e-ISSN 2720-7226

Packaging Review

1/2023

OPEN ACCESS: WWW.PACKAGINGREVIEW.EU

SCIENTIFIC QUARTERLY JOURNAL
OF THE PACKAGING INDUSTRY

LIFECYCLE ASSESSMENT
OF BIODEGRADABLE POLYMERS

Packaging Review

PUBLISHER / WYDAWCA:
Alfa-Print Sp. z o.o.
Świętokrzyska 14A Str. / 00-050 Warsaw, Poland
Phone: +48 22 828 14 00 / contact@packagingreview.eu
www.packagingreview.eu

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ADVERTISING AND MARKETING /
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DESKTOP PUBLISHING / SKŁAD I ŁAMANIE:
Alfa-Print Sp. z o.o. / Świętokrzyska 14A Str.
00-050 Warsaw, Poland / Phone: +48 22 828 14 00

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Dear Readers!

„Future and challenges of packaging market" - such was the title of the first scientific conference of the Research Network Łukasiewicz – Łódź Institute of Technology, which was held on March 16, 2023 in Warsaw. The organizer of the mentioned conference was Warsaw Department of the Network – COBRO; it was attended by ca. 80 participants.
Sector of packaging in Poland is worth 60 billion PLN what makes it significant from the viewpoint of industry. During the pandemic, it proved at the international forum that it was able to reach growth and construct competitive advantages in the most difficult conditions. It should be stressed that Poland is the European Union leader of export of packaging made from wood. It is also satisfying that we occupy the third place on the podium after Germany and the Netherlands in the field of packaging, based upon paper. As far as glass and metals is concerned, we occupy the 6^{th} – 7^{th} position. It is evidence that the discussed sector can answer correctly to the current challenges of the market but it is faced with the successive problems in this respect. The aim of the conference was to define the mentioned problems.
I invite to reading!

Stefan Jakucewicz, D.Sc, Ph.D, Prof. emeritus Warsaw University of Technology. A graduate of Łódź University of Technology in the field of cellulose and paper technology, as well as Warsaw University of Technology in the field of printing. From 1974 he was a researcher at TU Warsaw. Since September 2018 he has been a pensioner. The editor of the sections in the periodicals: Opakowania (Packaging) and Przegląd Papierniczy (Paper Review). Research interests: printing materials science, paper technology and printing techniques of various substrates, with particular emphasis on plastics and the production of printed packaging, production of banknotes and postage stamps (security prints), certification of new base materials for both classic and digital printing techniques. Author or co-author of over 300 scientific articles published in Ukrainian, Slovak and German national journals, and 70 scientific and scientific-technical books published in Polish, German, Slovak and Ukrainian.

Drodzy Czytelnicy!

„Przyszłość i wyzwania rynku opakowań" - pod takim tytułem odbyła się w Warszawie 16 marca b.r. pierwsza naukowa konferencja Sieci Badawczej Łukasiewicz – Łódzkiego Instytutu Technologicznego. Jej organizatorem był warszawski oddział Sieci – COBRO, a uczestniczyło w niej ok. 80 osób.
Branża opakowań w Polsce jest warta 60 miliardów złotych, co czyni ją istotną z punktu widzenia przemysłu. W czasie pandemii udowodniła na arenie międzynarodowej, że potrafi osiągać wzrosty i budować przewagę konkurencyjną w najtrudniejszych warunkach. Warto podkreślić, że w Unii Europejskiej Polska jest liderem eksportu opakowań drewnianych. Cieszy również fakt, że zajmujemy miejsce na podium – za Niemcami i Niderlandami – także w zakresie opakowań na bazie papieru. Jeśli chodzi o szkło i metale, zajmujemy 6-7. pozycję. Świadczy to o tym, że dobrze odpowiada na aktualne wyzwania rynku, ale przed nią jako branżą kolejne, które wspomniana konferencja starała się zdefiniować.
Zapraszam do lektury!

Dr hab. inż. Stefan Jakucewicz, em. prof. PW. Absolwent Politechniki Łódzkiej w zakresie technologii celulozy i papieru oraz Politechniki Warszawskiej w zakresie poligrafii. Od 1974 roku pracownik naukowo-dydaktyczny Politechniki Warszawskiej, od września 2018 emeryt. Redaktor działowy w czasopismach „Opakowanie" i „Przegląd Papierniczy". Zainteresowania naukowe: materiałoznawstwo poligraficzne, technologia papieru oraz techniki drukowania różnych podłoży ze szczególnym uwzględnieniem tworzyw sztucznych i produkcji opakowań drukowanych, produkcji banknotów oraz znaczków pocztowych (druki zabezpieczone), atestacja nowych materiałów podłożowych przeznaczonych tak do klasycznych, jak i cyfrowych technik drukowania. Autor lub współautor ponad 300 artykułów naukowych opublikowanych w czasopismach krajowych, ukraińskich, słowackich i niemieckich oraz 70 książek naukowych i naukowo- technicznych wydanych w językach polskim, niemieckim, słowackim i ukraińskim.

Packaging Review

Issue **1/2023** includes:

REVIEWED ARTICLES <<

INDUSTRY EVENTS <<

REVIEWED ARTICLE

DOI: 10.15199/42.2023.1.1

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ACTIVE AND INTELLIGENT FOOD PACKAGING REVIEW PAPER, PART 2

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

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

Active packaging is also defined as interactive packaging, i.e. such packaging in which the product, package and the surrounding are mutually affecting each other. Their properties are oriented to the product and its highest quality and, also, extension of its stability and the expiration date. Contrary to the traditional packaging of the products, they are able to control and monitor the occurring changes as well as to react directly to the mentioned changes [21, 25, 30].

The main task of active packaging is to change the conditions inside of them in order to preserve the quality of the packed product. The introduction of the active packaging systems is supported by the possibility of prolonging the stability period and expiration date of foodstuffs and a potential limitation of the application of additives, including, inter alia, preservatives. We may distinguish two basic types of the active packaging: ones absorbing the undesired substances and the other ones which emit favourable substances. The basic absorbents include oxygen, ethylene and carbon dioxide absorbents and those ones which absorb water excess. The most frequently emitted substances are: carbon dioxide, water, antioxidants and preservatives. The mentioned substances constitute usually the built-in part of packaging material or are found inside the packaging in a form of sachets, stickers or labels [1, 6, 7].

New generation packaging which includes active packaging has the influence on the packaged product, changes the conditions of the packaged foodstuff and, simultaneously, it

controls the quality of the product. The condition which decides on the possibility of classifying a packaging as the active one consists in covering the packaging materials with the coating, containing active substances, or introducing the active substances directly to the polymer matrix. The discussed substances should have a bactericidal or bacteriostatic effect on bacteria, yeasts or fungi, responsible for food poisoning [27]. Active packaging occur usually in a form of small additives or sachets, containing powdered iron and calcium hydroxide, placed in the packaging or in a form of active constituents, added directly to the packaging, e.g. to packaging films [12].
Apart from the protection of the product, active packaging plays the additional protective functions against external conditions. Their main functioning principle is cooperation with the packaged product. Interaction; product – packaging is very important and extends the storage period or improves sensory properties of the product. There are two methods of introducing the active substances into the discussed types of packaging – they are placed in small bags in the packaging or they are directly introduced to the packaging material [6, 33, 36, 41].
The active packaging has been created in order to prolong the shelf life of food products and to extend the period of a high quality of the products. The technologies employed in the active packaging contain physical, chemical or biological agents which change the run of interactions between the packaging and the product, with the aim to monitor the condition of their state in which they are found. The most popular active components include absorbers and emitters, being found inside the packaging or being built-in directly in the packaging [8].

The activity of the packaging consists in the following:

- inclusion of chemical or enzymatic substances to the packaging or to the packaging material; the mentioned substances are aimed at adsorption and/or removal of oxygen from the atmosphere inside the packaging;
- application of carbon dioxide-producing or absorbing substances in the packaging;
- control of ethylene content in the packaging by the utilization of adsorption, using oxidizing agent or organometallic compound;
- introduction of ethanol-emitting substance in a volatile form to the inside of the packaging as a factor, inhibiting microflora development;
- application of preservatives, bactericidal substances or antioxidants, secreted from the packaging material;
- use of humidity regulators;
- application of the technology, enabling control of smell and taste (flavour);
- introduction of light absorbents to the packaging;
- application of foils, emitting mineral substance, protecting the colour of the product;
- improvement of the film surface in order to change its permeability (“smart foils” and “intelligent foils”) [1, 3, 6, 9].

In food industry, the following systems of active packaging have been employed:

- oxygen, carbon dioxide and ethylene absorbents;
- carbon dioxide emitters;
- smell emitters and absorbents;
- regulators of relative humidity (water content of packaging atmosphere);
- substances with the antibacterial effect; and
- antioxidants [3].

Active packaging enables modification of the composition of environment inside the packaging due to limitation of the concentration of CO_2, fragrances and ethylene, i.e. absorption of the mentioned compounds. Another task of the discussed packaging consists in the emission of the inhibitors of microbial growth (ethanol, nisin, CO_2, lysozyme, SO_2, sorbic and benzoic acids and their salts) to the foods inside the packaging [4, 6, 8, 36]. The above mentioned properties of packaging have the influence on the longer storage of the product inside the given packaging [33, 39]. Such packaging cannot, however, mislead the consumer by adulteration of the food. We should also pay attention to the fact that owing to the active packaging it is possible to prepare more quickly a meal in microwave kitchen [31].
The example of innovative solutions in the field of active packaging may be the Ageless absorbers which may have

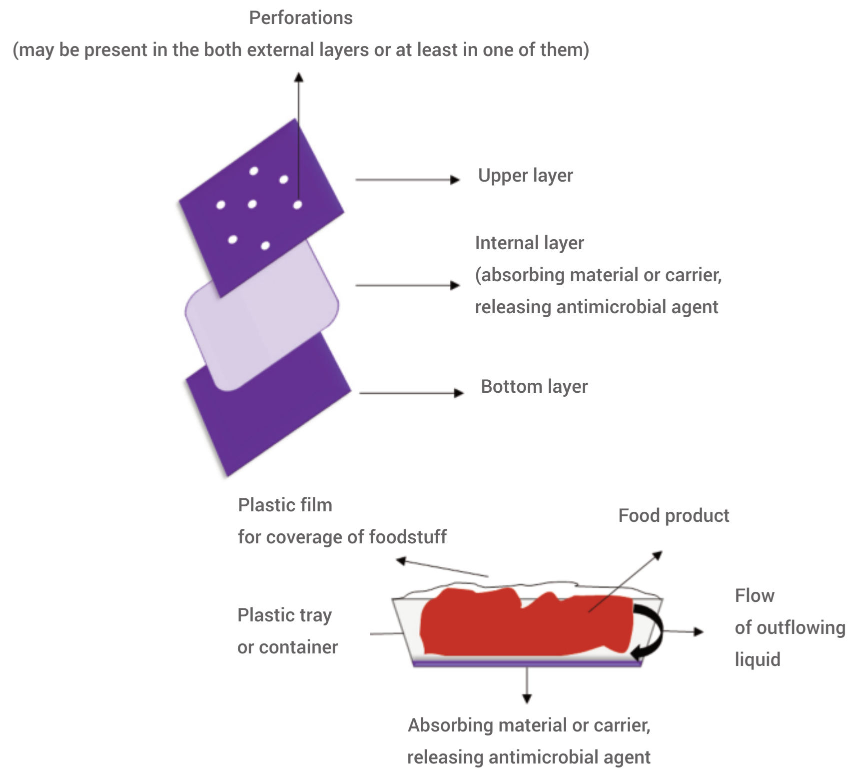

FIG.2. OUTLAY OF CONSTRUCTION AND APPLICATION OF ABSORBING MATERIAL (CARRIER, RELEASING ANTIMICROBIAL AGENT) [30]

different forms. They may include stickers, sachets or labels which are place in the packaging ot of the packaging seal. They are mainly employed in relation to foodstuffs. The discussed system is aimed at preventing the process during which the oxidation of fats occurs.

Technologies employed in active packaging are based upon the utilization of physical, chemical or biological factors, changing the run of interactions between the packaging and product with the aim to monitor the state in which they are found.

The most popular active components include absorbents and emitters being found inside the packaging or being directly built-in in the packaging [8].

The selected types of active packaging and their functions in food chain are given below:

- oxygen absorbers – they occur in a form of sachets, labels, films, bottle closure; they cause inhibition of product decomposition and vitamin degradation
- ethylene absorbers – they appear on a form of sachets and films; they cause prolongation of products freshness and regulation of fruit and vegetable ripening
- relative humidity regulators – they are found in a form of sachets and films; they cause maintenance of high sensory qualities of the product
- antibacterial agents – they occur as sachets and films; they cause inhibition of microbial growth
- antioxidants – they are found in a form of sachets and films, they cause inhibition of oxidation processes [8, 35].

OXYGEN ABSORBERS

The undesired oxygen presence in atmosphere of packaging may be a result of insufficient removal of oxygen during the packaging process and, also, its presence in food, or penetration of oxygen via the packaging, or introduction of the air as a result of insufficient sealing of the closure; it may be also a result of micro-perforation of packaging material [20, 28].

High oxygen content causes lowering of nutritive value of food and abbreviation of its shelf-life. It also accelerates the processes of degradation of many food products, inter alia, of meat, butcher's products, seasonings; it causes degradation of vitamins and rancidity of oils and/or solid fats (butter, lard), nuts and fat products and also, is favourable for bacterial growth [17, 29, 35, 42, 48].

To monitor and control actively the oxygen residues, the absorbers are employed; their presence allows reduction of oxygen content even to 0.01%. The oxygen absorbers in the food chain cannot contain any toxic substances or emit the undesired aromas or gases. Their compactness is also important in aspect of minimizing the use of space in the packaging.

At present, the discussed type of packaging utilizes, inter alia, sachets, liners and, also, absorption films. They are produced from the components with a low molecular weight, covered with polymers, indirectly built-in in the packaging by the method of injection moulding (injection-moulded polymers). Before their use, the discussed components cannot have any contact with the oxygen and they are stored in hermetically sealed packages or require activation by the participation of water, effect of light etc. [6, 7, 17, 18].

ANTIBACTERIAL PACKAGING

Antibacterial packaging is one of the types of active packaging [25, 30]. Its function is to inhibit the growth of pathogenic microorganisms, contaminating food, by the addition of a component or use of polymer with the antimicrobial properties. The antimicrobial components are as follows: organic acids, bacteriocins, enzymes, vegetal essential oils. The main antimicrobial constituents of the discussed packaging are benzoic acid, sorbic acid and their salts, nisin, lysozyme, essential oils and others. The mentioned components differ from each other by mechanism of action; they affect the cellular wall or metabolism or genotype of microorganisms; they inhibit the growth of microorganisms via modification of the conditions of the environment. They contain antibacterial components which are released to the environment of the packaging or directly on the product, or they contain immobilised substances with the antibacterial effect. When properly built-in to the matrix of packaging, they prevent of limit the development of many microorganisms, e.g. *Listeria monocytogenes*, *Salmonella typhimurium*, *Staphylococcus aureus*, and of moulds: *Penicillium, Aspergillus niger*. The effectiveness of antibacterial packaging is dependent on the choice of antimicrobial components to the packaging matrix and the type of foodstuff to be packed. Thus, it is possible to counteract the growth of undesired microflora on the surface of the product, or control the mentioned growth [25, 34, 35, 44].

In the packaging sector, there are frequently utilized such active compounds as bactericides, limiting the growth of Gram-positive bacteria, extracts of seasonings, essential oils, enzymes and organic acids which inhibit the growth of Gram-positive bacteria, Gram-negative bacteria and moulds. The mentioned substances should be effective in limiting or complete inhibition of bacterial growth but they must be safe for humans and environment-friendly [27, 49, 51].

Mizielińska et al. [27] studied the antibacterial properties of coated packaging film, obtained in industrial trials. Vegetal extracts, as obtained in laboratory experiments, were added to nitrocellulose varnish. Laminate of PE/PET film was coated with cover-creating carrier with the extract under the industrial conditions. As a result of the conducted experiments, the authors confirmed that the coating of nitro-cellulose varnish, containing extract of buckwheat husks, green tea, coconut and paprika waste reduced, to a certain degree, the number of Gram-negative and Gram-positive cells. The best results were obtained for coatings with the extract of coconut waste and of paprika waste; they reduced the number of *S. aureus* and *E. coli* cells only by 1 log order. Unfortunately, the obtained coatings did not limit the growth of *B. cinerea* cells.

CONSUMER VS. ACTIVE AND INTELLIGENT PACKAGING AT THE MARKET OF FOOD PRODUCTS

Packaging is one of the more important attributes of the product, affecting the purchase preferences of the consumers. The knowledge of the consumers' attitude towards the new generation of the packaging is a valuable source of information for the producers during development of marketing strategies, connected with the design and introduction of new products to the market [3].

Packaging is also one of the criteria for the choice of the food product, connected with its functional properties [10, 16, 20, 23]. Due to the increasing interest of the clients in the consumption of the fresh products with the prolonged shelf-life and controlled quality, the producers must ensure modern and safe packaging. It is a challenge to the sector of food packaging; it functions also as a driving force on development of new and improved technological conceptions of packaging [46, 49, 51]. The producers of packaging are looking for the new solutions which enable improvement of the properties of packaging materials such as appropriate barrier properties in relation to gases, protection from UV irradiation, prolongation of shelf-life (storage period), transparency and ecology-friendliness [3, 4, 29, 37, 40].

The expectations of the consumers as well as the producers in relation to the innovative packaging at the food market refer to the following packaging properties:

– new construction, shape and graphic form,
– possessing the function of product protecting;
– active,
– functional,
– with the improved barriers properties,
– environment-friendly (bio-renewable raw materials and bio-degradable materials) [2].

From the conducted survey studies concerning the application of innovative packaging of food products [3] it is followed that the respondents indicated the following products for which this type of packaging would be most suitable, i.e. first of all, meat, butcher's products, milk products and frozen foodstuffs. The mentioned groups of the products are mostly endangered with the lowering of their quality. The aim was also to ensure the safety of the discussed products during the transport and storage from the farmer's field to the consumer's table. At the same time, more than 50% of the respondents stated that they were not willing to pay more for the products in the active and intelligent packaging.

The studies of Pałkowska and Stenka [31] on the evaluation of perception of active and intelligent packaging by the consumers showed that a small group of the society possessed the knowledge and awareness relating to the mentioned above packaging. In connection with this fact, it is difficult to state whether the food purchased by the discussed respondents was found in the mentioned above packaging. Only small group of the examined persons was able to indicate the sectors where the application of active and intelligent packaging was possible. It concerned mainly food sector, pharmaceutical sector and cosmetic industry.

SUMMING UP

Nowadays, the food packaging is changing very dynamically. The packaging becomes more and more functional and innovative; in their manufacture, active substances affecting the packaged product as well as biodegradable raw materials are employed. Due to the interactions of the packed products and the packaging, the quality of packaging plays a key role in preservation of the product's safety and consumer's health. In connection with it, we should remember about the principles of Good Manufacturing Practice (GMP) on relation to the materials and products intended for the contact with food and observing other legal regulations the aim of which is to limit a health risk.

The rising newer and newer generations of active and intelligent packaging are the future of food packaging industry. The changes in the consumer preferences have led to innovations and development of new packaging technologies. A big advantage resulting from the implementation of active and intelligent packaging in the food industry consists in the prolongation of the period of food shelf-life, ensuring its safety, better control of the storage conditions and, also, better perception of a given mark by the consumers.

At present, the costs connected with the introduction of active or intelligent packaging to the food industry for common use are high. We hope that together with the development of the studies and popularization of the discussed currently innovative solutions, the costs could be lowered.

The research and development in the field of active and intelligent materials are very dynamic and are developing in combination with the searches for the environment-friendly solutions. The cooperation between the research centres and industry may be a very significant element to reach the success. It may ensure the advantage of active and intelligent packaging in comparison to traditional packaging which is nowadays employed in packaging of food products.

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DOI: 10.15199/42.2023.1.2

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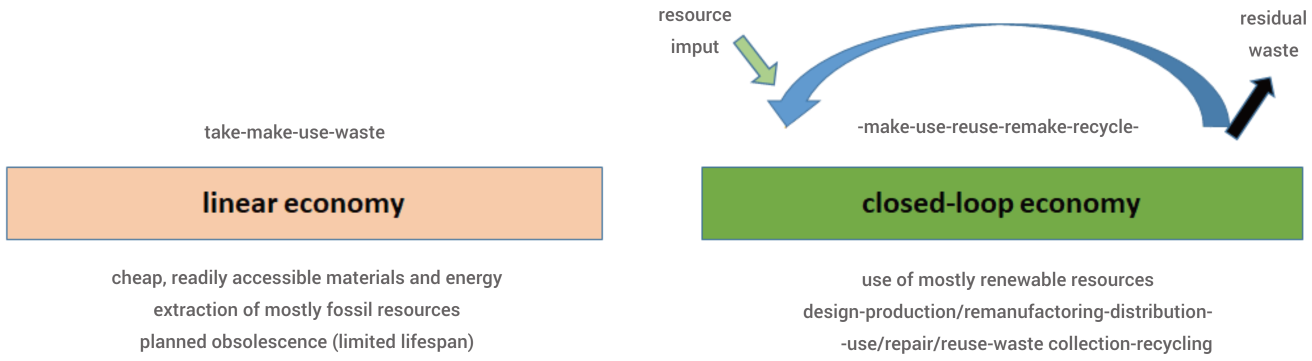
LIFE CYCLE ASSESSMENT OF (BIO)DEGRADABLE POLYMERS AS A TOOL TO ACHIEVE THE GOALS OF THE CIRCULAR ECONOMY

ABSTRACT: Closed-loop economy initiatives in Europe are still at an early stage. Progress in its implementation in industrial sectors, however, requires clarifying the concept from the perspective of balancing aspects covering environmental, economic and social issues, which may support the transformation process. Green polymer materials made from (bio)degradable, renewable, or recycled raw materials can help prevent and partially reduce waste and contribute to more sustainable life cycles. Furthermore, such materials could have a lower carbon footprint and, in some cases, may exhibit more favourable material properties in many applications. The article is an attempt to show that a systematic, standardised approach to quantifying the potential impacts of a product or process that takes from resource extraction to the end of a product life, such as life cycle assessment, can be an effective methodology for implementing sustainability in the circular economy.
Key words: green polymer, (bio)daegradable polymer, life cycle assessment, circular economy

STRESZCZENIE: Inicjatywy dotyczące gospodarki o obiegu zamkniętym w Europie są wciąż na wczesnym etapie. Postęp w jej wdrażaniu w sektorach przemysłowych wymaga jednak wyjaśnienia tej koncepcji z perspektywy równoważenia aspektów obejmujących kwestie środowiskowe, ekonomiczne i społeczne, co może wspomóc proces transformacji. „Zielone" materiały polimerowe pochodzące z surowców (bio)degradowalnych, odnawialnych lub pochodzących z recyklingu mogą pomóc w zapobieganiu powstawania odpadów i częściowemu ich ograniczeniu oraz przyczynić się do bardziej zrównoważonych cykli życia. Ponadto takie materiały mogą mieć mniejszy ślad węglowy i w niektórych przypadkach mogą wykazywać korzystniejsze właściwości w wielu zastosowaniach. Celem artykuł jest wykazanie, że systematyczne, ustandaryzowane podejście do kwantyfikacji potencjalnych wpływów tych procesów począwszy od pozyskania surowców do utylizacji produktu, takie jak ocena cyklu życia, może być skuteczną metodologią wdrażania zrównoważonego rozwoju w gospodarce o obiegu zamkniętym.
Słowa kluczowe: zielony polimer, polimer (bio)daegradowalny, ocena cyklu życia, gospodarka o obiegu zamkniętym

INTRODUCTION

The European Union (EU), producing more than 2.5 billion tonnes of waste a year, has forced the European Parliament to take appropriate legal action and update waste management regulations as well as promote the transition to a more sustainable model known as the circular economy [1]. Circular economy "is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible" [2]. This means use of raw materials more efficiently, reducing



PIC. 1. LINEAR ECONOMY VS CIRCULAR ECONOMY MODEL

waste to a minimum, and extending the life cycle of products through repeated use (repair, reuse, recycling) (see Pic. 1).

The principles of the circular economy are based on minimising waste and pollution, streamlining the circulation of products and materials in effect resource efficiency (countries depend on raw materials, the world's population is growing, and the supply of key raw materials is limited), and regeneration of nature, including primarily reducing emissions of greenhouse gases, and contributing to the preservation of biodiversity (extracting and use of raw materials destroys environment and increases energy consumption and carbon dioxide (CO_2) emissions). In the long run, waste prevention, eco-design and reuse can save businesses and consumers money. Environmental pressures will be reduced, security of supply of raw materials will increase, and competitiveness and innovation of companies and products will rise, resulting in economic growth. Thus, a circular economy can support the goals of reducing overconsumption of natural resources while providing economic benefits [2,3].

However, circular economy concept applied to real business cases it is still at an initial stage. Closed-loop business models require industrial implementation that faces more barriers than enablers. Circular economy is a management model and a systemic way of thinking. It is a more complex issue, supporting systems thinking as an integral part of the circular economy concept [4,5]. Despite various policy instruments to accelerate the transition from a linear to a circular economy, there are gaps in supply chains transparency, weak enforcement of EU waste legislation, limited use of closed-loop criteria in public tenders, and lack of standards and inconsistency in requirements across policy areas. There is also a lack of label of closed-loop products, knowledge-sharing platforms, business partnerships, financial incentives, awareness-raising campaigns and, above all, monitoring of progress towards circularity and investment in upscaling promising innovations [6,7].

It is optimistic that European companies are increasingly adopting closed-loop business models, however, focused mainly on operational efficiency and waste reduction (recycling, energy recovery and waste management), and there is a shift from product-based to service-based business models, but corporate culture, market factors and system complexity seem to be obstacles to this. Nevertheless, co-design, production, consumption, and reuse as part of the product life cycle are still poorly implemented [7].

Clarifying the concept of the circular economy from the perspective of balancing environmental, economic and social aspects and highlighting the knowledge gaps and aspects of the framing, implementation and evaluation of circular economy policies, as well as the importance of product-related aspects such as eco-design, incentives for innovation, business models, production and consumption trends are key to the success of the transition, and economic, technical, quality, sustainable and management tools should support the transformation process [8,9].

PLACE OF (BIO)DEGRADABLE POLYMERS IN THE CIRCULAR ECONOMY

Green polymers, i.e. polymers in line with the concept of sustainable chemistry, fit perfectly into a closed-loop economy. Products and processes that reduce or eliminate the use or production of substances that are hazardous to humans, animals, plants, and the environment are in line with the concepts of pollution prevention and zero waste on both laboratory and industrial scales. Green chemistry encourages the use of economical and environmentally friendly techniques that not only improve efficiency, but also reduce waste disposal costs at the end of a chemical process. However, green polymers do not necessarily mean environmentally friendly or bio-based polymers [10]. Environmentally friendly, degradable, or biodegradable polymers are aimed at providing materials with specific, time-limited applications in various sectors, especially in packaging and medical. However, more and more research is being done on long-term applications such as cosmetics packaging [11,12]. Differences in the terminology of environmentally friendly polymers are sometimes minor, but important as they indicate their properties and define their suitability and applications. According to the International Union of Pure and Applied Chemistry (IUPAC) terminology [10], degradable polymers are defined as "polymers in which macromolecules are able to undergo chain scissions, resulting in a decrease of molar mass." Biodegradation is "caused by enzymatic process resulting from the action of cells", but in vivo degradation resulting "only from hydrolysis by the water present in tissues and organs" must be referred to as hydrolytic degradation, while degradation taking place by isolated enzymes, an in vitro abiotic process, is "degradation caused by the catalytic action of enzymes" and is not considered biodegradation. The prefix "bio" gives words a strictly defined meaning (biomaterials, biopolymers, bioplastics, bio-based polymers, biodegradation). Biomaterials are "materials exploited in contact with living tissues, organisms, or microorganisms"; such as bio-based materials "composed or derived in whole or in part of biological products issued from the biomass" (plants) does not mean biodegradable materials, although they may be. Bio-based polymers have the same characteristics as regular polymers and may have the extra benefit of having a lower carbon imprint on the environment. What is bio-based is not necessarily biodegradable, and conversely not all biodegradable polymers are bio-based.

Biopolymers and bioplastics also differ significantly. Biopolymers are macromolecules formed by living organisms (including proteins, nucleic acids, and polysaccharides). They always undergo microbial degradation as they are created by nature, although they are not necessarily compostable. Talking about biopolymers, we limit ourselves only to natural polymers [13]. According to European Bioplastics, a plastic material is defined as a bioplastic if it is either bio-based, biodegradable, or features both properties [14]. According to the American Society for Testing and Measurement (ASTM) compostable plastics are defines as "capable of undergoing biological decomposition in a compost site as part of an available program, such that the plastic is not visually distinguishable and breaks down to CO_2, water, inorganic compounds, and biomass, at a rate consistent with known compostable materials (e.g. cellulose), and leaves no toxic residue" [15]. In individual countries, the conditions for both composting and biodegradation are covered by specific regulations (defining technological conditions in the form of technical standards) [16].

(Bio)degradable polymers made from renewable or recycled raw materials can help prevent and partially reduce waste and contribute to more sustainable life cycles. To produce such polymers materials with lower carbon imprint is used, and the end product can be reused (to a lesser extent, e.g. (bio)degradable polymer technological waste can be reused as an additive to make a new product) or recycled mainly organically (turned into compost or biogas). (Bio)degradable plastics could be a viable solution to decrease the impact on climate change and may, in some cases, exhibit favourable materials properties especially in medical applications. The use of (bio)degradable polymers also has some drawbacks, such as negative effects on agriculture – competition with food production, higher costs, and still unclear regulation for the end-of-life management of such polymers. There is also a lack of financial incentives and efforts to move from niche polymers (current production does not exceed 0.5% of the total plastics production) to larger-scale market applications, which would lead to a real sustainable impact [17,18].

Not all conventional polymers should be replaced by (bio)degradable polymers, but there are several key products and applications that can enhance the benefits and contribution of (bio)degradable plastics to the closed-loop economy such as compostable plastic bags for bio-waste, fruit and vegetable, lightweight shopping bags, coffee capsules and tea bags, cosmetic packaging, compostable fruit labels, thin film applications for fruits and vegetables packaging, dog poop bags, or agricultural mulch films. Compostable bio-waste bags for the selective collection of organic waste (other compostable bags can also be used for this purpose) reduce the rate of misthrow of conventional plastics in the organic waste stream. Organic contents (coffee or tea, cosmetics or oils leftovers, and poop) or fruits and vegetables, and their packaging (capsules, bags, bottles or jars, and thin films) or labels made of fully compostable plastics are not an obstacle to composting together [19]. Therefore, biodegradable polymers should be used mainly in agriculture, medicine, pharmaceutical sciences, and packaging [11,12,20].

Bio-based and (bio)degradable polymers are erroneously confused with each other as eco-friendly materials, while the concept of their use differs significantly. (Bio)degradable polymers have been developed from the viewpoint of biodegradability in order to reduce plastics wastes, whereas, for bio-based polymers, biomass is used just as the raw material for production. Nowadays, polymers are usually classified into four main groups given their biodegradability and raw materials origin [21,22]:

- non-biodegradable fossil-based polymers, e.g., polyethylene (PE), polypropylene (PP), polystyrene (PS), poly(ethylene terephthalate) (PET), or poly(vinyl chloride) (PVC);
- bio-based or partially bio-based non-biodegradable polymers, e.g., bio-based PE (bio-PE), PP (bio-PP), or PET (bio-PET);
- polymers that are both (bio)degradable and bio-based, e.g., poly(lactic acid) (PLA), polyhydroxyalkanoates (PHA) such as polyhydroxybutyrate (PHB) and poly(hydroxy-butyrate-*co*-hydroxyvalerate (PHBV);
- polymers that are based on fossil resources and are (bio)degradable, e.g., polycaprolactones (PCL), poly(butylene succinate) (PBS), poly(butylene adipate-*co*-terephthalate) (PBAT), or poly(vinyl alcohol) (PVA).

The most common fossil-based polymers i.e., polyolefins (PE, PP, etc.), PET, polyamides (PA6, PA66 etc.), have undoubtedly contributed to the development of human society. However, due to their non-biodegradability all fossil-based polymers are usually considered non-biodegradable. Whereas a lot of oil-based polymers are confused as non-biodegradable i.e., PCL, PBS, PBAT etc. are in fact biodegradable. It is because these polymers possess ester bonds in chemical structure, which are easily degraded in the appropriate environment or by some enzymes secreted by microorganisms. On the other hand, bio-based polymers are usually thought to be biodegradable. However, 100% bio-PE is not biodegradable, although is synthesised from bioethanol, which is produced as a fermentation of glucose process. As well as, non-biodegradable bio-PET is produced from biomass with the use of bio-based ethylene glycol (biomass content in bio-PET is approx. 30%) [23]. Therefore, polymers do not have to be necessarily also (bio)degradable, since the (bio)degradability feature of polymers depends on their chemical structure, not the carbon source.

LIFE CYCLE ASSESSMENT

Life cycle assessment (LCA) is a systematic, standardised approach to quantifying the potential environmental impacts of a product or process (ecosystems, human health and resources used) that occur from resource extraction to end of life (cradle-to-grave) and can be an effective methodology for implementing sustainability in the circular economy (cradle-to-cradle).

Due to its quantitative approach, LCA accounts for all the material, energy, emissions, and waste flows characterising the system under investigation. It calculates the potential environmental impacts associated with all the life cycle phases.

The methodology is defined and regulated by the ISO 14040 and 14044 standards [24,25]. The analysis shall be performed following the principles of the four main steps:

1. Goal and scope definition;
2. Life cycle inventory (LCI);
3. Life cycle impact assessment (LCIA);
4. Interpretation of results and improvement of the analysis.

In the first phase, the study goal and objective are defined, specifying the methodological framework and the primary approach of the study, defining several key aspects, such as the system boundaries and the reference unit. The LCI step lists and quantifies all the inputs and outputs flow, gathering process data and information of all the considered life cycle phases. The LCIA step quantifies and accounts for the environmental impact generated by all the life cycle phases, starting from the process data gathered in the LCI step and applying several impact assessment models to calculate the potential burdens of the system on different environmental categories and indicators. Finally, in the interpretation and improvement step, recommendations and conclusion are outlined, the main critical points (i.e., environmental hotspot) are identified, and suggestions on how to improve the LCA analysis and, at the very end, the environmental impact of the whole system are provided.

MEASURING CIRCULARITY WITH LCA

There are many different methodologies and metrics that can be employed to measure circularity [26]. The recent ISO Technical Committee (TC232) has been established with the intent to propose a common strategy for measuring circularity. The aim of the technical committee is to develop new guidelines to implement and assess circular economy strategies [27]. Although it is not yet clear how LCA-based methodologies can be a consistent support for evaluating sustainability in the context of circular economy, LCA has already been revealed as a powerful tool to assess the environmental performance of a system from a holistic point of view, with an eco-design perspective. This means that LCA can be applied to evaluate the potential future environmental impact of a system at an early-stage technological development, supporting future decisions and development strategies. This feature of the LCA methodology is crucial for evaluating sustainable circular economies because it enables the assessment of environmental performances and circularity of a system and the comparison of different circular economy strategies. The ability of LCA and LCA-based methodologies to bring a holistic perspective and an environmental, social, and economic evaluation into decision-making, put such methodologies in a pivotal role when providing robust technical support in terms of finding the trade-offs between a large set of impact indicators, assessing the overall sustainability of circular economy systems [28]. For instance, developing and implementing a circular economy project that aims to replace single-use plastics in the EU should be supported by various technical information and findings considering all environmental, social, and economic consequences of setting up such a flagship circular economy strategy [24]. However, it should be noted that several challenges need to be faced and overcome for a robust application of LCA and LCA-based methodologies to support the decision-making in the context of circular economy strategies [25].

LCA OF (BIO)DEGRADABLE POLYMERS

In recent years, the interest of the scientific community regarding the application of LCA and LCA-based methodologies to bio-based and (bio)degradable polymers raised massively. Performing an analysis of the life cycle sustainability of these innovative products is pivotal for an auspicial decrease in the future environmental impact of the polymer production sector, ensuring a practical application of circular economy strategies. Several scientific papers, technical reports, and position papers have been published in a very short time, and many essential outcomes and evidence have been revealed [29-32].

One of the most important outcomes is provided by some review papers on applying LCA to compare the environmental impact of conventional fossil-based vs (bio)degradable polymers. When considering the large amount of environmental impact results and findings, it is broadly accepted that one of the most specific outcomes is that there is a lack of agreement on the real best-performing polymers, whether suggesting that fossil-based is always worse than (bio)degradable in any impact category [33,34]. This is mainly due to the different choices made in the modelling set-up, particularly LCA assumptions, the allocation method employed, and the definition of system boundaries. The latter seems to be one of the key issues to be addressed in order to properly assess the environmental impact of (bio)degradable polymers. The importance of including the end-of-life (EoL) phase in the LCA has been highlighted as fundamental to having a complete carbon biogenic account. In fact only the inclusion of EoL stage can assure a balance between the carbon uptake taking place during the feedstock cultivation phases and the carbon emissions during the EoL. To avoid the dealignment among different LCA approaches, which could lead to a misinterpretation of the real sustainability of bio-based and (bio)degradable polymers, the European Commission (EC) and the Joint Research Centre (JRC) in particularly put much effort into investigating and developing a sustainable alternative to conventional fossil-based polymer production [35]. This effort resulted in the publication of a report which addressed all the methodological issues of applying LCA for the evaluation of the environmental impact of bio-based and (bio)degradable polymers. The mentioned report suggests a detailed standardised approach based on the product environmental footprint (PEF) methodology [36,37]. The main objective of PEF is to establish a standardised methodology for measuring and communicating the life cycle environmental performance of a system. It aims to spread a systematic approach to assessing the life cycle environmental footprint of products and organisations, supporting European policies and policymakers. The standardised approaches, principles, and guidelines described in the report have been defined through a review of several studies that applied the LCA to bio-based and (bio)degradable polymers. This report allows for considering all the reasonable methodological steps and parameters to be addressed in setting up a cradle-to-grave LCA of bio-based and (bio)degradable polymers and the comparison with fossil-based ones. One of the most relevant steps is the accounting of biogenic carbon emissions and removals throughout the whole life cycle, starting from the raw material acquisition (i.e., cultivation of feedstock) to the EoL management.

The proper assessment of the raw material acquisition and pre-processing goes through the analysis of the primary biomass sources supply chain, including all the agricultural production processes needed to (i) prepare the land, (ii) biomass cultivation and the use of fertilizers and pesticides (if any), (iii) convert the biomass into the intermediate chemical compound, and (iv) the final polymerisation to obtain the rough (bio)degradable polymer. During the raw material acquisition and pre-processing phase, one of the most significant impacts that need to be adequately addressed is the greenhouse gas (GHG) emissions occurring as an effect of land use change (LUC). This impact could be direct (dLUC) or indirect (iLUC), and they should be accounted for and described among the LCA results. This is commonly done when there is the need to assess in the LCA all the anthropogenic procedures which require the exploitation of a large area of land, such as feedstock cultivation. dLUC occurs when there is a transformation of one land use type to another, resulting in a remarkable change of the properties of the land, without influencing neighbouring systems (i.e., the conversion from forestland to cropland), while iLUC occurs when a transformation of a land use type also affected other land types outside of the investigated land boundaries [31]. Considering these impacts and establishing an approach to account for them (especially iLUC might be very challenging to assess) is essential to avoid an underestimation of the environmental sustainability of (bio)degradable polymers [31]. Another issue highlighted as critical by many studies in evaluating the environmental impact of (bio)degradable polymers is the modelling of EoL, which is strictly linked with the balance of biogenic carbon accounted for in the raw material acquisition phase. In fact, the quantification of the carbon uptake during biomass cultivation should always be balanced with the carbon emissions at the EoL, which makes modelling EoL processes essential for a reliable environmental assessment. Thus, applying a standardised approach to model the different processes occurring at the EoL of (bio)degradable polymer is essential. The JRC report provides technical solutions starting from applying the circular footprint formula (CFF) [31].

The CFF is a mathematical formula that aims to balance the environmental burdens and benefits of different EoL options in terms of recycling, energy recovery, and landfill. The final environmental impact calculation is performed through several parameters, which are defined based on many technical aspects related to the defined system boundaries, the quality of materials used in the life cycle, the technologies employed, the market sector of the products, etc.

Dealing with modelling EoL treatment of (bio)degradable polymers means that many peculiar aspects should be addressed appropriately. The main one is the polymers' biodegradability (or biodegradation rate), which should be product-specific information due to the high range of variation among different types of (bio)degradable polymers. However, the JRC report provides a detailed description of how to deal with the lack of information on biodegradability, reporting several alternatives based on different characteristics of the (bio)degradable polymers and EoL treatment conditions [31]. All the EoL options should be evaluated through scenario modelling. The specific ones related to the (bio)degradable polymers not used in the agri-food market sector are industrial composting through aerobic or anaerobic digestion (with the on-land application of resulting organic residues), mechanical recycling, incineration, and landfilling.

Industrial composting

Composting is a biological process that converts biodegradable waste into several products due to the action of enzymes. Under aerobic conditions, the waste is converted into inorganic chemical compounds (i.e., CO_2, water, methane, non-methane volatile organic compounds, and other minor elements) and a residual solid fraction, the compost. The latter can be used as a soil amendment, and it might be a possible replacement for mineral fertilizer. From an LCA point of view, this means that a potential environmental credit evaluation could be addressed for this product, but only if the same approach has been followed to model appropriately the above-mentioned agricultural cultivation procedures to guarantee the right balance between environmental burdens and credits.

The anaerobic digestion process is like the aerobic one. The difference is that the biodegradation occurs under anaerobic conditions, enabling the production of biogas (i.e., a mixture of a few gases that depends on the composition of the (bio)degradable waste in input) and the possible following upgrading to bio-methane. Both biogas and bio-methane can be used as fuel to produce energy or used in vehicles. Anaerobic digestion also produces a residual solid fraction that could undergo aerobic digestion to produce a more stable soil amendment. From an LCA point of view, fuel production can play a crucial role in accounting for potential environmental credits on the overall assessment of the (bio)degradable polymers' life cycle.

Mechanical recycling

In conventional mechanical recycling, the polymer wastes are sorted and shredded to be used as secondary raw material to produce new polymer-based products. This process can also be applied to (bio)degradable waste to produce secondary (bio)degradable polymers used to make new products via the “drop-in” process. However, because of physic-chemical characteristics, this process can’t be applied to all the (bio)degradable polymers. In terms of LCA analysis, under certain conditions and through the evaluation by applying the CFF, the recovery of (bio)degradable polymers could avoid the production of the primary one, leading to a potential environmental credit.

Incineration and landfill

Incineration and landfill processes should be used to model the share of (bio)degradable waste which cannot undergo the composting and recycling processes. Ideally, a poor amount of waste should be treated via incineration or landfill because the (bio)degradable polymers should be appropriately collected and sorted to be recycled via industrial composting processes to have a closed loop life cycle, enabling the circularity of the (bio)degradable polymers products.

CONCLUSIONS

The article presents ways of valuation of the environmental impacts of (bio)degradable polymers, which is necessary due to their growing importance in the circular economy. A closed-loop economy is a concept aimed at rational use of resources and reducing the negative environmental impact of manufactured products, which should remain on the market as long as possible, and waste generation should be minimised as much as possible. The (bio)degradable polymers such as PLA, PHA, and aliphatic-aromatic polyesters, fit well into the concept of the circular economy and appear to be a good alternative to conventional plastics. LCA is a tool supporting the achievement of circular economy goals, whether it concerns green polymers, including (bio)degradable polymers, or other existing environmentally friendly products or services.

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ACKNOWLEDGEMENTS: This work was supported by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 872152, project GREEN-MAP and an international project co-financed by the program of the Minister of Science and Higher Education entitled "PMW" in the years 2020-2023; contract No. 5092/H2020/2020/2.

REVIEWED ARTICLE

DOI: 10.15199/42.2023.1.3

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COMPARATIVE ANALYSIS OF DIGITAL INK-JET PRINTS, PERFORMED ON DIFFERENT TYPES OF PLASTICS

ABSTRACT: In the present paper, the problems connected with the printing technology in relation to manufacture of advertisement materials, including stands, i.e. the so-called product presenting packaging (POS marketing) on plastics have been discussed. The comparative analysis is based, first of all, upon colour aspects but other parameters concerning ready prints as well as their manufacturing process have been also considered.
On the grounds of the obtained data, diagrams were plotted and the respective calculations were carried out. After analysis of the results of the conducted measurements, it was concluded that in spite of using the same digital large-format machine, the same UV inks and identical technical arrangements, the overprints differed each other in respect of the quality; it was affected by the type of the employed plastic. The overprints made on a substrate from high-impact polystyrene were characterized by the best quality parameters. Polyvinyl chloride was only somewhat worse material which could be overprinted. On the other hand, acrylic glass was decisively interior in comparison to other plastics and may not satisfy the expectations of the most demanding producers.
Key words: digital printing, ink-jet, plastics, optical density, trapping, relative contrast, gamut

STRESZCZENIE: W niniejszym artykule poruszane są zagadnienia związane technologią drukowania w odniesieniu do produkcji materiałów reklamowych, w tym standów, czyli tzw. opakowań prezentujących produkt (POS marketing) na tworzywach sztucznych. Analiza porównawcza opiera się przede wszystkim na aspektach kolorystycznych, ale rozpatrywane są również inne parametry dotyczące gotowych wydruków, jak i procesu ich produkcji.
Na podstawie uzyskanych danych utworzono wykresy i dokonano odpowiednich obliczeń. Po analizie wyników pomiarów wywnioskowano, że mimo wykorzystania tej samej cyfrowej, wielkoformatowej maszyny, tych samych atramentów UV oraz identycznych ustawień technicznych, nadruki różnią się od siebie jakością, na co wpływ ma rodzaj wykorzystanego tworzywa sztucznego. Nadruki wykonane na podłożu z wysokoudarowego polistyrenu cechują się najlepszymi parametrami jakościowymi. Niewiele gorszym materiałem, który można zadrukować, okazał się polichlorek winylu. Natomiast szkło akrylowe zdecydowanie odstawało pod tym względem od pozostałych tworzyw sztucznych i może nie spełniać oczekiwań najbardziej wymagających producentów.
Słowa kluczowe: drukowanie cyfrowe, drukowanie natryskowe, tworzywa, gęstość optyczna, trapping, kontrast względny, obszar barw odtwarzalnych

INTRODUCTION

Digital technologies play greater and greater role in printing sector; they are constantly developed with the aim to create a real competition for analogue methods. At the beginning, due to the limitations connected with the performance of equipment and costs of inks, digital machines were employed only for printing of low and trial volumes.
Another problem, before which the discussed branch of printing industry was faced, concerned the direct contact of ink with the substrate, without printing mould. When the substrate was not sufficiently prepared, ink was absorbed too much by the structure of paper, causing defects of the print whereas in the case of too large quantity, of inaccurately dried layer, the print could become blurred.
The technology of ink-jet printing and UV ink-jet printing is responsible for the mentioned problems connected with the digital methods of printing. Its dynamic development satisfied all expectations of the customers, the problems connected with the mentioned above phenomena and the competition with the classical printing methods. To these ends, printing

heads which have been developed ensure the appropriate high quality of overprinting owing to the possibility of printing of image with 1200 dpi resolution, using the variable drop volume. The machines and inks have been improved and adjusted to the increase of the yield of printing by the ink-jet methods and the range of possible substrates to be used. The mentioned progress caused reduction of defects as compared to the analogue technology without loss of advantages which are characteristic of ink-jet printing.

The factors affecting quality of the print are widely differentiated and are dependent on many componential elements. In the case of ink, we have to pay attention to the composition, type of binder and the size of the individual particles of dye. The substrate is evaluated in respect of the structure and preparation of the surface to be overprinted. To obtain a high quality of overprint, the equipment (machine) must be appropriately calibrated and the supplied file must be well prepared. The mentioned earlier heads are discussed in respect of such parameters as their types, maximum resolution, performance and volume of the sprayed drops and the possibility of changing their size.

The technology of UV ink-jet printing is distinguished by the highest number of printable substrates. Apart from the traditional paper of cardboard carriers, we may mention textiles and plastic films or large-format panels made from glass or plastic such as PMMA, PET-G or PVC. Such comprehensive application makes that the discussed technology is an ideal competition for screen printing in the case of internal and external advertisement prints due to its high resistance to atmospheric conditions [1-3].

THE PURPOSE OF THE STUDIES

At the beginning, the quality of digital overprint, including that one made by inkjet technology, was comparable to the copies, performed by classical printing methods. It did not however solve the problems in the areas, requiring attention and parameterization. The established quality parameters have been recorded in standard ISO/IEC TS 24790:2012 and may be divided into two groups.

FIG. 1. GROUPS OF PARAMETERS USED IN EVALUATION OF THE DIGITAL OVERPRINT QUALITY IN ACCORDANCE WITH STANDARD ISO 15311

Groups of quality parameters	Criteria of quality evaluation	Typical method of evaluation
Reproduction of colour (precision of mapping the colour)	– Total coverage of area – Colorimetric and densitometric deviations – Curves of printing – Colour gamut (spectrum of colours) – Consistence of uniform colour of background (apla) and increase of raster halftone value and values indicated in ISO12647-2	– Measurement of colour and determination of difference in colours on colourful bands (fields) and test tables
Sharpness of details	– Resolution – Range of tonal reproduction – increase in raster tonal value – No matching: “image-to image” , “image –to-edge”, “obverse –to-reverse’	– Siemens star (visually) – Control band (visually) – Markers of cut (visually and measurements) – Blurriness and raggedness of line
Uniformity of overprint	– Uniformity of overprint on surface of printing sheet – Uniformity during printing a volume, – Uniformity of overprint on large areas of image (banding)	– Profiles of optical density – Nine-point measurement of overprint uniformity on a sheet in accordance with ISO 12647-7 – measurement of M-score in accordance with ISO 15311-1

The first group concerns the correct evaluation of the quality of the overprints in form of uniform colour background (in Polish: "apla"), raster and non-printed surface. We may distinguish such parameters as background haze and extraneous marks of the non-printed area, graininess and mottle of overprint, optical density (darkness) and voids (non-printed fields) in the case of large-format overprints.

The second group of parameters is connected with the evaluation of overprint line and font; it includes blurriness and raggedness of edges, optical density and width of the line, extraneous marks and background haze in the area of font, contrast and filling.

Apart from the discussed above classification, according to the mentioned standard, there is also another standard – ISO 15311, indicating another possibility of parameterization and evaluation of the quality of prints without classification into the techniques of printing. It has been presented in the form of fig. 1.

The choice of plastic materials in advertisement sector is dependent on the site and conditions in which a final product will be exposed: whether it will be a flat plate, or a packaging made from it and presenting a promoted product. The quality of overprint is not a condition, determining the mentioned choice, so, nobody performs the comparison of the discussed quality between different types of plastic materials. Within the frames of the experiment, the selected quality parameters of the overprints, performed in UV inkjet technology were tested, valuated and compared; the experiment was carried out in one machine on the plates (panels), made from different types of plastics.

PLASTIC PANELS

In the studies, the plates made from three different plastic materials in standard white colour were used.

HIPS – is polystyrene with the addition of rubber with the aim to increase its impact strength, i.e. resistance to tensile stress at a room and lower temperature. Owing to this fact, the fragility of common polystyrene is eliminated and one meaningful defect is a very quick yellowing and ageing of material as affected by sun light what eliminates the product as an element of external advertisement. Its advantages include good dielectric and plastic properties and a very high resistance of the effect of chemical and organic substances.

PPMA, being commonly called Plexiglas or acrylic glass, is most widely used plastic from those three ones used in the experiment. It is characterized by a high resistance to UV radiation, high resistance to chemical substances and by transparency. Additionally, it is easily subjected to recycling process.

PVC, i.e. polyvinyl chloride, can be distinguished by a perfect resistance to effect of chemical agents and by dielectric properties. It is a very light material, with a high elasticity module but also, a high rigidity. In advertisement sector, it is popular due to the great resistance to external conditions such as temperature fluctuations, humidity or natural light [5-8].

ARIZONA 350 GT BY CANON

Plastic panels were overprinted using large-format digital machine Arizona 350 GT by Canon company. It employs ink-jet technology with the preservation of inks by UV radiation. VariaDot technology enables obtaining almost photographic quality of overprint with resolution of 1440 dpi and using the set of only four basic colours. The variable volume of drop within the limits of 6-42 picoliters allows a precise reproduction of font of 6 pt as gradients or total passages as well as obtaining uniform, saturated colours. Additionally, it has the possibility of printing with white colour which – as the remaining dyes – is found n easily replaceable bags. The maximum area of overprinting the flat surfaces is 1.26 m x 2.51 m, with the possible bleed, from edge to edge. Manufacturing speed is 22.2 m^2 of good copy per hour and in the case of additional use of white colour, the mentioned value oscillates within 7.6 m^2 [4].

VISUAL EVALUATION

The selected elements from the first page of control test, using the mentioned three substrates were subjected to visual evaluation. The results of the observations were compared each other with the aim to find out the differences between the overprints performed on different plastic materials. The following elements were evaluated and compared:

TAB. 1. OPTICAL DENSITY ON HIPS PANEL

Colour	Series of measurements					Mean of measurements
	1	2	3	4	5	
C	1.00	1.00	1.02	1.00	1.02	1.01
M	1.25	1.19	1.25	1.18	1.21	1.22
Y	0.97	0.96	0.97	0.96	0.96	0.96
K	1.92	1.93	1.88	1.89	1.91	1.91

TAB. 2. OPTICAL DENSITY ON PMMA PANEL

Colour	Series of measurements					Mean of measurements
	1	2	3	4	5	
C	1.70	1.70	1.69	1.69	1.70	1.70
M	1.85	1.84	1.85	1.84	1.84	1.84
Y	1.15	1.14	1.15	1.15	1.15	1.15
K	2.11	2.10	2.10	2.10	2.10	2.10

TAB. 3. OPTICAL DENSITY ON PVC PANEL

Colour	Series of measurements					Mean of measurements
	1	2	3	4	5	
C	1.48	1.50	1.50	1.51	1.49	1.50
M	1.63	1.64	1.66	1.63	1.65	1.64
Y	1.02	1.02	1.02	1.03	1.02	1.02
K	2.01	2.04	2.03	2.06	2.04	2.04

– illustrations – food, nature, human skin and details in darker surrounding;
– line and geometric figures; and
– two types of typeface, serif and sans serif.

The images overprinted on HIPS panels are best reproduced; those made on PVC are little worse. The colours are distinct, the details on the food and nature-containing images as well as the details on the darker background are reproduced in a good quality. Unfortunately, the illustrations overprinted on PMMA panel are distinctly of worse quality, the colours are more weathered. The details in the shadow are invisible and generally, the images are less contrastive in comparison to the earlier compared ones.

Triangles and circles with the inscribed line are similar on all substrates, irrespectively of the type of used plastic. Shapes and lines are distinctly visible even at thickness of 0.01 mm with only small deformations.

Inscriptions made with the use of Arial and Times New Roman font are also reproduced on a similar level on all substrates. The texts in opposition to background (white letters on dark background) can be read without greater problems at 5p and black inscriptions on a white background at 4 p are readable in the case of sans serif as well as serif fonts.

STABILITY OF COLOURS

To evaluate the stability of colours, field no 1 from the first age of control test, i.e. bands of CMYK colours, was used. Five measurements of optical density of each colour of uniform background ("apla"), being printed on each plastic material, were performed. The results are given in tables 1, 2 and 3.

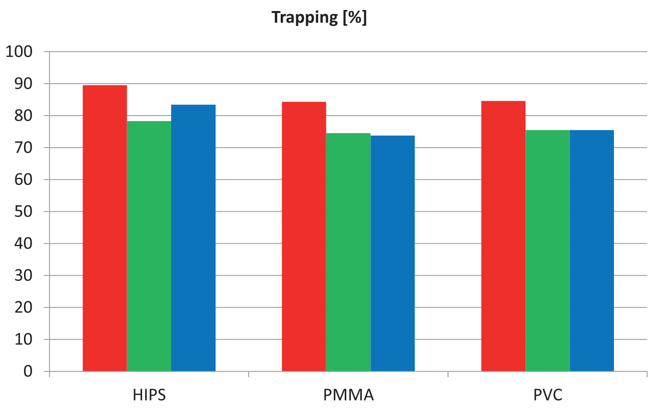

FIG. 1. TRAPPING ON DIFFERENT PLASTIC PANELS; R, G, B

CONCLUSIONS FOLLOWING FROM THE MEASUREMENTS OF COLOURS' STABILITY

Optical densities of all colours on all plastic materials are stable, mostly on PMMA panel. It may be stated that physical properties of plastic materials did not affect negatively any of the overprinted colours.

TRAPPING

The measurements conducted with the use of spectrophotometer of test fields, being found under number 9 at page 3 of the control test allow examination of the capabilities of absorbing ink by another ink, i.e. trapping. The data and the results for each plastic have been illustrated in the tables and diagram, being given below, respectively.

CONCLUSIONS RESULTING FROM TRAPPING MEASUREMENTS:

It has been assumed that value of trapping must be no less than 80% in order to obtain good quality of printing in offset technology.

TAB. 4. VALUES OF TRAPPING FOR HIPS PANEL

Optical density				Trapping [%]		
C	M	Y	K	YM (R)	YC (G)	MC (B)
0.87	1.13	0.88	1.78	89.5	78.3	83.4

TAB. 5. VALUES OF TRAPPING FOR PMMA PANEL

Optical density				Trapping [%]		
C	M	Y	K	YM (R)	YC (G)	MC (B)
1.25	1.43	0.81	1.70	84.3	74.5	73.8

TAB. 6. VALUES OF TRAPPING FOR PVC PANEL

Optical density				Trapping [%]		
C	M	Y	K	YM (R)	YC (G)	MC (B)
1.30	1.47	0.88	1.87	84.6	75.5	75.5

YM – acceptance of magenta colour by yellow ink YC – acceptance of cyan colour by yellow ink MC – acceptance of cyan colour by magenta ink

TAB. 7. PARAMETERS L*, A* AND B* FOR HIPS PANEL

Parameter	Colour						
	C	M	Y	K	R	G	B
L*	59.85	50.01	88.35	19.63	47.26	54.13	26.04
a*	-31.56	67.27	-5.97	3.36	63.69	-60.94	25.9
b*	-35.89	-8.7	89.29	-4.14	44	25.92	-50.31

TAB. 8. PARAMETERS L*, A* AND B* FOR PMMA PANEL

Parameter	Colour						
	C	M	Y	K	R	G	B
L*	59.85	50.01	88.35	19.63	47.26	54.13	26.04
a*	-31.56	67.27	-5.97	3.36	63.69	-60.94	25.9
b*	-35.89	-8.7	89.29	-4.14	44	25.92	-50.31

TAB. 9. PARAMETERS L*, A* AND B* FOR PVC PANEL

Parameter	Colour						
	C	M	Y	K	R	G	B
L*	59.85	50.01	88.35	19.63	47.26	54.13	26.04
a*	-31.56	67.27	-5.97	3.36	63.69	-60.94	25.9
b*	-35.89	-8.7	89.29	-4.14	44	25.92	-50.31

In the case of digital printing on the different plastic panels, only YM parameter exceeded the discussed limit value in all variants. The copies made on PMMA and PVC panels had similar although insufficient results. On the other hand, the overprint on HIPP substrate, with a small exception, met the adopted assumptions and it may be evaluated as being of good quality.

SPECTRUM OF COLOURS

On the grounds of field no 1 from page 3 of the control test, the data were collected; they are presented in the tables as given below. Parameters L*, a* and b* were measured using spectrophotometer for colours C, M, Y, K, R, G and B on three panels and allowed to plot the diagrams of the spectrum of colours, being otherwise called gamut, for all the examined plastic materials.

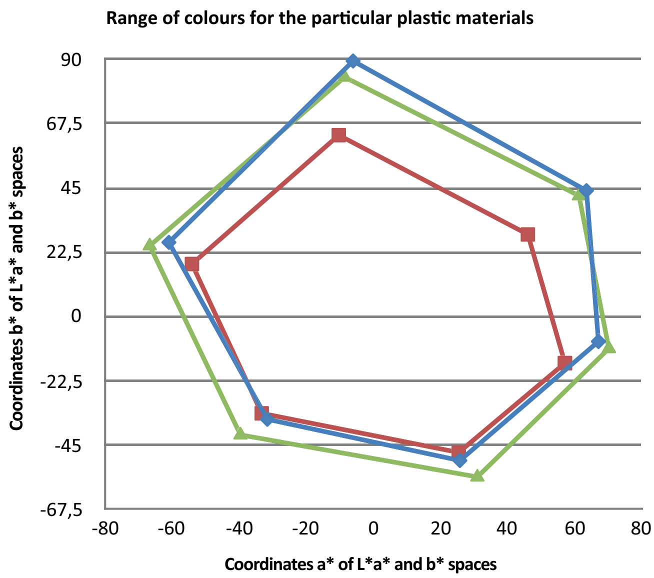

FIG. 2. RANGE OF COLOURS FOR PANELS MADE FROM DIFFERENT TYPES OF PLASTICS; PMMA, PVC, HIPS

CONCLUSIONS RESULTING FROM THE MEASUREMENTS OF GAMUT

After the illustration of the data obtained from all performed measurements, using spectrophotometer, we may conclude that the overprint on the substrate produced from PMMA differed from the two remaining materials in respect of the width of colour space. It is probably caused by a difference in physical properties of the discussed plastic materials, and especially, mainly due to the greater own transparency of Plexiglas as compared to the high-impact polystyrene of polyvinyl chloride.

RELATIVE CONTRAST

The relative contrast was determined by the measurement of the fields of element no. 8 at page 3 of the test and by the calculation according to the following formula:

$$Relative\ contrast = \frac{D_{100} - D_{75}}{D_{100}} * 100\ \%$$

D_{100} – optical density of field with 100% coverage

D_{75} – optical density of field with 75% coverage

Value of the discussed parameter should be equal to no less than 30% as to be recognized as a correct and satisfying the respective standards. The data obtained from the measurements using the spectrometer are found in the tables given below, together with the calculated parameters for the panel produced from each plastic material. The tables are accompanied by the diagram.

CONCLUSIONS, RESULTING FROM THE MEASUREMENTS OF RELATIVE CONTRAST:

The adopted approvable value of relative contrast cannot be less than 30%. The conducted studies showed that any

TAB. 10. RELATIVE CONTRAST FOR HIPS PANEL

Area coverage [%]	Optical density			
	C	M	Y	K
100	0.98	1.18	0.97	1.84
75	0.74	0.82	0.65	0.96
Relative contrast [%]	24.49	30.51	32.99	47.83

TAB.11. RELATIVE CONTRAST FOR PMMA PANEL

Area coverage [%]	Optical density			
	C	M	Y	K
100	1,61	1,77	1,14	2,04
75	1,3	1,3	0,93	1,48
Relative contrast [%]	19,25	26,55	18,42	27,45

TAB.12. RELATIVE CONTRAST FOR PVC PANEL

Area coverage [%]	Optical density			
	C	M	Y	K
100	1,45	1,61	1,02	2
75	1,1	1,13	0,77	1,26
Relative contrast [%]	24,14	29,81	24,51	37,00

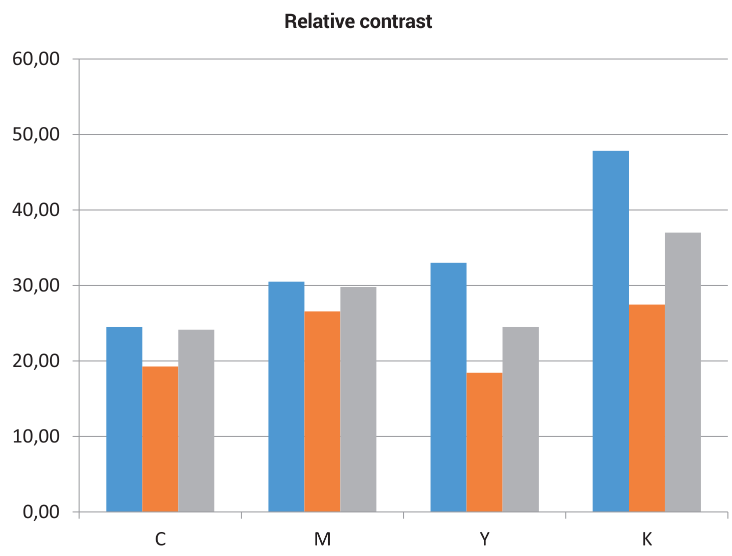

FIG. 3. RELATIVE CONTRAST FOR PARTICULAR MATERIALS; HIPS; PMMA, PVC

overprint, irrespectively of the substrate material, did not meet the mentioned condition in 100%. The overprint performed on HIPS panel was closest to obtaining a good result; however the value of relative contrast of cyan in all cases was found on a very low level, even below 20%. It shows that the details in dark areas may be very weakly reproduced and almost or even completely invisible for human eye.

FINAL CONCLUSIONS

In final comparison of the overprints made on different types of plastic materials, using large-format digital ink-jet machine with UV ink, we should consider all the conducted tests, both visual and those ones, conducted with the use of measuring devices.

The purpose of the present study was to check and eventually, indicate the difference in the quality of the overprints, made on three plastic substrates: white HIPS, PMMA and PVC panels. It would allow the representatives of advertisement sector and the producers of POSM and POS marketing to consider not only physical and chemical properties, being important in location of the advertisement but also the quality aspect of the overprint when choosing the appropriate material.

Visual evaluation included subjective feeling concerning the quality of reproduction of the element of control test. The illustrations were expected to help in the recognition of the colour intensity, precision of details in lights and shadows and general contrast of images. Lines, geometrical shapes and font types printed normally and in the opposition facilitated observations of reproducing the small elements on the substrate. On visual examination, the overprint made on PMMA panel differed decisively from other ones, as it was characterized by image blurring and poor reproduction of colours and details. It was visible especially during the evaluation of illustrations with darks details and human skin. The study of colour stability did not reveal any defects in printing. Optical densities of each colour on all substrates were stable what was shown in measuring series, performed by spectrophotometer. It may be followed that different physical properties of the particular plastic materials do not have any negative effect on colour stability.

The measurements of trapping, i.e. capabilities of accepting one ink by another ink showed the satisfactory results only in the case of HIPS panel. The overprint which is aimed at having a good quality must be characterized by the discussed parameter art the level of at least 80%, at least in offset printing. Trapping of the print on PMMA and PVC substrates is considerably different than the mentioned minimal limit value; theoretically, it leads to the statement that the quality of the overprint made on the mentioned above substrates is of a worse quality ac compared to the colours reproduced on high-impact polystyrene.

The evaluation of the spectrum of colours, i.e. gamut, indicated again the lower quality of overprint made on PMMA panel. The data obtained when using spectrophotometer and being utilised in plotting the diagram showed the small differences in respect of the width of colour space on HIPS and PVC substrates. On the other hand, the text printed on Plexiglas confirmed clearly the definitely smaller range of colours. It may be caused by a greater transparency of the discussed material.

The parameter of relative contrast was calculated using a formula and the data which were obtained with the utilization of spectrophotometer. The examination of the areas of CMYK colours with coverage of 100% and 75% highlighted the discussed problem with all plastic substrates. Any of the examined overprints has not exceeded the limit value of relative contrast at the level of 30%. The overprint made on HIPS panel occurred to be the best although still insufficiently good in this respect. Nevertheless, the value of relative contrast of cyan in all discussed cases is too low, sometimes even below 20%. It makes that the details in dark areas may be very poorly reproduced and perhaps even completely invisible for the observer.

Summing up: visual evaluation and the conducted tests revealed as follows: in spite of the utilization of the same digital large-format machine and the same UV inks and the identical technical parameters, the overprints were different in respect of quality as affected by the type of the employed plastic material. The overprints made on substrates made from high-impact polystyrene were characterized by the best quality parameters. Polyvinyl chloride occurred to be only somewhat worse material which may be overprinted. On the other hand, acrylic glass differed decisively from the remaining plastic materials in this respect and it may not satisfy the expectations of the most demanding producers and customers. It may also generate higher costs due to the necessity of performing more complicated treatment such as production of white sub-print, decreasing the transparency of the material.

The quality of printing is not, however, the most important criterion of the choice of the appropriate material as the substrate to be overprinted, for example, in advertisement sector. In spite of its worse overprinting quality, Plexiglas has many advantages, physical and chemical properties which make it one of the most popular plastics, employed all over the world in many sectors. On the other hand, as was revealed in the discussed study, we should pay also attention to differences in the quality of prints made on different plastic materials.

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ANNA NARUSZKO, M.Sc.

TRADESHOW TRIO FOR FLEXIBLE AND CORRUGATED PACKAGING – SUCCESS BUILT ON QUALITY

From 14th till 16th of March ICE Europe, CCE International, and InPrint Munich took place at the Munich Trade Fair Centre, offering attendees three full days of business opportunities, ranging from bespoke product sourcing, industry-specific educational forums, all the way to networking and investment opportunities. Throughout the shows, a total of 6,944 trade visitors from 78 countries came to Munich to discover the latest machinery, systems, materials, and accessories, which is an increase of some 23% in visitor numbers compared to the previous event editions in 2022.

Shaping the future of the corrugated, industrial print and converting industry, 438 exhibitors from 24 countries showcased their products and services on a net exhibition space of more than 11,300 square metres. *It was great to witness the return of such a vibrant atmosphere, which matched the energy and enthusiasm of our shows before the pandemic! Both exhibitors and visitors were highly satisfied with the opportunity of meeting existing and new business contacts in person, here at CCE International, InPrint Munich and ICE Europe* – states Patrick Herman, Event Director of the Converting, Paper and Print Events, on behalf of RX, the organizer of the show.

THE MAJORITY OF VISITORS CAME FROM GERMANY, ITALY, AUSTRIA, SWITZERLAND, UNITED KINGDOM, POLAND, SPAIN, CZECH REPUBLIC, FRANCE, TURKEY, AND THE NETHERLANDS.

THE CCE OPEN SEMINAR SESSIONS FEATURED TECHNICAL TALKS ON THE LATEST TRENDS AND DEVELOPMENTS IN THE CORRUGATED AND FOLDING CARTON SECTOR

The majority of visitors came from Germany, Italy, Austria, Switzerland, United Kingdom, Poland, Spain, Czech Republic, France, Turkey, and the Netherlands. The first results of the show analysis have also shown that the visitors mainly came from the following industry sectors:

- printing, packaging, corrugated board plants and sheet plants, packaging design and specifying, folding carton converters, corrugated sheet feeders, surface imaging, automotive, electrical appliances and electronics, rigid carton manufacturers **(CCE International / InPrint Munich)**.
- Packaging, engineering, printing, plastics, paper, chemical, automotive, textiles/ nonwovens, electronics, pharma/ healthcare/ medical, and others **(ICE Europe)**.

Visitors were primarily interested in:

- Printing machinery, systems and solutions, corrugating line and corrugated converting equipment, machine and plant controls, inks/ fluids/ chemicals/ additives, folding carton converting equipment, consultancy for print technology and applications, print components and special parts, materials handling and warehousing, software solutions, and consumables **(CCE International / InPrint Munich)**.
- Coating/ laminating, slitting/ rewinding, print technology, accessories and machine upgrades, control, test & measurement technology, finishing, drying/ curing, film extrusion, materials/ (semi) finished products and (pre) treatment **(ICE Europe)**.

The top exhibitor countries included Germany, Italy, Turkey, China, Great Britain, Spain, the United States, Switzerland, France, Poland, and the Netherlands.

CCE INTERNATIONAL OPEN SEMINARS PROVIDE TOP-TIER INDUSTRY KNOWLEDGE

The CCE Open Seminar Sessions featured technical talks on the latest trends and developments in the corrugated and folding carton sector. Over the course of three days, top industry experts presented technical solutions and services aimed at optimising the production process and value creation. This year's topics included: corrugated e-commerce packaging, retail-ready microflute solutions, advanced digital cutting and creasing, short run box production, digital manufacturing, corrugator moisture control, no-nick die-cutting, warehouse retrofitting and energy-regeneration, client data management, and many more.

POPULAR INPRINT MUNICH CONFERENCE

CCE International featured the offerings of InPrint Munich, which included the popular InPrint Conference on print applications in the industrial production sector. With around

50 well-attended sessions delivered over the course of three days, there were plenty of topics to choose from, including the latest applications in printed electronics, smart packaging, direct-to-shape, data management, and carbon footprint reduction. Sessions were delivered by top industry experts, including representatives from AGFA, Fraunhofer ENAS, FujiFilm, HP, Inkatronic, MABI, Meteor Inkjet, Seiko Instruments, Xeikon, and many more. The InPrint Munich conference was sponsored by Xaar, a world-leading printhead manufacturer, and hosted by Werner Zapka, WZA-Consulting.

ICE EUROPE 2023: RECORD NUMBERS OF PRE-PANDEMIC TIMES

The 13th International Converting Exhibition ended with a total of 4,850 trade visitors from 64 countries who came to Munich to discover the latest machinery, systems, materials, and accessories, which is a more than 30% increase in visitor numbers compared to the previous event. Shaping the future of the converting industry, 338 exhibitors from 20 countries showcased their products and services on a net exhibition space of some 8,700 square metres at the world's leading exhibition for the conversion of flexible, web-based materials, such as paper, film, foil and nonwovens. With the success of this year's edition, the show organisers announced the next ICE Europe to take place from 12-14 March 2024.

ICE AWARDS 2023: INNOVATIVE EXHIBITORS HONOURED WITH PRESTIGIOUS AWARDS

The award ceremony was hosted by RX, and for the very first time, in cooperation with C2 Magazines, where best practice,

excellence, innovation and outstanding achievements of exhibitors were honoured with the ICE Awards, in the following categories: 'Digital Converting Solutions', 'Sustainable Products and Converting Processes', and 'Efficient Production Solutions'. Nicola Hamann, Managing Director of RX, in cooperation with Martin Hirschmann, Editor-in-Chief of C2 Magazines, presented the ICE Awards 2023 to three exhibiting companies on the first day of the show. The winners had previously been determined via a verified online voting. The competition received more than 30 entries from a wide spectrum of start-ups and leading brands, where over 2,500 converting specialists submitted their casting vote to determine the winners of the individual categories.

The company **DIENES Werke für Maschinenteile GmbH & Co.KG.** received 34% of all votes in the category 'Digital Converting Solutions' and won an ICE Award for its TEOC ("The End of Coincidences"), which combines DIENES' digitalisation activities. Within this framework, the recently launched TEOC Service Packages include a modular architecture with hardware and software features, which can be combined in accordance to individual customers' needs.

In the category 'Sustainable Products and Converting Processes', the company **INOMETA GmbH** received 38% of all votes and won the ICE Award for its heating roller, which has been designed to meet the needs and requirements for laminating foils and other substrates. It ensures a reliably constant and homogeneous surface temperature distribution, as this is the prerequisite for uniform web tempering.

With 29% of all votes, the company **tesa SE** won the ICE Award in the category 'Efficient Production Solutions' for its highly durable roller wrapping tape: the silicone tape tesa Printer's Friend 4863 with an embossed surface. The product design ensures high resistance to wear and offers easy application and removal, even after a prolonged time period and exposure to high temperatures.

DATES FOR THE NEXT SHOWS

Existing and new exhibitors have already expressed their interest in participating at the upcoming show edition in 2024. ICE Europe will take place from **12-14 March 2024 at the Munich Trade Fair Centre**.

In the ICE series of dedicated trade events for the converting industry, ICE China will be held from 11 - 13 October at the Shenzhen World Convention and Exhibition Centre. Early next year, RX will organise ICEC USA, from **9-11 January 2024, in Orlando, Florida**.

The exhibition trio for the converting, corrugated and industrial print industries will take place again from **11-13 March 2025, at the Munich Trade Fair Centre**.

STEFAN JAKUCEWICZ, D.Sc., Ph.D., PROF. EMERITUS

FUTURE AND CHALLENGES OF PACKAGING MARKET

It was the title of the first scientific conference of the Research Network Łukasiewicz – Łódź Institute of Technology, being held on March, 16, 2023 in Warsaw. Its organizer was Warsaw Department of the Network – COBRO; the event was attended by 80 participants.

The conference was opened by Dr Radosław Dziuba, director of Łódź Institute of Technology: "Sector of packaging in Poland is worth 60 billion PLN what makes it significant from the viewpoint of industry. During the pandemic, we proved - at the international forum - that we are able to reach growth and construct competitive advantages in the most difficult conditions. It should be stressed that Poland is the European Union leader in the export of packaging made from wood. It is also satisfying that we occupy the third place on the podium after Germany and the Netherlands in the field of packaging, based on paper. As far as glass and metals is concerned, we occupy the 6th – 7th position. It is evidence that we answer correctly to the current challenges of the market; nevertheless, the discussed sector is faced before the successive problems in this respect. We will try to define the coming challenges during the conference. At the Research Network Łukasiewicz – Łódź Institute of Technology, COBRO is acting – it is one of the main centres for certification of packaging and development of innovations. In total, the discussed Institute has been created by 450 creative, involved persons who are ready to undertake any challenge. In the new financial perspective, we may obtain more than 95 billion EURO. Let's fight for it together".

The hosts of the conference were engineer Beata Górska, M.Sc., and Krzysztof Wójcik, M.Sc.; the participants included entrepreneurs, scientists and representatives of the research institutes and higher education schools. The honorary partner was Azoty Group whereas "Packaging Review" and "Packaging" were one of the media patrons of the meeting.
The debate of the Conference was carried out in three sessions which were presided by engineer Beata Górska, M.Sc., and Krzysztof Wójcik, M.Sc.. There was also organized the fourth, poster session.
During the first session, five lectures were delivered. Their discussion is given below.

The first lecturer was **Maciej Nałęcz from Santander Bank Poland** who submitted the lecture "Market perspectives of the producers of packaging in 2023". In the lecture, the analysis of profitability of demand on packaging industry in 2022 was presented and the perspectives for 2023 were discussed. The impact of pandemic and of War at Ukraine on the development of packaging sector was analysed.

The next lecture was entitled: "Bioplastic materials – necessity, trend or alternative?. It was delivered by **Magdalena Pantoł, representing Azoty Group SA from Tarnów**. In her speech, bioplastic materials were characterized, with the stress put on the fact that "they are polymers, subjected to biodegradation or/and coming from renewable raw materials", mentioning that not every bioplastic material is biodegradable but every biodegradable material is biomaterial. The main attention was

FUTURE AND CHALLENGES OF PACKAGING MARKET WAS THE TITLE OF THE FIRST SCIENTIFIC CONFERENCE OF THE RESEARCH NETWORK ŁUKASIEWICZ – ŁÓDŹ INSTITUTE OF TECHNOLOGY, BEING HELD ON MARCH, 16, 2023 IN WARSAW.

dedicated to cellulose derivates and modified starches. The plastic product envill®, being thermoplastic, chemically non-modified starch, produced at Azoty Group, has been presented and discussed. The mentioned material is produced in three varieties: for injection moulding, for film production and for extrusion. Biomaterials of envill® brand contain up to 95% of components deriving from renewable raw materials. The plastics industry produces ca. 360 million tons annually, including biomaterial amounting to ca. 2.2 million tons (about 0.6%). Packaging sector is the greatest market of biomaterials which is estimated at the level of 8-13%.

The third lecture in the session was delivered by **Dr hab. Barbara Ocicka, Professor of Warsaw School of Economics (SGH)** and **Dr Jolanta Turek from Warsaw School of Economics**. Its title was "Management of supply chains of packaging in circular economy (in Polish: **GOZ**) – a study of the case of compostable packaging intended for food". It included the characteristics of the circular system of compostable packaging for food products. There are only 53 solutions, being taken into consideration for the closure of the discussed system for compostable packaging. The main solutions for this action are closed in three points: national strategy for development of compostable packaging market, technological platform B2B and sector's organization. In the social sciences as well as in the economic practice, there is a need of deeper reconnaissance of the problem of management of life cycle of compostable packaging according to the principles of circular economy in cooperation with the internal and external stakeholders of the chain supplies.

The authors of the mentioned lecture have stated that the market of compostable packaging, as being a niche market, is still found in the very early stage of development. The design work allowed identifying the problems and barriers affecting its development in Poland. The mutual understanding of the needs and aspirations of the suppliers of raw materials, production and distribution enterprises and the entities from the business environment, including public institutions, has a key meaning for the effective implementation of the circular economy system in respect of compostable packaging.
The development of social innovations in relation to the identified challenges proceeds towards the circularity of compostable packaging in the economy.
Transformation of the market of compostable packaging according to GOZ principles has the evolutionary (not: revolutionary) character and requires a systemic approach and multi-subject integration.
The fourth lecturer was delivered by Prof. Dr hab. Ryszard Cierpiszewski from University of Economy in Poznań, from the

THE EVENT WAS ATTENDED BY 80 PARTICIPANTS.

Institute of Quality Science. He presented the lecture "Active and intelligent packaging. The perspectives of the development". In his speech, Prof. Cierpiszewski submitted, according to the EU Regulation (packaging intended to come into contact with food) the following topics:

- **Active materials and articles** mean the materials and products the task of which is to extend the period of the shelf-life (expiration date) or to maintain or improve the condition of the packed food; they are designed to deliberately incorporate the components that would release or absorb substances into or from the packaged food or the environment surrounding the food;
- **Intelligent materials and articles** mean such materials and products which monitor the condition of the packaged food or its surrounding.

The discussed packaging has been known and employed for more than 30 years; their further development seems to be interesting.
In summing up, the perspectives for development of active and intelligent packaging have been outlined. The following facts speak for their development: high interest, manifested by a large number of publications, interest of the enterprises, a high number of the solutions, suggested in literature. The other factors include also as it follows: social changes, forcing the further development of this type of packaging; better utilization of food; lower wastage; environmental protection, high innovativeness, the possibility of traceability of each product and communication with the consumer.
The following facts are against the further development: lack of the increase in the number of patents; the knowledge about active and intelligent packaging (AIP packaging); lack of the studies in this area; AIP elements are not suitable for recycling; a high number of the solution is not properly developed what causes the necessity of developing the new business solutions, also with the aim to prevent the cyber-crimes.

The next speaker was **Prof. Bartłomiej Mazela, PhD., Eng., from University of Life Sciences in Poznań**. He delivered not a lecture but rather a message or information about the ongoing research, being performed within the frames of NCBR grant "XyloMatrix – production of packaging from recycled lignin-cellulose fibres". In his speech, the method for processing of MDF panel wastes after removal of resin, fixing the fibres and rendering the water resistance to the mass of lignin-cellulose fibres, with their destination for bulk packaging was discussed.

During the second session, four lectures were delivered:

1. **Grzegorz Ganczewski, MSc, from the Leon Koźmiński University** – he submitted the lecture "LCA (Life Cycle

THE HOSTS OF THE CONFERENCE WERE ENGINEER BEATA GÓRSKA, M.SC., AND KRZYSZTOF WÓJCIK, M.SC.

Assessment) as a tool for study of the sustainable development of packaging". We should understand the sustainable development as "development which meets the needs of the contemporary world with the simultaneous consideration of the needs of future generations and the possibilities of their implementation" The sustainable development contains three elements – economic, social and environmental – which should be equally treated.

LCA is the abbreviation of Life Cycle Assessment which is one of the models of environmental management. It may be employed in evaluation of the products, processes, services and even total enterprises. It serves for studying of the environmental impacts during the whole life cycle of a given product/service.

The author of the lecture shows the "life cycle assessment" data on the example of the shopping bags which are expected to carry 5 kg of shopping products at the distance of 500 m. The evaluation included 4 types of shopping bags made from cotton, polyethylene foil LDPE, from polypropylene fabric and from paper. When employing the method of "eco-indices 99", it was revealed that 'the best bag' was that one made from polypropylene fabric.

2. The next lecturer was **Robert Szyman – managing director of Polish Association of Plastic Processors**. His lecture's title was: "Planned EU regulation in relation to plastic packaging" in which he characterized Polish legal ecosystem in respect of packaging and packaging wastes. This system is lacking many rules, such as, inter alia: rules which would comprehensively regulate the problems concerning the Extended Responsibility of the Producers; the rules, implementing the Directive on single-use plastic products and the regulations arranging the introduction and functioning of the system in total. We have, therefore, a lot to do. The new draft of the Regulation of the European Union on Packaging and Packaging Waste, as being under the state of consultation, was discussed.
3. The lecture on "The role of packaging in circular economy" was delivered by **Krzysztof Wójcik, MSc, from the Research Network Łukasiewicz – Łódź Institute of Technology, Centre of Packaging**. He characterized the circular economy system which is defined by the following requirements:
   – it is a model of production and consumption which consists in sharing, borrowing, reuse, repair, renovating and recycling of the existing materials and products as long as it is possible → limitation of the waste to minimum;
   – in the discussed model, when the life cycle of the product is near to be ended, the raw materials and waste which derive from it, should be employed in the economy. They may be successfully utilized again, generating thus the additional value;
   – such approach stays in contrast with the traditional, linear economic model which is based on the scheme: 'take – produce – use – discard";
   – the linear model is based on large quantities of cheap and easily accessible materials and energies. The discussed model includes also the so-called planned consumability that is, designing the products in such a way as they would stop functioning after a defined time period.

The lecturer submitted also the principles of eco-designing and 9 Golden Principles of Plastic Packaging Designing (as contained in Polish Plastics Pact).

The last lecture in the mentioned session entitled "Composites made from biodegradable polymers – the new possibilities "was delivered by Dr Marta Musioł, Eng., from the Centre of Polymer and Carbon Materials of Polish Academy of Sciences (PAN). The author presented the structure of the selected biodegradable polymers and their application. They are employed in medicine, cosmetics, packaging and agro-chemistry. The author posed the question: why biodegradable composites? When answering, she stressed that the decisive factors included: reduction of the weight of the product, change of the external appearance and, of course, lower price. The author submitted the employed natural fillers which are used when producing composites from biodegradable polymers. They include as follows: sawdust, coffee grounds, wheat brans, disintegrated cork, ash, ramie (Boehemeria nivea) fibres, sisal fibres, jute (burlap) fibres and cotton fibres. Packaging made from biodegradable composites is subjected to recycling; they are the alternative in production of certain types of packaging. In the third session, also four lectures were presented.

The first one was delivered by Marta Krawczyk from Organization of Packaging Recycling Rekopol SA. Her lecture was entitled: "Eco-designing and selective collection as the tools of reaching the aims of recycling". The author submitted the range of the activities of her Organization and the employed systems of the selective collection of post-use packaging. She discussed the details of the principles of eco-designing of packaging.

The lecture "The research methods for food products in the context of packaging intended to come in the contact with food" was presented by Eng. Magdalena Lason-Rydel, MSc, from the Research Network Łukasiewicz – Łódź Institute of Technology. In the mentioned lecture, there were analysed the legal rules and the research methods concerning food packaging made from cardboard, plastics, paper, glass and packaging produced with the addition of the recycled materials. Recently, the problem of determining the impact of nanoparticles on the content of the packaging has been arisen

IN THE SPEECH OF MAGDALENA PANTOŁ, REPRESENTING AZOTY GROUP SA FROM TARNÓW BIOPLASTIC MATERIALS WERE CHARACTERIZED, WITH THE STRESS PUT ON THE FACT THAT THEY ARE POLYMERS, SUBJECTED TO BIODEGRADATION OR/AND COMING FROM RENEWABLE RAW MATERIALS.

in connection with the application of nanotechnologies in food packaging. The conclusion coming from the discussed lecture in this respect has been given below.

The main problem in production of functionalised packaging with nanoparticles is to guarantee food safety and to determine the degree of migration and absorption of nanoparticles from packaging materials to food products. In the nano-scale, the materials act in a completely different way and there is a lack of the established research methods how to study the discussed process. At the moment when the migration and toxicity of nanomaterials is better understood, the improvement of their pragmatic application will take place and the safety standards will be established. It is difficult today to determine the migration of nanoparticles from packaging to food, using prognostic models which consider only migrations based on diffusion. In the future, we should determine three sub-processes for the discussed studies; they could be differentiated for different nanoparticles in respect of migration: (I) due to the difference in concentration; the particle "penetrates" to the polymer of the packaging, (II) during the process of food packing, the nanoparticle dissociates to polymer and penetrates

PROF. BARTŁOMIEJ MAZELA, PHD., ENG., FROM UNIVERSITY OF LIFE SCIENCES IN POZNAŃ DELIVERED AN INFORMATION ABOUT THE ONGOING RESEARCH, BEING PERFORMED WITHIN THE FRAMES OF NCBR GRANT "XYLOMATRIX – PRODUCTION OF PACKAGING FROM RECYCLED LIGNIN-CELLULOSE FIBRES".

food product; (III) as a result of differences in concentration, the nanoparticle penetrates directly to food.

Dorota Żmudzińska, representing Polish Plastics Pact, delivered the lecture: "All begins from the project – Golden Principles of Polish Plastics Pact". The mentioned principles are as follows:

1. Increase of the volume of PET bottles for recycling
2. Elimination of problematic packaging and packaging elements
3. Elimination of empty space in packaging of too large volume as compared to its contents
4. Reduction of the excessive wrapping made from plastics
5. Increase of the suitability of PET thermoformed trays and other PET thermoformed packaging for recycling
6. Increase of the suitability of flexible packaging for recycling
7. Increase of the suitability of HDPE and PP stiff packaging for recycling
8. Reduction of primary plastics in B2B packaging
9. Placing the instructions for correct classification of waste, on the packaging

All this is so simple that it should function, but in a wider scale it somehow does not work.

The last lecture during the discussed conference was delivered by **Dr Ewa Kopania, Eng from the Research Network Łukasiewicz – Łódź Institute of Technology**. Its title was "Certification of UN packaging and products".

The certification of packaging may be voluntary or mandatory. The mandatory certification includes certification of packaging destined for transport of dangerous materials for UN sign. The discussed certification concerns packaging, big containers for bulk transport (DPPL) and large packaging and packaging accessories, bags, sacks, and also, boxes, chests and cages intended for road, railway, sea and air transport of dangerous materials – UN sign, in accordance with the rules of ADR, ADN, RID, IMDG-Code and IATA-DGR.

Voluntary certification: certification and certification sign appearing on the labels of the producers are the evidence of the involvement of the producer in the care of the highest quality and safety of the product delivered to the market, meeting the requirements of the consumers in 100%.

The voluntary certificate of the product means placing the symbol of certificate on the product (packaging) and attitude of the company in relation to the changes aiming at the quality improvement and product safety.

Depending on the needs, the Research Network Łukasiewicz – Łódź Institute of Technology conducts, apart from the mandatory certification, the voluntary certification, as well.

The fourth session was submitted in a form of posters – there were 7 posters in total and all of them presented the current studies of the employees of the Research Network Łukasiewicz – Łódź Institute of Technology, both those ones made at the order as well as the own ones.

The Conference was very popular event; it was the first such scientific conference held after the pandemic.

Packaging Review

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  - ensure that there is no conflict of interests – they should have no personal relationships or business relations with Authors,
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- The final version of the article is sent to the Author.
- Non-scientific articles do not need to be reviewed and they are accepted for publication by the Editor-in-Chief.

INFORMATION FOR THE AUTHORS

We kindly ask to submit to the editorial office author's application form available at www.packagingreview.eu with contact details, a title of the proposed article, number of pages, illustrations and tables as well as a brief abstract. After receiving information about the acceptance of the proposed article please submit the entire text prepared according to the editorial instructions as well as a complete declaration form.
Submitted articles are subjected to editorial assessment and receive a formal editorial identification number used in further stages of the editorial process. Every submitted article is reviewed. Publication is possible after receiving positive reviews.

GUIDELINES FOR PREPARING THE ARTICLES

- Articles for publication in „Packaging Review" should have scientific and research character and focus on innovations, trends and challenges of the industry.
- Articles must be original, not previously published (if the article is a part of another work i.e. PhD thesis, habilitation etc. the information about that should be placed in the reference section).
- The article should involve a narrow topic but treated thoroughly without repeating general knowledge information included in the widely known literature.
- If the problem is extensive, it should be it split into few articles for separate publications.
- Articles should be of a clear and logical structure: the material should be divided into parts with titles reflecting its content. The conclusions should be clearly stated at the end of the paper.
- The article should be adequately supplemented with illustrations, photographs, tables etc. however, their number should be limited to absolute necessity.
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- The article should not exceed 10 pages (1 page – 1 800 characters).
- The article should include post and e-mail addresses of the author (s).
- The article should be electronically submitted in *doc or *docx format and additionally PDF format. Equations should be written in the editors, with a clear distinction between 0 and O. If the equations exceed the width of column (8 cm) they must be moved, otherwise use double width column (16 cm).
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- Drawings and graphs must be clear and fit A4 size of the column.
- The text on the drawings cut to the size must be legible and not less than 2 mm.
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