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ACTIVE AND INTELLIGENT FOOD PACKAGING REVIEW PAPER, PART 1

AKTYWNE I INTELIGENTNE OPAKOWANIA W PRODUKCJI ŻYWNOŚCI. ARTYKUŁ PRZEGLĄDOWY – CZĘŚĆ 1.

ABSTRACT: In the present paper, the role and tasks of food packaging were discussed. The definitions, functions, forms and principles of intelligent and active packaging acting have been presented. The application of intelligent and active packaging in food industry has been characterized. The newer and newer generations of active and intelligent packaging are the future of food packaging systems. The development and application of new packaging generations will be greatly dependent on perceiving the benefits, coming from their utilization by the consumers. At present, the costs connected with the introduction of intelligent element into packaging are high.
Key words: active and intelligent packaging, application, food

STRESZCZENIE: W artykule przedstawiono rolę i zadania opakowań do żywności. Podano definicje, funkcje, formy oraz zasady działania opakowań inteligentnych i aktywnych. Scharakteryzowano zastosowanie opakowań inteligentnych i aktywnych w przemyśle spożywczym. Powstające coraz to nowsze generacje opakowań aktywnych i inteligentnych stanowią przyszłość opakowalnictwa żywności. Rozwój i stosowanie nowych generacji opakowań będą w dużej mierze zależały od postrzegania korzyści płynących z ich wykorzystania przez konsumentów. W chwili obecnej koszty związane z wprowadzeniem elementu inteligentnego do opakowania są wysokie.
Słowa kluczowe: opakowania aktywne i inteligentne, zastosowanie, żywność

ROLE AND TASKS OF PACKAGING

Packaging is an integral part of product, it decides on its attractiveness and quality and protects from the external conditions and possible mechanical damages. Dynamic increase of the role of packaging contributes to constant improvement of manufacturing methods and the ways of their production. The design enterprises and the companies-producers of food packaging compete with each other; invent new shapes, forms, sizes, conveniences in respect of utility function of a given packaged product (e.g. the possibility of multiple utilization of function: open, close, the way of opening etc.). The packaging companies use different packaging materials which attract the customer to their product and, in consequence, encourage to the purchase. Packaging is one of the best means of advertisement, owing to which the entrepreneur may obtain new, confidential and loyal customers. The dynamic technical and technological development and the increase of the manufacture of food processing articles contribute to a greater demand on packaging [1, 4].

The exemplified trends and technologies of fresh meat packaging for the years 2020-2028 have been given in Fig.1. They concern the type of the packaged meat (beef, poultry and pork), the employed technologies or packaging techniques (under vacuum, in a modified atmosphere) as well as the regions of the world. The mentioned prognoses include especially meat packaging in such regions as North America, Latin America and the West Europe [2, 11, 24].

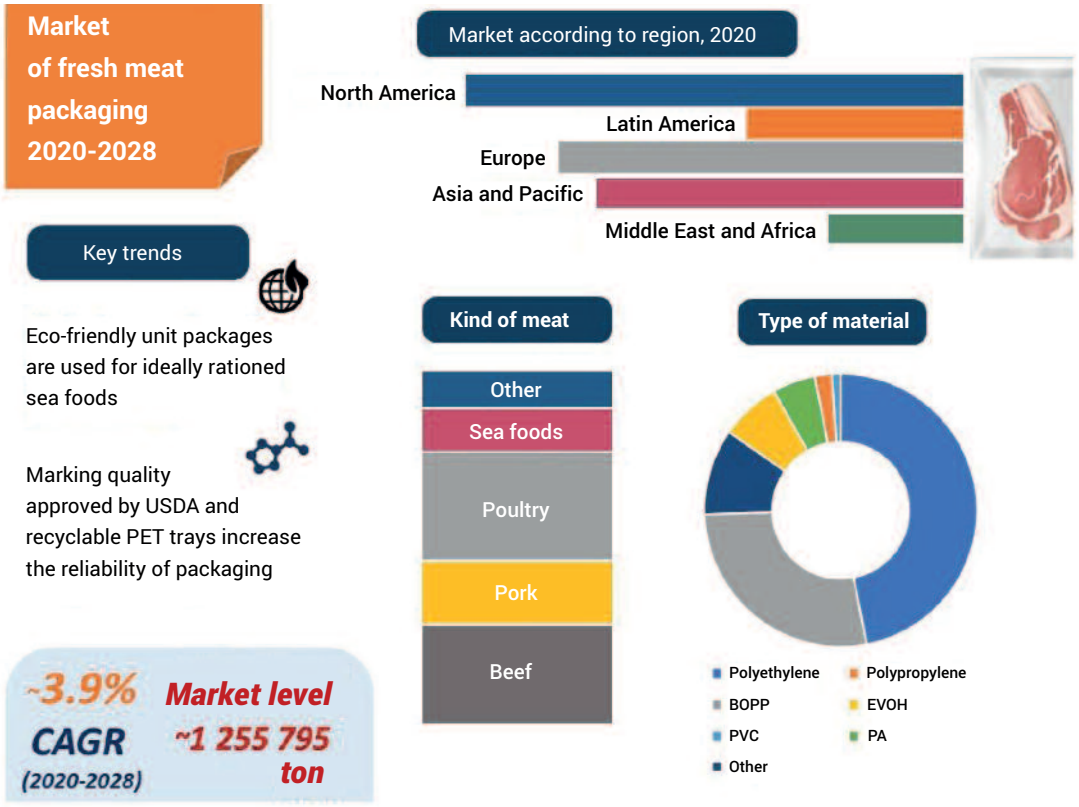

FIG.1. PROGNOSES FOR MARKET OF FRESH MEAT PACKAGING FOR THE YEARS 2020-2028 ACCORDING TO THE REPORT OF TRANSPARENCY MARKET RESEARCH [11. 24]. EXPLANATIONS: USDA – DEPARTMENT OF AGRICULTURE OF THE USA, CAGR – INDEX OF ANNUAL GROWTH RATE; BOPP – BIAXIAL ORIENTED POLYPROPYLENE; PVC – POLYVINYL CHLORIDE; PA – POLYAMIDE, EVOH – ETHYLENE-VINYL ALCOHOL

The basic task of packaging is to make a border between the packaged product and the surrounding environment. It facilitates the limitation of the impact of external environmental factors on the products inside the packaging. The traditional packaging materials such as plastics, glass or paper/cardboard are designed in such a way as to ensure their neutrality in relation to the packaged products. Modern packaging must play the additional, active functions, mainly in order to ensure the safety and high quality of the products. Such packaging contains substances which affect the atmosphere inside the packaging or have the interactive influence on the packaged products.

Each packaging should be adapted to the properties of a given product. Foodstuffs belong to a specific group of the products which are subjected to constant chemical changes (e.g. rancidity of fat, degradation of vitamins as affected by oxygen and light etc.) as well as also, physical processes (e.g. water evaporation or its absorption). Additionally, certain food products such as fish or coffee emit a strong smell, the other ones e.g. butter or bread, absorb foreign smells [15].

The expiration date (best before...) has a very significant meaning for the packaged food. It is equally important for the food consumer and the processor that the mentioned date could be as long as possible and the product inside could be safe and attractive. Unfortunately, we may state the multiplication of microorganisms, responsible for deterioration of foodstuffs, especially in the case slightly processed food products, being transported over long distances, It is, therefore, important to introduce such packaging to the market which would limit the growth of undesired microflora and ensure food safety [43].

Demographic changes, life style, environmental protection and development of outlet markets during the recent years, have contributed to newer and newer requirements in relation to packaging. On the one hand, we expect the increase of its

protective functions, preventing natural contamination, and on the other hand, protection from contamination of the packaged product. Thus, the search for new solutions such as increase of the tightness and barrier of the packaging as well as more restrictive methods of testing of the content of toxic substances in the packaging materials, generate a problem which the packaging industry is faced with.

The increasing requirements of the consumers concerning the purchase of safe, minimally processed foods as well as the extended time of its storage under the home conditions mobilize the food industry to introduce a new generation of packaging – active, intelligent or appropriate food packaging systems, adapted to a type of product.

ACTIVE AND INTELLIGENT PACKAGING

Active and intelligent packaging has been more and more frequently utilized in food industry all over the world. In Poland, the discussed generation of packaging has not been universal yet; it is not well known, as well. Nevertheless, the producers of foodstuffs become more and more interested in the mentioned above products. The application of active and intelligent packaging results also from the interest of aware consumers in high quality foods, and their health safety and their new preferences which affect the changes in the approach to food packaging [5, 17, 45]. Moreover, the development and employment of active and intelligent packaging systems in Europe contributes to improvement of competitiveness of the European foodstuffs as well as packaging industry in relation to the USA, Australia and Japan [35].

In Commission Regulation (EC) No 450/2009 of 29 May 2009, there were established specific requirements for the marketing of active and intelligent materials and articles intended to come into contact with food. It was stated that "active materials and articles" mean materials and articles that are intended to extend the self-life or to maintain or improve the condition of the packed food. They are designed to deliberately incorporate components that that would release or absorb substances into or from the packaged food ofr the environment surrounding the food [38].

INTELLIGENT PACKAGING

According to the definition given in Commission Regulation (EC) No 450/2009 of 29 May 2009,: "intelligent materials and articles mean materials and articles which monitor the condition of the packed food or the environment surrounding the food" [38]. From the definition it is followed that the task of the intelligent packaging is to ensure for the user obtaining the reliable and fair information about the conditions under which the food is stored. It refers also to integrity of the packaging. The intelligent packaging, therefore, extends the communicating function of the traditional food packaging, additionally informing the consumer about the changes, detected in the packaging or its environment [4, 15].

In contrary to the active packaging, the intelligent packaging is not aimed at release the substance to food product; therefore, it is usually placed on the external side of the packaging material and is properly separated from the product by a functional barrier, i.e. the layer which makes the migration of substance from the outside of the barrier to the product impossible.

The intelligent packaging consists in monitoring of the conditions under which the packaged food is found with the aim to deliver the information about its quality during transport and storage. Such packaging plays the following intelligent functions: detection, feeling, recording, tracing and, first of all, application of scientific logics in order to facilitate undertaking the decisions concerning extension of the shelf-life of the product, improvement its quality, delivery of information and warnings against the possible problems. The intelligent packaging does not have the impact on the foodstuffs, that is, does not release the monitoring indicators to the packaging, containing the product. It only provides the customer, seller or producer with the information about the state of the product [5, 8, 26, 50].

The intelligent materials appear mostly in a form of indicators. We can distinguish the following indicators: temperature, oxygen, freshness of the product, carbon dioxide and the presence of pathogens. The indicators give also the "history" of the temperature ("traceability of temperature") during the storage of a given product in the whole distribution chain. The principle of indicator's functioning consists in presentation of the information based upon the visual signal [6].

TAB.1. THE SELECTED APPLICATIONS OF THE INTELLIGENT PACKAGING IN FOOD INDUSTRY [4, 19, 30]

Indicator	Principle of acting	Information	Application
Gas sensor (CO_2 and O_2)	Chemical pH indicators and dyes, chamical and mechanical reactions	About the storage conditions, leakage of the packaging	Food packed in modified and controlled atmpsphere
Time-temperature (TTI)	Chemical, enzymatic and mechanical reactions	About the conditions of storage	Food product, requiring preservation of the temperature regime
Biosensor	Chemical pH indicators, dyes reacting with metabolites of microorganisms	About microbiological quality of food	Easily deteriorating foods
RFID System	Emission of radio waves	About the site of the product in the supply chain	Universal, for all types of food

At present, functions of the intelligent packaging are mainly implemented by three methods: using sensors, indicators and RFID system. The mentioned solutions differ from each other not only in construction but also the quantity and type of the data which may be introduced, downloaded as well as transferred [5].

For the discussed type of packaging, there are employed the materials which due to their specific composition absorb different compounds; it is dependent on the indicator (internal or external) which changes its colour and informs about the change in the composition of the atmosphere inside the packaging or about the changes occurring on the surface of the product itself [4]. Time and temperature integrators (TTI), freshness indicators and leakage indices may be employed as indicators [4, 14, 19].

TIME AND TEMPERATURE INTEGRATORS (TTI – TIME-TEMPERATURE INDICATORS)

The indicators of time and temperature integrator (TTI) are used with the aim of continuous monitoring of the current temperature of the product and its environment. Temperature is one of the most important factors, deciding on the appearance of unfavourable physico-chemical changes and the presence of microorganisms in the product which requires storage under refrigerator conditions e.g. in meat, fish and dairy products. The principle of TTI functioning consists in the irreversible change in its properties as affected by temperature higher than the set value, or as a result of thermal effect, accumulated during the storage and transport. The consequence of the mentioned change is visual effect, proportional to its intensity; it is most frequently expressed as discoloration of the surface of the label. It is especially important in the case of frozen products and chilled food, e.g. fresh meat, stored in a cold room or a frozen product. The mentioned indicators allow, inter alia, registration of temperature rise in the cold room or temporary thawing of the product what causes the change in the colour of the indicator. IIT enables also monitoring of any deviations from optimum temperature during the total distribution period and, simultaneously summing up their intensity and time of occurrence. Signal of integrator informs indirectly about the abbreviation of the period, being safe for the quality of the time of food storage [13, 23].

The application of time and temperature indicators (TTI) which are reliable, precise and characterized by a relatively simple construction, allows forecasting the remaining period of the shelf-life of the food product, based on the time of its exposure to the temperature above the admitted values. TTI indicators facilitate the mentioned control in the case unit products [45]. The principle of their functioning consists in the irreversible change in colour, as affected by too high temperature. The mechanism of the discussed change of colour relies on the chemical and/or microbiological reactions [4, 32]. At present, all over the world, there are known following three types of integrators:

– Life Line™ - is consists of polymer, being situated inside a circle, surrounded with a reference ring. The darker colour

of polymer in the central part informs the consumer that the packed product is not suitable for consumption due to the expiration date which is placed on the packaging;

- 3M Monitor Mark® – signalizes the change, e.g. in temperature by a coloured ring (or band) moving on a white background. It is an effect of physical diffusion of the solution with the chemically changed colour. Such type of indicator signalizes the moment of exceeding the temperature higher than that one which is recommended for the product to maintain the appropriate quality. The mentioned moment is signalised by a red colour of indicator;
- Label Vitsab® – activation of the indicator occurs by destruction of the partition between two elements, i.e. liquid containing the lipolytic enzyme and its lipid substrate and pH indicator. Together with the change in pH value, the dye added to the system changes the colour from green into sharp-yellow or orange-red.

TTI indicators are already employed for packaging of food requiring refrigeration in many European countries. The self-adhesive labels may be found, inter alia, on packaging with fresh meat, butcher's products, poultry, fish, salads and dairy products [4, 5, 31, 32].

FRESHNESS INDICATORS

Freshness indicators are the second group of intelligent packaging. They differ mainly from TTI (time-temperature integrator) in that the quality of the product is signalised by direct reaction to the change in the composition of the atmosphere inside the space of the packaging, or to the changes occurring on a surface of the product itself. Freshness indicators detect the presence of metabolite of microorganisms such as carbon dioxide, sulphur dioxide, ammonia, amines, hydrogen sulphide, organic acids, ethanol, toxins and enzymes. In the discussed method, there are used electronic and optical detectors and also, colour compounds generated in reaction with the substances absorbed from the inside of the packaging. Labels Fresh Tag®, intended for signalizing freshness of fish and fish products and of the packed poultry elements have been most widely applied. They contain plastic liner with the ring fixed inside (from the side of packaging). The ring contains chemical substance, being in a direct contact with the gases, which diffuse from the inside of the packaging and it creates a colour reaction with volatile amines, resent in the gas. Together with the increase of amine concentration, the sharp-yellow stain is shifted on thermometric scale of the ring, thus determining the quality of e.g. meat product. There are also the systems, reacting to different types of pathogenic bacteria, e.g. *Salmonella spp.*, *Campylobacter, Listeria spp.*, or *Escherichia coli* [4, 6, 46, 47].

The advantages of the indicators of such type include relatively simple construction, low cost, practically lack of the possibility of any interference (manipulation). The drawback may cover the necessity of performing the additional protection during packaging, often short period of their functioning, so such instruments must be properly stored on packaging before their installation [6].

INDICATORS OF LEAKAGE (FAILURE OF TIGHTNESS)

In the packaging which is not hermetical, the protecting effect of modified atmosphere on the product is decreased and the microbiological and health danger for the consumer is increased. The indicators of measurement of oxygen and carbon dioxide content in the packaging may be used for monitoring of food quality, in particular, meat and meat products, fish and fish products and dairy products. The principle of functioning of the discussed indicators consists in the change of their colour as a result of chemical or enzymatic reaction. Blue methylene is the most frequently employed oxidising-reducing colour in tightness indicators in relation to oxygen. Indicators of carbon dioxide serve for monitoring of the amount of the mentioned gas e.g. in meat products, packed in MAP atmosphere. The example of CO_2 indicator is, for example, Reflex indicator, produced in a form of label. The mentioned indicator is used for determination of the desired composition of gas mixture and identification of shortcomings connected with the improper functioning of gas supplying equipment [17, 24, 31, 39].

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