APPLICATION OF VARIOUS TYPES OF COATINGS IN FOOD PACKAGING MATERIALS: SENSORIAL ASSESSMENT AND HEALTH SAFETY

PRIMENA RAZLIČITIH VRSTA OMOTAČA KOD PREHRAMBENIH AMBALAŽNIH MATERIJALA: SENZORNA OCENA I ZDRASTVENA BEZBEDNOST

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ABSTRACT

Food safety is a crucial aspect, when designing food packaging. It is necessary to assess every layer of the material that could be interacting with food. There are various substances that could be used to produce coatings for the cardboard materials, safe for the application in the food packaging materials. By introducing additional layer to the packaging material, it is possible to enhance food safety, improve packaging and food quality, and extend food shelf-life.

The aim of this work is to present the background of some applications of paper coatings based on proteins, polysaccharides, lipids and others. Moreover the food safety aspect of paper and cardboard was described.

Key words: packaging, food, films, coatings, sensory quality, migration.

REZIME

Prehrambena bezbednost je ključni faktor u dizajniranju ambalaže za pakovanje hrane. Neophodno je stoga da se oceni svaki sloj materijala koji dolazi u dodir s hranom. Postoje različite zdravstveno bezbedne supstance koje se koriste kao omotači za kartonske ambalažne materijale. Dodavanjem slojeva na ambalažne materijale poboljšava se ambalaža, odnosno bezbednost, kvalitet i rok trajanja hrane.

Cilj rada je da predstavi proces primene nekih papirnih omotača koji su bazirani na proteinima, polisaharidima, lipidima, itd. Štaviše, rad se bavi i prehrambeno-bezbednosnim aspektom upotrebe papirnih i kartonskih ambalažnih materijala.

Ključne reči: pakovanje, hrana, omotači, jestivi filmovi, senzorni kvalitet, migracija.

INTRODUCTION

Packaging is one of the essential aspects in ensuring a safe food product (Veraart and Coulier, 2007; Simoneau, 2008). With the distance that the resources and products travel, it is an emerging issue to develop new, innovative, efficient, effective and, if not the most important, safe packaging. Introducing new materials or the variations of existing ones, the food technology could possibly have a great impact on product and its features (Mansour, 2011; Nowacka et al., 2014). However, any change or development must follow rigid safety criteria required by the laws. It is a crucial aspect to ensure that the packaging is safe both food and human health (Brown and Williams, 2003; Simoneau, 2008). All of the possible interactions between food and packaging must be controlled not to exceed the migration limits. Those interactions could happen not only with the direct contacting food materials, but also with the more outdoor layers. Thus it is of the highest importance to assess the safety of all the layers together. With the introduction of new types of the coatings to packaging materials it is even more important to correctly and precisely assess the qualitative and quantitative interactions between new materials and food (Castle, 2001; Nowacka et al., 2013). Food packaging materials play a major role during various parts of the food supply chains. They create a protection for both environment and food, extend the time to distribute and make space for communication about the product. Within the packaging, the producer can give numerous messages to the client including expiration date, nutritional value, advertisement, allergens, compounds and the instructions about

the conditions of the storage. All of these functions, must however concur with the safety requirements of the packaging material. Even with the constant improvements of the packaging materials, it is still an emerging issue to ensure the safety and that the maximal limits for the migration between the package and the food product (Salvage, 2005; Raheem, 2012; Lazić et al., 2013). Paper and cardboard are widely used which is associated with their low price and weight, wide availability, ease of print and relatively good mechanical strength (Berk, 2009). Unfortunately, paper materials due to their properties cannot be applied to all products. Due to their high hygroscopic properties, permeability to gases and fats, they are used primarily to dry the products and/or with a short shelf life (Mauer and Ozen, 2004). Moreover, paper packaging has limited number of shapes. These defects can be eliminated, among others, by the composition of the pulp production process or different surface treatments. For example, the permeability for moisture and fat content can be reduced by wax covering (Berk, 2009).

The aim of this work is to present the background of some applications of paper coatings to improve the quality of paper food packaging. The different coating based on proteins, polysaccharides, lipids and others were presented in this article. Moreover, the food safety aspect of paper and cardboard was described.

MATERIAL AND METHOD

Paper

Paper and cardboard are characterized by poor barrier properties and this limit their use. To obtain improved paper

food packaging the applications of various types of coatings are used.

Coatings

The properties of different coatings for paper food packaging was study. The coatings was divided on various groups depending on the coating composition - coating based on:

- proteins,
- polysaccharides,
- lipids,
- others.

RESULTS AND DISCUSSION

Types of materials used for the coatings of paper

There are multiple biopolymers possible for using to apply in the paper packaging materials. They could be made from various proteins, lipids, polysaccharides or applied together. Those substances could be also described as renewable biopolymers, which could be their advantage nowadays, when the sustainability becomes one of the emerging issues. Mainly, the choice of the material for the coatings depends on the functions and aim of the packaging. The effect of using paper or cardboard can be improved by adding an active agent into the coating (Berk, 2009; Khwaldia et al., 2010).

Protein based coatings

Proteins could be used as part of the coatings and films for various food products. For instance they might be applied in meats, nuts, eggs, fruit, vegetables, dry foodstuff and paper packaging. Proteins could be derived from different sources, both animal and plant based. The typical animal based sources for proteins might be: milk, gelatin, and plant based: wheat, soy or corn. The advantage of applying is their extraordinary oxygen barrier property at low to intermediate relative humidity and acceptable mechanical properties. On the other hand, protein based coatings and films show relatively poor barrier features against water vapor. The reason for this is their hydrophilic nature (Khwaldia et al., 2010).

Caseins and caseinates are proteins derived from milk. Their natural features such as: solubility in water and ability to act as emulsifiers makes them a possible source for coatings and edible films for food industry.

Next type of protein based coatings from animal based sources is whey protein. Within the production of cheese, whey protein is a by-product and applying it as a coating material could be one of the possible ways of its usage. Whey protein can be characterized by its ability to constitute a barrier towards aromas, oils and oxygen. Studies conducted by Han and Krochta (1999) suggested that paper which was coated with whey protein had higher oil resistance and reduced water vapor permeability. Application of whey protein might increase the quality of the packaging within reduction in oxygen permeability (Chan and Krochta, 2001) and increase in gloss in paper coating with whey protein isolate, increase in smoothness and homogeneity. Application of whey protein isolate and whey protein concentrate increased the strength and toughness (Gällstedt et al., 2005). However the mechanical resistance of whey protein coatings decreased with the addition of the lipids (Galus and Kadzińska, 2016). Even though, the application of whey protein might be an efficient and effective alternative source for packaging coatings, there are still unsolved problems concerning the demands on that kind of material and the details of the process (Khwaldia et al., 2010).

The other source of proteins might be plants. Wheat gluten is derived from wheat and has properties that might be used in

the production of coatings. Selective gas barrier properties, insolubility in water, viscoelastic behaviour or film-forming properties might be justification for further research towards wheat gluten containing coatings. Wheat gluten is mainly used as a binder, showing good formation properties (Khwaldia et al., 2010).

The other type of plant protein is soy. With regards to the amount of produced soy plants it might be good source of coating. However researchers are still studying how to improve and enable its application in coatings. Soy protein coating characterized by not effective mechanical properties and not efficient moisture barriers. Because of that soy protein is not widely used for packaging coatings materials (Khwaldia et al., 2010).

Polysaccharide based coatings

Polysaccharides are safe and globally available sources for coating application. Polysaccharide based coatings are good aroma, gas and lipid barriers. Paper coatings might be produced from the polysaccharides, for instance from starch, alginates, chitosan and carrageenan. Those polysaccharides have hydrophilic nature, thus their application might be limited (Khwaldia et al., 2010).

Starch is the most used agriculture resource, because of its relatively low price and global availability. However, besides its popularity, it has not sufficient physical properties. By the addition of cellulose and proteins and blending, its features could be improved. Most common purpose of using dispersed starch granules is to smooth the surface of the packaging material, without influencing its barrier features (Khwaldia et al., 2010).

Alginates and agar might be good source of coatings. Alginates are the salts of the alginic acid, extracted from the seaweeds. They are resistant to oil, solvents and grease and shows the ability to form a film. Nowadays, the interest in usage of seaweeds in different foodstuff is constantly increasing and coatings may also be a part of this trend. The application of agar in the form of the biofilm on the ready to heat pieces of boiled chicken decreased the time needed to heat it. They have many advantages including low cost of the production, wide availability, relatively easy production process and sustainability (Albert et al., 2013).

Similarly chitosan is a natural polysaccharide, which might be used as edible and biodegradable material. Coatings derived from chitosan are long – lasting, elastic and hard to tear. Chitosan shows effective oxygen and grease barrier properties. Based on those properties, chitosan might be an interesting alternative for food and food packaging purposes (Khwaldia et al., 2010; Kurek et al., 2014).

Lipids and composite coatings

The hydrophobicity might be the main reason for introducing lipid compounds such as long-chain fatty acids or waxes into the coating of the packaging material. Of those substances, waxes show the best features for reducing moisture permeability, because of their hydrophobic character. Moreover, lipid and wax coatings are good barrier generally for gases. However their properties depend on the film composition. Water resistance and thus increased shelf life of the packed foodstuff are frequently waxed coated (Rhimi and Shellhammer, 2005; Berk, 2009; Khwaldia et al., 2010).

Other coatings

There is a big group of active coatings, which allows to minimize microbiological contamination of the food or packaging surface. Substances limiting the growth of the microflora are different kinds of natural antimicrobial substances e.g. bacteriocins, spice extracts and essential oils, enzymes, organic acids, food preservatives and additives and silver

(Appendinia and Hotchkiss, 2002; Nowacka, 2010). For example, application of a cinnamon coating to paper packaging reduces microbial growth and prolongs the life of strawberries to 7 days storage in 4 °C (Rodríguez et al., 2007). The antimicrobial coatings are barriers delaying a negative impact of the environment on the quality of food product and have a positive impact on the both, environment of the product and the product itself (Nowacka, 2010).

Food contact materials requirements

Progress in the field of new packaging technologies and food contact materials is associated with both increasing requirements of packaging producers and new food products which are the answer for growing consumers' need. Nevertheless, the most important issue that always needs to be considered when designing new food contact materials is safety of the consumers. Such situation reveals from the fact that food contact materials can interact with food which can result in change of food sensory properties and, what more, can cause the migration of packaging constituents to food matrix (Simoneau, 2008).

Coatings for packaging materials may contain many versatile substances. It is an emerging issue to ensure that they are safe for both food and consumers. The general requirements on every food packaging material are set in Regulation (EC) No. 1935/2004 of the European Parliament and of the Council of October 27, 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC. This regulation presents requirements for sensory quality and migration of chemical compounds for food contact materials.

Flavor is one of the most important food feature. At the same time it is considered as very important and robust indicator of food quality (Bart, 2006). Hence, sensory analysis is useful tool for detection of the interferes between food and packaging material. It allows determining the impact of packaging on taste,

aroma and appearance of food (Duncan i Webster, 2009).

Sensory analysis is the basic and the first analysis performed in the case of food contact materials evaluation. In this type of research human senses are used to provide information about food properties (Aurela, 2007). Unfortunately, despite the training of sensory panel (people performing sensory analysis) such evaluation is still considered as subjective. The differences in samples assessment can reveal from congenital ability to verbalize sensory stimulus, different sensitivity and threshold for stimulus, which is linked to unique psychic and physiology of each individual person (Reineccius, 2006; Duncan i Webster, 2009). Thus, due to different sensitivity for stimulus some people may not detect any changes whereas other people will overreact in its presence (Reineccius, 2006). Therefore, the aim of research conducted all over the world is an attempt to replace sensory analysis by instrumental methods (Aurela, 2007).

Since the last decade a rapid development of modern analytical devices for non-selective sensing, known as electronic noses and electronic tongues, is observed. They are based on the recognition of sample "fingerprint" by the use of sensor arrays for signal acquisition coupled with chemometric techniques for numerical processing of the sensor data (Figure 1). Thus, such systems are biomimetically inspired by natural chemical senses, where chemical information sensed by receptors is processed by the nervous system – therefore devices dedicated to gaseous samples are called electronic noses, and dedicated for liquid samples are called electronic tongues or taste sensors (Ciosek and Wróblewski, 2007; Gliszczyńska-Świgło and Chmielewski, 2016).

The characteristic fingerprint / signature of the sample can be classified, identified or used to estimate chosen components of the sample through the use of statistical methods, artificial intelligence and chemometrics models. Moreover, in those cases where it is impossible to apply selective sensor to determine the

Fig. 1. Electronic tongue set-up: sensor array (A) with a sample (B); signal acquisition by multi-channel potentiometer (C); data analysis system (D, E)

analyte of interest, modeling of the ingredient content based on the signals of the whole sensor array comprising the so-called cross-sensitivity/partially selective sensors can be accomplished (as in the case of soft sensors / software sensors often used in the industry).

Dozens of publications describing an extremely wide range of applications of electronic tongues: from environmental monitoring through quality control in the industry, to medical diagnosis, has appeared (Ciosek and Wróblewski, 2007; del Valle, 2010; Bratov et al., 2010). Research on electronic tongues conducted in our group has led so far to the development of many multisensor systems dedicated to quality control in the food industry (Ciosek and Wróblewski, 2011; Kutyla-Olesiuk et al., 2013a), environmental monitoring (Kutyla-Olesiuk et al., 2013b), pharmaceutical analysis (Wesoły et al., 2016; Wesoły et al., 2017), medical diagnostics (Jańczyk et al., 2013) and biotech industry (Ciosek and Wróblewski, 2015). Various systems adapted to bioanalytical applications, where small volume samples are usually considered, were developed: flow-through potentiometric sensor array (Ciosek et al., 2015), planar integrated sensor array (Ciosek and Kraszewska, 2009), flow-through microsystem with integrated sensor array (Witkowska Nery et al., 2014). They were used in various modes of measurements: batch (Ciosek and Wróblewski, 2011; Wesoły et al., 2017), flow-through (Kutyla-Olesiuk et al., 2013b, Witkowska Nery et al., 2014), flow injection (Ciosek et al., 2015) and sequential injection (Wesoły et al., 2016) analysis. It was shown, that the developed electronic tongues were capable of effective classification of samples, as well as semi-quantitative and quantitative analysis. It was found also, that electronic tongue responses were correlated with taste properties of foodstuffs (Ciosek and Wróblewski, 2011; Kutyla-Olesiuk et al., 2013a) and pharmaceutical samples (Wesoły et al., 2017).

Another feature which is a subject of food packaging evaluation is migration of packaging constituents to food. It is extremely important parameter regarding both safety issues assessment and quality of packaging systems especially regarding the interactions between material and food and their impact upon health of consumers (Simoneau, 2008).

The level of migration can be evaluated as (Huang et al., 2011):

- global migration – total amount of all non-volatile substances which can be transferred to a model solution in certain time and temperature is determined and expresses in mg/dm^2 or mg/kg .
- specific migration – a specific and particular substance, which can migrate to food or model solution (which imitates a certain type of food) in certain time and temperature is determined and expressed in mg/dm^2 or mg/kg .

Therefore, it can be stated that on the basis of global migration analysis a migration of chemical compounds from packaging to food can be estimated. Limits of global migration are determined by specific regulations and are equal to $10 \text{ mg}/\text{dm}^2$ of packaging-food (model solution) contact surface or to $60 \text{ mg}/\text{kg}$ in the case when it is not possible to estimate the area of contact (Nel et al., 2006). In turn, the limits of specific migration cannot exceed values given in particular regulations for each individual chemical compound.

CONCLUSIONS

Application of various types of coatings based on proteins, polysaccharides, lipids, waxes on paper and cardboard was described. However the possibilities for introducing new

substances and mixtures seems infinite, all of the changes or alternations must be safe, both for food and consumers. Implementing that kind of changes must not exceed the migration limits from packaging materials as well as ensure the unchanged sensory properties of food. Biopolymer-coating of cardboard and paper packaging are still a promising improvement in safety, functionality and convenience of foodstuff. Nowadays, when the ecological issues are emerging, using natural, renewable resources might be a great opportunity for everyone.

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