

RYSZARD CIERPISZEWSKI / ORCID: 0000-0002-8022-7453 / Ryszard.Cierpiszewski@ue.poznan.pl

DEPARTMENT OF INDUSTRIAL PRODUCTS AND PACKAGING QUALITY

INSTITUTE OF QUALITY SCIENCE, POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS

ACTIVE AND INTELLIGENT PACKAGING. PERSPECTIVES FOR DEVELOPMENT

OPAKOWANIA AKTYWNE I INTELLIGENTNE. PERSPEKTYWY ROZWOJU

ABSTRACT: During the recent years, we may observe a quick development of packaging sector. One of the promising directions of development includes the so-called active and intelligent packaging. It is commonly considered that the demand on the packaging of such type results from the new preferences of the consumers who more and more frequently seek for the products of a higher quality but less processed and containing the smaller number of additives which improve their properties. At the same time, the consumers expect longer storage period (shelf-life) and easier preparation of food for consumption. Somewhat different functions are played by the intelligent packaging which facilitates monitoring of possible changes by the consumer. The important task of the active and intelligent packaging is to limit food losses.

In the present paper, the definitions, used in literature concerning active and intelligent packaging and legal acts enabling their introduction to the market, have been analysed. On the grounds of it, the classification of active and intelligent packaging was carried out. Their characteristics were performed and then, the analysis of publishing and patent activity concerning the discussed solutions was conducted.

There were also presented the data illustrating the degree of the knowledge of active and intelligent packaging among the consumers and also, their inclination to buy food products in the discussed packaging. Based on the conducted analyses, it was found that active and intelligent packaging has a considerable potential for further development but their attractiveness is not univocal.

Key words: packaging, active and intelligent packaging, packaging market, smart packaging

STRESZCZENIE: W ostatnich latach obserwuje się szybki rozwój branży opakowaniowej, a jednym z obiecujących kierunków rozwoju są tzw. opakowania aktywne i inteligentne. Uważa się, że zapotrzebowanie na takie rodzaje opakowań wynika z nowych preferencji konsumentów, którzy coraz częściej poszukują produktów o wyższej jakości, ale mniej przetworzonych i zawierających mniejszą liczbę dodatków poprawiających ich właściwości. Jednocześnie, konsumenci oczekują dłuższego okresu przechowywania oraz łatwego przygotowania żywności do spożycia. Ważnym zadaniem, które stawia się przed opakowaniami aktywnymi i inteligentnymi jest ograniczenie strat żywności. W pracy podano definicje dotyczące opakowań aktywnych i inteligentnych oraz akty prawne umożliwiające ich wprowadzanie na rynek. Na tej podstawie dokonano podziału opakowań aktywnych i inteligentnych oraz krótko je scharakteryzowano, a następnie dokonano analizy aktywności publikacyjnej i patentowej dotyczącej tych rozwiązań. Przedstawiono również wyniki badań znajomości opakowań aktywnych i inteligentnych wśród konsumentów oraz ich skłonność do zakupu produktów żywnościowych w takich opakowaniach. Podano także wartość sprzedaży tych opakowań oraz jej prognozy na przyszłość.

Słowa kluczowe: opakowania, opakowania aktywne i inteligentne, rynek opakowań, opakowania smart

1. DEFINITIONS OF ACTIVE AND INTELLIGENT PACKAGING

In literature, we meet a great number of definitions, with the help of which we define the active and intelligent packaging. Apart from the term "active and intelligent packaging", we may find very often the names: "smart packaging", "interactive packaging" or sometimes, "innovative packaging". The mentioned terms are very frequently used without giving the

definition or explanation, what the author meant when employing a given name [Robertson 2006].

In spite of the fact that the names: "active packaging" and "intelligent packaging" are very often used simultaneously, there is a significant difference between them. In scientific literature, it is most often understood that active packaging means the packaging in which the additional components were intentionally introduced to material from which it was made, or

introduced to the inside of the packaging, or fixed to its external side with the aim to improve the degree of the function, played by the discussed packaging. On the other hand, the role of the intelligent packaging is to monitor the properties of food products and informing the used about the eventual changes. Such packaging is aimed at improvement of the quality and increase of the value of the product owing to the improvement of the convenience of use, detecting the attempts to open the packaging or makes stealing of the packaged product impossible [Robertson 2006]. As the lack of the official regulation had the impact on the lower interest of the solutions of such type in Europe, the European Commission published the Regulation of the Commission (EU) no 450/2009 of 29 May, 2009 on materials and articles intended to come into contact with food. The mentioned regulation defines these materials in a following way: “active materials and articles means materials and articles that are intended to extend the shelf-life or to maintain or improve the condition of packed food; they are designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food”

“intelligent materials and articles” mean materials and articles which monitor the condition of the packed food or the environment surrounding the food”

Unfortunately it was proved that we may encounter difficulties in the appropriate classification of a given packaging or material e.g. when oxygen is removed from the inside of packaging but the effect is unintentional and small, then the packaging is not classified as active [European Commission 2011].

In literature, many authors extend the definition of intelligent packaging by the additional functions. Such solutions are very often called smart packaging. Some persons think that smart packaging has the properties of active and intelligent packaging at the same time. We may also find opinion that smart packaging means such packaging that allows following the product for its total life cycle (traceability) and analysis and control of the environment inside or outside the packaging with the aim to inform the producer, seller or consumer about the condition of the product at a given moment [Schaefer and Cheung 218]. Such functions allow employing the packaging

in the Internet of Things [Hareza and Cierpiszewski 2019]. In the preface to book “Smart Packaging Technologies for Fast Moving Consumer Goods” the authors classified all types of packaging where it played more tasks as typical functions of protection, easing the storage and giving information about the product, as smart packaging. Such definition of active and intelligent packaging includes the projects of packaging where mechanical, chemical, electric and electronic solutions were employed, separately or in combination, with the aim of quality maintaining or informing about the condition of the product [Kerry and Butler 2008]. In most of the review papers concerning intelligent packaging, there are also considered the so-called data carrier. They include bar codes and RFID markers.

A lack of the univocal definition is the evidence of constant development of the discussed systems and may also contribute to misunderstanding.

2. ACTIVE AND INTELLIGENT PACKAGING

– CLASSIFICATION AND EXAMPLES

2.1. ACTIVE PACKAGING

Active packaging may be classified into three groups: absorbing systems, emitting systems and the remaining ones. The solutions from the first group are intended for removal of the undesirable substances from the atmosphere of packaging (Fig. 1). The mentioned group includes: oxygen absorbers, carbon dioxide absorbers etc. The task of the emitting systems is to introduce the substances, which cause the prolongation of the shelf-life of food, to the atmosphere of the packaging, e.g. CO₂, antibacterial

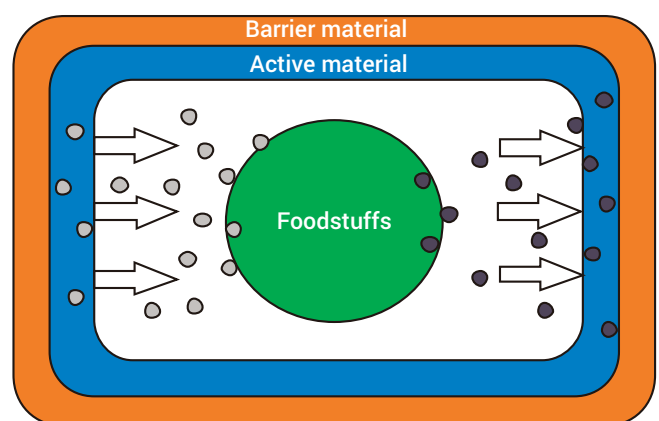


FIG. 1. THE PRINCIPLE OF FUNCTIONING OF ACTIVE PACKAGING

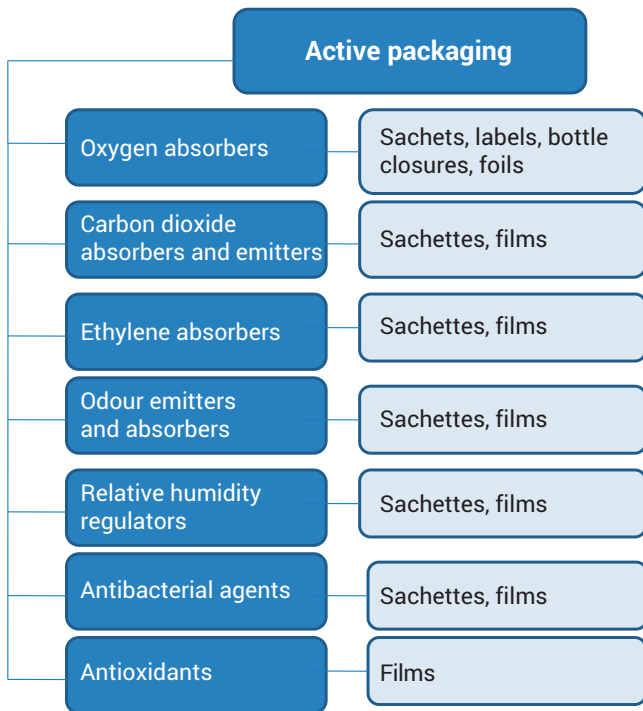


FIG.2. CLASSIFICATION OF ACTIVE PACKAGING ACCORDING TO ABSORBED OR EMITTED SUBSTANCE

substances. The third group of the solutions includes the systems allowing, for example, heating up or cooling down the can, modification of the heating rate in the microwave oven in order to heat appropriately up the meals by the consumer.

We may meet however, very often, the classification of the packaging according to the substances which emit or absorb (Fig. 2). They are divided, therefore, as follows: oxygen absorbents, water vapour absorbents, carbon dioxide absorbents or emitters, ethylene absorbents etc. [Cierpiszewski 2016]. Tab. 1 shows certain commercially available active packaging whereas Tab. 2 contains the intelligent packaging.

2.2 INTELLIGENT PACKAGING

In literature, the intelligent packaging is most frequently classified into three groups [Robertson 2016]:

- those monitoring product's quality;
- those improving convenience of use; and
- those which protect from stealing, destruction (damage) etc.

The elements that monitor the quality of the products include: indicators of freshness, indicators of temperature and time and the indicators of gas presence. The first of them, as placed inside the packaging, react with the compounds generated during the decomposition of the organic substance of the packed food and when changing the colour, they inform the consumer about the occurring changes (Fig. 3). The example of such element may be indicators of fish freshness [Tichoniuk, Radomska and Cierpiszewski 2017] or those based on the reaction with CO_2 [Hong and Park 1999].

The indicators of temperature and time are the elements allowing the user to get informed how long a given product was exhibited to the impact of undesirable temperature [Taoukis 2001]. The third group of the indicators includes the labels indicating the presence of gases, e.g. oxygen or carbon dioxide. If a given gas appears or is removed from the packaging, it means that the mentioned packaging was opened or damaged or the undesirable processed occurred in the packaging [Mills 2005]. As is can be seen, the discussed above indicators remain in compliance with the definition, proposed in the regulation of the European Commission. The successive group, improving the convenience of use, comprises e.g. milk or beer packaging, covered with thermochromic paint, indicating that the best temperature for consumption of a given product has been

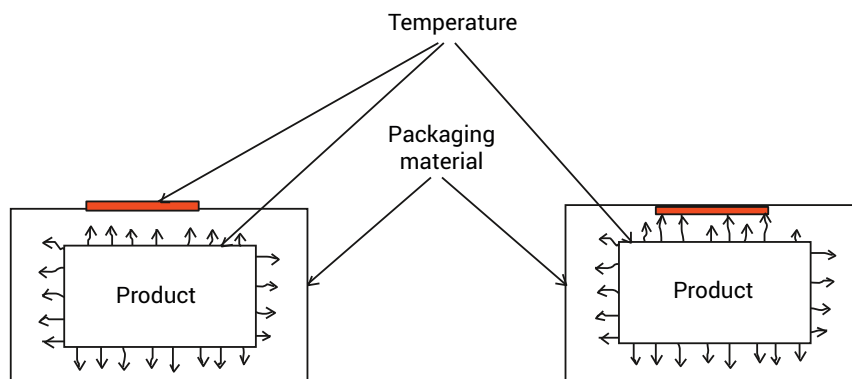


FIG.3. IDEA OF FUNCTIONING OF INTELLIGENT PACKAGING

TAB.1. THE EXAMPLES OF THE COMMERCIALY AVAILABLE ACTIVE PACKAGING

System	Trade name	Producer
Oxygen absorbents	Ageless G, Amosorb®, ATCO®, Bioka Oxygen Cryovac®, Desi Pak®, Sorb-It®, Tri-Sorb®, Getter Pak®, 2-in-1 Label Cryovac®, OS2000 FreshPax®,	Mitsubishi GasChemical, Japan Amosorb SoLO ₂ , ColorMatrix Group Inc., USA Laboratories STANDA Bioka Ltd., Kantvik, Finland OS Film Sealed Air Corporation, USA Enzyme-based, Bioka Ltd., Kantvik, Finland
Carbon dioxide emitters	Ageless G, CO ₂ ® Fresh Pads, Freshpax, Freshlock, UltraZap® Xtenda Pak pads, Verifraise package,	Mitsubishi Gas Chemical, Japan CO ₂ Technologies, USA Multisorb Technologies, USA Multisorb Technologies, USA Paper Pak Industries, Canada SARL Codimer, France
Antibacterial	Aglon™, Bioka, Biomaster®, Ethicap™, Irgaguard®, Microban, Microgarde™ and Microsphere™,	Agion Technologies, USA Bioka Ltd., Finland Addmaster Ltd., UK Freund, Japan BASF, USA Microban Prod., UK Bernard Technologies, Toagosei, Japan

Source: Fuertes G., Soto I., Carrasco R., Vargas M., Sabattin J., Lagos C., Intelligent Packaging System: Sensors and Nanosensors to Monitor Food Quality, Journal of Sensor, Vo. 2016, 1-8. <https://doi.org/10.1155/2016/4046061>

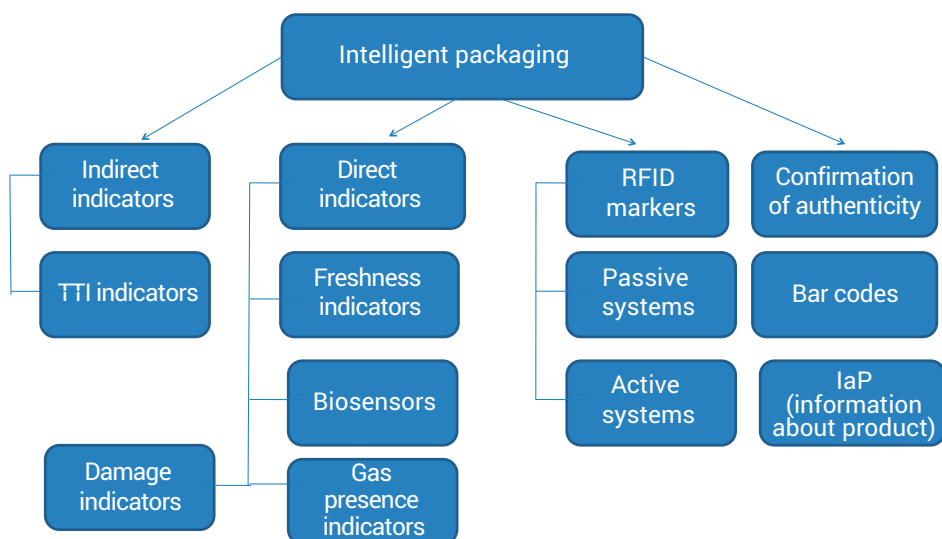


FIG.4. CLASSIFICATION OF INTELLIGENT PACKAGING

TAB.2. THE EXAMPLES OF COMMERCIALY AVAILABLE INTELLIGENT PACKAGING

System	Trade name	Producer
Freshness indicators	Fresh Tag® Food Sentinel System Raflatac RipeSense SensorQ® Toxin Guard	COX Technologies SIRA Technologies Inc. VTT and UPM Raflatac RipeSense DSM NV nd Food Quality Sensor International Inc
TTI indicators	3M Monitor Mark™ CheckPoint® Fresh-Check® FreshCode® Keep -it® OnVu™ VITSAB® Tempix® Timestrip® PLUS™	3M company VITSAB Temptime Corp. Varcode Ltd. Keep-it Technologies Freshpoint and Ciba VITSAB International AB Temptix AB Timestrip Plc
Gas presence indicators / / packaging integrity indicators	Ageless Eye® O2Sense Tell-Tab	Mitsubishi Gas Chemical FreshPoint Lab IMPAK
RFID	CS8304 Easy2log® TempTRIP	Convergence Systems Ltd. CAEN RFID Srl TempTRIP LLC

Source:Fuertes G., Soto I., Carrasco R., Vargas M., Sabattin J., Lagos C., Intelligent Packaging Systems: Sensors and Nanosensors to Monitor Food Quality and Safety, Journal of Sensor, Vo. 2016, 1-8. <https://doi.org/10.1155/2016/4046061>

reached. We may classify here also the indicators informing about obtaining the appropriate temperature of the syrup, heated up in the microwave oven [Cierpiszewski 2016]. The discussed category includes bar codes, QR codes and the elements, enabling dosage and those ones, improving the access to information, etc. The example may be blisters "Helidac Therapy Kit" by Procter& Gamble Pharmaceuticals, facilitating the intake of drugs. The examples of the solution, enabling the access to information may be: speaking packaging "Self Talk" and markers "NFC tags" [Pareek and Khunteta, 2014]. The third mentioned group, as protecting from theft, damage, or adulteration consists of many solutions. It is most frequently referred to RFID markers which enable tracing the product from the producer to a final user (traceability). It is, however,

indispensable that the mentioned RFID markers are cheap and with a high effectiveness. The combination of sensors and RFID markers ensures them the additional functionality. Such sensors allow monitoring of temperature, humidity or they discover the bio-components and, simultaneously, at a real time, they transfer the obtained results to the management system [Bibi et al. 217]. RFID markers have been employed in Viagra packages (Pfiser) [O'Connor 2006], and Caen RFID Easy2 Log®, TempTRIP, placed on packaging, may record the information about temperature of the product's storage [<http://www.portalrfid.pl>] (Fig. 4). The group of the intelligent solutions comprises also the appropriate inks, holographic signs and labels that indicate the infringement of the packaging content, printing of micro-text on the packaging, embossing, etc. The inks which make the

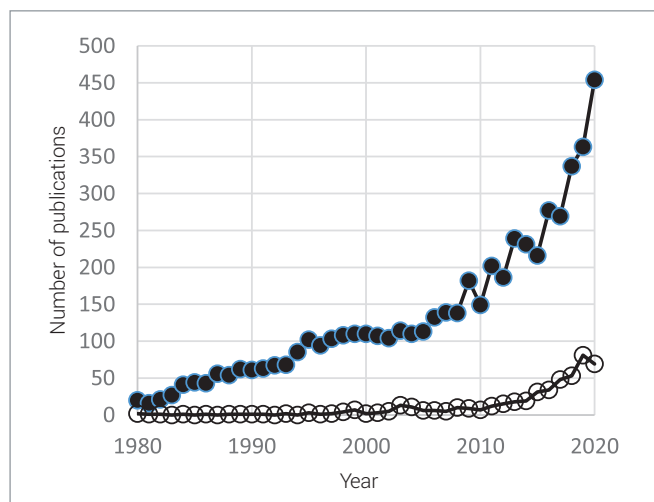


FIG. 5. THE NUMBER OF PUBLICATIONS IN THE SCIENTIFIC PERIODICALS, CONCERNING ACTIVE AND INTELLIGENT PACKAGING

● – ACTIVE PACKAGING; ○ – INTELLIGENT PACKAGING

falsification difficult contain pigments which reflect the light and change the colour during moving of the packaging [O'Connor 2006].

The cited above examples are the evidence of the enormous variety of the solutions classified as active and intelligent packaging. Such diversification causes that it is difficult to indicate what areas will be developing and which are rather condemned for stagnation.

3. ACTIVE AND INTELLIGENT PACKAGING IN SCIENTIFIC AND PATENT LITERATURE

During the several recent years, we have been able to observe a growing interest in active and intelligent packaging, reflected in the increasing number of publications in this respect. Also, we may find more and more information dedicated to the mentioned subject at the Internet pages. In Fig. 5, the number of the publications, dedicated to active and intelligent packaging is given. The query in Elsevier database for the period of 1980 – 2020 was carried out. From the obtained data, it is followed that the interest in the active packaging is absolutely greater as compared to the intelligent packaging. Many solutions, discussed in the papers are not, however, determined by their authors as active or intelligent packaging in spite of the fact that they belong to the mentioned group. Hence, the number of the found publications may be decidedly lowered.

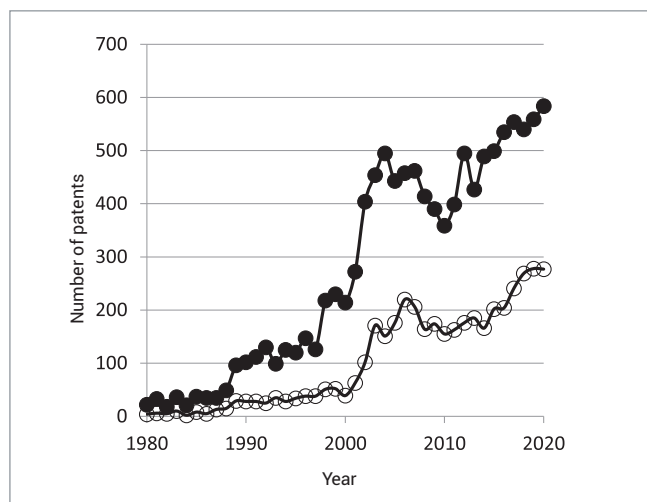


FIG. 6. NUMBER OF PATENTS CONCERNING ACTIVE AND INTELLIGENT PACKAGING

● – ACTIVE PACKAGING; ○ – INTELLIGENT PACKAGING

The second group of publication comprises patents which allow effective utilization (application) of the patented technologies and obtaining profits from the own means born on the studies [Wrześniak 2009]. They may be the reflection of the interest of the enterprises in the intelligent and active packaging. Fig. 6. illustrates the number of patent applications and the granted patents in respect of the active and intelligent packaging. The studies were carried out based on the Lens database. When comparing the obtained results and the data concerning publications (Fig. 5) we may notice a similar increasing tendency in the number of the applications and the granted patents after 2000 and a similarly higher interest in active packaging.

From the data submitted in Fig. 5 and 6, it is followed that the number of patents and publications may be the evidence of the great interest in the discussed above techniques. However, the number of publications and patent applications concerning all food packaging is similarly increasing. In order to explain whether covering of active and intelligent packaging with the patent rights is a research priority, the decomposition analysis by LMDI method was carried out [Cierpiszewski, Korzeniowski and Niemczyk 2019] with the consideration of the number of patents, patents concerning food packaging and patents concerning active and intelligent packaging. In Fig.7, the results of the conducted work have been given.

Fig.7. The interest in patents for the solutions in the field of active and intelligent packaging (the continuous line means the change in the number of patents; the change connected with the interest in active and intelligent packaging, the change resulting from the interest in food packaging and the change in field of patent activity

The increase in the number of patents in the years 1980 – 2010 was affected by increase of the interest in the discussed solutions as well as in the interest of patent applications in respect of food packaging and by the increase of the number of all patents. On the other hand, during the recent ten years we may observe a decline of the interest in active and intelligent packaging as compared to the interest in patent applications of other solutions.

4. ACTIVE AND INTELLIGENT PACKAGING IN THE OPINION OF THE CONSUMERS

Active and intelligent packaging has been employed already for few decades in Japan and the USA. On the other hand, in Europe, such solutions were blocked for many years by the legal conditions and lack of the knowledge of the consumers [Restuccia 2010]. It is positive, however that certain developments indicate the interest of the customers in the discussed solutions. They were most frequently focused on particular solutions [Aday and Yener 2015]. For example Finnish consumers were open to the idea of utilizing oxygen absorbents in food packaging and the greatest approval was revealed by

in the case of application of the oxygen absorbents in pizza packaging (62%) and the smallest one was found in the case of fresh meat (29%) [Mikkola,1997].

From the studies on the freshness indicators, conducted in the USA, it is followed that although a considerable part of the respondents considered the meat products and salads as safe and fresh products, they has stipulations as to the freshness and were ready to pay additionally for the packaging with the freshness indicators [Fortin, Goodwin and Thomsen 2009]. Also, the Belgian consumers are ready to pay for addition of the Fresh-Check® indicator. 75% of the respondents perceived the profits resulting from the application of the mentioned indicator and 71% of them recognised it as useful tool of food safety and quality [Fortin and Goodwin 2008]. In turn, from the studies conducted in Ireland, it may be concluded that the consumers would eagerly accept the prolongation of the shelf-life of cheese but they were not prone to pay additionally for the application of the appropriate elements to this end [Callaghan and Kerry 2016]. The studies of the approval of TTI indicators, conducted in France, Greece, Germany and Finland show that the consumers appreciate the TTI technology and think that its application could bring profits [Pennanen et al. 2015].

The studies on the appreciation of the active and intelligent packaging by the consumers in Poland were conducted in different regions of our country and by different authors [Ucherek 2011; Popowicz and Lesiów 2014; Pałkowska and Stenka 2013; Barska and Wyrwa 2016]. The studies showed that the level of

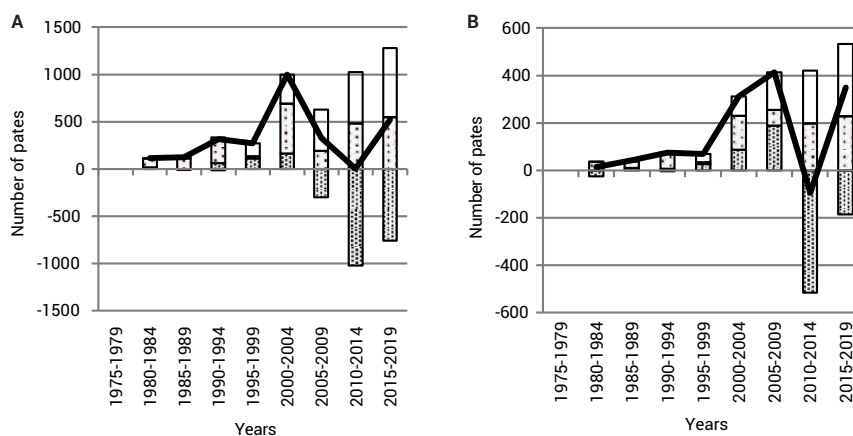


FIG.7. THE INTEREST IN PATENTS FOR THE SOLUTIONS IN THE FIELD OF ACTIVE (A) AND INTELLIGENT (B) PACKAGING (THE CONTINUOUS LINE MEANS THE CHANGE IN THE NUMBER OF PATENTS; ▨ THE CHANGE CONNECTED WITH THE INTEREST IN ACTIVE AND INTELLIGENT PACKAGING, ▤ THE CHANGE RESULTING FROM THE INTEREST IN FOOD PACKAGING AND □ THE CHANGE IN FIELD OF PATENT ACTIVITY

the knowledge of active and intelligent packaging was low. Only 13 – 29% of the respondent recognized that they knew the idea of active packaging and the knowledge of intelligent packaging was confirmed by 4%-38% of the respondent. On the other hand, the question concerning the purchase of the packaging with the active element was positively answered by 70% of the respondents. After explanation of the principle of functioning of the discussed solutions, the approval increase up to 89%. When the discussed purchase had been connected with the increase of the price, the interest in buying of such product was definitively decreased [Barska and Wyrwa 2016]. Summing up, we may state that the attitudes of the consumers in this respect in different countries are similar; most frequently, the knowledge on active and intelligent packaging is small but after getting familiarized with the offered profits, it is considerably increased.

5. THE MARKET OF ACTIVE AND INTELLIGENT PACKAGING

The development of active and intelligent packaging is decidedly affected by their perception by the companies which produce the consumer goods. The results of the survey conducted among the managers of higher degree in more than 400 enterprises show that the intelligent packaging will be the object of considerable investments. The innovative packaging is employed, first of all, in three areas, management of reserves, protection of the product's integrity and its perception by the user. The conducted survey shows that the probability of investing in the solutions confirming the authenticity in the nearest future was estimated at 15-20%. The probabilities of investing in a sustainable development are equal to 25-35% whereas the traceability, safety and quality amount to 40-50% [Armstrong et al. 2019]. The profits resulting from the application of intelligent packaging in the management of reserves of perishable products are also indicated by the computer simulations. It is followed that in the stable conditions of the storage, the application of TTI is not profitable but the employment of cheap TTI indicators in the dynamic stochastic environments, may be very advantageous [Herobon 2012]. Value of sales is the most important factor being the evidence of interest in a given product. According to the report of

Smithers Pira [2018] the total value of the market of active and intelligent packaging should reach to 5.69 billion USD in 2018, including the market of active packaging equal to 4.62 billion USD and market of intelligent packaging amounting to 1.06 billion USD. It is estimated that the total sales will be increasing 5.9% annually in average and will reach 7.56 billion USD in 2023. The market of the intelligent packaging will be quicker increased (12.9%) whereas that of active packaging – only 4%. It is difficult, however, to consider the cited above results as exceptionally optimistic because the prognoses of growth for the total market of packaging were estimated at the level of 6% [portalspozywczy.pl 2018} and value of the packaging market alone in 2018 is estimated at 876 billion USD [https://viki.com.pl]. It means that the active and intelligent packaging make ca. 1% of the packaging market.

CONCLUSIONS

When taking into account all the cited above facts, it can be distinctly seen that the future of materials and elements of active and intelligent packaging is not univocal. The problems appear already at the level of definition which was somewhat differently formulated in the regulation of the European Commission as compared to the definitions found in the scientific literature. This fact causes that in most of the publications, there is a need of defining what the author considers as active and intelligent packaging.

The differences in defining are probably the reason for discrepancies in the estimation of the size of the active and intelligent packaging market, as given in different elaborations. High prognoses of the rise of the market of intelligent packaging are connected with the quick development of printed electronic, activity in cloud and Internet of Things; the mentioned solutions exceed the definition, formulated by the European Commission. Moreover, the growth of the market of active and intelligent packaging is comparable with the increase of the total packaging market and is not the reason for indication of the discussed solutions as a priority.

A big number of publications results not only from the interest and meaning of the problem but also from the relatively high simplicity of the majority of the offered solutions. Many

systems, studies in literature are functioning but the problems appear in respect of repeatability and unambiguity of the obtained results. It is probably the cause of the considerable lower number of the solutions, offered at the market as compared to the number of publications. Many of commercial products were suggested very long ago and the number of the new solutions seems to be relatively low.

The profits, coming from the application of active and intelligent packaging that contribute to meeting the requirements of the consumers have been indicated, as well. Unfortunately, in most cases, the consumers have not met or have not known the discussed solutions.

From the cited examples, it is followed that we may recognize the active and intelligent packaging as being an interesting group of the solutions but their market success will be dependent on their popularization and technical development.

BIBLIOGRAPHY

- Aday M.S., Yener U., Assessing consumers' adoption of active and intelligent packaging, *British Food Journal*, 2015, Vol. 117: 1, s.157-177.
- Armstrong M., Fazio F., Herrmann D., Hetland C., Capturing Brand value from the smart packaging revolution, *BXP Smart Packaging*, 2019, Vol 3 No. 4, s. A5-A12.
- Barska J., Wyrwa A., Consumer perception of active and intelligent food packaging, *Problems of Agricultural Economics*, 2016, 4(349) s. 138-159.
- Bibi F., Guillaume C., Gontard N., Sorli B., A review: RFID technology having sensing aptitudes for food industry and their contribution to tracking and monitoring of food products. *Trends in Food Science & Technology*, 2017, 62, s. 91-103.
- Cierpiszewski R., *Opakowania aktywne i inteligentne*, Wydawnictwo UEP, Poznań 2016.
- Cierpiszewski R., Korzeniowski A., Niemczyk A., Decomposition in analysis of factors influencing interest of companies in code systems for multiple packages in Poland, *LogForum* 2019, 15 (1), 85-92.
- European Commission Final Report – Preparatory Study on Food Waste October 2010.
- Fortin, C., Goodwin, H.L., Valuation of Temp-Time's Fresh-Check® Indicator on Perishable Food Products in Belgium, *Southern Agricultural Economics Association Annual Meeting Dallas, Texas February 2-5*, Hajkovicz, S., Moody, J., 2010, *Our Future World. An Analysis of Global Trends, Shocks and Scenarios*, CSIRO, Canberra.
- Fortin, C., Goodwin, H.L., Thomsen, M.R., Consumer Attitudes toward Freshness Indicators on Perishable Food Products, *Journal of Food Distribution Research*, 2009, 40(3), 1-15.
- Fuertes G., Soto I., Carrasco R., Vargas M., Sabattin J., Lagos C., Intelligent Packaging Systems: Sensors and Nanosensors to Monitor Food Quality and Safety, *Journal of Sensor*, 2016, s. 1-8.
- Hareza P., Cierpiszewski R., *W Internecie Rzeczy, Przemysł Farmaceutyczny*, 2019, 3, 19-22.
- Herbon A., Levner E., Cheng E., Perishable Inventory Management and Dynamic Pricing using TTI Technologies, *International Journal of Innovation, Management and Technology*, 2012, Vol. 3, No. 3.
- Hong, S.-I., Park, W.-S., Development of Color Indicators for Kmchi Packaging, *Journal of Food Science*, 1999, 64, 255-257.
- <http://www.portalrfid.pl/> (data dostępu: 7.04.2015).
- <https://viki.com.pl/przyszlosc-globalnego-ryнку-opakowan-do-roku-2020/> „Przyszłość globalnego rynku opakowań do roku 2020 (data dostępu: 10.04.2020).
- https://www.allpack.com/Media/All-4-Pack-Medias/Files/FicheMarche_Emballage_Monde (data dostępu: 10.04.2020).
- <https://www.portalspozywczy.pl/technologie/wiadomosci/swiatowy-rynek-opakowan-powinien-roznac-w-tempie-ok-6-proc-rocznie,150936.html> (data dostępu: 7.04.2015).
- Mikkola, V., Lähteenmäki, L., Eero, H., Heiniö, R.L., Järvi-Kääriäinen, T. and Ahvenainen, R., *Consumer Attitudes Towards Oxygen Absorbers in Food Packages*, Technical Research Centre of Finland, Espoo. 1997.
- Mills, A., *Oxygen Indicators and Intelligent Inks for Packaging Food*, *Chemical Society Reviews*, 2005, 34, s. 1003–1011.
- O'Callaghan K. A.M., Kerry J.P., Consumer attitudes towards the application of smart packaging technologies to cheese products, *Food Packaging and Shelf Life*, 2016, 9, s. 1–9.
- O'Connor C. M., 2006, Pfizer Using RFID to Fight Fake Viagra, <http://www.rfidjournal.com>. (data dostępu: 28.01.2017).
- Pałkowska A., Steinka I., *Opakowania aktywne i inteligentne w świadomości konsumentów*, *ZESZYTY NAUKOWE AKADEMII MORSKIEJ W GDYNI*, nr 80, listopad 2013.
- Pareek V., Khunteta A., *Pharmaceutical packaging current trends*, *International Journal of Pharmacy and Pharmaceutical Science*, 2014, 6(6), 480-485.
- Pennanen, K., Focas C., Kumpusalo-Sanna V., Keskitalo-Vuokko K., Matullat I., Ellouze M., Pentikäinen S., Smolander M., Korhonen V., Ollila M., *HUMAN-PACKAGING INTERACTION European Consumers' Perceptions of Time-Temperature Indicators in Food Packaging*, *Packag. Technol. Sci.* 2015, 28, s. 303–323.
- Popowicz R., Lesiów T., *Innowacyjne opakowania aktywne w przemyśle żywnościowym*, *NAUKI INŻYNIERSKIE I TECHNOLOGIE ENGINEERING SCIENCES AND TECHNOLOGIES*, 2014, 2(13).
- Restuccia, D., Spizzirri, U.G., Parisi, O.I., Cirillo, G., Curcio, M., Iemma, F., Puoci F., Vinci G., Picci, N., 2010, *New EU Regulation Aspects and Global Market of Active and Intelligent Packaging for Food Industry Applications*, *Food Control* 21, s. 1425–1435.
- Robertson, G.L., *Food Packaging: Principles and Practice*, Second Edition, CRC Press Taylor & Francis Group. 2006.
- Rozporządzenie Komisji (WE) nr 450/2009 z dnia 29 maja 2009 r. w sprawie aktywnych i inteligentnych materiałów i wyrobów przeznaczonych do kontaktu z żywnością *Dz.Urz. L 135 z 30.5.2009*, s. 3 – 11.
- Schaefer, D., Cheung, W.M., *Smart Packaging: Opportunities and Challenges*, 51 st CIRP Conference on Manufacturing Systems, 2018, *Procedia CIRP* 72, s. 1022-1027.
- Smithers Pira, *The Future of Active and Intelligent Packaging to 2023*, 2018.
- Taoukis, P.S., 2001, *Modelling the Use of Time Temperature Indicators in Distribution and Stock Rotation*, w: Tijskens, L., Hertog, M., Nicolai, B., (ed.), *Food Process Modelling*, Woodhead Publishing Ltd, Cambridge, UK, 200, 1 s. 402-431.
- Tichoniuk M., *The Potential of Intelligent Packaging in the Reduction of Food Waste*, in: Salerno-Kochan R. *Towaroznawstwo w badaniach i praktyce – Nauki o zarządzaniu i jakości wobec wyzwań zrównoważonego rozwoju*, Sieć Badawcza Łukasiewicz – Instytut Technologii Eksploatacji, Radom, Poland, 2019, s. 121-130.
- Tichoniuk M., Radomska N., Cierpiszewski R., 2017, *Application of food freshness indicators in intelligent packaging*. In Śmigielska, H. (Ed.), *Current trends in commodity science: food safety and analysis of bioactive substances*, PUEB, Poznań, s. 189-202.
- Ucherek M., *Opakowania inteligentne i ich postrzeganie przez konsumentów*, *Marketing i Rynek* 2011, 1, s. 12-17.

Safe CONFERENCE packaging¹²

November 16-17th

Airport Okęcie Hotel, Warsaw

www.konferencja.opakowanie.pl



BOBST



SCODIX



HEIDELBERG

hubergroup

ML MARK ANDY



COMEF

Wolff Poligrafia Clarifoil