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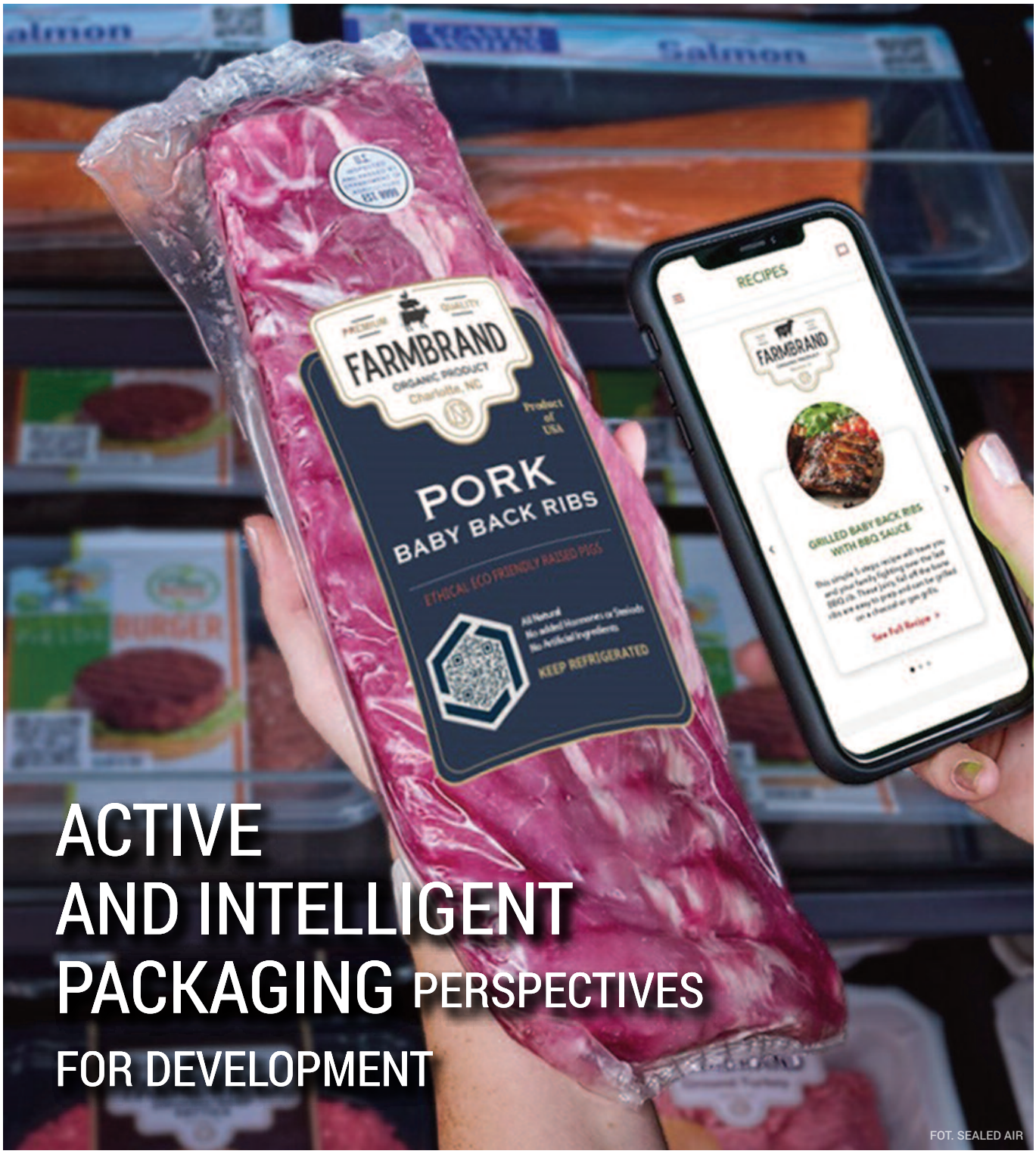


## ACTIVE AND INTELLIGENT PACKAGING PERSPECTIVES FOR DEVELOPMENT

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**Dear Readers!**

We proudly announce that after publishing 6 issues of the scientific quarterly "Packaging Review" we have been included by the Commission for the Evaluation of Science in the so-called ministerial list, i.e. the list of scientific journals and peer-reviewed materials from international conferences. Authors of publications appearing in the "Packaging Review" from this year on therefore receive 20 points.

In this magazine we present scientific findings and professional achievements from bona fide scientists. The articles highlight the focused efforts of those professionals on all issues related to packaging science working in research centers and the most innovative companies in both Poland and abroad. We communicate findings and report on scientific conferences. We are also a bridge between science and business - by communicating technological innovations we hope to make breakthroughs executable throughout the industry.

In the "Packaging Review" quarterly we address the most current innovations, packaging automation solutions and sustainability issues.

We invite scientific centers and R&D departments to cooperate!

**Marek M. Kowalczuk** is a professor at the Centre of Polymer and Carbon Materials, Polish Academy of Sciences, Zabrze, Poland, and head of the Group of Innovation, Technology and Analysis Service. He received a PhD degree in 1984 from the Faculty of Chemistry, Silesian University of Technology, Gliwice, Poland, and a D.Sc. degree in 1994 from the same University. Since 2010 he has been a professor of chemistry, nominated by the President of Poland. He was a visiting professor at the Ohio State University (Columbus, OH, USA), a visiting lecturer at the University of Massachusetts (Amherst, MA, USA), a Marie Curie EU fellow at the University of Bologna (Italy), and a professor in chemistry at the University of Wolverhampton (UK). Recently, he has been elected as a member of the Chemistry Committee of the Polish Academy of Sciences. He is the author and co-author of over 170 scientific papers and a score of patents.

**Drodzy Czytelnicy!**

Z dumą informujemy, że po wydaniu 6 numerów kwartalnika naukowego „Packaging Review" zostaliśmy uwzględnieni przez Komisję Ewaluacji Nauki na tzw. liście ministerialnej, czyli wykazie czasopism naukowych i recenzowanych materiałów z konferencji międzynarodowych. Autorzy publikacji ukazujących sią na łamach „Packaging Review" otrzymują zatem od tego roku 20 punktów.
W czasopiśmie prezentujemy naukowe i zawodowe osiągnięcia naukowców dotyczące całokształtu zagadnień związanych z opakowaniami, pracujących w ośrodkach badawczych i najbardziej innowacyjnych firmach zarówno w Polsce, jak i za granicą. Informujemy o konferencjach naukowych oraz je relacjonujemy. Jesteśmy także pomostem łączącym naukę z biznesem – popularyzując innowacje sprawiamy, że mają one szansę na wdrożenie i zastosowanie w przemyśle.
W kwartalniku „Packaging Review" podejmujemy najaktualniejsze innowacje, rozwiązania automatyzujące produkcję opakowań, a także kwestie związane ze zrównoważonym rozwojem.
Zapraszamy ośrodki naukowe oraz działy badawczo-rozwojowe do współpracy i publikacji!

**Marek M. Kowalczuk** jest profesorem w Centrum Materiałów Polimerowych i Węglowych Polskiej Akademii Nauk w Zabrzu oraz kierownikiem Zespołu Innowacji, Technologii i Analiz. Stopień doktora uzyskał w 1984 r. na Wydziale Chemicznym Politechniki Śląskiej w Gliwicach oraz stopień naukowy doktora habilitowanego w 1994 roku na tej samej uczelni. Od 2010 roku jest profesorem chemii z nominacji Prezydenta RP. Był profesorem wizytującym na Uniwersytecie Stanowym Ohio (Columbus, OH, USA), wykładowcą wizytującym na Uniwersytecie Massachusetts (Amherst, MA, USA), stypendystą Marie Curie EU na Uniwersytecie Bolońskim (Włochy) oraz profesorem chemii na Uniwersytecie w Wolverhampton (Wielka Brytania). Ostatnio został wybrany na członka Komitetu Chemii PAN. Jest autorem i współautorem ponad 170 prac naukowych oraz kilkunastu patentów.

# Packaging Review

Issue **3/2023** includes:

## REVIEWED ARTICLES <<



## INDUSTRY EVENTS <<

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# ACTIVE AND INTELLIGENT PACKAGING. PERSPECTIVES FOR DEVELOPMENT

## OPAKOWANIA AKTYWNE I INTELIGENTNE. 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 in 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 is 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 [Haręza 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 absorbents, 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. $CO_2$, antibacterial

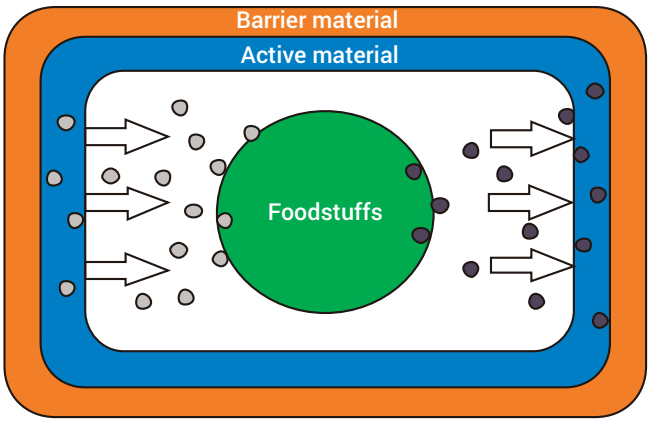


**FIG.1.THE PRINCIPLE OF FUNCTIONING OF ACTIVE PACKAGING**

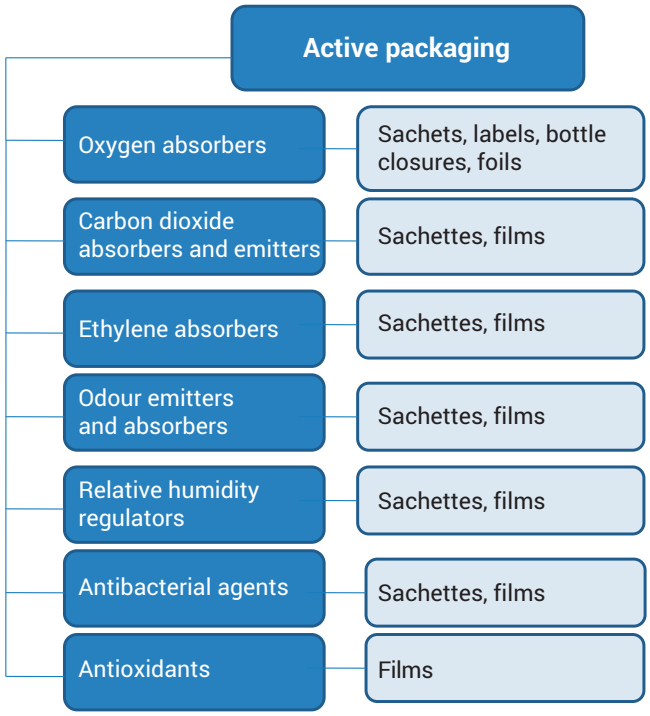


**FIG.2. CLASSIFICATION OF ACTIVE PACKAGING ACCORDING TO ABSORBED OR EMITTED SUBSTANCE**

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 form 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

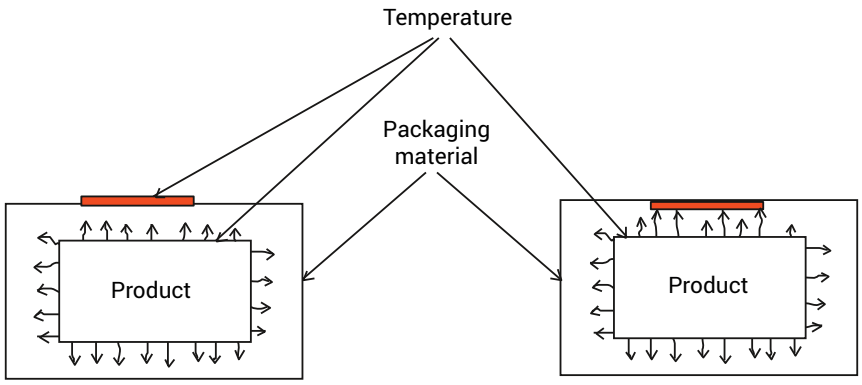


**FIG.3. IDEA OF FUNCTIONING OF INTELLIGENT PACKAGING**

**TAB.1. THE EXAMPLES OF THE COMMERCIALLY AVAILABLE ACTIVE PACKAGING**

| System | Trade name | Producer |
|---|---|---|
| Oxygen absorbents | Ageless G,<br>Amosorb®,<br>ATCO®,<br>Bioka Oxygen<br>Cryovac®,<br>Desi Pak®, Sorb-It®, Tri-Sorb®, Getter Pak®, 2-in-1<br>Label Cryovac®, OS2000<br>FreshPax®, | Mitsubishi GasChemical, Japan<br>Amosorb $SolO_2$, ColorMatrix Group Inc., USA<br>Laboratories STANDA Bioka Ltd., Kantvik, Finland<br>OS Film Sealed Air Corporation, USA<br>Enzyme-based, Bioka Ltd., Kantvik, Finland |
| Carbon dioxide emitters | Ageless G,<br>$CO_2$® Fresh Pads,<br>Freshpax,<br>Freshlock,<br>UltraZap® Xtenda Pak pads,<br>Verifraise package, | Mitsubishi Gas Chemical, Japan<br>$CO_2$ Technologies, USA<br>Multisorb Technologies, USA<br>Multisorb Technologies, USA<br>Paper Pak Industries, Canada<br>SARL Codimer, France |
| Antibacterial | Aglon™,<br>Bioka,<br>Biomaster®,<br>Ethicap™,<br>Irgaguard®,<br>Microban,<br>Microgarde™and Microsphere™, | Agion Technologies, USA<br>Bioka Ltd., Finland<br>Addmaster Ltd., UK<br>Freund, Japan<br>BASF, USA<br>Microban Prod., UK<br>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

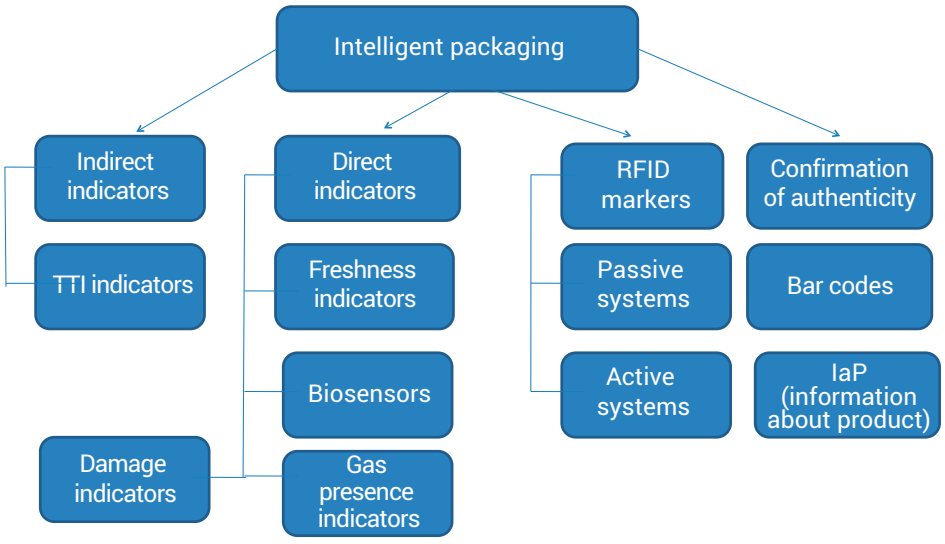


**FIG.4. CLASSIFICATION OF INTELLIGENT PACKAGING**

**TAB.2. THE EXAMPLES OF COMMERCIALLY AVAILABLE INTELLIGENT PACKAGING**

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

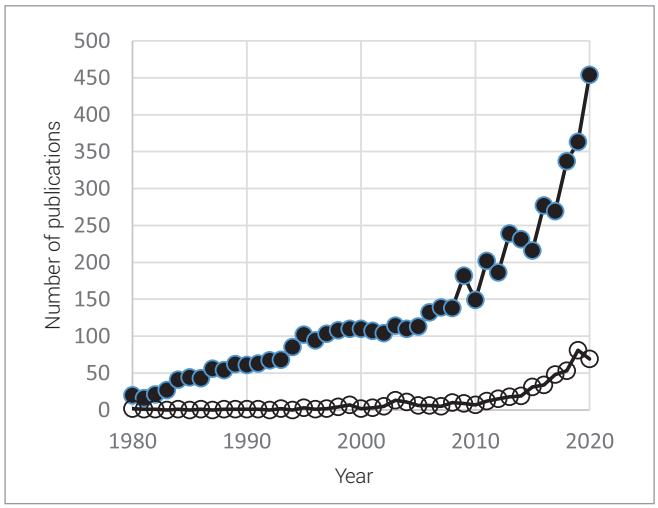


**FIG. 5. THE NUMBER OF PUBLICATIONS IN THE SCIENTIFIC PERIODICALS, CONCERNING ACTIVE AND INTELLIGENT PACKAGING**

**● – ACTIVE PACKAGING; ○ – INTELLIGENT PACKAGING**

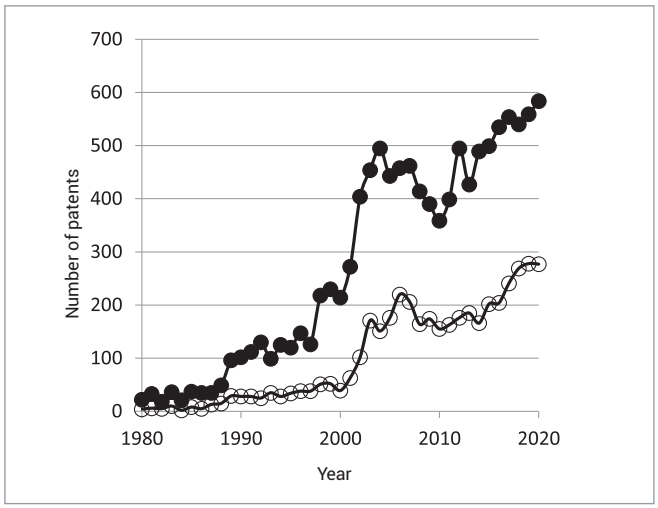


**FIG. 6. NUMBER OF PATENTS CONCERNING ACTIVE AND INTELLIGENT PACKAGING**

**● – 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.

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

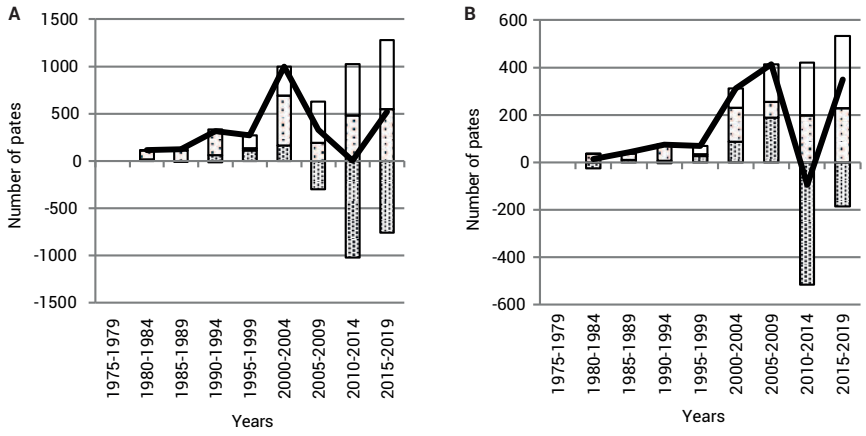


**FIG.7. THE INTEREST IN PATENTS FOR THE SOLUTIONS IN THE FIELD OF ACTIVE (A) AND INTELLIGENT (B) PACKAGING (THE CONTINUOUS LINE MEANS THE CHANGE IN THE NUMBER OF PATENTS; ⊞ THE CHANGE CONNECTED WITH THE INTEREST IN ACTIVE AND INTELLIGENT PACKAGING, ⊡ THE CHANGE RESULTING FROM THE INTEREST IN FOOD PACKAGING 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.

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# SAFETY FACTORS IN THE DESIGN OF CORRUGATED BOARD PACKAGING

## WSPÓŁCZYNNIKI BEZPIECZEŃSTWA W PROJEKTOWANIU OPAKOWAŃ Z TEKTURY FALISTEJ

**ABSTRACT:** The paper briefly presents the most important safety factors that are most often used in the process of estimating the load-bearing capacity of corrugated board packaging. First, the coefficients taking into account storage and transport under various environmental conditions are discussed. These factors directly increase the safety of the transported packaging by increasing the required load capacity. Coefficients that indirectly affect the value of the estimated load capacity of the packaging are discussed next. They are usually added during the estimation of the theoretical load-bearing capacity by taking into account the uncertainty related to the declared quality of the material, as well as the impact of damage to the structure of corrugated board during converting. Both types of coefficients are shown through the schemes adopted by packaging manufacturers. Unfortunately, these procedures are subject to errors or simplifications, which often lead to overestimation or underestimation of the load-bearing capacity of packaging. In both scenarios, wrong estimation involves additional costs that can be easily avoided. Therefore, determining the appropriate values of these coefficients is very important, but at the same time difficult, especially when the designed packaging will be stored in varying environmental conditions, with multiple handling and additionally transported by different means of transport.
**Key words: corrugated cardboard, packaging strength, safety factors**

**STRESZCZENIE:** W pracy pokrótce przedstawiono najważniejsze współczynniki bezpieczeństwa, które najczęściej stosuje się w procesie szacowania nośności opakowań z tektury falistej. W pierwszej kolejności, omówiono współczynniki uwzględniające warunki magazynowania i transportu. Współczynniki te bezpośrednio wpływają na zwiększenie bezpieczeństwa transportowanego opakowania poprzez zwiększenie wymaganej nośności. Omówiono również współczynniki, które pośrednio wpływają na wartość szacowanej nośności opakowania. Najczęściej są one wykorzystywane w trakcie estymacji wartości teoretycznej nośności, poprzez uwzględnienie niepewności związanej z deklarowaną jakością materiału, a także wpływem uszkodzenia struktury tektury falistej w trakcie przerobu. Oba rodzaje współczynników pokazano przez pryzmat schematów przyjętych przez producentów opakowań. Procedury te obarczone są niestety błędami lub uproszczeniami, które często prowadzą do przeszacowania lub niedoszacowania nośności opakowań. W obu scenariuszach błąd oszacowania nośności wiąże się z dodatkowymi kosztami, których łatwo można uniknąć. Dlatego tak ważne, ale jednocześnie trudne, jest określenie odpowiednich wartości tych współczynników, szczególnie gdy projektowane opakowanie będzie magazynowane w zmiennych warunkach środowiskowych, z wieloma przeładunkami i dodatkowo przewożone będzie różnymi środkami transportu.
**Słowa kluczowe: tektura falista, wytrzymałość opakowań, współczynniki bezpieczeństwa**

## INTRODUCTION

Each professional plant converting corrugated board has implemented certain standards and procedures for selecting the optimal cardboard for packaging production. In large enterprises, this is done in centralized units by experienced designers who, in addition to skills in designing various packaging geometries, also have basic knowledge about the strength of material. Other packaging manufacturers assign to this task the quality control employees or experienced laboratory technicians, who deal with corrugated board on a daily basis, performing dozens of mechanical tests on cardboard and packaging. Finally, some companies, have set up special units in their production management departments responsible for selecting the best papers for the production of corrugated board converted into packaging. However, even the most experienced designer or quality department employee occasionally falls into the trap of routine, which can lead to costly mistakes. Sometimes these are simple mistakes, and sometimes they are long-term, systematic errors that may never have revealed themselves in any serious crisis. This article

presents certain knowledge and guidance that may be useful to those responsible for the selection of the right quality material for the production of corrugated board packaging, to protect them against the pitfalls lurking ahead. Especially when routine and many years of experience begin to blind them to problems that may lead to erroneous habits.

Most of the problems related to the design of corrugated board packaging stem not from the geometry of the box but from the strength of the corrugated board, which, unlike other typical construction materials, depends to a large extent on: (a) weather conditions, (b) storage conditions and (c) transport conditions. If, on top of all these correlations, one adds a strong relationship between the static strength of corrugated board and (i) the type of paper for individual layers, (ii) the geometry of the corrugated layer, (iii) the gluing quality, (iv) the amount and type of printing, (v) the cutting technique, etc., one can quickly come to the conclusion that corrugated board is a very complicated material. The effects of the complex mechanics of corrugated board are felt by both cardboard producers and convertors.

Corrugated board manufacturers specify produced materials by providing basic information such as grammage, thickness, and, among others, the resistance of cardboard to edge crushing, popularly called in papermaking jargon the ECT parameter (from the laboratory test name – Edge Crush Test [14]). Cardboard converters base the box strength calculations primarily on the ECT specification. In order to accurately estimate the load capacity of packaging, the simple analytical calculators [1,2,6,7,10-13,16,17] or advanced numerical tools [3,8,9] can be utilized. However, in the face of a possible complaint, in addition to verification of the accuracy of the formula that was used to calculate the load capacity, other factors must also be verified. In the complex decision-making chain, there are other important factors that influence the final value of the packaging's load-bearing capacity. They are called correction or safety factors and they result from: (a) the types and number of processes that the corrugated board has gone through during the production of the packaging, (b) the environmental conditions in which the packaging is to be transported, (c) the dynamic impacts of transport (d) the palletization scheme, (e) the type of goods transported in the box, (f) the time and conditions during long-term storage, and (g) the discrepancy between the actual value of ECT and the technical specification of the material given by the cardboard manufacturer.

## LOAD CAPACITY OF PACKAGING ENHANCED WITH SAFETY FACTORS

The following paragraphs describe all the most important factors influencing the assessment of the load-bearing capacity of the box. The discussion ignores the obvious uncertainty in the load acting on the most vulnerable package, usually located at the bottom of the pallet. This load depends on the number of packages placed in a single stack (i.e. above the lowest box on the pallet) and on the weight of the goods contained in each package (see Figure 1).

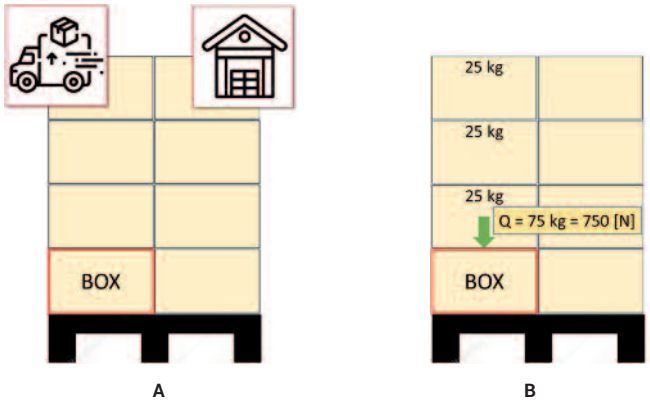


**FIG.1. PALLETIZATION: (A) BOTTOM BOX DURING STORAGE AND TRANSPORT ; (B) LOAD ACTING ON THE MOST STRESSED PACKAGING**

The load, *Q*, estimated in this way (given in [N] or [kN], less often in [kg] - remembering that [1kN] is approximately [100kg]) can be interpreted as a computational indicator determining the static load capacity of the packaging. The actual or required load capacity of the packaging is therefore obtained from the following equation:

$$P_T = Q \cdot \hat{\gamma}_d \cdot \hat{\gamma}_t \cdot \gamma_e \cdot \gamma_p, \quad (1)$$

where: $\hat{\gamma}_d \geq 1$ is a factor related to the impact of the dynamic load on the load-bearing capacity of the packaging (see Fig.2a),

$\hat{\gamma}_t \geq 1$ is a factor related to the impact of storage time (see Fig.2b) and the type of goods in the box, $\gamma_e \geq 1$ is a factor related to the influence of humidity and temperature on the load-bearing capacity of the packaging (see Fig.2c), $\gamma_p \geq 1$ is a factor related to the influence of palletization on the load-bearing capacity of the box.

The values of these coefficients depend on several parameters, e.g. on: (1) material, *m*, i.e. the type and quality of cardboard used to produce the packaging; (2) dimensions of the box, *l* x *b* x *w* (where: *l* is the length, *b* – width, and *w* – height of the packaging); (3) storage/transport time, *t*, and (4) temperature/humidity, *e*. An additional parameter may also be the type of transport, *r* (i.e. plane, ferry, car, train, etc.). Figure 2 summarizes these impacts.

Assuming that in the logistic chain the packaging may be in one of two 'states': (i) it may be stored for a certain period of time, under known or expected humidity and temperature conditions or (ii) it can be transported by one of the possible means of transport for a specified period of time and under specified environmental conditions. Of course, these states can be repeated in any configuration and for a certain finite number of cycles. If one additionally assumes that the palletization coefficient depends only on the type of cardboard, *m*, the dimensions of the box, *l* x *b* x, and the arrangement of the package on the pallet, *g*, then equation (1) takes the form:

where $\gamma_d$ is a coefficient that takes into account the dynamic loads acting on the packaging under various temperature and humidity conditions, while $\gamma_t$ is a coefficient taking into account long-term storage (often leading to permanent deformations, so-called material creep) under different environmental conditions.

Therefore, the correct definition of the coefficients $\gamma_d, \gamma_t$ and $\gamma_p$ requires, in addition to determining the material used to produce the packaging and its main dimensions, also the exposure time (i.e. storage or transport), the type of transport, the temperature and humidity conditions under which boxes will remain, as well as the geometric placement of the packaging on the pallet (see Fig. 3). It should be noted that the use of a cardboard spacer between subsequent layers of packaging allows the $\gamma_p$ coefficient to be significantly reduced.

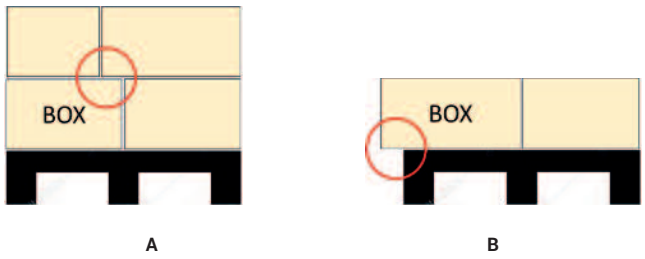


**FIG. 3. PALLETIZATION: (A) SHIFTING BETWEEN SUBSEQUENT LAYERS OF BOXES (WITHOUT SPACER); (B) OVERHANGING THE PACKAGING BEYOND THE PALLET.**

$$P_T = Q \cdot \gamma_d(m, l \times b \times w, t, r, e) \cdot \gamma_t(m, l \times b \times w, t, e) \cdot \gamma_p(m, l \times b \times w, g), \quad (2)$$

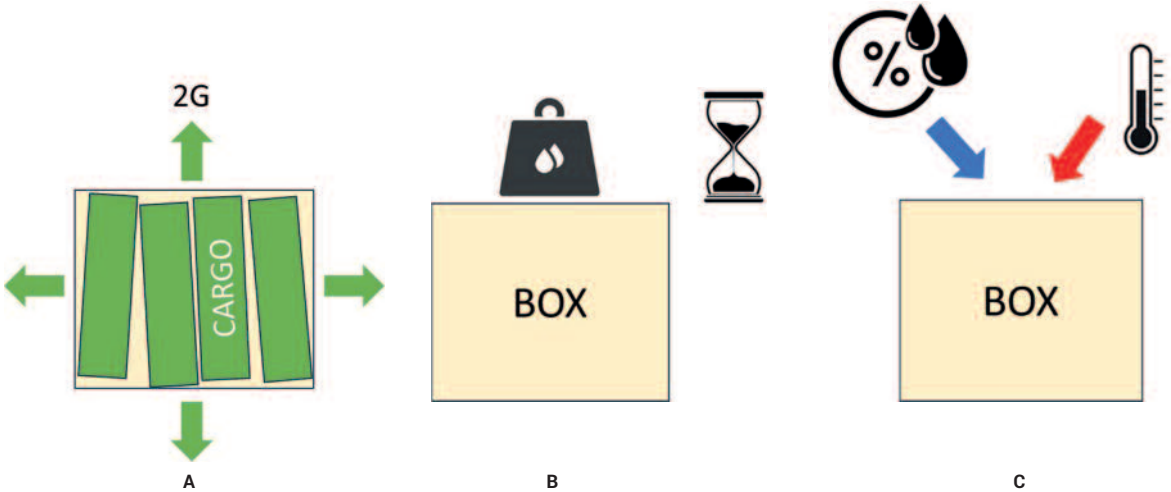


**FIG.2. IMPACTS AFFECTING THE LOAD-BEARING CAPACITY OF THE PACKAGING: (A) DYNAMICS; (B) LOADING TIME; (C) TEMPERATURE AND HUMIDITY.**

These coefficients are therefore complex functions of multiple variables with an a priori unknown equation. Of course, one can try to define these equations, e.g. by performing hundreds of tests and building a metamodel based on, for example, artificial neural networks. In both cases, the task is very complicated and without the use of numerical calculation tools rather impossible. In reality, many simplified tables and guides or standards are used, which are often based on simplified empirical observations.

In the next step, the value of the required load capacity of the packaging, $P_T$, should be verified with a static column compression test. If the obtained load-bearing capacity value, the abovementioned BCT [15], is higher than the required load-bearing capacity, then the goods transported in the packaging designed in this way should be completely safe.

Before discussing the impact of individual correction/safety factors, it should be added that in the design process, especially for repetitive transport packaging structures, various analytical formulas are increasingly being used to estimate their load capacity, instead of or in parallel with laboratory verification [1,2,10-12,16,17], analytical-numerical [6,7,13] or numerical [3,8,9]. In the case of the theoretical packaging design based on an automatic corrugated board selection procedure, further factors related to the material specification error and the impact of cardboard processing (printing, cutting, lamination, etc.) on its load-bearing capacity should be additionally taken into account. In order to illustrate this procedure, for simplicity, the most popular formula for BCT estimation is chosen, called the short McKee formula [12]:

$$P_M = \alpha \cdot ECT \cdot \sqrt{\hat{h}Z}, \tag{3}$$

where: $\alpha$ is the correlation coefficient, which should be determined by fitting the model to a selected, laboratory-tested set of packaging (it is often forgotten that this coefficient is not universal for all types of packaging), *ECT* is the value of edge crushing resistance of corrugated board – optimally, the *ECT* value of the exact material from which a given series of packaging will be produced should be used here (unfortunately erroneously, the average value given by the manufacturer in the specification often appears here – see Fig. 4), $\hat{h}$ is the thickness of the corrugated cardboard taking into account the impact of cardboard converting (unfortunately a cardboard thickness without taking into account the crushing caused by converting often appears here, which artificially inflates the BCT value), while *Z* is the circumference of the packaging base (*2l* + *2b*).

The incorrect use of the average value and the initial (uncreased) cardboard thickness value does not have to be noticed, even by experienced designers. This is due to the 'magical' properties of the $\alpha$ coefficient, which can take any value during the calibration process. Unfortunately, the incorrect determination of this coefficient results in a systematic underestimation or overestimation of the BCT values of other packages estimated using formula (3) calibrated with incorrect *ECT* and $\hat{h}$ values. Figure 4 shows the average value of ECT compared to the actual values obtained during the year. This chart clearly shows that using the average value instead of the actual ECT value in formula (3) can introduce significant error, especially when strength calculations are performed during periods when the relative air humidity reaches extreme values.

In order to take into account material uncertainties and crush effects, the following relationships can be introduced:

$$ECT = \gamma_m \overline{ECT}, \tag{4}$$

where: $1 \leq \gamma_m \leq 1$ is a reducing or increasing factor to account for the error related to the mismatch between the manufacturer's specifications and the actual *ECT* value, while $\overline{ECT}$ is the average value given in the specification.

The uncertainty associated with cardboard converting can be taken into account as follows:

$$\hat{h} = \gamma_n \cdot h, \tag{5}$$

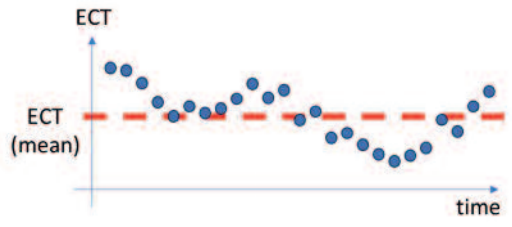


**FIG.4. AVERAGE VALUE ($\overline{ECT}$) VS ECT VALUES AS A FUNCTION OF TIME**

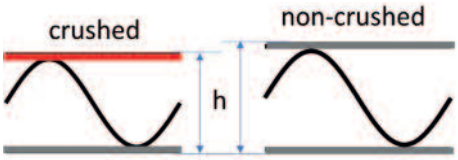


**FIG.5. THICKNESS OF CORRUGATED BOARD, $h$, AFTER AND BEFORE CONVERTING.**

where: ≤ 1 is a reducing factor that allows to take into account micro-damage to the cardboard caused by printing (number of colors and printing area), lamination, die used, etc., while $h$ is the initial thickness of undamaged cardboard.

Figure 5 shows the impact of crushing the fluting on the change in height of the cardboard (unfortunately, the additional change in the thickness of the corrugated board often remains "hidden", among others, in micro-damages in the fluting, which, due to its elasticity, often returns almost to its original shape, although the actual change in thickness as a result of crushing is much greater than the change in thickness that we observe with the naked eye).

The theoretical load capacity of the packaging, taking into account material uncertainties and the impact of converting, is therefore:

$$P_M = \alpha \cdot \gamma_m \overline{ECT} \cdot \sqrt{\gamma_n h Z}. \quad (6)$$

Finally, one can obtain the following relationship:

$$P_T \leq BCT \leq P_M, \quad (7)$$

from which an important observation can be derived – the calculated value of $P_T$ should be lower than the actual (measured) value of *BCT*, which in turn should be lower than the theoretical (estimated) $P_M$ value.

Using the above relationship, one can directly determine, for example, the optimal cardboard through an iterative process of maximization the load-bearing capacity of the package or by directly modifying equations (3) and (6) to determine the *ECT* value for the selected flute.

For example, for an initially adopted three-layer corrugated board with B flute and an a priori assumed thickness of h = 2.5 mm (which in the general should not take a constant value, because it depends on the type and grammage of the utilized papers) and for an exemplary packaging with base dimensions of 200 mm and 200 mm, one gets:

$$\overline{ECT_B} = \frac{Q \cdot \gamma_d \cdot \gamma_t \cdot \gamma_p}{\alpha \cdot \gamma_m \cdot \sqrt{\gamma_n 2.5 \cdot 800}}. \quad (8)$$

The $\alpha$ coefficient can be estimated relatively quickly on the basis of many laboratory tests and the experience of designers or quality control staff. It is equally easy to obtain the load value *Q*, which can be obtained by multiplying the weight of one package with the goods by the number of layers of packaging in a single stack on a pallet (see Fig. 1b).

However, estimating the remaining coefficients is not a trivial issue – selecting appropriate values requires extensive experience, and their underestimation may result in costly complaints. Therefore, these coefficients are usually taken with a large margin, resulting in other underestimations (e.g. an incorrectly selected safety factor $\gamma_m$ related to the specification error is often omitted).

As already mentioned, each coefficient is responsible for certain specific environmental and transport conditions that directly or indirectly influence its decline. However, often these conditions are not known a priori or only limited information is available. In such situations, estimating correction factors is quite a challenge. So let's focus on those coefficients whose estimation is much simpler. These include, for example, $\gamma_m$ which takes into account the discrepancy of the actual *ECT* value with the manufacturer's specification.

The specification of corrugated board is usually based on average *ECT* values that have been determined for the individual qualities of cardboard offered by the manufacturer. However, adopting an average value for calculations may involve a significant error, which is related, among others, to the fact that the *ECT* of a particular corrugated board varies depending on the season in which it is produced. Additionally, manufacturers often change the input papers to produce a specific quality of corrugated board. This is due to a change in supplier or lack of a particular paper in stock. Of course, these changes are not recorded in the specification. This results

in differences ranging from several to dozen of percent (see Fig. 6). If we add to this the change in the mechanical parameters of corrugated board, that result from differences in humidity in different seasons, the differences between the current value and the averaged one (in the specification) may reach up to 20%. This leads to a situation where the correction factor $\gamma_m$ can reach a value of 0.8 in extreme cases.

Another underestimated correction (safety) factor is the $\gamma_n$ factor, which takes into account micro-damage to corrugated board resulting from cardboard converting. It is often forgotten that both the specification and the thickness of corrugated board provided by the manufacturer refer to freshly produced cardboard and do not take into account converting processes, i.e. printing, lamination and the type of die-cutting on flat or rotary dies. All the mentioned processes always have a destructive effect on the cardboard, but this impact is rarely taken into account by designers. Publication [5] presents a method for estimating the impact of micro-damage on corrugated board, i.e. the so-called crush created during converting, on its mechanical parameters. This work shows that this impact can again reach several dozen percent and can be easily estimated using, e.g., torsion tests [4].

Another safety factor should be related to the impact of holes and perforations on the load-bearing capacity of the packaging. Obviously, the formula presented in equation (3) does not allow for the inclusion of holes or perforations in the procedure for estimating the load-bearing capacity of corrugated board packaging. However, a number of methods can be found in the literature that make it possible to precisely determine the weakening of the packaging's strength, e.g. resulting from holes [6] or perforations [7]. However, the application of these techniques requires complex calculations of the critical forces of individual packaging walls. To avoid this, one can use commercially available calculation systems, e.g. BSE System [3], which also takes into account the impact of holes and perforations on the load-bearing capacity of packaging, but at the same time requires the correct definition of the hole geometry and the type of cutting used in the perforation.

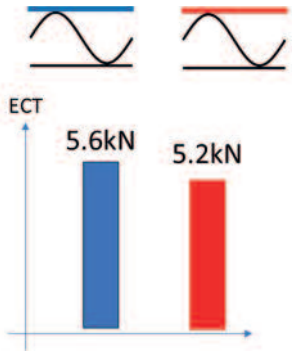


**FIG.6. VALUE FOR THE SELECTED CORRUGATED CARDBOARD (E.G. B300), FOR THE PRODUCTION OF WHICH TWO DIFFERENT PAPERS WERE USED ON ONE OF THE FLAT LAYERS (BLUE COLOR – PAPER FROM THE SPECIFICATION; RED COLOR - SUBSTITUTE PAPER).**

Incorrect definition of perforation (cutting type) and/or ventilation holes may result in errors of up to several percent.

## SUMMARY

Failure in determining all possible correction factors correctly can lead to errors of several dozen of percent in the estimation of the load capacity of the packaging. As already mentioned, the lack of negative effects resulting from not taking some of them into account at all (the value is one) or misestimating their value may still go unnoticed even by qualified designers, because even poorly chosen safety factors can compensate their impact with other overestimated factors in the global equation. This happens when the designer does not have full knowledge of the transport conditions or, out of pure precaution, assumes safety factors at a very high level, e.g.

$$\gamma_d \cdot \gamma_t \cdot \gamma_p = 5.0 \tag{9}$$

instead of e.g. 3.0 or 3.5. This is a significant overestimation, which of course allows to avoids costly claims, but at the same time completely blocks the possibility of real savings, and also limits the correct use of the full capabilities of computational tools, such as [3].

The correct determination of safety factors is not easy and requires many a great deal of research, both under the various climatic conditions affecting the packaging and taking into account the dynamic impacts arising during transport, as well

as combination of these factors, while taking into account the timing of the individual effects, their order (sequence of changes) and full interaction between them. Although this seems very difficult and time-consuming, intensive research is already being carried out worldwide, especially in Europe, including Poland, to determine all these coefficients. Ultimately, the stakes are high, because reducing safety factors by even a few or a dozen percent, while maintaining the required load capacity, can result in huge savings. Fortunately, more and more large packaging manufacturers, as well as their key customers, are increasingly aware that the sound knowledge of their own product and processes during production, as well as after leaving the factory, brings financial benefits. This allows us to remain realistically optimistic that newer solutions based on knowledge and science in the packaging and corrugated board industry will come sooner rather than later.

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# THE INTRODUCED AND PLANNED CHANGES IN THE LAW REGARDING FOOD CONTACT MATERIALS

## OBOWIĄZUJĄCE I PLANOWANE ZMIANY W PRAWIE DOTYCZĄCYM MATERIAŁÓW DO KONTAKTU Z ŻYWNOŚCIĄ

**ABSTRACT:** In the paper, the review of the implemented and planned changes in the legislation concerning packaging, including the packaging intended to come into contact with food, was presented.

**Key words: packaging, food packaging**

**STRESZCZENIE:** W artykule przedstawiono przegląd wdrożonych i planowanych zmian dotyczących otoczenia prawnego opakowań w tym do kontaktu z żywnością.

**Słowa kluczowe: opakowania, opakowania do żywności**

### AMENDMENT TO THE REGULATION (EU) NO 10/2011[1]

In July and August 2023, the European Commission (EC) published two amendments to Regulation (EU) 10/2011. The Regulation (EU) 2023/1442 of 11 July 2023[2] introduces the ban for the employment of the additive to plastic in a form of wood flour and fibres. It has a very big importance in manufacture of the products which are expected to make the impression of 'ecological", i.e. containing the additive of natural materials. From the viewpoint of recyclability, such material cannot be subjected to mechanical or biological recycling. The European Commission excluded the application of the discussed materials due to the impossibility of ensuring the compatibility with the Regulation (EU) No 1935/2004. It refers to the presence of naturally occurring substances with a low molecular weight. Due to the differences in the composition of raw wood material, it is necessary to evaluate each wood species separately, considering – apart from a species, its origin, processing and treatment. Due to the above reason, the mentioned regulation admits the application of wood addition but after obtaining individual opinion of EFSA (European Food Safety Authority) and consent of the European Commission. In practice, it eliminates the employment of such additive in plastic products. On the other hand, a popular bamboo is not formally a wood but a grass and as such, it has been never considered in the list of the substances allowed in the Regulation (EU) No 10/2011; so, theoretically, it is not subjected to the described limitation. A final decision in this matter will belong to national control organs. In the same regulation, the problem of phthalates' migration has been developed. The table given below contains the adopted limitations and group limits of specific substance migration (table).

The Commission Regulation (EU) No 2023/1627 of 10 August 2023[3] introduces (in Annex I to the Regulation – list of the admitted substances) bis (2-ethylhexyl) cyclohexane-1,4-dicarboxylate (FCM no 1079) with a limit of a specific migration 0.05 mg/kg exclusively *"as an additive (plasticizer) in Poly(vinyl*

| No FCM | Regulation. (UE) no 10/2011 | Regulation 2023/1442 |
|---|---|---|
| DBP (157) | SML= 0.3 mg/kg<br>Group limitation 32 | SML = 0.12 mg/kg<br>Group limit 32 and 36 |
| BBP (159) | SML = 30.0 mg/kg<br>Group limit 32 | SML = 6.0 mg/kg<br>Group limit 32 and 36 |
| DEHP (283) | SML = 1.5 mg/kg<br>Group limit 32 | SML = 0.6 mg/kg<br>Group limit 32 and 36 |
| DINP (728) | - | Ban for use of DINP together with DBP (157), BBP (159), DEHP (283), DIBP (1085) |
| DIBP (1085) | - | Phthalate is not listed as a substance admitted to consumption. It may, however, occur in other phthalates as a result of its application as a polymerisation-supporting agent and is covered with the group limits with allocation to FCM (Food Contact Materials) no 1085. |
| Sum | - | Sum of DBP, DIBP, BBP, DEHP expressed as equivalent of DEHP using the following equation:<br>DBP*5 + DIBP*4 + BBP*0.1 + DEHP*1. |

*chloride) (PVC) at up to 25% w/w in contact with aqueous, acidic and low-alcohol food for long-term storage at room temperature or below (refrigerated and frozen) for which food stimulants A and B were assigned in Tab.2 of Annex III".*

## RECYCLING OF PLASTIC MATERIALS

Since 2008, the principles of admitting the recycled plastic materials to contact with food were specified by the Commission Regulation (EC) 282/2008 of 27 March 2008[4]. It required the consent for each recycling process. In 2010, the EU register of the mentioned authorizations was planned to appear. The European Commission has never published this register. During the several successive years, a few draft versions of the changes in the discussed regulation were published. As late as after 14 years, i.e. in September 2022, the European Commission introduced the Commission Regulation (EC) 2022/1616 of 15 September 2022 into life[5].

On one hand, the published document gives the hope to push forward the problem of admission of recycled plastic materials to contact with foods, but from the other hand, it imposes a great number of administrative barriers. The most important limitation includes admission of only PET materials to mechanical recycling. The second condition which increases considerably the costs is the necessity of issuing the compliance declaration for each batch of recyclate and for the product, manufactured with its participation. The discussed regulation is very complicated by itself, and difficult in practical application. It concerns principally the administrative way of obtaining the permission for recycling. The discussed document splits the total process into the main authorizations, that is, into the process of recycling "RAN" and a series of "auxiliary" registrations: the number of the entity dealing with recycling "RON", the number of its recycling plants "RFN", the employed installations for decontamination of recyclate "RIN". Oppositely to the earlier situation, the European Commission published draft register of the granted authorizations. On the market, there have already appeared PET plastic materials with a correctly filled compliance declaration. The requirements concerning the quality of the input raw materials were subjected to a certain change, i.e. apart from the fraction of the waste which had been earlier admitted to contact with food, the 5-% participation of non-food waste is allowed. Similarly as earlier, the quality of a final product cannot be a threat to the consumer.

## PACKAGING WASTE

For the first time since 1992, the European Union undertook the fundamental work on the amendment of Directive 94/62/EC[6] of 20 December 1994 on packaging and packaging waste (Proposal for Packaging and Packaging Waste Regulation, PPWR). The most important change consists in

establishing of the regulation which enters into effect directly at the territory of the whole EU instead of directive which requires implementation to the national law of each country separately. The amendment considers all current trends concerning procedures with packaging and packaging waste i.e. reduction of the quantity of the waste and increase of the level of packaging recycling.

The mentioned requirements will be referred to all types of packaging. The listed below assumptions are not the only ones which are assumed by the discussed amendment:

- Up to 2025 – all single-use packaging of fruits and vegetables and additional packaging for the products already packed-in shall be prohibited;
- Since 2030 – the quantity of packaging must be reduced by 5% and then, by the additional 1% in each successive year – target: by 15% in 2040

The aims of recycling:

- Up to 31.12.2025 – at least 65% of all packaging waste shall be subjected to recycling
- Up to 2030 – all packaging must be recyclable at least in 70%
- Up to 2040 – the packaging must contain at least 50 – 65% of recyclate.
- Up to 31.12.2025 – recycling shall include as follows: 50% of plastics, 25% of wood, 70% of iron metals, 50% of aluminium, 70% of glass, 75% of paper and cardboard.

Minimum content of recyclates in packaging since 01.01.2030:

- 30% of packaging intended to come into contact with sensitive products, made from PET as the main component
- 10% of packaging intended to come into contact with sensitive products, made from plastic materials different than PET, excluding single-use plastic bottles for beverages. The mentioned requirement will require the change e.g. in pharmaceutical law which, at present, does not allow for application of recyclates.
- 30% of single-use plastic bottles for drinks
- 35% of other packaging

## SUMMING UP

Based on the total work conducted in the European Union on the packaging we may recognize that the most important direction of the changes is a widely understood problem of waste management, not only of packaging waste. All other requirements and legal regulations will be subordinated to the mentioned target. We may expect further tightening and extension of the requirements in this respect for the producers, processors and users of the packaging.

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TOMASZ KRAWCZAK

# PACKAGING INDUSTRY FACING MARKET CHALLENGES

**On September, 26th 2023, at the eve of opening Taropak Fair, Polish Chamber of Packaging organized the 5th edition of Congress of Packaging Industry. The event took place at the territory of International Poznan Fair. The leading subject of the mentioned Congress was "Packaging industry facing the challenges of the market" and the aim of the lecturers was to show the packaging sector as the branch of industry which plays a service function in relation to other sectors of the market and ensures stability of the packed products, effectiveness for their producers, ease of use and safety for the users and all this, with the respect for the environment and recognition of sustainable development.**

Polish Chamber of Packaging as the organization integrating all persons, institutions and enterprises interested in packaging, attaches great importance to educational activity. One of its elements is to determine the directions in which packaging sector in Poland and in the world will be developing, and to share the conclusions with all stakeholders. The mentioned changes will affect, in the near future, not only on functioning of the total market, but also on the consumers, i.e. each of us. The programme of this year's meeting provided the speeches of experts dedicated to the trends in packaging industry development, the challenges which it will be coping with during tthe coming years and, also, to new products and technologies which allow the sector to adapt to the future market expectations. The lectures were grouped in three thematic blocs, dedicated to trends and directions of changes in packaging industry, problems of environment protection and sustainable development and modern packaging solutions.

## TRENDS AND DIRECTIONS OF CHANGES IN PACKAGING SECTOR

The first topic group, as moderated by **Dr Adam Koliński**, Eng, the Rector of Higher Logistics School in Poznań, was commenced by webinar lecture of Dr Johannes Bergmair, Secretary General of the World Packaging Organisation (WPO). The title of the lecture was *"Trends in packaging on constantly varying, global and European market"*. As the respectable guest said, "the trends cover the problems from designing in aspect of circular economy and sustainable development up to personalised packaging which may ensure the exceptional experiences. The subjects which are common for practically each place in the world (being currently discussed by packaging sector) include also the issues of ecology, building of mark, extension of the shelf-life of the products and safety of food and packaging in e-commerce". The lecturer paid attention to the merits of WPO in adaptation of sector companies to the present market requirements, cooperation with Save Food initiative in respect of extension of the shelf-life of packaged products, as well as promoting of modern solutions in the competition WorldStar Packaging Awards.

**Maciej Nałęcz**, sector analyst from Santander Bank Polska, focused his appearance on the problem of the position of Poland at the European map of the packaging market. From the statistical data, collected by the economists it is clearly followed that the packaging sector belongs to the key specialities of our

country and 8.5-% participation in the sector turnovers in the whole EU exceeds more than twice the mean value of the total Polish economy. Apart from many data, submitted by Maciej Nałecz during his presentation, the 2.3-% participation in Gross Domestic Product (in Polish: PKB) (or 0.7-% in terms of value added, produced by the sector) and a chance for obtaining the level of 180 billion PLN of the value sold by the packaging industry during the nearest decade show that Polish packaging sector, at the national and EU level (the 5th place in ranking of the EU producers) gets along very well. This situation exists in spite of the untypical of the EU disintegration (Polish packaging companies are by 60-70%, in average, smaller than their European competitor) which paradoxically does not negatively affect the scale of investments in automation and standardization of manufacturing processes. "On the example of Poland, Bulgaria and Portugal, it may be seen that the relatively low labour costs and considerable ‚outlays on investments make the 'prescription' for success at our market" – the lecturer emphasized.

*"Maintenance of high investment outlays will be crucial for keeping a quick rate of expansion of national packaging producers at the EU market and outside it. Due to this reason, the enterprises need the clearly defined regulation structure as well as time framework in which the key changes for the sector will occur"* – summed up the speaker. He paid also attention to the growing meaning of ecological awareness of the consumers as a factor, favourable for the changes in the consumption models and promotion of packaging companies capable of suggesting the new innovative and eco-friendly solutions.

**Konrad Nowakowski**, the President of the Polish Chamber of Packaging Recovery and Recycling delivered the lecture entitled: *"Legal changes in the area of environmental aspects of packaging. PPWR, GOZ, SUP (Packaging and Packaging Waste Regulation; Circular Economy; Single-Use Plastic Products, respectively) – revolution in thinking about the packaging". In his speech, he paid attention to the importance of the rules, regulating the principles of designing and recovery of the packaging for the sustainable development. "We should design a packaging in such a way that the basket to which it will be discarded after use is not the end but the transitory stage of their life cycle"* – he said. The packaging industry faces, at present, many legal changes: ban for introduction of certain types of packaging to the market, the duty to use recyclates for production of packaging, limitation of the application of single-use cups in gastronomy, duties of marking and building a quite new deposit system of collecting the waste packaging of drinks etc. *"The time will show whether the compostable packaging, that of multi-use and perhaps paper-based packaging will increase their share at the market at the cost of plastic packaging. We should be aware that without development of segregation of packaging waste and their recycling, it is not possible to meet the assumed requirements"* – Konrad Nowakowski stressed.

## ECO-FRIENDLINESS AND SUSTAINABLE DEVELOPMENT

The second group of lectures – moderated by **Prof. Dr hab. Halina Podsiadło**, Eng, was commenced from the lecture: *"Tsunami in the field of plastic packaging" – How can the Pact solutions support the companies in the light of the ongoing*

*challenges?*. It was delivered by **Dorota Żmudzińska** from Polish Plastics Pact (PPP). The lecturer focused the attention on the activity of the Pact from the perspective of planned legislation changes, first of all the implementation of the regulation concerning packaging and packaging waste (PPWR).

PPP is a part of the Plastic Pact global network, coordinated by Ellen MacArthur Foundation. It is the first such initiative in Central and Eastern Europe (and the 8th one in the world scale). All organisations are linked by a common vision of a new economy, where the plastics are all the time in a closed cycle. As it was stressed by Dorota Żmudzińska, *"the strategy of the Pact is focused on the most important three directions of activity: limitation of the application of plastics, innovations and closing the circulation of raw materials; it is expressed by six strategic targets, common for the members of initiative"*. The mentioned targets include: obligatory reduction of packaging waste via the duty of re-use or recycling, introduction of the binding deposit systems and, also, improvement of quality and effectiveness of education of the consumer in respect of segregation, recycling, re-use and limitation of packaging use. The discussed goals may be achieved owing to Roadmap of the Pact, i.e. set of the key effects and measures which would allow implementing the aims of PPP – said the lecturer in her speech. Pact invites the interested companies to cooperation in respect of the implementation of the changes, serving the sustainable development. *"Let's conquer the mountain together. The road is not easy but it is worth to follow it"* – the representative of the Pact emphasized.

The appearance of **Katarzyna Grabarska**, manager for packaging in Jeronimo Martins Polska SA, was a sort of specific supplementation of the lecture by **Dorota Grudzińska**. The mentioned lecture was dedicated to the subject: *"Packaging of the products sold in the Biedronka ("Ladybird") commercial network – the sustainable development and eco-friendly design"*. The lecturer presented the actual changes introduced in the field of packaging used by a popular chain of the discount shops within the frames of seven principles of designing the own brand. They include, inter alia: reduction of weight of packaging, elimination of packaging, using dyes of carbon origin, application of elements made from single-use materials, ensuring the possibility of ease separation of the components in the composite packaging, and, also, application of pictograms enabling segregation.

**Monika Sommer**, manager for the sustainable development in Tetra Pak company dedicated her speech to the problems of environmental challenges for the sector of packaging which is intended for liquid foods and to the innovative solutions in practice. When taking into consideration the fact of the increasing demand on the sustainable food packaging, as being helpful in mitigation of climate changes and solution of the problems with hunger, she told about the methods employed by Tetra Pak – the company being known for its cardboard packaging, destined for food products. She also tried to dispel the popular (but erroneous in her opinion) belief that the laminated substrates, linking the paper with plastics and aluminium were not sustainable and were not suitable for recycling. *"The technology of aseptic filling in combination with innovative packaging, including aseptic cartons for drinks, allows to preserve the safety and taste of food and drinks for 6-12 months without the necessity of using freezers and preservatives"* – she stressed.

Then, she told about the activities of the company in favour of recycling (inter alia, work on the fibre barrier, replacing aluminium, the increase of the content of recyclates in packaging and introduction of screw cap fixed permanently to packaging); she spoke about the support of the collection and recovery of the packaging produced by Tetra Pak; about investing of 120 million EURO in the recycling infrastructure and also, about building a very big line for recycling of 50 thousand cartons for liquid foods in Ostrołęka.

In the final part of the second session, the representatives of Air Products company, **Katarzyna Góra** and **Katarzyna Małecka** submitted the lecture dedicated to role of gases in packaging process. The technology of packaging at a modified atmosphere (Modified Atmosphere Packaging, MAP) becomes popular as the effective method for maintaining shelf life and quality of food products owing to the modification of the air content in the packages in which food is sold. The technology, employing such gases as carbon dioxide, nitrogen and oxygen, minimizes product losses, limits the need of using the artificial preservatives and ensures the new possibilities of distribution.

## MODERN PACKAGING MATERIALS AND PACKAGING TECHNOLOGIES

The last part of the Congress was conducted by **Prof. Dr hab. Ryszard Cierpiszewski**, Eng, the Head of the Department of the Quality of Industrial Products and Packaging at the Poznań University of Economics and Business. **Alicja Bednarek** from Digiprint company was the first lecturer and presented the *"Possibilities of digital printing which we still know little about, in the international production of packaging"*. At the beginning, she discussed the advantages of the application of digital printing in production of packaging and labels (lack of printing moulds, shorter preparation to printing, the possibility of profitable low-volume printing, personalisation, serialisation, printing on demand, and the profits for the natural environment) and then, she submitted the practical methods for application of the discussed technology, on the example of effective marketing campaigns all over the world, being implemented with the utilization of HP Indigo machines.

**Łukasz Chruśliński**, the manager for the European sales at Mark Andy presented a vision of development of RFID technology. In his speech, he showed the market situation and the problems encountered by the entrepreneurs in the sectors connected with the packaging and labels (*inter alia*, lack of the employees, too slow manufacture and logistics processes, growing needs of the customers and the need of ensuring the better protection and safety of the products); then, the lecturer explained why the technology of identifying the products with the use of radio waves (RFID) may be the effective tool for elimination of the problems. Machines produced by Mark Andy may be equipped with a special module which facilitates production of labels with RFID tag.

**Marek Motylewski**, senior technical at Mondi Group delivered the lecture entitled: "Hybrid papers as a sustainable future of corrugated board packaging". The lecturer discussed the degradation of natural environment by man, the disgraceful examples of which include climate changes (global warming up, rise of water level) and contamination (see: Great Pacific Waste Area); then, he presented the examples of hybrid paper packaging which, owing to the application of primary fibres and the secondary fibres, coming from recycling, the so-called Kraft Tops, may be recognized as the most sustainable product from the viewpoint of natural environment protection.

The last lecture was delivered by **Andrzej Kornacki**, regional sales manager at Futamura company. The title of his speech was: "How to reach 'zero waste' goal in 2030, in packaging produced from the flexible plastic materials". If we assume that the beginning of packaging is at the end of its life cycle, let's analyse how it might look like. We want that the packaging which will be not re-used, may be subjected to any available methods of recycling, so as in 2030 any of them is found at the landfill; it will allow us to reach our aim: zero waste" – he commenced his lecture. Then, he made a concise review of the available methods of recycling (mechanical, organic, thermal, chemical and raw material recycling), and their advantaged and drawbacks. Afterwards, he focused his attention on flexible plastics as the most problematic materials in respect of recovery as they usually are produced from the combination of polymers with different properties what makes their re-processing (re-granulation) impossible.

In the opinion of Andrzej Kornacki, the answer to this problem may be found in bioplastics which – under the unfavourable conditions – in contact with microorganisms, at the correct temperature and humidity – are subjected to biodegradation process during only few weeks. The lecturer paid also the attention to the necessity of differentiating between the biodegradable raw materials (which are subjected to degradation in natural conditions but are non-compostable due to the content of undesirable chemical substances) and compostable (chemically "pure" substances which may be simply dug-in in the ground of the home gardens). The appropriate management of plastic waste owing to mechanical recycling (re-granulation) or activation of organic recycling (composting) will allow us to implement the principles of circular economy and reach the target mentioned in the title: zero waste" – Andrzej Kornacki summed up his speech.

The 5th Congress of Packaging Industry was ended by handing over the occasional diplomas to the partnership companies, supporting this year's event and to the lecturers who shared their professional knowledge with the participants.

# LABELEXPO EUROPE 2023 SHOWCASES VIBRANT INDUSTRY

**The first edition of Labelexpo Europe since 2019 has closed on a high note, with a total of 637 exhibitors taking part in the show, which took place between 11-14 September at Brussels Expo in Belgium. Spread across nine halls and covering 36.588 sqm of floor place, this year's show featured over 250 product launches focused particularly on flexible packaging, digitization and automation.**

The unprecedented heatwave in Brussels did not deter 35.889 visitors from 138 countries attending the four-day show. Countries such as Germany, France and Italy were especially well represented, with large visitor delegations. Equipment manufacturers announced multiple sales across the four days and an exhibitor rebook rate of 96% was reported for Labelexpo Europe 2025.


Demonstrating how Labelexpo Europe is evolving into a package printing show, digital printing of paper-based flexible packaging materials was evident on the show floor, with paper-based packaging printed by Xeikon on the new TX-500 Titon toner press and SCREEN on the Truepress Pac520P – seen for the first time at a Labelexpo.

HP launched the 200k mid-web digital press, successor to the hugely successful HP Indigo 20000. The company also ran a 'digital pouch factory' ecosystem demonstrating pouch manufacture and finishing of other unsupported films including shrink sleeve labels.

Flexo made a major comeback at this show, with Nilpeter, Lombardi and BOBST demonstrating printing of flexible packaging and unsupported label film materials on 26in/670mm mid-web UV flexo press lines on the show floor. OMET made the show debut of its KFlex modular flexo platform and Mark Andy launched the Pro Series flexo press, upgradable to a hybrid machine.

## WHAT A SHOW IT HAS BEEN!

**Jade Grace, managing director, Labelexpo Global Series** said: *We've just delivered Labelexpo Europe 2023 after a four-year break*

*Jade Grace: It has been the hardest show yet for us to deliver, but the most rewarding. We are looking forward to the next chapter in 2025 where we will be bringing Labelexpo Europe to its new home at the Fira in Barcelona, with many plans to stimulate growth and collaboration in the industry*

*and what a show it has been! The feedback we have received from visitors and exhibitors alike has consistently shown the high quality of leads, enquiries and contacts made at the show, with an incredible number of sales secured on the exhibition floor. We have also secured a rebook rate of 96% for Labelexpo Europe 2025, which bodes well for our first show in Barcelona. It has been the hardest show yet for us to deliver, but the most rewarding. We are looking forward to the next chapter in 2025 where we will be bringing Labelexpo Europe to its new home at the Fira in Barcelona, with many plans to stimulate growth and collaboration in the industry.*

Echoing this sentiment, **Jules Lejeune, managing director, FINAT** said: *FINAT was once again proud to be the lead association partner of Labelexpo Europe this year. In spite of the heat at the beginning of the show, there was a vibrant mood and general state of pleasure especially among the overseas visitors to reconnect with the global label community after such a long absence. For us, Labelexpo is always an excellent opportunity to meet with members, potential members and other interested parties and to engage in conversations about our current and future programmes, and to recruit members and enlist volunteers for our working groups and taskforces. This year, we featured our efforts to facilitate value chain collaboration on sustainability such as CELAB-Europe, UV FoodSafe and Product Carbon Footprint, and to act as spokesperson of the label industry towards European legislators and stakeholders. We will miss the Atomium and the World Expo 1958 building as the background images for many selfies taken during the show, but we are convinced that the Fira and its Olympic Montjuich will be a worthy replacement in 2025.*

## PERFECT END TO THE BRUSSELS ERA

**Noam Zilbershtain, VP & general manager of HP Indigo & Scitex** said: *It's through trade shows like Labelexpo, industry leaders have the opportunity to connect, network and discuss the trends driving our industry, such as digital innovation and sustainability. I love being in the thick of it all connecting with our customers and partners. This year, we were thrilled to have the opportunity to showcase the leading LEPx-based HP Indigo V12 and HP Indigo 200K digital presses for the first time in Europe. This was also a key moment for us to showcase the HP Indigo First mindset and how it can deliver flexibility at speed for converters.*

**Robert Rae, managing director of sales, GEW** said: *It was fantastic to return to Labelexpo Europe for the first time since 2019. The exhibition was exceptional for GEW, with a record number of visitors to our stand, and a very healthy order book to show for it. We displayed our full product range but UV LED was top of the agenda for most of our visitors. Our air-cooled AeroLED UV curing system was the subject of particular interest, and our ability to demonstrate this technology in action, live on OEM presses at the show, meant that we could clearly demonstrate the huge energy and cost savings that printers can expect with a switch to UV LED.*


**AUTOMATION ARENA, LACATED IN THE HALL 11 FOCUSED ON A FULLY AUTOMATED WORKFLOW FROM FILE CREATION TO TURRET REWIND WITH AUTOMATED INSPECTION AND MIS INTEGRATION, WITHOUT ANY MANUAL INTERVENTION. THE PARTICIPANTS INCLUDED CERM, ESKO, XEIKON, KURZ, GRAFOTRONIC AND FEDRIGONI SELF-ADHESIVE**


*We measured and published our energy consumption live, and were able to repeatedly demonstrate a 77% saving when compared to conventional UV arc technology. To see Malcolm Rae, my father and GEW's founder, being honoured at the Label Industry Global Awards made it the perfect end to the Brussels era.*

Other major show features for Labelexpo Europe 2023 included the Automation Arena which drew in large crowds to every one of its ten live demonstrations. Visitors witnessed a fully automated workflow from file creation to turret rewind with automated inspection and MIS integration, without any manual intervention. The participants included CERM, Esko, Xeikon, KURZ, Grafotronic and Fedrigoni Self-Adhesive.

Another key show feature was the Flex Pack Trail, where visitors could deep dive into digital and conventional press technologies, flex pack material constructions, coating, laminating, ink and curing requirements, in-line and near-line decoration options, QC and migration testing.

**IN THE NINE HALLS, COVERING 36,588 SQM OF FLOOR PLACE THIS YEAR'S SHOW FEATURED 637 EXHIBITORS WITH OVER 250 PRODUCT LAUNCHES FOCUSED PARTICULARLY ON FLEXIBLE PACKAGING, DIGITIZATION AND AUTOMATION**

Also well received was Flexo's Future – ECG, a series of presentations on Expanded Color Gamut (ECG) printing led by Dr Kai Lankinen. This was supported by guided tours across the showfloor.

Two expert-led Label Academy-hosted master classes covered the hot topics of flexible packaging and sustainable labels.

## SEE YOU IN BARCELONA!

*I believe there will be more than one theme that will lead the next edition of Labelexpo Europe in 2025 including automation, diversification (the 'One-stop-shop') and sustainability being key focus areas for the labels and package printing industry in the years ahead* – concludes Jade Grace. – *Automation means not only automated setup, but also integration of the press and finishing equipment into the wider factory network.*

*Diversification means the ability to handle a wide range of unsupported materials including primary packaging formats alongside core pressure-sensitive materials.*

*Sustainability means label substrates are evolving rapidly to meet the growing number of legislative and brand mandates for the circular materials economy. As a result, diverting packaging from landfill and towards recovery and clean separation of materials, which then become feedstock for new labels and packaging products.*

**ZRÓWNOWAŻONY ROZWÓJ POWODUJE, ŻE PODŁOŻA ETYKIET W SZYBKIM TEMPIE EWOLUUJĄ, ABY SPROSTAĆ ROSNĄCEJ LICZBIE REGULACJI PRAWNYCH I WYMAGAŃ WŁAŚCICIELI MAREK W ZAKRESIE GOSPODARKI O OBIEGU ZAMKNIĘTYM**

# Packaging Review

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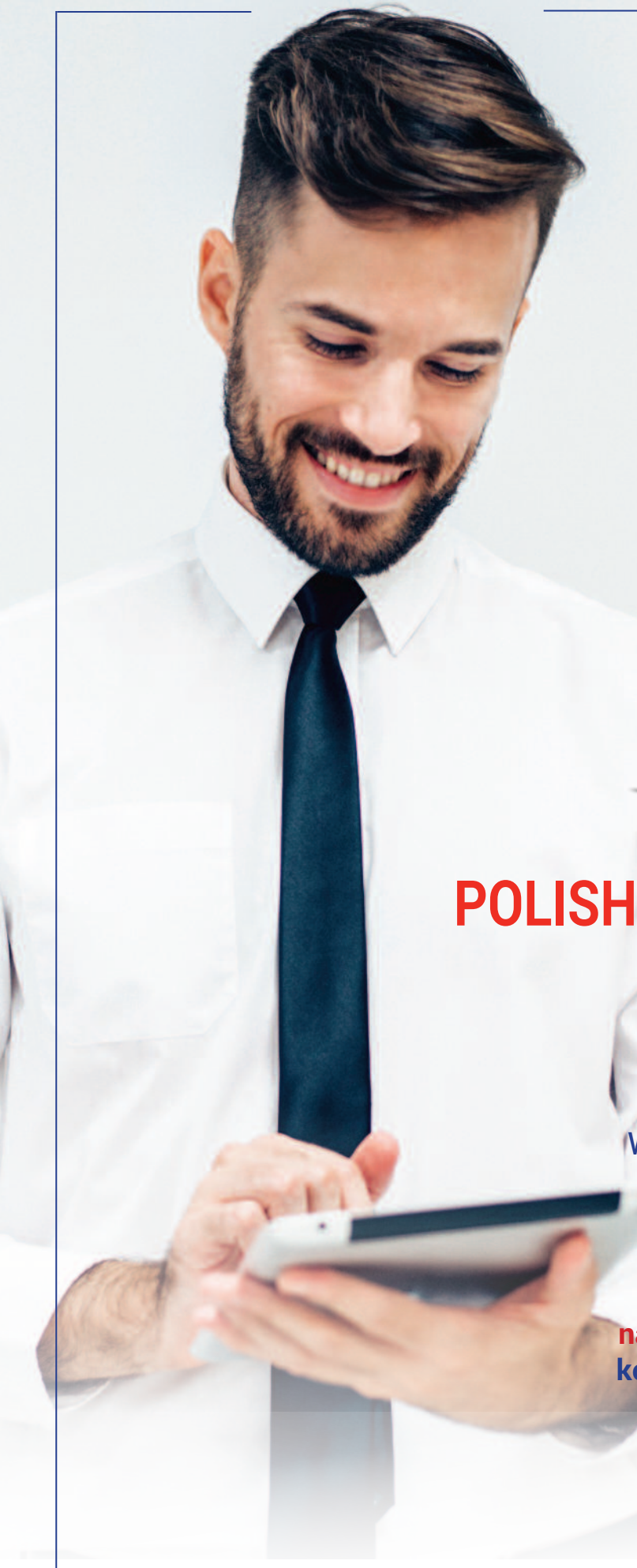


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