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PACKAGING SYSTEMS FOR ANIMAL ORIGIN FOOD

Agnieszka Bilska

Poznań University of Life Sciences, Poznan, Poland

ABSTRACT. The main task of food packaging is to protect the product during storage and transport against the action of biological, chemical and mechanical factors. The paper presents packaging systems for food of animal origin. Vacuum and modified atmosphere packagings were characterised together with novel types of packagings, referred to as intelligent packaging and active packaging.
The aim of this paper was to present all advantages and disadvantages of packaging used for meat products. Such list enables to choose the optimal type of packaging for given assortment of food and specific conditions of the transport and storing.

Key words: vacuum packaging, modified atmosphere packaging, smart packaging, intelligent packaging.

INTRODUCTION

Packaging of foodstuffs is one of the primary procedures which prevent the penetration of microbiological and biochemical contamination to the product. It facilitates transport and distribution of the final product (particularly in supermarkets) and the maintenance of an appropriate form of the product, its shape and structure [Appendini and Hotchkiss 2002, Olborska and Lewicki 2005, Świątkowska et al. 2006, Rak 2007, Korzeniowski 2010, Zhou et al. 2010]. It also prevents the loss of aroma, extends shelf life and maintains adequate moisture content [Olborska and Lewicki 2005, Świątkowska et al. 2006, Rak 2007, Zhou et al. 2010].

Production of food safe for the consumer, being of high quality and the longest possible shelf life, are tasks faced by food producers. An essential role in this process is played by packagings as well as packaging methods: vacuum packaging and modified atmosphere packaging (MAP).

Since mid-1990's interest of researchers has focused on new types of packagings, defined as intelligent packaging and active packaging.

The aim of this study was to indicate methods of packaging for food of animal origin, which would be optimal for selected assortments and different buyers, taking into consideration transport conditions and the assumed shelf life of the product.

MATERIALS USED IN PACKAGING PRODUCTION

When selecting packaging material we need to know the characteristics of the final product, e.g. its chemical composition, consistency and texture. It is also necessary to consider whether the packaged

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product can stand storage, distribution and sale conditions until it is delivered to the consumer [Korzeniowski and Kubera 2000, Jeremiah 2001].

At present almost entirely composite, multi-layer materials are used. In composite plastic films some of the following materials and their derivatives are used: polyethylene (PE), polyester (PET), polyamide (PA, particularly polyamide PA6), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyvinylidene dichloride (PVDC), ethylene-vinyl alcohol (EVOH), copolymers with an addition of acrylic acid, vinyl acetate, etc.

The outer layer of multi-layer plastic film packaging is assigned mainly tasks connected with mechanical stability, the core layer plays the role of a barrier for oxygen, while the inner layer provides bursting strength and rupture strength of the weld and the packaging [Czerniawski and Michniewicz 1998, Korzeniowski and Kubera 2000, Michniewicz 2000, Jeremiah 2001].

Materials used in the production of packagings should meet many requirements. First of all they need to be non-toxic, chemically inert (product - environment) as well as transparent and smooth. They should exhibit an adequate permeability for gases and water vapour, and be water-resistant [Jeremiah 2001, Gajewska - Szczerbal 2004].

VACUUM PACKAGING

Vacuum packaging consists in the removal of air from the packaging, which is next sealed tightly, usually by welding. The presence of oxygen in the packaging results in many adverse changes, e.g.: autoxidation of fats (rancidity), changes of taste and aroma, oxidation of pigments, vitamin C, vitamin E, beta-carotene and certain amino acids, as well as the development of aerobic microflora, particularly moulds. For this reason by removing oxygen from the medium we may inhibit the development of aerobic bacteria as well as yeasts and moulds, which cause food spoilage [Danyluk et al. 2004, Gajewska - Szczerbal 2005, Kerry et al. 2006, Czerwńska 2006, Zhou et al. 2010]. This system is applied e.g. in packaging of meat and meat products, cheeses and dairy produce [Kačeňák et al. 2005].

For many consumers the decisive factor in the purchase of fresh meat is its colour. The natural, red colour of raw meat is caused by the presence of myoglobin. In order to preserve an appropriate colour, the used packaging should be characterised by high or the lowest possible oxygen permeability [Issanchou 1996, Jeremiah 2001, Kačeňák et al. 2005, Troy and Kerry 2010]. High oxygen permeability (oxymyoglobin is formed) is found in polyethylene and cellulose acetate. Meat packaged in this manner retains its colour for 1 - 2 days [Kačeňák et al. 2005, Gajewska - Szczerbal 2005a]. When meat is packaged in a packaging with very low oxygen permeability (composite materials), the process of metmyoglobin is inhibited. Thus in meat industry the materials used in vacuum packaging of meat include typically three-layer plastic films containing e.g. vinyl ethyl acetate/vinylidene polychloride/vinyl ethyl acetate, which usually have lower oxygen permeability [Jenkins and Harrington 1991, Zhou et al. 2010].

Vacuum packaging is most frequently used in storage and distribution of cooled parts and culinary elements of beef. It is a particularly common method in the USA, used mainly for large meat elements. This packaging method practically replaced wholesale of whole carcasses.

At vacuum packaging in the corners, the so-called dead spaces are formed, in which drip mat accumulate, which looks unappetizing and deteriorates the appearance of packaged meat. This may be avoided when in packaging a plastic film is used, which sticks to the meat surface very closely and leaves very little space for the accumulation of drip [Jeremiah 2001, Gajewska - Szczerbal 2005a]. Presently used packagings include vacuum sealing bags and shrink wraps. After the removal of air, the product has to be completely covered with plastic film, which should be impossible to detach. Oxygen content in the vacuum packaged product may not exceed 2% [Michniewicz 2000, Jeremiah 2001, Gajewska - Szczerbal 2005a].

Vacuum packaging may be applied only for meat with good microbiological quality. Another very important index, which needs to be carefully watched, is the pH value. Meat with pH 6.0 or higher should not be vacuum packaged. High microbial contamination and high pH values may result in a considerable shortening of meat shelf life [Jeremiah 2001, Gajewska - Szczerbal 2005a].

Another factor limiting shelf life of meat is the temperature of its storage. The best effects may be obtained during meat storage at a temperature close to cryoscopic. Vacuum packaged beef may be stored at 0^oC for 14 - 28 days. Shelf life of beef with pH over 6.0 is considerably shorter at the same temperature [Jeremiah 2001].

The more comminuted a product is, the shorter its shelf life during cold storage. Vacuum packaged ground meat will keep for a much shorter time than meat in large pieces [McDonald 2000, Czerwińska 2006]. Studies on the stability of raw meats, conducted at a temperature of 2 - 4^oC by Polak et al. [2005] showed that vacuum packaged beef and veal may be stored for 10 days, while deboned turkey cuts - up to 14 days.

Processed finely and medium-comminuted meats (wieners, luncheon meat), in comparison to e.g. ham, have a shorter shelf life [Jeremiah 2001, Czerwińska 2006].

Stability of vacuum packaged products depends also on physico-chemical properties of the product, primarily:

- Water activity, e.g. beef-pork hamburgers at a_w = 0.985, stability for 7 days, while at a_w of 0.953 it is up to 28 days,
- Applied heat processing, e.g. cooked foreshank - stability under cold storage conditions up to 14 days, while roast foreshank - stability up to 28 days [Polak et al. 2005].

MODIFIED ATMOSPHERE PACKAGING

Modified atmosphere packaging consists in the replacement of air in the packaging with a mixture of gases with a composition specially selected, depending on the type of the packaged product. The primary gases used in the MAP system include carbon dioxide, nitrogen and oxygen. Carbon dioxide is a gas readily soluble in water and in fats. It is used as a protective gas typically at a concentration of 20 - 30%. It is neutral in terms of taste and aroma. It exhibits bacteriostatic and fungistatic properties [Czerniawski 1999, 2001, Kotsianis et al. 2002, Anonymous 2005, Gajewska-Szczerbal 2005b, Grzesińska 2005, Polak et al. 2005, McMillin 2008, Koutsoumanis et al. 2008]. Nitrogen in the MAP system serves the role of a filling gas. It protects the packaging against "caving in". It results from its poor solubility in water and fats. It does not have a direct effect on the stability of the packaged product. The application of nitrogen before the packaging is filled with other gases aims at the removal of remaining oxygen, undesirable in the packaging. It also delays rancidity processes and prevents the development of aerobic bacteria [Czerniawski 2001, Kotsianis et al. 2002, Gajewska-Szczerbal 2005b, Bilska et al. 2004, Polak et al. 2005, Grzesińska 2005, Zhou et al. 2010]. Oxygen is used in packaging of raw meat. Its addition is used to maintain the characteristic red colour, i.e. oxymyoglobin [Jeremiah 2001, Gajewska-Szczerbal 2005b, Zhou et al. 2010].

Carbon oxide (CO) is a component of modified atmosphere used in packaging of meat and fish. Carbon oxide binds with haeme in hemoglobin or myoglobin and forms a stabile light-red coloured protein complex [Stenzel and Feldhusen 2004]. This leads to the stabilization of meat colour (particularly on its surface) and an extension of its shelf life. However, it may also mask symptoms of meat spoilage and constitute a threat for consumer health. Meat may be exposed to the action of CO before packaging or carbon oxide may be used to remove gas from VSP plastic film before sealing. Small amounts of carbon oxide are enough to provide the desirable red colour of meat [Belcher 2006; Eilert 2005, Sebranek et al. 2006, Zhou et al. 2010]. However, the use of carbon oxide as an additive in meat and fish processing is illegal in view of food law regulations.

One of the advantages of modified atmosphere packaging of raw meat is very small drip of meat juice. However, in packagings containing fresh meat oxygen should be present at an amount sufficient to provide partial pressure of at least 0.4 hPa (40 millibar) [Jeremiah 2001, Gajewska-Szczerbal 2005b]. Storage of fresh meat in modified atmosphere leads to the dominance of lactic acid bacteria and/or thermosphacta B. [Koutsoumanis et al. 2008].

The selection of the composition of a gas mixture (table 1) should be adapted to a specific type of meat and the type of processed meats, taking into consideration expected temperature conditions during storage and distribution [Zin et al. 2004].

Table 1. The composition of a mixture of gases in modified atmosphere packaging of meat products [Czerniawski 1999, Polak et al. 2005]
Tabela 1. Skład mieszanek gazów w opakowaniach produktów mięsnych o zmodyfikowanej atmosferze [Czerniawski 1999, Polak et al. 2005]

Type of product	Composition of gas mixture [%]		
	O_2	CO_2	N_2
Raw meat	60-85	40-15	-
Fresh beef or pork	70	20	10
fresh meat and sausage made from raw meat	80	20	-
Cooked ham (incl. sliced)		40	60
Smoked sausage	-	30	70
Sausage for grilling	-	25-30	75-70
Meat-filled dumplings	-	30	70
Cooked meat	-	25-30	75-70

When packaging products in modified atmosphere we need to consider not only the composition of gases, but also the packaging material. It should exhibit high impermeability in relation to gases [Czerniawski 2001, Grzesińska 2005].

ACTIVE AND INTELLIGENT PACKAGING SYSTEMS

Production of high quality food with an extended shelf life, which is safe for consumer health is a task faced by producers. Advanced packaging systems have been developed in order to protect the product and extend its stability. These technologies are known as active packaging and intelligent packaging [Zmarlicki 2000, Kačeňák et al. 2005]. Active packaging consists in the spontaneous change in conditions surrounding packaged foodstuffs. Such an action results in an extension of shelf life, improved safety and sensory attributes at the maintenance of product quality [Zmarlicki 2000, Korzeniowski and Czaja 2004, Kačeňák et al. 2005, Dainelli et al. 2008, Zhou et al. 2010]. Intelligent packaging makes it possible to monitor specific parameters in the medium of the packaged product. It informs the consumer on the condition of the product during transport and storage, with no need to open the packaging [Czajkowska 2005, Kačeňák et al. 2005, Kerry et al. 2006, Otles and Yalcin 2008, Dainelli et al. 2008, Kozak and Cierpiszewski 2010].

Active packaging was developed to meet high requirements of consumers, connected among other things with an extension of shelf life of products, improvement of its organoleptic attributes and protection. In order to be able to satisfy these requirements active packagings contain several specific additives. These include oxygen absorbers, substances producing or absorbing CO_2 or sulfur dioxide, antimicrobial substances, ethylene absorbers, moisture content regulators, packagings releasing antioxidants, packagings releasing or absorbing taste and aroma compounds, plastic films protecting product colour and suspectors [Zmarlicki 2000, Panfil-Kuncewicz and Kuncewicz 2001, Korzeniowski and Czaja 2004, Czajkowska 2005, Trzcińska 2006, Kerry et al. 2006]. Examples of applications for different absorbers and applied compounds are given in table 2.

Table 2. Absorbers, their applications and used compounds
Tabela 2. Substancje absorbujące, ich zastosowanie i stosowane składniki

Type of absorber	compounds	applications
Oxygen absorbers	Iron compounds, ascorbic acid, metal salts, glucose oxidases	cheese, bakery products, sweets, nuts, milk powder, coffee, tea, beans, cereals, meat
Moisture absorbers	Silica gel, glycerol	Bakery products, meat, fish, poultry, vegetables and fruit
CO_2 absorbers	Calcium, sodium or potassium hydroxide	Roasted coffee beans
Substances exhibiting antimicrobial activity	Encapsulated ethanol, silver containing compounds, sorbic and benzoic acids. benomyl and imazalil, lysozyme, bacteriocins (nisine, pediocine, lactacine), components of spices/herbs	fats, cereal products
Ethylene absorbers	Aluminum oxide, active carbon, potassium tetraoxomanganate	fruits (apples, apricots, bananas, avocado) and vegetables (carrot, potatoes, tomatoes, cucumbers)
Absorbers of aroma compounds	Citric acid, cellulose esters, polyamide	Readily oxidizable products, e.g. fats in fish products, fruit juices

Packaging absorbing oxygen

Packagings with a system removing oxygen may inhibit or slow down the growth of aerobic microflora (particularly moulds). At the same time they may prevent oxidation of certain food components, e.g. fats. In this type of packaging numerous chemical substances are found, such as iron compounds, ascorbic acid, glucose oxidase, alcohol oxidase and certain unsaturated hydrocarbons. Chemical substances are contained in a small bag, which is placed in the packaging or they may be incorporated in plastic materials (components of a low molar mass are dispersed in plastic during production or this plastic may be laminated with an absorber carrier) [Vermeiren et al. 1999, Zmarlicki 2000, Panfil-Kuncewicz and Kuncewicz 2001, Kačeňák et al. 2005, Kerry et al. 2006, Trzcińska 2006, Dainelli et al. 2008, Lee 2010].

Packaging with a system producing or absorbing CO_2

The presence of carbon dioxide results in the inhibition of growth of aerobic microflora, e.g. moulds. In order to obtain an atmosphere rich in CO_2 the sachets placed in packagings may contain iron carbonate, mixtures of ascorbic acid with acid sodium carbonate or a mixture pf iron(II) carbonate with metallic halides. Such packagings may be used to package fresh meat, poultry, fish and cheeses.

In some cases (e.g. when packaging coffee) carbon dioxide should be removed from the packaging to prevent its deformation or rupture. Calcium hydroxide is a typical absorber of carbon dioxide used in the form of sachets [Vermeiren et al. 1999, Zmarlicki 2000, Panfil-Kuncewicz and Kuncewicz 2001, Czajkowska 2005, Kacenak 2005, Kerry et al. 2006, Lee 2010].

Packagings with a system reducing moisture content

Packagings with a system reducing moisture content are used in the packaging of fresh meat and meat products, and to extend shelf life of fruits (tomatoes, melons) as well as fish and shellfish. The most promising solutions are offered by polymer structures with microchannels used for the transport of diffused moisture particles. Drying agents are placed on the surface of microchannels. Examples here include packagings composed of an outer layer (e.g. polyethylene or polypropylene), constituting a barrier for moisture from the outside, and an active inner layer (with microchannels), made from polyethylene glycol [Panfil-Kuncewicz and Kuncewicz 2001, Czajkowska 2005, Kerry et al. 2006, Trzcińska 2006].

Packaging with antimicrobial substances

Packaging with substances exhibiting antimicrobial activity may effectively delay the development of certain microorganisms and extend stability of final products. Sachets with microporous material saturated with ethylene alcohol may be used. Slowly released alcohol vapours are deposited on the surface of food and destroy microorganisms. It is used to extend shelf life of biscuits, bread and dried fish products [Vermeiren et al. 1999, Zmarlicki 2000, Panfil-Kuncewicz and Kuncewicz 2001, Czajkowska 2005, Trzcińska 2006]. The list of substances of antimicrobial character used in food packagings includes e.g. organic acids - sorbic and benzoic acids, and anhydrates of these acids, fungicides, enzymes (lysozyme), bacteriocins (nisine, pediocine and lactacine), components of spices and herbs, e.g. cinammic, lauric and coumaric acids, plant extracts e.g. grapefruit seeds, East Indies bluestern, red pepper and camellia [Vermeiren et al. 1999, Zmarlicki 2000, Panfil-Kuncewicz and Kuncewicz 2001, Czajkowska 2005, Trzcińska 2006, Kerry et al. 2006, Zhou et al. 2010, Lee 2010]

In packaging systems involving chemical preservatives we usually face the problem of active agent migration. Packagings with chemical substances usually take a multi-layer structure. The outer layer serves the protective function. The inner layer, the so-called matrix, contains a chemical substance, while the adjacent layer controls the rate of active agent release [Vermeiren et al. 1999, Zmarlicki 2000, Panfil-Kuncewicz and Kuncewicz 2001, Czajkowska 2005, Kačeňák et al. 2005].

Simultaneously with active packagings the so-called intelligent (i.e. indicator) packagings were developed. These packagings are to monitor and supply information on the product, on its quality during transport, storage, retail sale and storage at the household. They contain an external or internal indicator, which supplies information on the history of the packaged product [Czajkowska 2005, Kerry et al. 2006, Otles and Yalcin 2008, Dainelli et al. 2008, Kozak and Cierpiszewski 2010]. Intelligent packagings most often contain:

- Quality indicators,
- Time and Temperature Indicators - TTI,
- Gas Indicators.

Temperature is the most essential factor affecting the rate, which adverse physical and chemical changes and changes caused by microorganisms appear in the food product. The time-temperature indicators (TT) are found in the form of various types of labels attached on the outer surface of a bulk packaging or individual retail unit packagings. Deviations in the intensity of indicator colour, observable with the naked eye, make it possible to recreate changes in temperature during storage, transport and distribution of food. It is particularly important in case of cold stored and frozen food. The system of TT indicators is also applied in packagings of half-finished products to be processed in microwave ovens or conventional ovens. They are also often used as indicators of critical temperature, i.e. temperature required in storage of a specific product [Czajkowska 2005, Kerry et al. 2006, Otles and Yalcin 2008, Kozak and Cierpiszewski 2010].

The composition of gases inside the packaging changes during food storage and it is the resultant of the respiration process in fresh food, gas permeability through the packaging material, the formation of different gases by microflora causing food spoilage and potentially the presence of invisible damage to the packaging itself. Changes in the gas composition are monitored by gas indicators applied as different types of labels. Gas indicators should be applied particularly in packaging of food stored in modified atmosphere. Most typically indicators of oxygen content are used, while indicators of water vapour, carbon dioxide, ethanol, hydrogen sulfide or other gases are used relatively rarely. Recently it has been attempted to design intelligent packagings with biosensors - "intelligent" devices comprising a bioreceptor recognizing an enzyme, antigen, microorganism, hormone or nucleic acid and a transductor (of the electrochemical, optical or acoustic type), closely related to the specific character of the measured parameter. The focus is on biosensors, which may be placed inside the packaging or which may be directly linked to the food packaging itself [Czajkowska 2005, Kerry et al. 2006, Otles and Yalcin 2008, Kozak and Cierpiszewski 2010].

The best known intelligent label indicating the content of oxygen inside the packaging is Ageless Eye. In the presence of oxygen a redox reaction occurs and an appropriate indicator displays the result. A high oxygen content may suggest a lack of tightness of the packaging, as well as potential bacterial contamination. An intelligent packaging may also serve the function of a controller in the active packaging, indicating appropriate operation of the active agent, e.g. an oxygen absorber.

In Poland the application of indicators is becoming increasingly popular, particularly in the brewing industry. Such breweries as Browary Żywiec and Browary Lech advertise their use of intelligent labels with changes in the thermochrome pigment as indicators. The moment a desirable temperature is reached, a notice appears on the label indicating that the temperature of beer is optimal for consumption.

FOOD SAFETY HAZARDS DURING THE PACKAGING PROCESS

Biological (microorganisms), chemical (reside of hygienic treatments, microbial origin substances) and physical factors (pieces of packaging, machines and devices, sand, hair, jewelry, buttons) during the packaging process may cause health hazard or threaten the maintenance of product quality.

The biggest hazard is posed by physical factors. Such raw materials as raw meat, fats and sauces are at the highest risk of microbial contamination. They require adequate temperature, moisture content, limited access to oxygen and light. Storage conditions of these products additionally promote proliferation of harmful microflora. In order to enhance stability microbiologically unstable raw materials should be preserved using physical or chemical methods (meat, fish, ready-to-eat products) or processed (an addition of appropriate substances, pH modification, etc.) or subjected to the packaging process. Thus first of all the preservation process in the packaging and packaging of preserved food cause considerable reduction of hazards for the final product. In the other cases the packaging process becomes a stage in food production, in which quality and safety of the product are at risk. For this reason packaging usually becomes a critical control point (CCP).

In the packaging process the biggest threat for product safety is posed by contacts with:

- Non-sterile packaging materials (secondary contamination from handling operation facilities by workers),
- Contaminated surfaces on the production line (design of machines and equipment),
- Air in the facilities where the process is run,
- Personnel (the number and state of hygiene of the personnel).

SUMMARY

The packaging of the product has an important role in the protection of the stability of the final product. It is particularly important for products subjected to external factors, especially for food products. The new methods of packaging (e.g. intelligent packaging) are very suitable but also very expensive. The aim of this paper was to list all advantages and disadvantages of packaging used for meat products. Such list enables to choose the optimal type of packaging for given asortment of food and specific conditions of the transport and storing.

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SYSTEMY PAKOWANIA ŻYWNOŚCI POCHODZENIA ZWIERZĘCEGO

STRESZCZENIE. Głównym zadaniem pakowania żywności jest ochrona produktu w trakcie przechowywania i transportu przed działaniem czynników biologicznych, chemicznych i mechanicznych. W pracy przedstawiono systemy pakowania żywności pochodzenia zwierzęcego. Scharakteryzowano pakowanie próżniowe i w atmosferze modyfikowanej oraz nowe typy opakowań, określane terminami „opakowania inteligentne" i "opakowania aktywne".
Celem opracowania było zestawienie zalet i wad opakowań stosowanych dla wyrobów mięsnych. Zestawienie to umożliwia wybór opakowania optymalnego dla konkretnych asortymentów oraz konkretnych warunków transportu i przechowywania.

Słowa kluczowe: pakowanie próżniowe, pakowanie w atmosferze modyfikowanej, opakowanie aktywne, opakowania inteligentne.

VERPACKUNGSSYSTEME FÜR FLEISCHERZEUGNISSE

ZUSAMMENFASSUNG. Die Hauptaufgabe von Lebensmittelverpackungen ist der Schutz der Waren während der Lagerung und des Transport gegen die Wirkung der biologischen, chemischen und mechanischen Faktoren. Der Artikel stellt die Verpackungssysteme für Fleischerzeugnisse vor. Solche Verpackungssysteme wie die Vakuumverpackung, die MAP-Verpackung und die neue so genannte „intelligente Verpackung" und „aktive Verpackung" wurden gekennzeichnet.
Das Ziel dieser Arbeit war, alle Vor- und Nachteile von Verpackungen für Fleischerzeugnisse zusammenstellen. Solche Zusammenstellung ermöglicht die optimale Verpackung für das gegebene Warensortiment und für spezifische Bedingungen des Transport und der Lagerung zu wählen.

Codewörter: Vakuumverpackung, MAP-Verpackung, „intelligente Verpackung", „aktive Verpackung" .

Agnieszka Bilska
Instytut Technologii Mięsa
Wydział Nauk o Żywności i Żywieniu
Uniwersytet Przyrodniczy w Poznaniu
ul. Wojska Polskiego 31, 60 - 624 Poznań
tel. +48 61 846 6086
e-mail: abilska@up.poznan.pl