraddistinguono. Tra i materiali utilizzati per la produzione d'imballaggi "attivi", destano particolare interesse i materiali biodegradabili. Si tratta di materiali che non soltanto possono ricoprire il ruolo di portatore dei componenti attivi nell'imballaggio "attivo", ma sono anche più rapidamente biodegradabili e comestibili, conferendo a questo tipo d'imballaggio ulteriori proprietà positive. I composti organici come quelli polifenolici possono essere aggiunti al materiale da imballaggio come composti attivi. Anche se l'aggiunta dei polifenoli agli imballaggi "attivi" è ancora in fase sperimentale, dai risultati sinora ottenuti si evidenzia il loro potenziale uso commerciale nel confezionamento alimentare. Lo scopo di questo studio consiste nel descrivere sinteticamente l'uso dei composti polifenolici come composti attivi negli imballaggi di tipo "attivo".

Parole chiave: polifenoli, imballaggio biodegradabile, imballaggio commestibile, imballaggio attivo