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– THE INFLUENCE OF PAPER AND PLASTICS ON THE CONSUMER CHOICES

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Dear Readers!

The 14th edition of the "Safe Packaging" conference, organized by Alfa-Print publishing house, took place on November 19-20 in Lodz.
Gradually with the time, the idea of "safe packaging" was evolving and during the successive conferences it changed its range. The lecturers of the first events paid their attention, on the quality of performing the packaging in the light of protection and recognition of the packaged product and the utility of the packaging itself. The successive problems include barrier properties of the produced packaging and migration of different compounds to and from the packaging.
Today, according to the EU (and global) trends, the majority of the lectures is dedicated to sustainable production of packaging what results in protection of the environment from the waste load.
This year's event continues the sustainability direction. Such approach to packaging safety is an attempt to replace the most of the plastic packaging by paper products and barrier film coatings by the coating based on the natural raw materials, i.e. plant extracts and the processed natural materials e.g. starch. The successive current trend includes minimization of the production waste, together with the application of artificial intelligence (AI) for control of manufacturing processes.
I think we will hear even more about it next year, so I invite you to the 15th edition of the Safe Packaging Conference in November 2025!

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!

W dn. 19-20 listopada br. w Łodzi miała miejsce 14.edycja konferencji „Bezpieczne Opakowanie, zorganizowana przez wydawnictwo Alfa-Print.
W ciągu lat pojęcie „bezpieczne opakowanie" ewaluowało i podczas kolejnych konferencji zmieniało swój zakres. Podczas pierwszych konferencji prelegenci przede wszystkim zwracali uwagę na jakość wykonania opakowania w kontekście ochrony i rozpoznawania pakowanego produktu oraz użyteczność samego opakowania. Kolejne zagadnienia to właściwości barierowe wykonanych opakowań oraz migracja różnych związków do i z opakowania.
Dziś zgodnie z unijnymi (i światowymi) trendami większość wystąpień poświęcona jest zrównoważonej środowiskowo produkcji opakowań, co się przekłada na zabezpieczenie środowiska przed obciążeniem odpadami. Tegoroczna konferencja kontynuowała ten kierunek. Takie podejście do bezpieczeństwa opakowań jest próbą zastąpienia większość opakowań z tworzyw sztucznych produktami papierowymi oraz foliowych powłok barierowych powłokami opartymi na surowcach naturalnych tj. wyciągach roślinnymi i przetwarzanych materiałach naturalnych np. skrobi. Kolejny tegoroczny trend to minimalizacja odpadów produkcyjnych dzięki zastosowaniu sztucznej inteligencji do sterowania procesami produkcyjnymi.
Myślę, że w przyszłym roku usłyszymy o tym jeszcze więcej, więc już dziś zapraszam na 15. edycję konferencji Bezpieczne Opakowanie w listopadzie 2025!

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.

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THE IMPACT OF SCIENTIFIC RESEARCH ON CORRUGATED BOARD ON THE LIFECYCLE OF PACKAGING

WPŁYW BADAŃ NAUKOWYCH NAD TEKTURĄ FALISTĄ NA CYKL ŻYCIA OPAKOWAŃ

ABSTRACT: Corrugated board, a highly versatile and sustainable material, is widely used in both transport packaging and shelf-ready packaging (SRP). This article examines how scientific research has significantly contributed to understanding and improving the lifecycle of corrugated cardboard packaging. Through advancements in material design, structural optimization, and enhanced recycling processes, research has extended the usability and durability of corrugated packaging, while minimizing its environmental footprint. By focusing on both transport and SRP packaging, this paper highlights how scientific innovation promotes a circular economy, reduces waste, and increases resource efficiency. Additionally, the studies emphasize the importance of raising public awareness and fostering engineering practices that contribute to the sustainable development of packaging systems, playing a crucial role in modern logistics and retail.
Key words: corrugated board, packaging lifecycle, transport packaging, shelf-ready packaging, sustainability, recycling

STRESZCZENIE: Tektura falista, niezwykle wszechstronny i zrównoważony materiał, znajduje szerokie zastosowanie zarówno w opakowaniach transportowych, jak i półkowych (SRP). Artykuł analizuje, w jaki sposób badania naukowe znacząco przyczyniły się do pogłębienia wiedzy i poprawy cyklu życia opakowań z tektury falistej. Dzięki postępom w projektowaniu materiałów, optymalizacji konstrukcji oraz ulepszonym procesom recyklingu, badania wydłużyły okres użytkowania i trwałość opakowań, jednocześnie minimalizując ich wpływ na środowisko. Skupienie się na opakowaniach transportowych i SRP podkreśla, jak innowacje naukowe promują gospodarkę o obiegu zamkniętym, redukują ilość odpadów oraz zwiększają efektywność wykorzystania zasobów. Dodatkowo, badania te wskazują na znaczenie zwiększania świadomości społecznej oraz wspierania praktyk inżynierskich, które przyczyniają się do zrównoważonego rozwoju systemów opakowaniowych, odgrywając kluczową rolę we współczesnej logistyce i handlu detalicznym.
Słowa kluczowe: ektura falista, cykl życia opakowań, opakowania transportowe, opakowania SRP, zrównoważony rozwój, recykling

1. INTRODUCTION

1.1 THE ROLE OF CORRUGATED BOARD IN THE MODERN PACKAGING INDUSTRY

Corrugated board is one of the most widely used materials in the global packaging industry, especially in the fields of product transport and presentation. Its unique properties, such as lightness, mechanical strength, and shock absorption capability, make it an ideal material for protecting goods during transport. Corrugated board can be easily tailored to various shapes and sizes, making it highly versatile for both large transport packaging and smaller shelf-ready packaging (SRP).

1.2 THE IMPORTANCE OF TRANSPORT AND SRP PACKAGING

Transport and shelf-ready packaging (SRP) play a crucial role in logistics and retail. Transport packaging must provide maximum protection for products during transport, storage, and distribution to minimize the risk of damage. In contrast, SRP packaging, aside from its protective function, serves a significant marketing role by allowing products to be displayed directly on store shelves in an attractive and easy-to-handle manner.

1.3 THE RISE IN DEMAND FOR SUSTAINABLE PACKAGING

In recent years, there has been a global increase in demand for sustainable packaging due to growing environmental awareness among consumers and regulatory pressures related to environmental protection. Corrugated board, as a fully renewable and easily recyclable material, has become one of the key solutions supporting a circular economy. Increased attention to sustainable development has led manufacturers and distributors to increasingly choose corrugated board, thereby minimizing the use of non-renewable materials and reducing the carbon footprint.

1.4 PURPOSE OF THE ARTICLE

This article aims to demonstrate how scientific research on corrugated board impacts the lifecycle of packaging, both for transport and shelf-ready applications. The article will discuss key issues related to packaging design optimization, environmental impact, and the role of corrugated board in promoting sustainable development. The analysis based on scientific research will show how advances in computational mechanics, material strength, and recycling technology contribute to extending the lifecycle of these packaging materials, reducing waste, and increasing recycling efficiency. Additionally, the article will emphasize the importance of raising public awareness about the role of corrugated board in the modern packaging industry.

2. LITERATURE REVIEW – SCIENCE IN THE DEVELOPMENT OF CORRUGATED BOARD PRODUCTS

2.1 MECHANICAL PROPERTIES OF CORRUGATED BOARD

Corrugated board, widely used in packaging, has a complex structure that impacts its strength and flexibility. Both theoretical and experimental research provides insights into essential mechanical properties, such as elasticity and compression strength. Notably, Aboura et al. [1] and Biancolini [7] examined the elastic behavior of corrugated board through experimental analysis, demonstrating that numerical modeling can predict this material's mechanical properties. The work of Buannic et al. [8] and Cheon and Kim [9] expands this analysis by using plate models that account for homogenization to simplify the structural analysis of corrugated board. Additionally, Bartolozzi et al. [4-5] developed an equivalent material model for sinusoidal cores in sandwich structures, enabling accurate mechanical property predictions when applied to corrugated board.

2.2 APPLICATION OF HOMOGENIZATION IN CORRUGATED BOARD ANALYSIS

Homogenization techniques are crucial for analyzing corrugated board, allowing for the transformation of a complex structure into a simpler equivalent material model. Doghri et al. [11] extended this technique to composite materials with diverse plastic properties, which is particularly beneficial for materials like corrugated board. Altmann et al. [2] further expanded homogenization methods to multiscale structures, useful for modeling advanced corrugated board properties. The research of Garbowski and collaborators often highlights the importance of homogenization in analyzing corrugated board [14,20], exploring aspects such as mechanical properties under different conditions. For instance, Garbowski and Borecki [15] investigated the impact of futuristic flute shapes on mechanical parameters and production costs, suggesting the potential to adapt the structure for more robust and economical materials.

2.3 IMPACT OF ENVIRONMENTAL FACTORS ON CORRUGATED BOARD PROPERTIES

Environmental factors, such as humidity and temperature, significantly affect corrugated board properties, which is crucial for transport packaging. Szewczyk and Głowacki [24] examined the impact of humidity on the strength indicators of corrugated board, while Beck and Fischerauer [6] used homogenization techniques to model board deformations during production, improving the understanding of external conditions on packaging stability. Cornaggia and colleagues [10] broadened this analysis with numerical modeling of humidity and temperature impacts on the mechanical properties of corrugated board, which is essential for the packaging industry.

2.4 STRENGTH ANALYSIS OF CORRUGATED BOARD PACKAGING

A critical aspect of the lifecycle of corrugated board packaging is strength analysis, which enables design optimization and resource efficiency. Mrówczyński and colleagues [21] focused on the influence of boundary conditions on the bending stiffness of multilayer corrugated board, essential for transport packaging. Andrzejak et al. [3] studied the effect of perforations on load-bearing capacity, directly affecting the safety and functionality of SRP packaging. In this context, Garbowski [13] described common mistakes in load-bearing capacity estimation, underscoring the importance of accurate analysis methods.

2.5 REVIEW OF CORRUGATED BOARD APPLICATIONS IN ENGINEERING AND PACKAGING

Lastly, it is worth noting the broad applications of corrugated board, not only as packaging material but also as a construction component. Garbowski and Rutkowski [18] reviewed applications in various fields, from engineering to packaging, highlighting the material's potential as a cost-effective and sustainable solution in engineering and logistics. Park et al. [22] analyzed the properties of corrugated board as a layered composite, further supporting its role as a versatile and environmentally friendly material.

2.6 ARTIFICIAL INTELLIGENCE AND SOFT COMPUTING IN CARDBOARD CHARACTERIZATION

In the realm of packaging innovations, artificial intelligence (AI) is increasingly being utilized to enhance material classification processes. A recent study by Rogalka et al. [23] compared two AI-based methods for classifying types of corrugated board using images of deformed cross-sections. The first method combined a genetic algorithm with a feedforward neural network, while the second employed a convolutional neural network (CNN) for direct image classification. Both approaches achieved high accuracy, with the CNN slightly outperforming the first method. This advancement underscores AI's potential to improve efficiency and precision in the packaging industry.

2.7 SUMMARY AND FUTURE OUTLOOK

The studies reviewed in this section indicate that research on corrugated board significantly impacts the optimization of its lifecycle, especially for transport and SRP packaging. By analyzing mechanical properties, using homogenization techniques, and examining environmental impacts, researchers contribute to extending the lifespan of corrugated board packaging and enhancing its eco-friendliness.

The visionary outlook on the future of corrugated board has been presented in the work of Garbowski and Borecki [15], who explored new flute shapes previously unused in production. Their analysis of these futuristic fluting profiles, differing from traditional sinusoidal shapes, reveals corrugated board's design potential and the possibility of adapting its structure for specific mechanical requirements. This innovative approach not only broadens the material's potential applications but also suggests the potential for reduced production costs and improved strength parameters. As a result, these studies offer new perspectives for the packaging industry, suggesting directions for the development of composite materials like corrugated board to further support sustainable development and resource efficiency.

3. CHARACTERISTICS OF CORRUGATED BOARD PACKAGING

3.1 MECHANICAL AND STRUCTURAL PROPERTIES OF CORRUGATED BOARD

Corrugated board is a composite material consisting of one or more layers of flat paper sheets (liners) and at least one layer of corrugated paper (fluting). Due to its structure, corrugated board combines lightness with exceptional mechanical strength. The corrugated layer acts as a cushion, absorbing shocks and impacts, which is crucial for protecting products during transport. Additionally, the appropriate selection of paper weight and the number of layers allows tailoring the properties of corrugated board to specific packaging requirements, such as resistance to compression, tension, moisture, and bending. The mechanical properties of corrugated board, such as elasticity modulus, edge crush test (ECT) strength, and box compression test (BCT) strength, are essential for evaluating its suitability for various packaging applications. Scientific research in this area enables a better understanding of the behavior of corrugated board under load, facilitating the optimization of packaging design.

3.2 TRANSPORT PACKAGING: FUNCTIONS AND REQUIREMENTS

Transport packaging made of corrugated board must meet several requirements to effectively protect products throughout the extended supply chain, which includes loading, transportation, storage, and unloading. Compression strength and structural stability are key characteristics determining the effectiveness of protection against mechanical damage. Besides the protective function, transport packaging must be easy to stack on pallets, which enhances logistical efficiency.

An important aspect emphasized by scientific research is the optimization of transport packaging in terms of material usage. Reducing packaging weight while maintaining its strength helps lower transportation costs and CO_2 emissions. Research on corrugated board layer compositions and their arrangement allows maximizing strength with minimal material use.

3.3 SHELF-READY PACKAGING (SRP): MARKETING AND LOGISTICS FUNCTIONS

Shelf-ready packaging (SRP) serves two essential functions: product protection during transport and direct product display on store shelves. SRP is designed to be quickly and easily opened, displaying its contents without the need for repackaging. This type of corrugated board packaging plays a vital role in retail, especially in large retail chains, where rapid product turnover and minimal time for sales preparation are crucial.

From a scientific and engineering perspective, SRP must meet requirements related to aesthetics, durability, and ease of use. In corrugated board research, particular emphasis is placed on ensuring SRP is not only functional but also easily recyclable after its lifecycle ends. Additionally, SRP design involves research on printing, color durability, and visual quality, which directly impacts brand perception by consumers.

3.4 TECHNICAL CHALLENGES IN DESIGNING CORRUGATED BOARD PACKAGING

Designing corrugated board packaging involves numerous technical challenges. The main objective is to create packaging that is lightweight, strong, and easy to recycle. One primary challenge is optimizing the mechanical properties of corrugated board to provide adequate product protection while minimizing material use. The proper design of packaging is crucial not only for product protection but also for production and transportation costs.

Research on new technologies in corrugated board production, such as boards with increased strength at reduced thickness, aims to decrease raw material consumption and reduce packaging weight. There is also significant interest in researching biodegradable coatings and barrier layers that could replace traditional, more difficult-to-recycle materials coating packaging.

4. THE IMPACT OF SCIENTIFIC RESEARCH ON PACKAGING DESIGN

4.1 RESEARCH ON THE OPTIMIZATION OF CORRUGATED BOARD PACKAGING DESIGN

The optimization of corrugated board packaging design is one of the key research areas aimed at increasing material efficiency and improving mechanical properties. Research focuses on analyzing the structure of the board itself, as well as methods of forming and designing packaging that must meet specific requirements related to product protection, transport efficiency, and aesthetics.

Modern research on packaging design optimization frequently utilizes advanced computer simulation tools that enable modeling the mechanical properties of packaging under various loads. Using tools like the finite element method (FEM), engineers can accurately predict packaging behavior under real-life operational conditions, allowing the creation of more efficient designs that minimize material use.

A key research issue is finding a balance between packaging strength and weight. Advanced research enables creating designs that provide adequate product protection while reducing raw material usage. Research on innovative solutions, such as corrugated board with varying thicknesses or internal structures, helps create packaging better suited to the demands of the logistics and retail industries.

4.2 APPLICATION OF COMPUTATIONAL MECHANICS IN PACKAGING STRENGTH ANALYSIS

Computational mechanics, particularly the finite element method (FEM), plays a crucial role in analyzing the strength of

corrugated board packaging. These tools enable precise modeling of packaging mechanical behavior under various loads, such as vertical pressure, impacts during transport, or compression in warehouses.

Computer simulations allow for the prediction of packaging deformations in real conditions, helping engineers optimize their design. Research in this field shows that by using computational techniques, it is possible to significantly improve packaging strength without increasing its weight, which is essential for transport efficiency and environmental protection. The application of computational mechanics also enables the study of new, innovative solutions, such as variable layer thicknesses in different parts of the packaging, which allows for better adaptation to specific needs, for example, for products with irregular shapes or high weight. Additionally, simulations can be used to test packaging in different environmental conditions, such as high humidity or low temperatures, allowing for the creation of packaging more resistant to external factors.

4.3 INNOVATIONS IN PACKAGING DESIGN TO INCREASE DURABILITY AND REDUCE MATERIAL USAGE

In recent years, scientific research has led to numerous innovations in corrugated board packaging design, contributing to increased durability while reducing raw material usage. Key innovations include changes in the structure of the corrugated board itself, such as the use of multi-layer compositions or new types of fluting (e.g., microflutes) that offer better strength with less thickness.

Another innovative approach is the development of more environmentally friendly coatings and adhesives used in packaging production. Traditional coatings often complicate the recycling process because they contain materials that are difficult to separate from the paper. Current research focuses on developing biodegradable coatings that not only protect the packaging contents but also easily decompose in recycling processes, reducing their environmental impact.

Moreover, innovations in corrugated board packaging production include automation of production processes, which allows for greater precision in cutting and folding packaging. This enables the creation of more complex structures that better meet logistical and marketing requirements while minimizing production waste.

4.4 EXAMPLES OF INNOVATIVE PACKAGING DESIGNS

Many companies use scientific research findings to introduce innovative packaging solutions that enhance both durability and sustainability. One example is modular packaging that can be easily folded and adjusted to different product sizes. Other innovations include dual-function packaging, which can serve as transport packaging and then, with minimal modifications, become shelf-ready packaging (SRP).

Another example of innovation is “smart” packaging, which includes built-in sensors to monitor storage and transport conditions, such as humidity or temperature. These technologies allow for even greater product protection and waste minimization, which is crucial in industries such as pharmaceuticals and food.

5. LIFECYCLE OF CORRUGATED BOARD PACKAGING

5.1 LIFECYCLE ANALYSIS OF PACKAGING (FROM PRODUCTION TO RECYCLING)

The lifecycle of corrugated board packaging encompasses several key stages, starting from the production of raw materials, through packaging manufacturing, usage, and finally, the end-of-life stage, where it is either disposed of or recycled. Current research focuses on each of these stages to minimize the negative environmental impact of packaging while maximizing its functionality.

During the production phase, particular attention is given to the sustainable sourcing of raw materials, such as paper from renewable sources, including forests certified by the Forest Stewardship Council (FSC). Another significant challenge is optimizing the corrugated board manufacturing process to reduce energy and water consumption and lower CO_2 emissions. Scientific research on new production technologies aims to not only reduce the environmental footprint but also improve process efficiency, which has a direct impact on production costs and competitiveness.

The usage stage of packaging includes its utilization in logistics, storage, and retail. Corrugated transport packaging must provide maximum product protection, helping to minimize losses due to damage during transport. Shelf-ready packaging (SRP), in turn, must be functional and aesthetically pleasing to meet both logistical and marketing needs.

At the final stage of the lifecycle of corrugated board packaging, recycling plays a key role. Due to the high recyclability of corrugated board, most packaging can be reprocessed and reused in the production of new packaging, significantly reducing the demand for primary raw materials and lowering waste generation. Research on improving recycling processes, including the separation of board layers and reduction of material contamination, aims to further enhance this process.

5.2 RESEARCH ON EXTENDING THE USABILITY PERIOD OF CORRUGATED BOARD PACKAGING

One key research area is extending the usability period of corrugated board packaging to reduce its environmental impact by decreasing the need for producing new packaging. Longer-lasting packaging allows for multiple uses, reducing demand for raw materials and energy. Research on the durability of corrugated board in harsh conditions (e.g., high humidity, temperature fluctuations) and on material modifications that enhance its resistance to damage contributes to lengthening the lifecycle of packaging products.

Extending the usability period is particularly important for transport packaging, which must be durable enough to withstand multiple loading, transport, and unloading cycles without compromising its protective properties. In this context, research focuses on increasing compression resistance and improving the structural stability of packaging.

5.3 THE IMPORTANCE OF REUSE AND RECYCLING IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Reuse and recycling of corrugated board are crucial elements of sustainable development. From the perspective of the packaging lifecycle, the possibility of multiple uses and easy recyclability make corrugated board one of the most eco-friendly packaging materials. Research on packaging reuse focuses on developing logistics systems that enable efficient recovery and reintegration of packaging into the supply chain. Corrugated board recycling is one of the most advanced recycling systems worldwide, with recovery rates often exceeding [85%]. The recycling process involves separating cellulose fibers, which can then be processed into new packaging products. Research in this area focuses on improving recycling efficiency, including reducing contaminants and increasing the number of cycles in which cellulose fibers can be reused.

5.4 THE IMPACT OF CORRUGATED BOARD PACKAGING ON WASTE REDUCTION AND CARBON FOOTPRINT REDUCTION

One of the most important aspects of the lifecycle of corrugated board packaging is its impact on the environment, including waste reduction and carbon footprint. Due to its recyclability and reusability, corrugated board packaging contributes significantly to reducing the amount of waste reaching landfills. Compared to packaging made from materials that are harder to recycle, such as plastic, corrugated board offers a much more eco-friendly solution.

Scientific research shows that appropriately designed corrugated board packaging can also help reduce the carbon footprint associated with packaging production and transport. Lightweight packaging requires less energy for transport, and its production from renewable resources (paper) generates lower CO_2 emissions than packaging made from plastic or metal materials.

6. IMPORTANCE OF CORRUGATED BOARD PACKAGING FOR THE CIRCULAR ECONOMY

6.1 THE ROLE OF SCIENTIFIC RESEARCH IN PROMOTING A CIRCULAR ECONOMY

The circular economy (CE) is an economic model aimed at minimizing waste and maximizing resource utilization through recycling, material reuse, and reducing the consumption of primary raw materials. Corrugated board, as a packaging material, aligns perfectly with the principles of the circular economy due to its high recyclability and renewability.

Scientific research plays a crucial role in optimizing the lifecycle of corrugated board packaging, enabling the effective implementation of circular economy principles in practice.

Scientists and engineers are developing new technologies for corrugated board production that minimize waste at every stage of the production process. This includes reducing energy and raw material consumption in manufacturing and optimizing packaging for reuse and recycling. Through this research, it is possible to close the lifecycle loop of packaging products, which significantly reduces environmental impact.

Additionally, research on new, biodegradable coatings for corrugated board packaging contributes to further sustainability, eliminating the need for non-ecological coatings and adhesives that would complicate the recycling process. These innovations enable corrugated board to better meet the requirements of a circular economy.

6.2 THE IMPACT OF SUSTAINABLE PACKAGING ON RECYCLING PROCESSES AND MATERIAL REUSE

One of the main aspects of the circular economy is the efficient processing of used materials for reuse. Corrugated board plays a key role here, as it is one of the most recyclable packaging materials. This capability allows for a reduced need for primary raw materials and limits the amount of waste reaching landfills.

The corrugated board recycling process is already well developed, but scientific research is continually working to improve it. Modern recycling technologies allow for an increased number of cycles in which corrugated board can be reprocessed, directly impacting waste reduction. Besides traditional recycling processes, research is also focused on innovations such as using fibers derived from corrugated board for producing other materials, such as biodegradable composites or insulation.

Additionally, the reuse of corrugated board packaging before recycling is another vital element of the circular economy. Many companies are implementing return and reuse systems for packaging, which significantly extends their lifecycle. Research on packaging durability and on new technologies that enable multiple uses is essential for advancing this aspect of the circular economy.

6.3 EXAMPLES OF COMPANIES AND INDUSTRIES USING INNOVATIVE CORRUGATED BOARD PACKAGING SOLUTIONS

A growing number of companies across various industries are introducing innovative corrugated board packaging solutions that support the circular economy. In the e-commerce sector, for example, many companies are implementing reusable packaging that customers can return, reducing the need for new packaging. Examples include modular packaging that can be adjusted to different product sizes and shapes and reused in subsequent shipping cycles.

The food industry also uses innovative solutions, such as SRP packaging that can be transformed from transport packaging into display packaging without additional materials or processing. This type of packaging not only minimizes costs and handling time in retail locations but also reduces waste.

In the furniture and household appliances industries, corrugated board is increasingly used as a substitute for traditional packaging materials, such as styrofoam or plastic. Companies are introducing specially designed corrugated board packaging that provides the same level of protection with a significantly smaller environmental impact. Thanks to innovations in structure and strength, corrugated board is becoming more competitive with other materials.

6.4 CHALLENGES AND FUTURE OF SUSTAINABLE CORRUGATED BOARD PACKAGING

Despite the many successes in developing sustainable corrugated board packaging, there are still numerous challenges to overcome. One of the main challenges is ensuring that packaging is durable and resistant to mechanical damage while also being fully recyclable. The development of more advanced biodegradable coatings and adhesives is one of the most critical tasks researchers aim to solve.

Another challenge is educating consumers and companies about the benefits of recycling corrugated board packaging. Although the corrugated board recycling process is well-developed, it is not always fully utilized due to a lack of awareness about proper handling of packaging waste.

The future of corrugated board packaging lies in the ongoing development of production technologies that reduce raw

material and energy consumption while increasing functionality and the potential for multiple uses. Advancements in digitalization and automation of production processes may also bring significant benefits in terms of efficiency and waste reduction.

7. SOCIAL IMPACT OF RESEARCH ON CORRUGATED BOARD PACKAGING

7.1 INCREASING SOCIAL AWARENESS OF SUSTAINABLE PACKAGING

Scientific research on corrugated board packaging plays a crucial role in raising social awareness about sustainable development and eco-friendly packaging solutions. An increasing number of consumers and companies are beginning to understand the environmental impact of packaging materials. Through research based on lifecycle analyses (LCA) and technological innovations, consumers now have access to information that helps them make more environmentally conscious choices.

One of the primary educational outcomes of corrugated board research is the promotion of informed purchasing decisions. Consumers, equipped with knowledge about recyclability and the benefits of sustainable packaging, can make choices that support a circular economy. Consequently, demand is growing for products packaged in recyclable materials, placing pressure on manufacturers to adopt more eco-friendly solutions.

Additionally, educational campaigns led by industry organizations, supported by scientific research, encourage better management of packaging waste. The introduction of new recycling regulations and return programs, such as deposit systems, results from increased public and legislative awareness. In this way, research on corrugated board packaging directly influences consumer behavior and environmental policy.

7.2 EDUCATING CONSUMERS AND COMPANIES ON THE BENEFITS OF RECYCLING AND REUSING PACKAGING

Recycling and reusing corrugated board packaging are areas that require the involvement of not only producers but also consumers and the entire retail and industrial sectors. Scientific research contributes to developing effective recycling and reuse systems, and the results must be effectively communicated to both businesses and society.

In recent years, there has been a growing number of initiatives aimed at educating the public about recycling. Examples of such actions include informational campaigns in the media, ecological workshops, and educational programs in schools that promote responsible waste management. Thanks to these initiatives, awareness of the importance of waste segregation and the possibilities offered by corrugated board recycling is rising. Companies are increasingly engaging in Corporate Social Responsibility (CSR) activities, aimed at promoting sustainable practices, including using recyclable packaging and reusing resources.

Equally important is educating businesses, especially in the logistics and retail sectors, where corrugated board packaging plays a key role. Research on recycling and reuse opportunities provides companies with insights into optimizing packaging processes and waste management. For businesses, implementing sustainable development strategies is becoming increasingly important from a competitive standpoint, as customers are more attentive to the ecological approach of producers.

7.3 THE IMPACT OF SCIENTIFIC RESEARCH ON THE DEVELOPMENT OF ECO-FRIENDLY PRACTICES IN LOGISTICS AND RETAIL

Logistics and retail are sectors where innovations in corrugated board packaging can bring significant benefits to both the environment and operational efficiency. Research on transport and shelf-ready packaging (SRP) made from corrugated board contributes to the development of more sustainable practices in these industries.

In logistics, one of the key issues is reducing the weight and volume of packaging, which helps lower transportation costs and CO_2 emissions. Research on the optimization of corrugated transport packaging allows for the design of lighter and stronger packaging that protects goods with minimal raw material use. Innovations in this field, such as the use of variable thickness corrugated board or smart packaging that monitors transport conditions, help companies achieve their sustainable development goals.

In retail, SRP packaging plays a crucial role in enhancing the efficiency of warehousing processes and product display on shelves. Research on SRP packaging focuses on designing solutions that are both functional and aesthetically pleasing, which aids in product promotion and reduction of packaging waste. Sustainable SRP packaging can be easily recycled after use, reducing the amount of waste generated by retail operations. Additionally, research on packaging materials enables the creation of more environmentally friendly solutions that meet logistical and marketing requirements.

7.4 RESEARCH AS A TOOL FOR SUPPORTING THE DEVELOPMENT OF ECO-FRIENDLY PRACTICES

As more companies commit to achieving sustainable development goals, scientific research becomes crucial for developing and implementing innovative packaging solutions. This research provides companies with knowledge about modern technologies that can support more eco-friendly practices in both production and packaging use.

Scientists working with the private sector help companies identify opportunities to optimize packaging, warehousing, and transport processes, leading to more efficient resource utilization and waste reduction. Through the collaboration of science and industry, it is possible to develop innovative packaging materials that are not only efficient and durable but also easy to recycle or biodegrade.

For example, research on new forms of corrugated board and biodegradable coatings contributes to creating more eco-friendly alternatives to traditional packaging. Companies, by leveraging research results, can introduce more environmentally friendly products to the market, which not only helps protect the environment but also builds a positive brand image among consumers.

8. FUTURE OF CORRUGATED BOARD PACKAGING

8.1 PROSPECTS FOR THE DEVELOPMENT OF CORRUGATED BOARD PACKAGING: NEW TECHNOLOGIES AND MATERIALS

The future development of corrugated board packaging will be driven by growing demands for sustainable development, technological innovation, and regulatory changes related to waste management. Future corrugated board packaging will need to meet both logistical process optimization challenges and rising consumer expectations for eco-friendly products.

One of the key areas for future development will be further material optimization. Scientists are working on creating new forms of corrugated board with higher strength while using fewer raw materials. An example is the development of microflute board, characterized by reduced thickness but excellent mechanical properties, allowing for a decrease in packaging weight without compromising durability.

Additionally, new production technologies are being developed for manufacturing corrugated board from organic materials, such as plant waste or biopolymers. These innovations can significantly impact the sustainability of packaging, reducing dependency on primary resources and lowering greenhouse gas emissions associated with corrugated board production.

8.2 OPPORTUNITIES TO EXPAND THE USE OF SRP AND TRANSPORT PACKAGING IN VARIOUS INDUSTRY SECTORS

Corrugated board packaging already plays a key role in many industries, but its full potential has yet to be fully realized. In the future, a significant increase in the use of corrugated board packaging is anticipated in industries that have traditionally relied on other materials, such as plastic or metal.

In the e-commerce sector, with the rise of online shopping, demand for lightweight, durable, and eco-friendly packaging will grow. Corrugated board is an ideal solution due to its customizable structure for individual e-commerce needs and its easy recyclability by consumers. Innovations in packaging personalization, which allow for adjusting the packaging to diverse products, will also play an increasing role.

In the food sector, corrugated board can replace traditional materials such as styrofoam, especially for packing refrigerated and frozen goods. Research on moisture-resistant corrugated board suitable for low temperatures enables expanding its applications in food storage and transport. This makes it possible to create packaging that not only meets product protection requirements but is also more environmentally friendly.

8.3 THE ROLE OF COLLABORATION BETWEEN SCIENCE AND INDUSTRY IN THE FURTHER DEVELOPMENT AND IMPLEMENTATION OF INNOVATIONS

The future of corrugated board packaging largely depends on effective collaboration between the scientific sector and industry. Joint research and development projects involving both academic institutions and production companies enable faster implementation of innovative solutions that meet market requirements.

One of the most important aspects of this collaboration is the development of new packaging production technologies that reduce environmental impact while increasing operational efficiency. Scientists working with corrugated board manufacturers develop new manufacturing methods that reduce energy, water, and raw material consumption during production. These innovations may include developing more efficient, less energy-intensive recycling processes, as well as corrugated board processing techniques that improve its mechanical properties without increasing thickness.

Collaboration between science and industry is also key in establishing standards for sustainable packaging. Scientific research provides companies with data and tools to evaluate the environmental footprint of their products, which, in turn, influences strategic decision-making. Production companies can adjust their processes to meet growing regulatory requirements and consumer expectations.

8.4 FUTURE TRENDS IN SUSTAINABLE PACKAGING

In the coming years, the main trends in corrugated board packaging will involve further material optimization and sustainable practices. It is anticipated that new production technologies will emerge, enabling the manufacturing of packaging in an even more efficient way, with lower raw material and energy consumption. Digitalization and automation of production processes will also grow in importance, potentially contributing to increased precision in packaging production, waste minimization, and shorter production times.

Another key trend will be the development of smart packaging that can monitor storage and transport conditions, such as temperature, humidity, or vibration levels. These types of solutions could be especially significant in industries such as pharmaceuticals or food logistics. Smart corrugated board packaging will combine functionality with a low environmental impact, making it an ideal solution for the future.

IN THE COMING YEARS, THE MAIN TRENDS IN CORRUGATED BOARD PACKAGING WILL INVOLVE FURTHER MATERIAL OPTIMIZATION AND SUSTAINABLE PRACTICES

9. SUMMARY

9.1 KEY FINDINGS ON THE IMPACT OF RESEARCH ON CORRUGATED BOARD ON PACKAGING LIFECYCLE

Scientific research on corrugated board plays a crucial role in understanding and improving the lifecycle of packaging made from this material. Studies clearly show that corrugated board is an exceptionally versatile material, offering high mechanical strength while being environmentally friendly. The impact of this research includes the development of new production technologies, optimization of packaging design for strength and sustainability, and improvements in recycling processes, which significantly extend the lifecycle of packaging.

One of the key findings is that innovations in the design of corrugated board, such as reducing thickness while maintaining strength, allow for reducing the amount of raw materials used, which directly impacts the reduction of the carbon footprint of packaging. Research on biodegradable coatings and adhesives further enhances the sustainable nature of corrugated board, enabling full recycling of the material without quality loss.

9.2 IMPORTANCE OF RESEARCH IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Research on corrugated board aligns with the global trend of seeking more sustainable solutions in the packaging industry. Thanks to scientific studies, corrugated board has become one of the leading materials supporting the circular economy, which aims to minimize waste and maximize resource use.

Studies on corrugated board packaging demonstrate how innovative design approaches can reduce waste and extend product lifecycles. Moreover, this research plays a key role in raising social awareness of recycling and reusing materials, which is essential for building sustainable practices among both consumers and companies. The packaging industry is constantly evolving, and scientific research contributes to the creation of new, eco-friendly products that support the responsible use of natural resources.

9.3 OPPORTUNITIES FOR FURTHER RESEARCH AND DEVELOPMENT DIRECTIONS FOR CORRUGATED BOARD PACKAGING

Although research on corrugated board has already yielded many valuable results, there are still numerous areas that can be further developed. One of the key development directions is the ongoing optimization of recycling processes to make them even more efficient and adaptable to changing market requirements. Studies on increasing the number of recycling cycles and improving the quality of recycled material can further reduce the need for primary raw materials.

Another area for future research is the development of smart packaging, which can monitor product transport and storage conditions. Combining sensor technology with eco-friendly materials like corrugated board could open up new possibilities in sectors requiring specific storage conditions, such as the pharmaceutical and food industries.

As sustainability demands increase, scientists will also need to explore ways to further reduce raw material use, both through improved packaging design and the development of new, biodegradable materials. Strengthening collaboration between research institutions and industry will be essential for further progress in this area, as this synergy enables faster implementation of innovations in the market.

9.4 THE ROLE OF SCIENCE AND INNOVATION IN THE FUTURE OF THE PACKAGING INDUSTRY

In the future, the role of science and research on corrugated board will become even more critical, especially in the context of rising consumer expectations and environmental protection regulations. Scientific innovations will not only drive the development of new materials and technologies but also influence how the packaging industry operates, from design and production to usage and recycling.

The packaging industry faces the challenge of reducing its environmental impact, and corrugated board, with its unique properties, is becoming a material of the future that can meet these demands. Science will play a vital role in ensuring that this material continues to be developed and optimized to meet future challenges, while contributing to building a more sustainable world.

BIBLIOGRAPHY

1. Aboura, Z., Talbi, N., Allaoui, S., & Benzeggagh, M. L. (2004). "Elastic behavior of corrugated cardboard: Experiments and modeling." Composite Structures, 63(1), 53–62. https://doi.org/10.1016/S0263-8223(03)00131-4
2. Altmann, R., Henning, P., & Peterseim, D. (2021). "Numerical homogenization beyond scale separation." Acta Numerica, 30, 1–86. https://doi.org/10.1017/S0962492921000015
3. Andrzejak, K., Mrówczyński, D., Gajewski, T., & Garbowski, T. (2024). "Investigating the Effect of Perforations on the Load-Bearing Capacity of Cardboard Packaging." Materials, 17(17), 4205.

4. Bartolozzi, G., Baldanzini, N., & Pierini, M. (2014). "Equivalent properties for corrugated cores of sandwich structures: A general analytical method." Composite Structures, 108(1), 736–746. https://doi.org/10.1016/j.compstruct.2013.10.012
5. Bartolozzi, G., Pierini, M., Orrenius, U., & Baldanzini, N. (2013). "An equivalent material formulation for sinusoidal corrugated cores of structural sandwich panels." Composite Structures, 100, 173–185. https://doi.org/10.1016/j.compstruct.2012.12.042
6. Beck, M., & Fischerauer, G. (2022). "Modeling Warp in Corrugated Cardboard Based on Homogenization Techniques for In-Process Measurement Applications." Applied Sciences (Switzerland), 12(3). https://doi.org/10.3390/app12031684
7. Biancolini, M. E. (2005). "Evaluation of equivalent stiffness properties of corrugated board." Composite Structures, 69(3), 322–328. https://doi.org/10.1016/j.compstruct.2004.07.014
8. Buannic, N., Cartraud, P., & Quesnel, T. (2003). "Homogenization of corrugated core sandwich panels." Composite Structures, 59(3), 299–312. https://doi.org/10.1016/S0263-8223(02)00246-5
9. Cheon, Y.-J., & Kim, H.-G. (2015). "An equivalent plate model for corrugated-core sandwich panels." Journal of Mechanical Science and Technology, 29(3), 1217–1223. https://doi.org/10.1007/s12206-015-0235-6
10. Cornaggia, A., Gajewski, T., Knitter-Piątkowska, A., & Garbowski, T. (2023). "Influence of Humidity and Temperature on Mechanical Properties of Corrugated Board-Numerical Investigation." BioResources, 18(4), 7490–7509. https://doi.org/10.15376/biores.18.4.7490-7509
11. Doghri, I., el Ghezal, M. I., & Adam, L. (2016). "Finite strain mean-field homogenization of composite materials with hyperelastic-plastic constituents." International Journal of Plasticity, 81, 40–62. https://doi.org/10.1016/j.ijplas.2016.01.009
12. Duong, P. T. M. (2017). "Analysis and simulation for the double corrugated cardboard plates under bending and in-plane shear force by homogenization method." International Journal of Mechanics, 11, 176–181.
13. Garbowski, T. (2023). "The most common mistakes when estimating the load-bearing capacity of corrugated board packaging." Przegląd Papierniczy, 79(9), 485–488.
14. Garbowski, T. (2024). "The role of homogenization in predicting the load-bearing capacity of corrugated packaging – a short review of methods and applications." Przegląd Papierniczy, 5(80), 485–492.
15. Garbowski, T., Borecki, P. (2024). "Analysis of the impact of futuristic corrugated layer shape on mechanical properties and cost of single-wall corrugated board | Analiza wpływu futurystycznych kształtów warstwy pofalowanej na parametry mechaniczne i koszt jednościennej tektury falistej." Przegląd Papierniczy, 80(11), 271-277.
16. Garbowski, T., Cornaggia, A., Gajewski, T., & Grabski, J.K. (2024). "Identification of material and structural parameters of corrugated board in production and converting processes." EUROMECH COLLOQUIUM 642 International Colloquium on Multiscale and Multiphysics Modelling for Advanced and Sustainable MaterialsAt: Rome, Italy
17. Garbowski, T., Knitter-Piątkowska, A., & Mrówczyński, D. (2021). "Numerical homogenization of multi-layered corrugated cardboard with creasing or perforation." Materials, 14(14) 3786. https://doi.org/10.3390/ma14143786
18. Garbowski, T., Rutkowski, J. (2024). "Corrugated Board as a Versatile Material for Packaging and Engineering Structures – An Overview of Applications | Tektura falista jako wszechstronny materiał do opakowań i konstrukcji inżynierskich - przegląd zastosowań." Przegląd Papierniczy, 80(12) (in print).
19. Luong, V. D., Abbes, F., Hoang, M. P., Duong, P. T. M., & Abbes, B. (2021). "Finite element elastoplastic homogenization model of a corrugated-core sandwich structure." Steel and Composite Structures, 41(3), 437–445. https://doi.org/10.12989/scs.2021.41.3.437
20. Mrówczyński, D., Gajewski, T., Grabski, J.K., & Garbowski, T. (2024). "Verification of numerical homogenization for corrugated boards through experimental tests and simulations." 43rd Solid Mechanics Conference: SolMech 2024, 249.
21. Mrówczyński, D., Pozorska, J., Garbowski, T., & Pozorski, Z. (2023). "Bending Stiffness of Unsymmetrical Multilayered Corrugated Board: Influence of Boundary Conditions." BioResources, 18(4), 7611–7628. https://doi.org/10.15376/biores.18.4.7611-7628
22. Park, K.-J., Jung, K., & Kim, Y.-W. (2016). "Evaluation of homogenized effective properties for corrugated composite panels." Composite Structures, 140, 644–654. https://doi.org/10.1016/j.compstruct.2016.01.002
23. Rogalka, M., Grabski, J., & Garbowski, T. (2023). "A comparison of two various artificial intelligence approaches for the corrugated board type classification." The 4th International Electronic Conference on Applied Sciences, 1–6.
24. Szewczyk, W., & Głowacki, K. (2014). "Effect of humidity on paper and corrugated board strength parameters | Wpływ wilgotności na wskaźniki wytrzymałościowe tektury falistej." Fibres and Textiles in Eastern Europe, 22(5), 133–137.

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SUSTAINABLE PACKAGING – THE INFLUENCE OF PAPER AND PLASTICS ON THE CONSUMER CHOICES

ZRÓWNOWAŻONE OPAKOWANIE, CZYLI WPŁYW PAPIERU I PLASTIKU NA WYBORY KONSUMENCKIE

ABSTRACT: In the present paper, the effect of packaging materials, i.e. paper and plastics on the consumer choices and their role in the context of sustainable development have been analysed. The consumers perceive the packaging as the key element of the product's quality and trust in the mark; their preferences are more and more frequently addressed to the organic (ecological) solutions. Paper packaging, although being considered as more environment-friendly, has its functional limitations; on the other hand, plastics – in spite of negative ecological image – offers significant profits in respect of products' protection and energetic efficiency. In the paper, the role of the consumer education, effective communication and designing of packaging in accordance with the principles of sustainable development has been also discussed. It increases the approval of the packaging among the ecology-aware users.
Key words: sustainable packaging, plastics, paper, ecology consumer choices

STRESZCZENIE: Artykuł analizuje wpływ materiałów opakowaniowych – papierowych i plastikowych – na wybory konsumenckie oraz ich rolę w kontekście zrównoważonego rozwoju. Konsumenci postrzegają opakowania jako kluczowy element jakości produktu i zaufania wobec marki, a ich preferencje coraz częściej skłaniają się ku rozwiązaniom ekologicznym. Opakowania papierowe, choć uważane za bardziej przyjazne środowisku, mają swoje ograniczenia funkcjonalne, natomiast plastik, pomimo negatywnego wizerunku ekologicznego, oferuje istotne korzyści w zakresie ochrony produktów i wydajności energetycznej. W artykule podkreślono również znaczenie edukacji konsumentów, efektywnej komunikacji oraz projektowania opakowań zgodnie z zasadami zrównoważonego rozwoju, co zwiększa ich akceptację wśród świadomych ekologicznie użytkowników.
Słowa kluczowe: zrównoważone opakowanie, plastik, papier, ekologia, wybory konsumenckie

INTRODUCTION

Packaging is a fundamental element of communication between the consumer and product. It affects directly the purchasing decisions and the perception of the consumers, using the visual and sensory elements (Przewoźna-Skowrońska, 2016). In the conditions of the increasing ecological awareness, the consumers perceive often the paper packaging as being more environment-friendly and healthier in comparison to plastic packaging. The conducted studies indicate that safety is the most important requirement, expected for the packaging, in the case of 90% of the consumers whereas 70% recognises the safety of use as being very important (Kawecka& Cholewa-Wójcik, 2017). The purpose of the present paper was to analyse the effect of the packaging material (paper and plastics) on the purchasing decisions of the consumers in the light of the sustainable development. The article is aimed at evaluation how the different properties of packaging such as aesthetics, functionality, biodegradability and impact of the environment shape the perception of the consumers and their preferences. Moreover, the intention of the paper is to show the advantages and limitations of paper and plastic packaging, with the consideration of their impact on the environment, and to indicate the recommendations for design of packaging consistent with the principles of the sustainable development which satisfy the growing expectations of the consumers and the ecological challenges.

THE IDEA OF THE SUSTAINABLE DEVELOPMENT

The concept of the sustainable packaging is focused of design, manufacture and use of packaging materials in the way which minimizes their negative effect on the natural environment and society at the each life cycle of product. The mentioned process includes stages of production, transport and application and final stages of disposal or recycling. The key purpose of the of the sustainable packaging is to limit the emission of greenhouse gases (GHG), lowering of energy use and reduction of the waste, deposed of the landfills what stays in the conformity with the wider strategies of closed economy (Muthu, 2021). Wendy Jedlicka presents the complex approach to designing of packaging, with the consideration of the sustainable development principles. The authors stresses that the traditional role of packaging, consisting in the protection of, informing about and sale of the product, must be widened by the minimization of the impact on the environment (Jedlicka, 2009). The utilization of renewable and recyclable materials in the sustainable packaging is based on he principle of decreasing the requirements of the natural raw materials and minimization of the impact on the environment. In practice, it means the application of materials which may be easily transformed or they originate from renewable sources such as plant cultivation or secondary raw materials. The discussed strategy allows limitation of the use of natural resources what has a key meaning in the light of the increasing consumption and decreasing resources of the Globe (Marsh& Bugusu, 2007). Optimization of manufacturing processes in the context of the sustainable packaging consists in the implementation of technologies and practices which reduce the use of energy and natural resources and, also, minimize emissions of substances harmful to the environment. Such approach is a significant element of pro-ecological strategies because the manufacturing processes generate often big quantities of contamination and require considerable energy outlays. Designing of the packaging when thinking about the product's life cycle and education and involvement of the consumers create the integrated approach to the sustainable packaging which is focused on the minimization of the impact on the environment at every stage of the product' s use and on the active participation of the consumers in pro-ecological processes (Verghese et al., 2012).

PAPER VERSUS PLASTIC PACKAGING – ADVANTAGES AND DRAWBACKS

Paper packaging is universally recognised as a favourable solution within the frames of the sustainable development and it is often treated and more ecological alternative to plastics. The discussed packaging reveals, however, advantages as well as weak points (limitations) which shape their effectiveness and the range of application in various industrial sectors. Paper packaging is biodegradable what means that it is subjected to degradation relatively quickly in the natural conditions. In the countries where the recycling infrastructure is well developed, paper may be also easily processed what reduces the quantity of waste which are directed to landfills. Moreover, it is also subjected to natural decay, not causing the contamination of seas and oceans what takes place in the case of plastics. If the paper manufacture derives from the forests, managed in the sustainable way, we obtain the renewable resource of organic origin which is produced by the more environment-friendly method. The paper packaging is, however, characterized by certain limitations. The process of their production requires big outlays of water and energy and, also, generates potential chemical contaminations. In respect of functional properties, paper reveals lower resistance to humidity and mechanical damages what restricts its application in the storage and transport of certain products. To increase its stability, paper is often coated with the protective layers but it affects negatively its recyclability. Besides it, production of paper packaging may be more expensive than production of certain plastics what has an impact on their economic competitiveness. Additionally, paper's quality is lowered at each recycling cycle due to degradation of cellulose fibres what restricts its possibilities of multiple processing and use (Pivnenko et al., 2015).

Plastic packaging plays a key role in many sector of the economy, offering the significant functional and economic advantage and, simultaneously create the meaningful environmental challenges. Their advantages include, first of all,

lightness and strength which result in lower transport costs and effective protection from mechanical damages and effect of external factors such as moisture or chemical substances (Magnier&Schoormans, 2015). Additionally, plastics are characterized by a high elasticity in the design context what facilitates their adaptation to specific requirements of the products, and by the relatively low manufacturing costs. Plastic packaging s, however, characterized by important defects, especially in respect of their impact on the environment. Plastic waste is one of the main contamination sources, especially in the sea eco-systems where plastics may be subjected to degradation for hundreds of years, causing the lasting harms to nature. Moreover, only small percentage of the produced plastics is effectively subjected to recycling. The recycling processes are often expensive and limited to specified types of plastics and lack of the appropriate infrastructure in many regions leads to unproper disposal of the waste (Pivnenko et al., 2015). The successive problem connected with the plastic packaging includes emission of detrimental substances during their production as well as in the combustion processes. It creates the threat to human health and to the environment. A single-use character of many plastic packaging increases additionally the pressure on the systems of the waste management, generating considerable amounts of hardly degradable waste (Vecchio&Annunziata, 2015).

PACKAGING MATERIAL AND THE CONSUMER CHOICES

The consumers treat packaging more and more frequently as determinant of quality and confidence, especially in the context of premium products. The studies conducted by Przewoźna-Skowrońska and Dewicka (2016) show that the visually attractive premium packaging lead often to higher evaluation of the product's quality. Thus, the packaging becomes a tool of creating the perception which exceeds functionality, allowing shaping the stable relation with the customer (Przewoźna--Skowrońska, 2016).

Ecological and minimalistic packaging, as made from biodegradable materials, signalize the involvement of a given mark into environmental protection, what is especially appreciated by the contemporary consumers (GlobalWebIndex, 2021). The perceptions of the consumers have also the impact on adoption of ecological packaging. The studies indicate that in spite of the fact that the consumers express the preference for environment-friendly packaging, their understanding and behaviour are different. The factors such as knowledge on the packaging materials and their effect on natural environment have the influence on the purchasing choices; it stresses the need of effective communication and education in order to adjust the consumer behaviours to the aims of the sustainable development (Branca et al., 2024). The awareness of the consumers on the impact of the packaging materials on the environment is more and more wider. As it was indicated in the studies of Vecchio and Annunziata (2015), more and more numbers of the consumers are ready to pay more for the product in ecological packaging if it is compliant with their values and opinions concerning the environment protection. The mentioned growing interest in ecological packaging shows the change in the approach of the consumers who treat more frequently the purchasing choices as a form of responsibility for the environment (Vecchio & Annunziata, 2015). As it was indicated in the studies of Przewoźna-Skowrońska and Dewicka (2016), the packaging attracts the attention of the consumers owing to their visual properties such as colour, graphical form and shape and the type of the employed plastics. For many consumers, ecological packaging is attractive as it reflects their values and preferences relating to the sustainable life style. The consumers choose more willingly the packaging which is not only ecological but also modern and aesthetic in respect of their form. As it was noticed by Lindh et. al., visual attractiveness of ecological packaging rises meaningfully the perceived value and innovativeness of the product. Combination of aesthetics and pro-ecological functionality in design of packaging not only attracts the attention but also increases the interest of the consumers and their inclination to make the choice of the discussed products; it makes them more competitive on the market (Lindh et al., 2015). Paper packaging which employs neutral colours and simple shapes, is often perceived as more "authentic" and "healthy" (Magnier& Crié, 2015). Although plastics offer more abundant aesthetic possibilities, they may be perceived as less ecological and less natural.

In spite of growing criticism of plastic due to ecological reasons, it is still perceived by many consumers as a strong and functional material. Plastic material offers better protection from humidity and mechanical damage as compared to paper what may become an important factor in the case of food products (Farmer, 2016). However, the concerns connected with the effect of plastics on the environment make that the higher number of the consumers try to avoid the mentioned material what was confirmed by the report of GlobalWebIndex (Bayindir et al., b.d.). Although plastic causes negative ecological associations, it offers significant advantages in respect of the products' protection and energetic value, especially then it is subjected to recycling (Arena et al., 2003).

In the GlobalWebIndex report, the analysis of the varying approaches of the consumers in relation to the sustainable packaging, was carried out and indicated the growing meaning of the mentioned attitudes in the process of undertaking the purchase decisions. The results of the study showed that more than a half of the respondents 957%) declared the readiness to pay the higher prices for the products in environment-friendly packaging; it suggests the increase of the ecological awareness of the consumers and their preferences for the marks which reveal the environmental responsibility. The mentioned report indicates also that the interest in the sustainable packaging is especially visible in the younger age groups for whom the purchase choices become a form of expression of values and the support of activity in favour of environment protection (Bayindir et al., b.d). The intensified readiness of the consumers to pay for the sustainable packaging is also connected with the need of feeling the perpetration – the respondents express the will that their purchase choices have the real impact on the natural environment and the future of our Planet. The purpose of paper recycling includes not only the reduction of the waste but also protection of natural resources and reduction of GHG (greenhouse gases) what supports the aims of the environment protection (Byström & Lönnstedt, 1997).

The consumers undertake the purchasing decisions also on the grounds of information put on the label in respect of material and the methods for its disposal. As it was indicated in the studies of Steenis et al. (2017), the transparent marking on the packaging such as information on the possibility of recycling or composting, strengthen the positive perception of the products and increase their attractiveness. The consumers who receive clear information about the ecological properties of packaging, are more prone to choose the mentioned product what is an evidence of increasing role of education in building the pro-ecological purchase preferences.

The packaging material is a significant element which has a direct influence on the environment. The packaging systems are classified into three levels of hierarchy: primary, secondary and tertiary packaging (Jönson, 2000). The primary packaging has a direct contact with the product; the secondary one is composed of few primary packaging whereas the tertiary packaging serves for storage or transport of many primary and secondary packaging pieces (Molina – Besch et al., 2019). The studies on the life cycle of packaging (LCA, Life Cycle Analysis) stress regularly the mutual relations between the primary, secondary and tertiary packaging and indicate to the necessity of considering all level of packaging in LCA analyses (Silvenius et al., 2014). Moreover, it is recommended that the development of each level of packaging system runs in parallel what allows more coherent management of resources and optimization of the impact on the environment (Molina-Besch et al., 2019).

CONCLUSIONS

The paper as well as plastic packaging have their place in the economy; however, their effective application requires further innovations and activity in favour of the sustainable development. Promotion of the environment-friendly solutions which satisfy the growing requirement of the consumers and, simultaneously, minimize the negative effect on the environment, is crucial for the future of the sustainable packaging. Finally, the combination of aesthetics, functionality and ecology in designing of packaging may contribute to the change in the consumer preferences and to reduction of the pressure on the environment. Education of the consumers plays a significant role in building the pro-ecological preferences. Clear marking placed on the packaging such as information on the possibilities of recycling or biodegradability, may effectively strengthen the positive perception of the consumers. The conducted studies show that

the consumers more and more appreciate the packaging which combines the aesthetics and ecological functionality what additionally increases the perceived value of the product. In the context of designing the packaging in accordance with the principles of the sustainable development, the application of LCA analysis has a key meaning. The consideration of the correlations between the primary, secondary and tertiary packaging may lead to better management of resources and reduction of the emissions and the waste.

SUMMING UP

The choice of the packaging material has a meaningful impact on the purchasing decisions of the consumers. Paper packaging is often perceives as more environment-friendly what increases its attractiveness of the ecologically aware consumers. On the other hand, plastic packaging, although being negatively perceived due to their impact on the environment, offer significant profits in respect of the protection and functionality of the products. The future studies and innovations in respect of packaging materials should consider the needs of the consumers as well as environmental aspects in order to meet the growing expectations in relation to the sustainable packaging. The preferences of the consumers in respect of the packaging materials show the growing interest in the sustainable solutions which combine aesthetics, functionality and minimal influence on the environment. Introduction of the effective strategies of designing and recycling may not only reduce the pression on the environment but also satisfy the requirements of the ecologically aware customers. Paper and plastic packaging have their unique advantages and limitations which require further studies and innovations, with the aim to ensure their conformity with the principles of sustainable development.

BIBLIOGRAPHY

1. Arena, U., Mastellone, M., & Perugini, F. (2003). Life Cycle assessment of a plastic packaging recycling system. The International Journal of Life Cycle Assessment, 8, 92–98. [Dostęp: 27.10.2024] Access in: https://doi.org/10.1007/BF02978432
2. Bayindir, N., Gilsenan, K., Beer, C., Buckle, C., & Sekuj, V. (b.d.). Sustainable Packaging Unwrapped.
3. Branca, G., Resciniti, R., & Babin, B. J. (2024). Sustainable packaging design and the consumer perspective: A systematic literature review. Italian Journal of Marketing, 2024(1), 77–111. [Dostęp: 24.10.2024] Access in: https://doi.org/10.1007/s43039-023-00084-1
4. Jedlicka, W. (2009). Packaging sustainability: Tools, systems and strategies for innovative package design. John Wiley & Sons.
5. Jönson, G. (2000). Packaging Technology for the Logistician, 2nd edition.
6. Kawecka, A., & Cholewa-Wójcik, A. (2017). Jakość opakowania jako determinanta bezpieczeństwa żywności w kontekście wymagań społecznych konsumentów. Zywnosc Nauka Technologia Jakosc/Food Science Technology Quality, 112Access in [Dostęp: 22.10.2024] Access in: https://doi.org/10.15193/zntj/2017/112/205 (In English: Packaging quality as determinant of food safety in the context of the social requirements of the consumers)
7. Lindh, H., Olsson, A., & Williams, H. (2015). Consumer Perceptions of Food Packaging: Contributing to or Counteracting Environmentally Sustainable Development? Packaging Technology and Science, 29, n/a-n/a. [Dostęp: 4.11.2024] Dostępny in: https://doi.org/10.1002/pts.2184
8. Magnier, L., & Crié, D. (2015). Communicating packaging eco-friendliness: An exploration of consumers' perceptions of eco-designed packaging. (4/5), 350–366. [Dostęp: 27.10.2024] Access in: https://doi.org/10.1108/IJRDM-04-2014-0048
9. Magnier, L., & Schoormans, J. (2015). Consumer reactions to sustainable packaging: The interplay of visual appearance, verbal claim and environmental concern. Journal of Environmental Psychology, 44. [Dostęp: 24.10.2024] Access in: https://doi.org/10.1016/j.jenvp.2015.09.005
10. Marsh, K., & Bugusu, B. (2007). Food Packaging?Roles, Materials, and Environmental Issues. Journal of food science, 72, R39-55. [Dostęp: 27.10.2024] Access in: https://doi.org/10.1111/j.1750-3841.2007.00301.x
11. Molina-Besch, K., Wikström, F., & Williams, H. (2019). The environmental impact of packaging in food supply chains—Does life cycle assessment of food provide the full picture? The International Journal of Life Cycle Assessment, 24(1), 37–50. [Dostęp: 3.11.2024] Access in: https://doi.org/10.1007/s11367-018-1500-6
12. Muthu, S. S. (Red.). (2021). Sustainable packaging. Springer.
13. Pivnenko, K., Eriksson, E., & Astrup, T. (2015). Waste paper for recycling: Overview and identification of potentially critical substances. Waste management (New York, N.Y.), 45. [Dostęp: 20.10.2024] Access in: https://doi.org/10.1016/j.wasman.2015.02.028
14. Przewoźna-Skowrońska. (2016). Wpływ opakowania na zachowania konsumentów. [Dostęp: 15.10.2024] Access in: https://doi.org/10.21008/J.0239-9415.2016.071.18
15. Silvenius, F., Grönman, K., Katajajuuri, J.-M., Soukka, R., Koivupuro, H.-K., & Virtanen, Y. (2014). The Role of Household Food Waste in Comparing Environmental Impacts of Packaging Alternatives. Packaging Technology and Science, 27. [Dostęp: 28.10.2024] Access in: https://doi.org/10.1002/pts.2032
16. Vecchio, R., & Annunziata, A. (2015). Willingness-to-pay for sustainability-labelled chocolate: An experimental auction approach. Journal of Cleaner Production, 86, 335–342. [Dostęp: 2.11.2024] Access in: https://doi.org/10.1016/j.jclepro.2014.08.006
17. Verghese, K., Lewis, H., & Fitzpatrick, L. (2012). Packaging for Sustainability. [Dostęp: 27.10.2024] Access in : https://doi.org/10.1007/978-0-85729-988-8

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THE STUDY OF THE QUALITY OF OVERPRINT ON CARDBOARD PACKAGING, PRINTED WITH THE APPLICATION OF DIGITAL INK-JET AND ELECTROPHOTOGRAPHIC MACHINES

BADANIE JAKOŚCI NADRUKU NA OPAKOWANIACH KARTONOWYCH ZADRUKOWANYCH ZA POMOCĄ MASZYN CYFROWYCH NATRYSKOWYCH I ELEKTROFOTOGRAFICZNYCH

ABSTRACT: In the present paper, the problems connected with the digital printing and its types, and in particular electrophotography and ink-jet printing were discussed. In the introduction, the total printing technological process was presented. Digital printing was compared with the analogue printing and then, the selected printing technology with the advantaged and drawbacks was described.
The parameters of the equipment and substrata, employed in the present study were described. The following parameters were presented: tonal continuity, percentage covering of surface, relative contrast, trapping and gamut.
To perform the measurements, the measuring device X-Rite eXact Advanced Scan was used. It has many functions, enabling measurement of the mentioned parameters.
After conducting of all tests and profound analysis of the results, illustrated in a form of diagrams and tables, we may state that the both machines met the threshold of satisfying quality; on the other hand it is not possible to say univocally which machine has produced the prints better due to the fact that the quality parameters of the employed paper substrata differed each other.
Key words: digital printing, ink-jet printing, electrophotography, packaging printing, digital machines, quality of overprint

STRESZCZENIE: W niniejszym artykule przedstawiono zagadnienia związane z drukowaniem cyfrowym oraz jego rodzajami, w szczególności zaś z elektrofotografią i drukowaniem natryskowym. We wstępie przybliżono czytelnikowi całokształt technologii drukowania. Porównano drukowanie cyfrowe z drukowaniem analogowym, a następnie poprzez zalety i wady po krótce opisano wybraną technologię drukowania.
W artykule opisano parametry urządzeń i podłoży wykorzystanych w badaniu, przedstawiono parametry takie jak: ciągłość tonalna, procentowe pokrycie powierzchni, kontrast względny, trapping, gamut.
Do wykonania pomiarów wykorzystano urządzenie pomiarowe X-Rite eXact Advanced Scan, które posiada wiele funkcji umożliwiających zmierzenie wymienionych parametrów.
Po wykonaniu wszystkich badań oraz wnikliwej analizie rezultatów zobrazowanych w formie wykresów oraz tabel nasuwa się stwierdzenie, że obie maszyny spełniły próg zadawalającej jakości, natomiast nie można jednoznacznie stwierdzić, która konkretnie maszyna wykonała wydruki lepiej z uwagi na fakt, że parametry jakościowe użytych podłoży papierowych różniły się od siebie.
Słowa kluczowe: drukowanie cyfrowe, drukowanie natryskowe, elektrofotografia, drukowanie opakowań, urządzenia cyfrowe, jakość zadruku

TAB.1. SPECIFICATION OF THE SYSTEM

OF MACHINE ACCURIOPRESS C 120000E [4]

Resolution:	2400 x 3600 dpi x 8 bit
Weight (grams/m2)	52–450 g/m2
Double-side printing	Non-stack type; 52–450 g/m2
Dimensions of sheets	330,2 x 487,7 mm
330,2 × 900 mm (max. In double-side mode)	
330,2 × 1 300 mm (max. In one-side mode)	
Capacity of feeder	14 140 sheets
Speed of printing A4	120 pp./h
Speed of printing A3	69 pp./h

TAB.2. SPECIFICATION OF MACHINE RICOH PRO™ C7500 [12]

General	
Name of model	Pro C7500
Technology	4-drum (standard) / 5-drum (optional) dry electrostatic transfer with internal transfer band
Preservation	Method of non-oil band preservation
Speed of printing	85 pp./min (standard)
	95 pp. / min (with the option of increasing the yield)
Resolution	VCSEL 2400 x 4800 dpi
Time of warming up	below 300 seconds
Dimensions (width. X depth X height.)	1320 x 910 x 1870 mm (including signalizing mast)
Weight	Below 560 kg
Power source	220-240 V, 16 A x 2, 50/60 Hz
Energy consumption	Below 5000 W
Service life	14 400 000 pages A4 or 5 years

INTRODUCTION

Analogue printing has been, for many years, a dominating form of image and text reproduction. However, the development of digital technologies has introduced many new possibilities to the printing industry, changing the so-far existing approach to production of prints.

Digital printing is nowadays a dynamically developing sector of technology, which plays a key role in many manufacturing branches. Owing to the constant technological progress and innovations, it becomes more and more effective, precise and available, in a personalised way, for different applications. The commercial printing houses decide on the new technology due to its profitability, high standard of the performed copies and quick time of implementation. Moreover, digital printing facilitates production even of the smallest number of prints which, in comparison to the required higher outlays in the case of traditional technologies, may be even personalised by a final customer. The main advantage of digital printing consists in the fact that the mentioned technology does not require printing mould before printing. The data for printing are transferred in a form of digital file. After all, the described technology of printing has also certain drawbacks. In respect of quality, the offset printing still remains the leader; it is characterized by the most precise transfer of details on the substratum being overprinted during the manufacturing process. Additionally, offset inks are more economic as compared to the toners which are employed in digital technology. Hence, in spite of many advantages, digital printing has also some specified properties which do not allow conquer in the ranking of the available printing method [1 – 3], [5 – 6].

TAB.3. PARAMETERS OF PAPERS, EMPLOYED IN THE TESTS [10 – 11]

Parameter	Humidity (absolute) or Non-transparency [%]	Thickness [µm]	Brightness ISO	White-ness CIE [%]	Glim-mering (75°) [%]	Smooth-ness PPS top [µm]
Alasca White 220 g/m2	Humidity – 7.8	315	100	92	50	2.0
Kreda Matt 400 g/m2	Non-transparency – 99.9	404	100	127	24	2.5
Kreda Matt 220 g/m2	Non-transparency – 99	205	100	127	24	2.0
Daytona White 350 g/m2	Humidity – 8.9	535	90	120	45	1.0

THE PURPOSE AND RANGE OF THE STUDIES

The aim of the studies was to analyse the quality of printed packaging with the application of two digital ink-jet and electrophotographic machines. The both mentioned techniques were also compared. The prints were performed on 3 popular box cardboards, used in the sector. The tests were aimed also at checking which one from the digital techniques is the best in the implementation of the orders for packaging.

THE RUN OF THE TESTS

To make the measurements, the measuring device X-Rite eXact Advanced Scan was employed; it has many functions, facilitating the measurement of the mentioned parameters [9]. The copies were printed in two machines: ink-jet RICOH Pro TM C7500 and electrophotographic device AccurioPress C 12000e. The specification of the machines was presented in Tables 1 and 2 [4] [12].

TAB.4. THE RESULTS OF THE MEASUREMENTS OF OPTICAL DENSITY ON PRINT, OBTAINED FROM MACHINE RICOH PRO ™ C7500

Alasca White 220 g/m² with profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.24	1.24	1.25
M	1.21	1.19	1.2
Y	0.94	0.93	0.92
K	1.72	1.68	1.65
Alasca White 220 g/m² without profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.41	1.4	1.41
M	1.23	1.2	1.22
Y	0.92	0.92	0.91
K	1.68	1.68	1.63
Kreda Matt 400 g/m² with profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.67	1.69	1.69
M	1.45	1.46	1.46
Y	1.01	1.01	0.99
K	1.95	1.95	1.9
Kreda Matt 400 g/m² without profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.67	1.69	1.69
M	1.45	1.46	1.46
Y	1.01	1.01	0.99
K	1.95	1.95	1.9

TAB.5. THE RESULTS OF THE MEASUREMENTS OF OPTICAL DENSITY ON PRINT OBTAINED FROM MACHINE KONICA MINOLTA ACCURIOPRESS C 12000E

Kreda Matt 220 g/m² with profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.24	1.24	1.25
M	1.21	1.19	1.2
Y	0.94	0.93	0.92
K	1.72	1.68	1.65
Kreda Matt 220 g/m² without profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.41	1.4	1.41
M	1.23	1.2	1.22
Y	0.92	0.92	0.91
K	1.68	1.68	1.63
Daytona White 350 mg/m² with profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.67	1.69	1.69
M	1.45	1.46	1.46
Y	1.01	1.01	0.99
K	1.95	1.95	1.9
Daytona White 350 mg/m² without profile			
Tonal continuity	TOP	MIDDLE	BOTTOM
C	1.67	1.69	1.69
M	1.45	1.46	1.46
Y	1.01	1.01	0.99
K	1.95	1.95	1.9

TAB.6. THE RESULTS OF THE ARITHMETICAL MEANS OF OPTICAL DENSITIES OF PRINT OBTAINED FROM RICOH PRO ™ C7500

Alasca White 220 g/m² with profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.24	0.01
M	1.20	0.01
Y	0.93	0.01
K	1.68	0.04
Alasca White 220 g/m² without profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.41	0.01
M	1.22	0.02
Y	0.92	0.01
K	1.66	0.03
Kreda Matt 400 g/m² with profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.68	0.01
M	1.46	0.01
Y	1.00	0.01
K	1.93	0.03
Kreda Matt 400 g/m² without profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.67	0.03
M	1.42	0.03
Y	0.99	0.01
K	1.94	0.03

TAB. 7. THE RESULTS OF ARITHMETIC MEANS OF OPTICAL DENSITIES OF PRINT OBTAINED FROM KONICA MINOLTA ACURIO PRESS C 12000E

Kreda Matt 220 g/m² with profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.25	0.01
M	1.35	1.19 1.2
Y	0.92	0.93 0.92
K	1.53	1.68 1.65
Kreda Matt 220 g/m² without profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.32	0.02
M	1.53	0.01
Y	1.01	0.01
K	1.62	0.01
Daytona White 350 mg/m² with profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.19	0.01
M	1.27	0.01
Y	0.98	0.00
K	1.58	0.03
Daytona White 350 mg/m² without profile		
Tonal continuity	MEAN	STANDARD DEVIATION
C	1.24	0.00
M	1.45	0.01
Y	0.99	0.01
K	1.55	0.01

The following substrates were used in the experiment: box cardboard Alasca White (Carta Integra), one-side coated, weight 220 g/m^2 and cardboard (in Polish: Kreda Matt), coated paper, weight 400 g/m^2 (in RICOH) and Kreda Matt, coated, weight 220 g/m^2 and Daytona White, 350 g/m^2 (in AccurioPress C 12000e). The specification of box cardboards was presented in Tab.3 [10 – 11].

MEASUREMENT OF OPTICAL DENSITY OF CMYK COLOURS ON SOLID COLOURS

Firstly, the measurement of optical density of CMYK colours were carried out. The results were submitted in tables and diagrams.

To perform clear comparison of the obtained results, the arithmetical mean of optical density was calculated for each

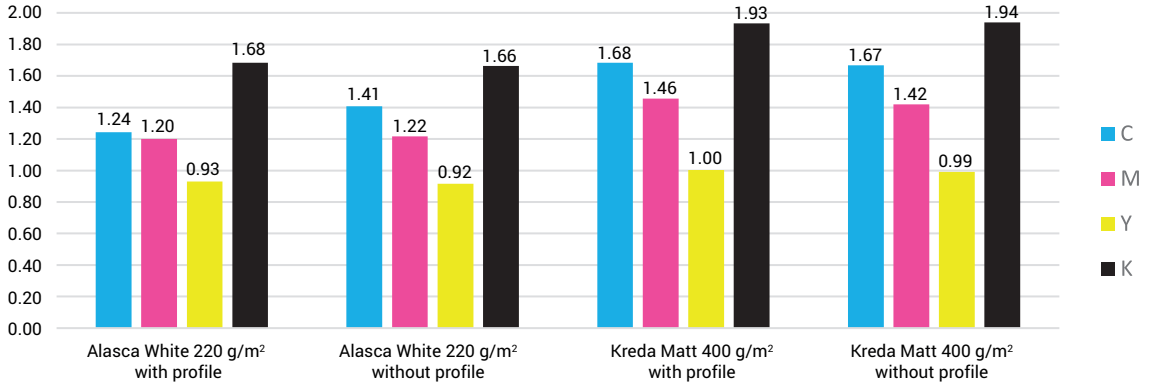

FIG.1. DIAGRAM OF THE MEAN OPTICAL DENSITIES OF PRINTS OBTAINED FROM RICOH PRO ™ C7500

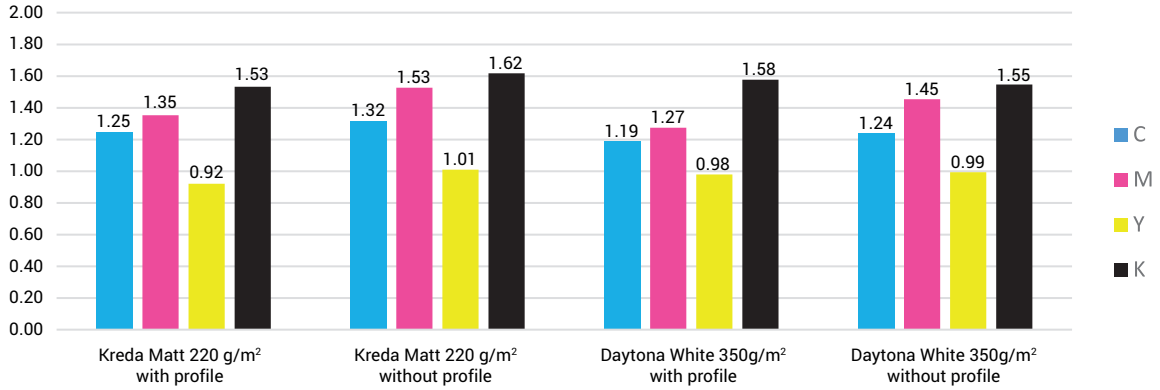

FIG.2. DIAGRAM OF THE MEAN OPTICAL DENSITIES OF PRINTS OBTAINED FROM KONICA MINOLTA ACCURIOPRESS C 12000E

band of solid colour in a given CMYK colour and, also, standard deviation from the mean.

The results were presented in a form of tables and diagrams, separately for prints made in RICOH machine and for those ones obtained from Konica Minolta machine.

CONCLUSIONS COMING FROM THE MEASUREMENTS OF OPTICAL DENSITY OF CMYK COLOURS ON SOLID COLOUR

The highest standard deviation in machine RICOH has a black colour on substratum Alasca White 220 g/m^2, printed with a profile.

The highest standard deviation in machine KONICA MINOLTA has a black colour on substratum Kreda Matt 220 g/m^2 printed without profile.

Machine Konica Minolta has a greater stability of optical density of the printed colours.

The prints performed in RICOH machine, with substratum weight of 220 g/m^2 are characterized by greater uniformity of density in comparison to the prints on substratum with the weight of 400 g/m^2 .

The prints made on Kreda Matt 400 g/m^2, in the case of printing without profile, colours have the highest standard deviation.

The prints produced by Konica Minolta machine had lower standard deviations than the prints obtained from RICOH machine. Therefore, the mentioned prints are of the better quality and possess the better tonal continuity.

The mean optical densities and their standard deviations facilitated conducting the analysis on which paper substratum the toner was overprinted the best.

TAB. 8. VALUES OF SPECTROPHOTOMETRIC MEASUREMENTS OF PRINTS FROM RICOH PRO ™ C7500 (DATA FOR DIAGRAMS)

	Arctic White 220 g/m²			
	with profile		without profile	
	a	b	a	b
M	68	-8	70	-9
R	60	42	60	49
Y	-8	86	-12	89
G	-65	24	-67	25
C	-27	-52	-26	-56
B	17	-45	18	-45
M	68	-8	70	-9
	Kreda Matt 400 g/m²			
	with profile		without profile	
	a	b	a	b
M	75	-3	74	-4
R	63	54	63	54
Y	-10	96	-10	96
G	-70	29	-69	28
C	-34	-52	-34	-52
B	10	-45	20	-44
M	75	-3	74	-4

TAB.9. VALUES OF SPECTROPHOTOMETRIC MEASUREMENTS OF PRINTS FROM KONICA MINOLTA ACURIO PRESS C 12000E

	Kreda Matt 220 g/m²			
	with profile		without profile	
	a	b	a	b
M	76	-6	74	-3
R	67	41	70	45
Y	-6	90	-7	97
G	-64	22	-70	25
C	-34	-50	-32	-50
B	20	-46	20	-48
M	76	-6	74	-3
	Daytona White 350 g/m²			
	with profile		without profile	
	a	b	a	b
M	73	-3	76	1
R	68	43	70	45
Y	-5	94	-4	94
G	-63	25	-67	24
C	-32	-46	-32	-48
B	21	-43	18	-44
M	73	-3	76	1

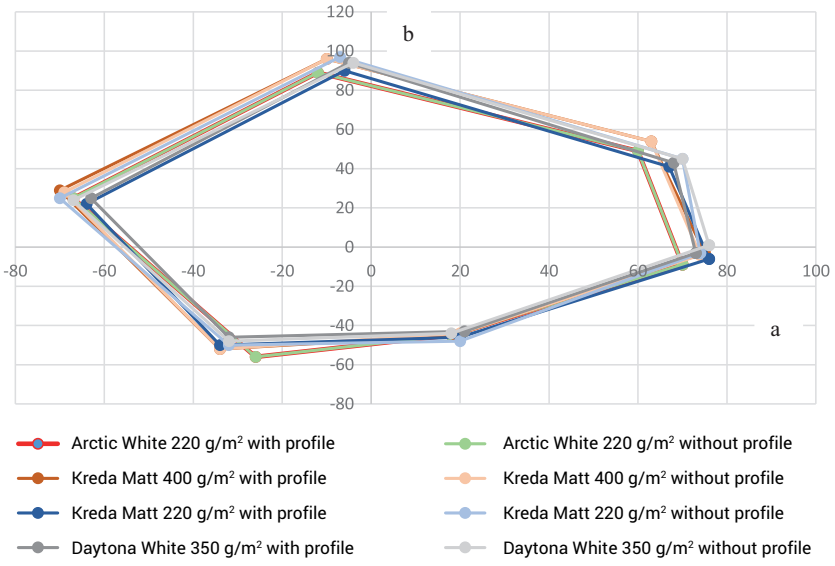

FIG.3. DIAGRAM OF CHARACTERISTIC CURVES OF SUBSTRATA USED IN THE STUDY

TAB.10. THE RESULTS OF THE MEASUREMENTS OF THE PERCENTAGE COVERAGE OF THE SURFACE OF THE PRINTS, COMING FROM RICOH PRO™ C7500 (DATA FOR DIAGRAMS)

Alasca White 220 g/m² with profile					Alasca White 220 g/m² without profile				
	C	M	Y	K		C	M	Y	K
0	0	0	0	0	**0**	0	0	0	0
5	2	3	3	5	**5**	2	3	3	1
10	6	8	7	4	**10**	7	8	7	3
40	28	23	34	31	**40**	24	22	30	29
60	39	37	52	44	**60**	42	39	55	70
80	77	68	84	72	**80**	79	61	81	66
100	100	100	100	100	**100**	100	100	100	100
Kreda Matt 400 g/m² with profile					**Kreda Matt 400 g/m² without profile**				
	C	M	Y	K		C	M	Y	K
0	0	0	0	0	**0**	0	0	0	0
5	4	3	4	6	**5**	4	4	0	3
10	9	8	8	10	**10**	7	6	9	8
40	22	24	33	33	**40**	25	17	36	35
60	45	40	57	73	**60**	41	44	49	67
80	75	70	77	85	**80**	70	74	78	79
100	100	100	100	100	**100**	100	100	100	100

COLOURFUL SPACE OF SUBSTRATA

The coloured space of substrates was also examined by spectrophotometer as it has also function of measuring the colourful space (gamut) on the print. Gamut is visually described by diagrams of the colourful spaces which appear in a form of blocks.

The mentioned study allowed measuring of 6 fields of control test from the test field IT8.7/3. In the mentioned equipment, the following colours were tested: CMYK and RGB. The ready diagrams of colourful space represent the projection on place a*b* in space CIELab. The results have been given in a form of tables and diagrams [7 – 8].

CONCLUSIONS COMING FROM THE SPECTROPHOTOMETRIC MEASUREMENTS

Substrates Arctic White with weight of 220 g/m² as printed with profile and without profile revealed almost identical

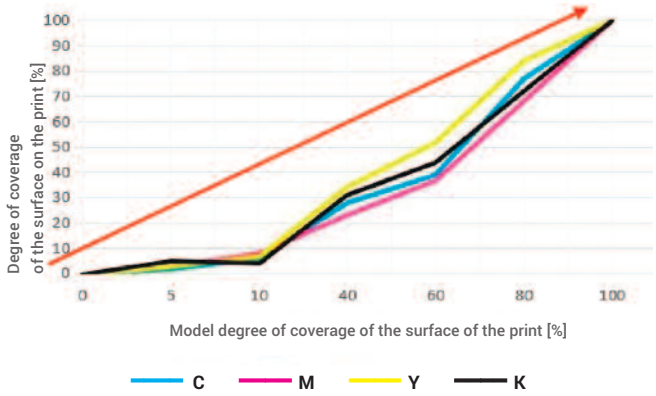

FIG.4. THE DIAGRAM OF THE CONFORMITY OF PERCENTAGE COVERAGE OF PRINT OBTAINED IN MACHINE RICOH PRO™ C7500 ON PAPER ARCTIC WHITE 220 G/M² BEING PRINTED WITH A PROFILE

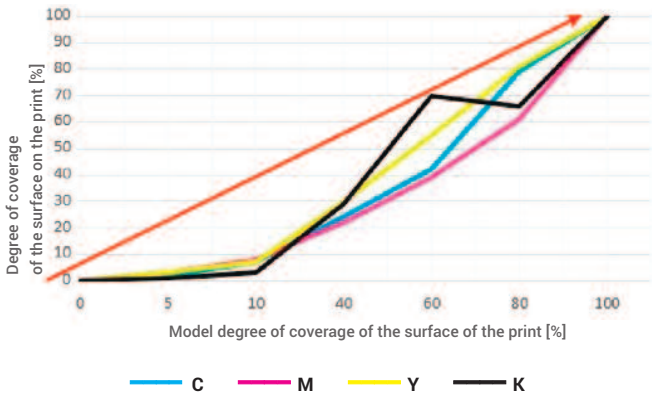

FIG.5. THE DIAGRAM OF THE CONFORMITY OF PERCENTAGE COVERAGE OF PRINT OBTAINED IN MACHINE RICOH PRO™ C7500 ON PAPER ARCTIC WHITE 220 G/M² BEING PRINTED WITHOUT PROFILE

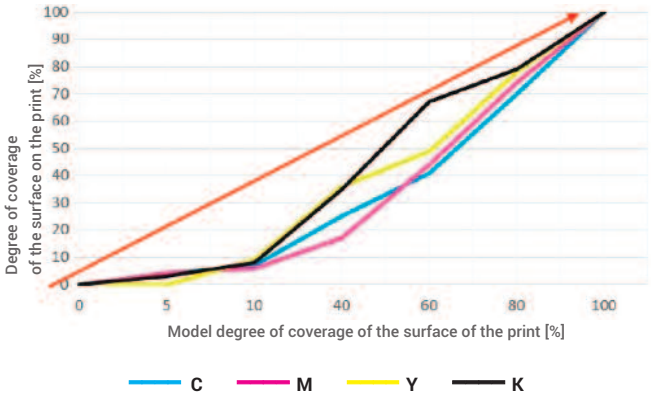

FIG.6. THE DIAGRAM OF THE CONFORMITY OF PERCENTAGE COVERAGE OF PRINT OBTAINED IN MACHINE RICOH PRO™ C7500 ON PAPER KREDA MATT 400 G/M² PRINTED WITH PROFILE

TAB.11. THE RESULTS OF MEASUREMENTS OF PERCENTAGE COVERAGE OF THE SURFACE OF THE PRINTS COMING FROM KONICA MINOLTA ACURIO PRESS C 12000E (DATA FOR DIAGRAMS)

Kreda Matt 220 g/m² with profile					Kreda Matt 220 g/m² without profile				
	C	M	Y	K		C	M	Y	K
0	0	0	0	0	**0**	0	0	0	0
5	3	2	4	2	**5**	3	2	3	1
10	5	3	5	9	**10**	5	4	5	7
40	22	23	21	33	**40**	25	25	24	36
60	36	41	38	54	**60**	42	46	41	56
80	64	70	62	85	**80**	67	73	65	87
100	100	100	100	100	**100**	100	100	100	100
Daytona White 350 g/m² with profile					**Daytona White 350 g/m² without profile**				
	C	M	Y	K		C	M	Y	K
0	0	0	0	0	**0**	0	0	0	0
5	3	2	3	2	**5**	3	3	2	1
10	3	5	6	4	**10**	6	5	6	4
40	21	23	33	24	**40**	21	22	30	21
60	37	44	38	55	**60**	40	38	54	37
80	73	60	88	64	**80**	70	62	85	64
100	100	100	100	100	**100**	100	100	100	100

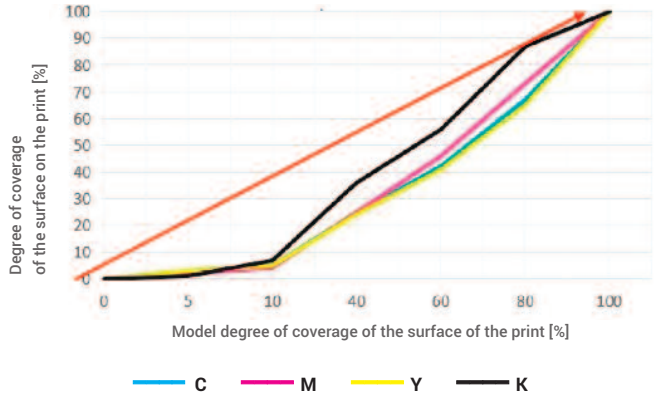

FIG.8. THE DIAGRAM OF THE CONFORMITY OF PERCENTAGE COVERAGE OF THE PRINT OBTAINED IN MACHINE KONICA MINOLTA ACURIO PRESS C 12000E ON PAPER KREDA MATT 220 G/M² PRINTED WITHOUT PROFILE

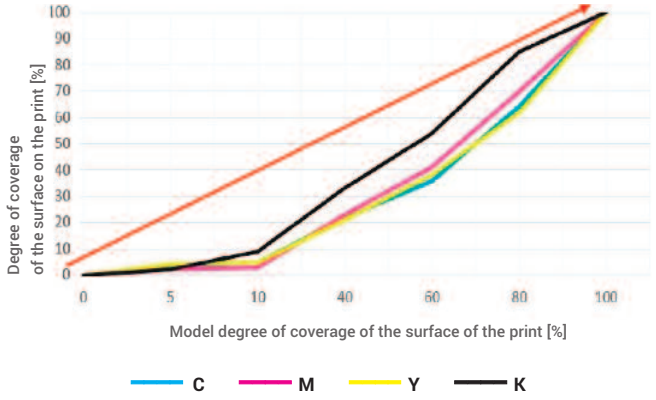

FIG.9. THE DIAGRAM OF THE CONFORMITY OF PERCENTAGE COVERAGE OF THE PRINT OBTAINED IN MACHINE KONICA MINOLTA ACURIO PRESS C 12000E ON PAPER KREDA MATT 220 G/M² PRINTED WITH PROFILE

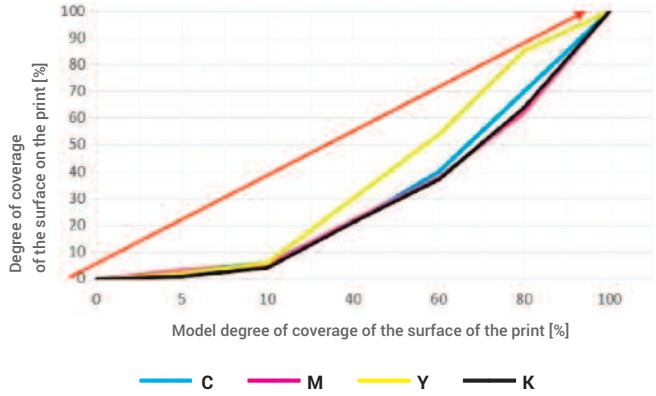

FIG.10. THE DIAGRAM OF THE CONFORMITY OF PERCENTAGE COVERAGE OF THE PRINT OBTAINED IN MACHINE KONICA MINOLTA ACURIO PRESS C 12000E ON PAPER DAYTONA WHITE 350 G/M² PRINTED WITHOUT PROFILE

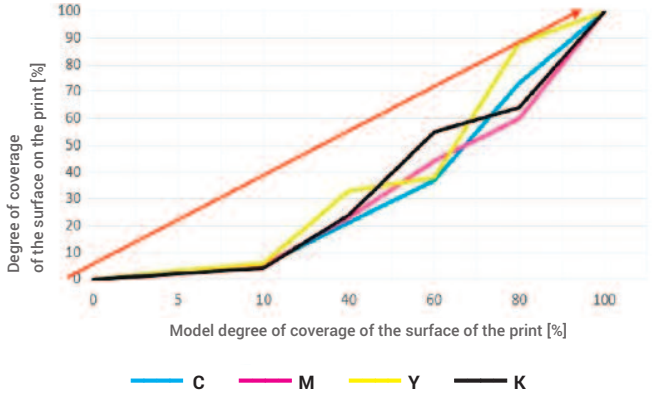

FIG.11. THE DIAGRAM OF THE CONFORMITY OF PERCENTAGE COVERAGE OF THE PRINT OBTAINED IN MACHINE KONICA MINOLTA ACURIO PRESS C 12000E ON PAPER DAYTONA WHITE 350 G/M² PRINTED WITH PROFILE

range of the possible obtained colours. The blocks of their measurements were overlapped.

The prints made on substrate Kreda Matt 400 g/m^2 represent ones of the widest ranges of colour.

The printed made in Konica Minolta machine have inconsiderably higher range of the possible- to-obtain colours as compared to those ones produced in RICOH machine.

The smallest colourful spaces were obtained on paper Daytona White 350 g/m^2 from machine by Konica Minolta.

The obtained gamuts of all employed printing substrates are very comparable each other; minimal difference occur in their coloristic spectra.

PERCENTAGE COVERAGE OF THE SURFACE

The following fields were analysed: 0%, 5,%, 10%, 40%, 60%, 80% and 100%. The obtained results have been given in tables and diagrams.

In order to analyse and assess the mapping of the surface's coverage, the diagrams of the printing conformity were developed. Axis OX describes the model degree of the surface' s coverage in percentage, and axis OY includes the degree of coverage of the surface on the print, in percentage, as well. A red arrow placed on each of the diagrams occurs as a line of model trend.

CONCLUSIONS COMING FROM THE MEASUREMENTS OF THE PERCENTAGE COVERAGE OF SURFACE CONFORMITY OF PRINTING

The diagrams show whether a given colour has been mapped (reproduced) correctly. Such statement necessitates a linear run of a given curve of colour in diagram; if the diagram is linear, it means that the mapping of the image is a model reproduction. The fields were measured with the increasing tendency for percentage coverage (0%, 5%, 10%, 40%, 60%, 80% and 100%)., so the increasing values were expected – the gains at the raster point; however, in the prevailing part, a decline of the mentioned values was observed.

The best mapping was revealed by black colour K; most frequently its values were approximate to the model line; in certain sites, they overlapped the red arrow whereas the remaining colours were considerably deviating from the ideal values.

Yellow colour on Daytona White substratum was also lined up with the model in substrates 80% and 100%.

Colours on the fields of raster points 60%, 80% and 100% revealed usually the greater linearity, approximate to the model.

When comparing the diagrams of surface coverage, obtained from two discussed machines, we may observe that the values of the prints coming from RICOH machine were most similar to the expected ones.

SUMMING UP

The present studies were aimed at the comparative analysis of the prints, performed by digital printing technique by ink-jet and electrographic method. To compare and give the opinion, the prints produced in Konica Minolta Acurio Press C 12000e and RICOH PRO™ C7500 machine were confronted. Each machine produced the prints on two substrates, in the both cases at density of 220 g/m^2 and 400 g/m^2. Printing of each substratum was carried out in two variants with a profile and without profile. The obtained prints from the first machine were compared with the others and also, with the prints coming from the second machine.

The studies were performed in aspect of observing the continuous bands of solid colour – full coverage with ink, TVI – increase in value of tone and the spectrophotometric measurements of the space of the printed colours on each print. After analysis of the results of all conducted experiments, it may be stated that the obtained qualities of the prints on each overprinted substrate were very similar each other. The mentioned phenomenon results from the fact that we cannot univocally state which substratum was most adequate for performing the specified test prints. In the case of one tested parameter, a given substratum occurred to be good while in another test, the mentioned parameter was worse in the respect of quality.

During the production of the prints in the printing house, any technical problems or limitations for the selected machines, due to which they could not serve the selected substrates, were not found. The paper was not choked during the passage through machines. All prints were performed correctly under the appropriate conditions. Any visible dirt, damages or other defects of printing were not found.

The obtained prints were assessed. In visual evaluation, the prints from the both employed machines, differed slightly visually in respect of such parameters as, inter alia, sharpness of the text – the prints made in machine by Konica Minolta had better quality of the text at the lowest degree of letters. Also, reproduction of lines, triangles and circles was more distinct. The saturation of colours was distinctly better.

When evaluating the tonal continuity, we may state what the mean optical densities of the fields of solid colour, as being performed in Konica Minolta machine were characterized by greater stability of toner on solid colour as compared to the

prints coming from RICOH machine. Therefore, the better optical densities were obtained for the prints made of substrates: Coated Paper Matt (in Polish: Kreda Matt) 220 g/m^2 and Daytona White 350 g/m^2. However, the control test was well printed also on substratum Alasca White 220 g/m^2 without profile. The least tonally continuous solid colour were obtained on paper Kreda Matt (coated paper) 400 g/m^2 with profile and without profile, performed in machine RICOH PRO™ C7500. Yellow colour was most stable.

The most surprising tests occurred to be the measurements concerning the conformity of the percentage coverage of the surface. It was expected that it would be possible to read out the gains in percentage coverage on the diagrams, developed from the data, measured by densitometer; however, the declines were stated. The mentioned anticipations were connected with the possessed knowledge on the offset printing. It is possible however that the lack of obtaining the gain in tonal value (Eng. dot gain) is justified as in offset it appears mainly due to pressure of rubber blanket; it does not appear in digital printing. It was assumed therefore that the best prints are those ones the optical densities of which are most similar to the model ones.

The conducted studies represent the data, indicating that any of machines did not reveal ideal qualities of printing on the substrates which were expected to play a function of cardboard packaging. The obtained parameters did not fully overlap with the guidelines. However, any print was not produced in the unsatisfactory quality or resulting in disqualification of the results. The choice of the appropriate digital ink-jet or electrophotographic machine in greatly individual and dependent on the quality parameters which become a priority for a given customer during production of cardboard packaging. Nevertheless, printers Konica Minolta Acurio Press C 12000e and RICOH PRO™ C7500 are the professional machines, intended for smaller volume as well as for the greater scale of production of packaging. There is only a requirement of setting the correct technical parameters and ensuring the appropriate environmental conditions as to obtain the fully satisfying print on the final product.

BIBLIOGRAPHY

[1] S. Jakucewicz, Vademecum podłoży drukowych dla wydawców i drukarzy, Stowarzyszenie Absolwentów Instytutu Poligrafii Politechniki Warszawskiej, Warszawa 2024 (in English: Vademecum of printing substrates, for editors and printers. Association of Graduates of Institute of Printing, Warsaw University of Technology)

[2] S. Khadzhynova, S. Jakucewicz Sposoby drukowania cyfrowego, Łódź: Wydawnictwo Politechniki Łódzkiej, 2016. (In English: The techniques of digital printing, Łódź, Publications of Łódź University of Technology)

[3] K. Piłczyńska, Wpływ parametrów papieru offsetowego na jakość zadruku cyfrowego natryskowego, Warszawa: rozprawa doktorska, 2015. (In English: Impact of the parameters of offset paper on the quality of digital ink-jet print, Warsaw, PhD dissertation, 2015).

[4] https://www.konicaminolta.pl/pl-pl/urzadzenia/druk-produkcyjny/accuriopress-c12000

[5] S. Khadzhynova, Badania jakości nadruku w drukowaniu cyfrowym, Łódź: Wydawnictwo Politechniki Łódzkiej, 2018. (In English: The studies of the print quality in digital printing, Łódź, Publications of Łódź University of Technology)

[6] K. Piłczyńska, Przemysłowe drukowanie cyfrowe materiałów opakowaniowych i opakowań, Warszawa, Oficyna Wydawnicza Politechniki Warszawskiej, 2022 (In English: Industrial digital printing of packaging materials and packaging, Warsaw, Publishing House of Warsaw University of Technology)

[7] Praca zbiorowa, Poligrafia. Sztuka, techniki, technologie. Warszawa: Centralny Ośrodek Badawczo-Rozwojowy Przemysłu Poligraficznego, 2021.(In English: Collective Work, Printing. Arts, Techniques, Technologies. (In English: Warsaw: Main Research and Development Centre of Priting Industry, Warsaw)

[8] Norma ISO12647-2, Strona internetowa Świat druku, [Online]: http://archiwum.swiatdruku.eu/archiwum/2000_10/01.htm. (In English: Standard ISO 12647-2, World of printing)

[9] https://www.xrite.com/pl-pl/categories/portable-spectrophotometers/exact-advanced

[10] https://www.igepa.pl/poligrafia/oferta/kartony/kartony-gc1/alaska-white-arktika

[11] http://www.papeete.pl/karty/Papiery%20kredowane/Novatech%20Matt.pdf

[12] www.ricoh.pl

STEFAN JAKUCEWICZ

SAFE PACKAGING, SUSTAINABLE FUTURE

In the days 19 – 20, November, 2024, in the Doubletree Hotel by Hilton, Łódź, the 14th Conference "Safe Packaging" was organized by the editorial offices of periodicals "Packaging" and "Printing". During the mentioned event, 11 lectures were presented, including two ones with double, differing topics, being delivered by two lecturers. The Conference lasted for two days – the second day was destined for the study tour to the Łukasiewicz Research Network- Łódź Institute of Technology

The main partners of the present edition of the conference were the following companies: Actega, Bank Pekao SA, Bobst, eProductivity Software, Graw with its partner Edale, Heidelberg, hubergroup, Metsä Board, ML Polyolefins, Wolff Poligrafia together with its partner MacDermid Graphic Solutions. The supporting partner was Cicero company and the professional partner – the Łukasiewicz Research Network – Łódź Institute of Technology. The discussed event was covered with the patronage of Polish Chamber of Printing, Polish Chamber of Packaging and Editorial Office Plastech.

EVOLUTION OF THE IDEA OF "SAFE PACKAGING"

During the Conference, eleven very interesting lectures at a high professional level were delivered. Two of them has few authors. The lectures were divided into four blocks, each of them included sessions of questions and answers and there was also provided a traditional coffee break. The problematics of the speeches was, as usually, connected with the widely understood "safe packaging", Traditionally, each of the speakers treated the discussed problem in a different way; in connection with this fact, the lectures concerned different problems. As being the person who conducted all so-far held conferences, the author of the present paper may state that the problems of the present conferences were very interesting, modern and revealed a high professional level. Gradually with the time, the idea of "safe packaging" was evolving and during the successive conferences it changed its range.

ANNA NARUSZKO, EDITOR-IN-CHIEF OF THE MONTHLY MAGAZINES "POLIGRAFIKA" AND "OPAKOWANIE", AND PROFESSOR STEFAN JAKUCEWICZ, DEPUTY EDITOR-IN-CHIEF OF THE SCIENTIFIC QUARTERLY "PACKAGING REVIEW" HAVE BEEN THE MODERATORS OF „SAFE PACKAGING" CONFERENCE SINCE IT'S FIRST EDITION.

THE EVENT WAS ATTENDED BY ABOUT 200 PRINTING AND PACKAGING INDUSTRY PROFESSIONALS

During the first meetings, the lecturers paid their attention, first of all, on the quality of performing the packaging in the light of protection and recognition of the packaged product and the utility of the packaging itself. The successive problems include barrier properties of the produced packaging and migration of different compounds to and from the packaging.
To-day, according to the EU (and international) trends, the majority of the lectures is dedicated to sustainable production of packaging what results in protection of the environment from the waste load.

This year's event continues the problems connected with the sustainable development. Such approach to packaging safety is an attempt to replace the most of the plastic packaging by paper products and barrier film coatings by the coating based on the natural raw materials, i.e. plant extracts and the processed natural materials e.g. starch. The successive current trend includes minimization of the production waste, together with the application of artificial intelligence (AI) for control of manufacturing processes. Reduction of the waste not only protects the environment from the necessity of the waste disposal but also increases use of materials and has an impact on the price of final product.
Within the frames of the first block, three lectures connected with the widely understood sustainable development were delivered.

The first lecturer was **Robert Kuczera from hubergroup**. In his presentation **"Adaptation to the future. Challenges and transformations in dynamically developing sector"** showed the futuristic prognosis of printing process. In the mentioned lecture, some questions connected with the printing process from the viewpoint of the future were submitted. Various possibilities of the mentioned problem were considered from which it is followed that printing as a process itself will not disappear. One of the reasons for such hypothesis includes demographic changes with the main accent on Asia. The geopolitical changes will not also cause the decay of printing. Unfortunately, the requirements of the consumers are changing, so certain printing products will disappear or decrease their volume. The modern visualisation systems will force the ecological approach to technologies with the application of environment-friendly materials, with the employment of renewable raw materials and those from recycling; they will constitute a part of the C2C (cradle-to-cradle) economy and the new technological development is expected (3D printing, intelligent and interactive printing, printing electronics and automation and artificial intelligence in the improvement of manufacturing process). The lecturer considered three scenarios of the printing future: optimistic – full adaptation to new technologies and needs of the consumers; neutral – a stable development with the consideration of geopolitical changes; pessimistic – decay of many traditional forms of printing process. In all mentioned

prognoses, printing as being perceived as the process for visualisation of packaging will not only be existing but also will be still developing.

Rafał Nowak from ACTEGA company was the author of the next presentation. His lecture was entitled: **"ACT Green® Barrier Coatings , as a sustainable alternative to packaging"**. The lecture concerned mainly the water barrier coatings, being produced by the company. The coatings of such type should be characterized by the appropriate effect of barrier at the minimal outlay of material and possess the admission to food packaging, have a short delivery time without storage (just-in-time production) and replace plastics and facilitate recycling of post-use packaging. Suggestion of the appropriate water coating requires a lot of information. It is not only one solution. Water varnish barriers are highly specialistic systems. The total production process has a key meaning – from production to recycling. Most frequently, the effect of barrier (water) is dependent on many factors such as final destination/filling of packaging; type of substratum, the possibility to apply varnish, type of ink, manufacturing process, finishing and further processing, assumptions of productivity, regulation where the coating is laid (external or internal side) and the time of waiting in delivery chain. ACTEGA company offers water barrier varnishes for different applications. In the summing up, the selected paper packaging, in which water barriers coating were employed, have been presented.

The successive lecture **"The highest level of optimization for the complex production time-tables"** was delivered by **Monika Nojszewska from eProductivity Software**. The ePS company (abbreviation of eProductivity Software) is a world leader in the field of complex technological solutions for packaging and printing. The authoress presented integrated system of automatic solutions for packaging (ePS Packaging). In the case of packaging sector, the system is composed of the following sections: automatization of order service, intelligent pricing of manufacturing costs, dynamic planning, data collection from manufacturing hall, KPI reports at a real time. The discussed system facilitates transparency of operating processes. It is intended for cardboard packaging, labels, packaging made from corrugated cardboard and packaging material overprinted with a wide band. The lecturer presented the examples of dynamic planning (Printflow), based upon the Lean Manufacturing approach i.e. planning of all machines /working centres in a given period and not planning machine after machine. Printflow may be manual or full automated. There was also submitted Intelligent Automation system. It considers the optimization of the whole manufacturing plant (factory) and includes as follows: management of exceptions and not of details, focusing attention of the users on the sites where they may have the greatest impact on the system, utilization of automation based on the rules for sequencing and equilibration of loads, undertaking decisions on the grounds of the real data. The appearance of Monika Nojszewska was very popular and raised a big interest of the participants of the conference.

After the turbulent session of questions and answers, **Paweł Drobek representing GRAW company** was the successive lecturer. He delivered the lecture: **"From a coil to box in 15 minutes – how goes one-run production of packaging?"**. The lecturer focused on minimization of waste and better use of machines. He suggested replacement of traditional production of cardboard packaging in a form of folded boxes by one-run production. It is possible to employ material in a form of coil as well as sheet. The traditional process runs according to the following scheme: winding, sheeting, storage, printing, storage, die shearing and cardboard bending (creasing), storage, glueing, and, finally dispatching to the customer. The described process requires several different machines, working as an independent equipment. Their application requires, each time, settlement of machine and transportation of the processed material to each successive device.

One-run production proposes flexographic technique in a form of one-run line Edaledo for production of FL5 (folded boxes and labels), FL3 (labels) and digital solutions of finishing and special orders. One-run production causes abbreviation of time for implementation of the orders, reduction of losses and waste; it requires lower financial outlays what results directly in lowering

TWO INTENSIVE DAYS FILLED WITH LECTURES, WORKSHOPS AND NETWORKING ALLOWED PARTICIPANTS TO LOOK AT PACKAGING ISSUES HOLISTICALLY - FROM ECO-DESIGNING IN LINE WITH THE PRINCIPLES OF THE CIRCULAR ECONOMY, TO OPTIMIZING PRODUCTION PROCESSES AND IMPLEMENTING INNOVATIVE MATERIALS

of the packaging price. One-run technological process may be employed in the case of high as well as low outlays.

The successive lecture had a collective title: **"Production of folded packaging without faults owing to BOBST solutions"**. The problems were presented by **Marcin Wicha and Krzysztof Dabrowski from BOBST company** and by **Corinne Loustalet from Packitoo HIPE**. The gentlemen focused on the presentation of the systems, protecting the error-free performance of packaging made from solid cardboard via increase of precision of register and digital inspection with the application of die shearing, creasing, stamping, gold plating and of the Braille system. In effect, we may obtain packaging without defects owing to the application of Bobst Connect system, supported by artificial intelligence (AI). It is resulted from the application of the discussed above system that we may obtain (at least theoretically) packaging without defects. In such case, machines and service are integral. The mentioned system ensures communication, digitalization, automation and the sustainable development. Bobst Connect end-to-end means complex, digital solution, increasing productivity of packaging. BOBST Connect system combines a powerful data platform and intelligent service, helps to organize manufacturing process of packaging and facilitates the productive flow of data between machine and digital solutions, enriched by advanced analytical possibilities; it supports the operations connected with the preparation to printing, die shearing, optimization, preservation and supply.

The problems concerning support of the sales are implemented owing to the solutions of Packitoo – HIPE system. Packitoo company, as founded in 2017 and having its seat in France has become, since May 2024, a componential part of Bobst concern. The system of the packaging sales support was presented by Corinne Loustalet.

After lunch, **Beata Górska, the leader of the Research Group of Ecology and Innovations of Packaging, COBRO, Łódź Institute of Technology**, the host of the second day of the Conference, took the floor. She submitted the possibilities of performing the tests of the packaging at Łódź Institute of Technology. They include, inter alia, as follows:

- Evaluation of the compatibility of materials, unitary, bulk (outer) and transport packaging and all systems of product packaging;
- Eco-design of packaging;
- Live cycle assessment (LCA);
- Calculation of GHG (greenhouse gases) emissions;
- Training;
- Opinions and expert work;
- Certification of the content of renewable and mineral raw materials.

Former COBRO runs the scientific and research activities, advisory and educational activity in respect of sustainable development of packaging and packaging materials in conformity with the principles of closed economy.

The successive lecturer, **Zbigniew Kosior vel Kosiorek from Heidelberg company** delivered the presentation **"Optimization of technological lines, ensuring safety of packaging production"**. In his lecture, the speaker focused on the analysis of the spot of the errors' appearance during the process of paper packaging

manufacture. From the viewpoint of the producer of printed packaging it is important at which stage of production the defect is discovered. The author analysed the reasons for occurrence of errors directly after offset printing the paper volume of packaging. In his analysis, the lecturer focused on deformation (distortion) of paper which is connected with the process of the offset printing. Its size is dependent on the direction of arrangement the fibres in paper, the way of finishing the surface, paper weight or thickness, ink coating, printing process parameters, number of printing units, climate conditions and other factors. Distortion of paper during printing of packaging is manifested by non-fitting of the text or of small graphic elements, improper balance of greyness and instability of the colours of the first copies within one sheet. Definition of paper may be corrected mechanically (directly in the printing machine), by the edition of extracts before raster or by correction the geometry of image subjected to raster. If we speak, however, about Heidelberg equipment, the best method is to employ the system of automatic compensation of paper i.e. Prinect Automatic Paper Stretch Compensation. The mentioned system allows eliminating or minimizing the effect of deformation of paper on the quality of the printed packaging.

The lecture **"Sustainable solutions in flexographic print: Photopolymer plates and technologies Mac Dermid Graphics Solution"** was presented by **Piotr Pazik and Hubert Borzym from Wolff Poligrafia**.

Piotr Pazik focused his attention on the possibilities of abbreviating the time of the device in printing machine and elimination or reduction of machine standstill in favour of prolongation of the time of printing. We assume that during the whole printing time, it is just the process of printing that brings profits. The factors which have the impact on the reasons of long setup and standstills are as follows: gain of dots (dotgain), streaking, halo effect, readability of bar codes, lack of homogeneity of solid colour, bad quality of print at the edges and connections, vibrations and resonance (streams). Elimination or reduction of the impact of the mentioned above factors causes the possibility of prolonging the time intended for printing.

A design of the process of photopolymer plates' recycling was submitted by Hubert Borzym. The mentioned cycle is based upon the technologies PlateCycle by American Mac Dermid technology. The flexographic plates (of course, the worn out moulds) are subjected to recycling into the products for the supply chains for flexography – in the discussed case, as substratum foam. Technology PlateCycle enables also processing the products of the competitors. The products obtained from recyclate are: substratum foam, used in printing of corrugated cardboard and fibreboard plates as constructional material. During the process of recycling the flexographic plates, the work is conducted on obtaining eco-methanol which would become the basis for synthesis of polymer compounds.

The discussed group of lectures was ended by the presentation of **Piotr Orliński from Metsä Board**. He delivered the lecture **"Reduction of the impact on the environment owing to the solutions in the field of closed system packaging"**.

In his appearance, Piotr Orliński concentrated his attention on the analysis of the reasons for carbon footprint generation and, more precisely, on the technological operations aiming at its reduction. The lecturer has stated that in Metsä Board concern there is a potential for reduction of the carbon footprint to 40-60% until 2030 via the change in construction of cardboards serving for production of folded boxes. Technical report on the life cycle assessment (LCA) of packaging produced from the mentioned innovative cardboards was verified by the Swedish Institute of Studies on the Environment IVL.

Light solid fibreboards by Metsä Board are produced from wood fibres obtained in the sustainable way, employing manufacturing processes which use the resources and energy, not-derived in a greater degree from fossils what allows reduction of the carbon footprint.

The above mentioned technology gives the possibility to the trade marks to create the projects of packaging which are lighter in comparison to those produced from traditional types of cardboard, with the preservation of stability and functional properties, characteristic of the fibreboards of higher weight.

The effect exerted on the environment: "from cradle-to-gate" + EoL (withdrawal from exploitation) of the packaging produced

THE PRESENTATIONS ENDED WITH A DISCUSSION ON EU LEGISLATION, LED BY ANNA NARUSZKO (CENTER). HER INTERLOCUTORS WERE ANNA KOZERA-SZAŁKOWSKA (PLASTICS EUROPE POLAND FOUNDATION) AND KRZYSZTOF NOWOSIELSKI (ML POLYOLEFINS)

from Metsä Board cardboard – ProFBB Bright and Metsä Board Classic FBB is by 61% to 64% lower than in the case of waste multilayer cardboard (WLC), representative for the European market.

Light (low weight) cardboards, produced by Metsä Board concern are characterized by a low carbon footprint.

After the break destined for session of questions and answers and for coffee break, **director foe sector analyses at Bank Pekao SA, Krzysztof Mrówczyński** delivered the lecture **"Situation and perspectives for Polish packaging sector"**. He presented the characteristics of the sector of packaging production in Poland and in the EU, with the particular highlighting of the section of wood, paper, glass, plastics and metal packaging.

He discussed also the situation in the EU sector, with the special analysis of the current trends in the national sector, together with the situation in export.

He presented also the analysis of demand in the discussed sector and the problems concerning ecology in respect of packaging and outlines the developmental perspectives if the discussed sector in the coming years, as well.

The lecture contains several dozens of diagrams and figures. It would be worthy that the decisions makers of the sector could be familiarized with the elaboration of Bank Pekao SA, being published in a form of 40-page brochure.

LEGISLATION OF THE EU – WHAT IT MEANS FOR THE PRODUCERS OF PACKAGING

The last event of the first day of the Conference included discussion: **"Legislation of the EU – where are we, what is our future and what is means for the producers of packaging"**. The participants of the discussion were: **Krzysztof Nowosielski from ML Polyolefins Ltd., and Dr Anna Kozera-Strzałkowska, Eng., managing director of Foundation Plastic Europe Polska. The discussion was moderated by Anna Naruszko, Editor-in-Chief of periodicals: "Packaging" and "Printing"**.

The discussion was focused on packaging regulation PPWR (Packaging and Packaging Waste Regulation), that is, the new solutions in respect of waste management in the EU. The EU legislator strives also at the increase of the participation of materials derived from recycling in manufacture of packaging, especially those made from plastics where its level is still low. The discussed regulation introduces the duty to employ the so-called recyclates in manufacturing process of packaging. The mentioned products are the secondary materials coming from recycling, inter alia, from the previous packaging. The draft packaging (PPWR) regulation differentiates distinctly the requirements recyclate, according, inter alia, to the following factors:

- Material from which a given packaging has been made;
- Destination of a given packaging
- Type of packaging.

THIS YEAR AS MANY AS 19 COMPANIES WERE AWARDED WITH PACKAGING CIRCULAR ECONOMY CERTIFICATES FOR THEIR EFFORTS IN PROPER WASTE MANAGEMENT.

Thus, from 2030 the minimum percentage of materials coming from recycling, recovered from the post-consumption plastics waste per unit of package will be principally equal to 30-35%. On the other hand, from 2040, the content of recyclate in packaging will have to be found within the range of 50% - 65%. The current draft regulation provides implementation of many assumed recycling targets as early as until the end of 2025. It will be, however, functioning at a full range as late as since 2030 and even 2035.

The run of discussion revealed that we will not satisfy the discussed assumptions for 2025, in respect of time or materials, in spite of shifting the time of commencing the application of recyclates from 1,January to 1, October 2025. We will not have the appropriate quantities of plastics recyclates at our disposal.

THE 7TH EDITION OF PCE CERTIFICATES

At the evening meeting, during a solemn dinner, the granting of PCE (Packaging Circular Economy) certificates was performed by ML Polyolefins company. This year, 19 companies were awarded. The following companies received the mentioned certificates: AMCOR, AMERPLAST, A-Z, COLOR, CDM, FOR-DRUK FLEXO, LIMPACK, LORENZ BAHLSEN LAJKONIK, MONDI, MPAK, FLOREK PLAST, PAK TORUŃ, Pałucka Packaging Printing House, Pakfol and Wedel.

The distinction went to Constantia Teich, Nitrochem and Prograf. The silver PCE certificates were granted to the companies which were distinguished by PCE certificate for the fifth time – Drukpol Flexo and Grafix.

THE STUDY TOUR

On the second day of the Conference, i.e. 20, October, 2024, there was organized a study tour at the Research Network Łukasiewicz – Łódź Institute of Technology, situated in Łódź, 19/27 Maria Skłodowska-Curie str.

During the visit at the Institute of Technology in Łódź, the participants of the Conference visited the specialistic accredited laboratories such as:

- Laboratory of Paper Research;
- Laboratory of Materials Research and Unit Packaging;
- Laboratory of Transport Packaging Research;
- Laboratory of Biodegradation and Microbiological Research.

For most of the participants, the visit at the Łódź Institute of Technology was their first contact with the research unit. They were very much satisfied with the discussed possibility.

The 14th Conference Safe Packaging has already passed to history. **We will meet in November 2025 during the 15th edition of the discussed event. We will be informed soon where it will be held**.

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