ÓBUDA UNIVERSITY

REJTŐ SÁNDOR FACULTY OF LIGHT INDUSTRY AND ENVIRONMENTAL ENGINEERING

IJCELIT 2021

Conference ISBN 978-963-449-262-7

https://ijcelit2021.rkk.uni-obuda.hu/

8TH INTERNATIONAL JOINT CONFERENCE ON ENVIRONMENTAL AND LIGHT INDUSTRY TECHNOLOGIES

18-19 NOVEMBER 2021

ONLINE

ÓBUDA UNIVERSITY
REJTŐ SÁNDOR FACULTY OF LIGHT INDUSTRY
AND ENVIRONMENTAL ENGINEERING

IMPRESSUM

It is a booklet of abstracts of the **8th International Joint Conference on Environmental and Light Industry Technologies** held online on 18-19 of November 2021. The conference was organized in the framework of the Hungarian Scientific Season. This publication was carried out by the Rejtő Sándor Faculty of Light Industry and Environmental Engineering of Óbuda University, Budapest, Hungary.

Conference homepage: https://ijcelit2021.rkk.uni-obuda.hu/

The Conference Book of Proceedings ISBN: 978-963-449-262-7

A MAGYAR TUDOMÁNY ÜNNEPE

MAGYAR TUDOMÁNYOS AKADÉMIA · 1825 ·

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FULL PAPERS

PLENARY SESSION

THE POTENTIAL CONTRIBUTION OF PSYCHOLOGY TO THE EXPERTISE OF DESIGNERS AND ENGINEERS - THEORETICAL DIMENSIONS AND PRACTICAL APPLICATIONS

Manuela Zambianchi

University Institute ISIA, Faenza, Italy

Abstract

Theoretical Background

Several recent and growing areas of research in Psychology such as Positive Psychology and Environmental Psychology intercept the contemporary issues of how improving the well-being of individuals and communities and how promoting the adoption of a more sustainable lifestyle in every life-stage. These contemporary challenges request for Designers and Engineers acquiring knowledge and skills that can enable them in creating new concepts, ideas and manufactures. The systemic approach to these complex issues about well-being and environment will request to future experts the ability to work in multi-professional teams and integrate their expertise in order to reach a multidimensional solution. **Method.** Through a mixed methodology, theoretical and with active participated laboratory, students enrolled in Design and Engineering Courses improve their knowledge in these psychological topics and then apply it in group laboratories, producing new ideas through the creative team techniques such as brainstorming. A special attention is reserved to the interpersonal communication processes for their pivotal role in favouring a positive psychological climate among the participants that increases motivation and creativity at work. **Results.** The experience of the experimental Course of Creative Thinking and Psychology for well-being of population and for sustainable behaviours that took places at Obuda University and in Italy will be discussed and some elaborations produced by students will be presented.

Keywords: Psychology; Positive Design; Soft Skills; Creative thinking

INTRODUCTION

Several recent and growing areas of research in Psychology such as Positive Psychology and Environmental Psychology intercept the contemporary issues of how improving the well-being of individuals and communities and how promoting the adoption of a more sustainable lifestyle in every life-stage.

Particularly, Positive Psychology, a research area born in the early 2000s (Seligman & Csikszentmilhanyi, 2000) [1] adopts a systemic and innovative perspective on individual, group and social well-being. Instead of highlighting, as happens in other areas of Psychology, the difficulties, maladjustment and critical situations, it focuses its attention on the resources and strenghts possessed at the individual level and by social structures. The analysis of the dimensions of well-being carried out by Positive Psychology has led to the identification of different, fundamental concepts and components of well-being. On the individual level, there are two fundamental dimensions: the Hedonic well-being (Kahnemann et al., 1999)[2] and the Eudaimonic well-being (Ryff, 1989; Ryff & Singer, 2008). [3]; [4]

The well-being defined as *Hedonè* derives from the ancient Greek philosopher Aristippo (435-366). According to this perspective, happiness is determined by the presence of a high level of life satisfaction (global life satisfaction and declined in its affettive-relational, social, working realities..), together with the presence and prevalence of positive emotions as inner affective states. This component of well-being posits the emotional dimension as essential for a high level of happiness and life quality, especially as subjective perception.
The individual psychological well-being defined as *Eudaimonia* derives from the ancient Greek philosopher Aristotle (383-322), which in the Nicomachean Ethics sustained that happiness consists in the actualization of talents and potentials of the individuals in favour to the development of the society. Ryff [3], one of its most important scholars, has identified six components of the Eudaimonic well-being: Self-acceptance; Autonomy; Positive Social Relationships; Personal Growth; Purpose in Life; Environmental Mastery. The psychological well-being declined in a Eudaimonic key, posits the places the self-realization tension as its essential, core element.
In addition to the development of individual well-being, Positive Psychology deals with the identification of modality for improving the well-being of groups, communities and society more generally (Zambianchi, 2015) [5]. There are several theoretical models developed on the social side: one of the most relevant was proposed by Keyes (1998;) [6], who defines Social well-being as the result of five components: Social Integration, Social Actualization, Social Coherence, Social Contribution, Social Acceptance. The proximal community also represents a field of investigation and planning of interventions: the Sense of Community model proposed by Mc Milan and Chavis (1986) [7] indicates four components for a positive sense of community: Integration and Fulfillment of Needs; Shared Emotional Connection, Influence; Sense of Belonging.
Which could be the potential contribution of Design to the improvement of individual and social well-beng? This design potential has been the subject of theoretical analysis and design development only in recent years (Desmet & Pohlmeyer, 2013; Yoon et al., 2020) [8], [9]. Through the new construct of Positive Design (Desmet et al., 2013) [8] some fundamental objectives of this integration between the two disciplines and its theoretical-methodological aspects have been identified.
Thinking at Design as a resource for the promotion of well-being in its various components represents a new, interesting area of intervention with a social function (Munari) [10]. The production of artifacts, concepts, communications aimed at the development of a specific component of well-being (e.g. design of interventions in the cultural-museum context for personal growth through cultural fruition implies the encounter with the Eudaimonic dimension of well-being; design of benches for a city park, implies thinking about the impact in terms of activating relationships and social communication, and therefore promoting the sense of community) is currently a promising path for research in a multidisciplinary key. As Desmet et al. [8] (2013) underline, design can contribute to Hedonic well-being (design for pleasure), Eudaimonic well-being (design for personal meaning) and Social well-being (design for virtues), thus adopting a dimension and objectives not only of an economic nature, but also of promoting the development of the individual and society.
An area of recent development but of growing importance is represented by the Psychology of Sustainability and Social Responsibility (Di Fabio, 2017) [11]. This is an area of study of an interdisciplinary vocation and has among its aims the reach of global well-being that includes also socio-economic dimension and the care of the environment. The Psychology of Sustainability and Sustainable Development (Di Fabio & Rosen, 2018) [12] has, as its specific focus, paying attention to positive sustainability and positive sustainable development processes. Positive sustainability includes the following aspects: attention to both respect and regeneration of resources; renewable resources, as well as purification and oxygenation processes for people and the environment; taking responsibility for health / wellness improvement and renewal. Construction and management of a sustainable project can be based not only on the use of ever smaller quantities of resources (materials), but also on regenerating resources. On the theoretical level, fundamental is the interaction between scientific discovery, technological application, good design and positive social effect (Positive Psychology & Sustainability Psychology), which require a multidisciplinary approach with points of contact (and collaboration of research and intervention) between Positive Psychology and Sustainability Psychology also through the concept of Positive Environment (Corral-Verdugo, 2019) [13], defined as " A *condition, or a*

context, that allow people to meet their needs and thrive, while simultaneously motivating the conservation of the resources it offers. Such conservation is aimed at protecting current environmental resources, but, most importantly, resources for future generations " (Corral-Verdugo, 2019). The concept of Positive Environment involves: Tourism (sustainable tourism); Aesthetic appreciation; Spiritual experience; Recreation; Education. Positivity is the result of the interaction between persons and the environment. As stated Corral-Verdugo (2019), the perception of the restorative quality of the environment predicted 23% of the variance in general ecological behaviors.

The systemic approach to complexity as a paradigm of analysis and intervention in human and environmental contexts represents an essential point of theoretical study for the training of designers and environmental engineers. The paradigmatic change that took place in the 1970s (Engel, 1977)[14] has changed the way of observing, reading, interpreting and intervening on reality, being it physical or bio-psycho-social. The central concept of "system", understood as a structure composed by many variables, whose functioning is qualitatively more than the simply sum of them and characterized by the interactionist-recursive logic, has replaced the linear-monocausal model of explanation, typical of systems with greater simplicity (generally two variables involved in a connection of a linear nature). Understand, on the part of the students, that their action, their design intervention takes place in a complex system characterized by the multiplicity of relationships and that any modification in a point of the system (such as the introduction of a new object in a domestic environment; the modification of a cycle path in an urban context; the introduction of innovative objects for environmental sustainability in a tourist resort of particular aesthetic value) involves, over time, the modification of the perception and characteristics of the entire system, offers them a fundamental competence for planning and dialogue with other professionals in a multidisciplinary approach (Leporelli, Santi & Di Sivo, 2018; Santi & Leporelli, 2019) [15], [16]: for these authors there is urgency of a vision capable of reconstructing a reconnection between health, urban planning and architectural design in line with research on sustainable development and environmental sustainability. The concept of "*Systemic Design*" implies therefore the fundamental role of the Designer and of the Engineers for the conservation and respect of the environment. It is based on the awareness that every solution they found in the planning phase will have an impact on the ecological system, setting in motion a transformation of it. Design and Engineering, in particular Environmental Engineering, play a central role in promoting environmental sustainability and promoting ethical development that fosters the social responsibility of individuals, groups and society in a broad sense. A key concept in this direction is represented by sustainable design. The sustainable design is defined as the result of the best compromise between environmental and technical -economic parameters, on the evaluation of environmental impacts and on the choice of materials, shapes and structures (Tamborrini, 2009) [17].The interventions of designers and engineers can also acquire an educational value; eg. the creation of sustainable objects of aesthetic value can suggest to an adult public that sustainability is combined with aesthetic usability, with a strong positive emotional value. as an intervention to promote sustainable behavior. This also through the support of effective communication to promote the designer product: going beyond the development of environmentally friendly products, tending to suggest sustainable behaviors (Tamborrini, 2009).

2. Confronting the complexity and uncertainty of post-modern society. Skills to "navigate" contemporaneity in a proactive and responsible way by the "emerging adults".

Contemporary society, defined as "post-modern society and of complexity" (Bauman, 2007; Beck, 1991) [18], [19] is characterized by a progressive opacity of the future, which becomes increasingly difficult to plan and reconnect with the actions produced in the present, together with a growing flexibility of roles and life biographies (Zambianchi, 2018; 2016; 2019) [20], [21], [22]. These characteristics, also summarized in the acronym VUCA (Volatility, Uncertainty, Complexity, Ambiguity) (Bennet & Lemoine, 2014) [23] require skills and resources to be able to deal with it in a positive and productive way, in particular, even if not only, by the younger generations, in particular by the "Emerging adults" (Arnett, 2010; Zambianchi, 2018) [20], [25], which include university students by age.

The Division of Mental Health of the World Health Organization highlighted, since the nineties (WHO, 1994) [26], the growing importance of Life-Skills, defined as a set of cognitive, social and relational skills that allow young people to face the needs of daily life in an effective way, relating with trust to oneself, to others and to the community. The life skills identified by the WHO are the following: Self-awareness; Management of emotions; Stress management; Critical thinking; Decision making; Problem solving; Creativity; Effective communication; Empathy; Interpersonal relationships. They have been designed with a view to increasing skills and abilities that can both guarantee an effective management of life transitions (such as, for example, entry into workforce, the construction of a family), and the ability to manage situations of criticality and stress. Similarly, the concept of Soft Skills (Robles, 2012) [27] offers a set of skills useful for entering the world of work, such as, for example, effective communication and social skills. These skills, or at least some of them, can be thought of within university curricula such as a specific subject area, or within courses in the psychological area as a module for in-depth study of cognitive, social and relational skills and processes. Degree Courses in Design and Engineering could enrich their training offer in this sense as a complement to strictly specialized training.

The construction of a didactic proposal of the psychological area for the cultural and professionalizing profiles of the future graduate Designer and Environmental Engineer. The teaching methodology.

Considering the future professionalism of the undergraduate student in Design and Environmental Engineering, that implies the possession of strong projecting abilities coming from the acquiring of theoretical and laboratory knowledge, the didactic proposal of psychological area involved the methodological choice of a mixed methodology of theoretical analysis and subsequent concrete application through the activity of laboratory groups. Through indeed a mixed methodology, theoretical and with active participated laboratory, students enrolled in Design and Engineering Courses improve their knowledge in these psychological topics and then apply it in group laboratories, producing new ideas through the creative team techniques such as brainstorming (leaned during the theoretical part of the Courses). A special attention is reserved to the interpersonal communication processes for their pivotal role in favouring a positive psychological climate among the participants that increases motivation and creativity at work.

Results

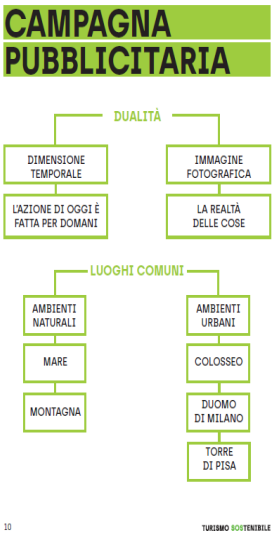
The didactic experiences from University Institute ISIA, Italy, and Obuda University, Hungary.

1-A. *The workshop on Psychology of Sustainability and Social Responsibility at ISIA University Institute.*

The Workshop that has been proposed to the ISIA students (enrolled in every Course, both Bachelor and II Level Degree) had its theoretical and practical focus on Psychology of Sustainability and Social Responsibility. They than applied the principles of creative- divergent thinking and the techniques of brainstorming to their group-work.

In the first part of the Course, the key concepts of the Psychology of Environmental Sustainability and Social Responsibility were studied in depth, together with the Theory of complex systems (von Bertalanffy, 1980) [28]. Sustainability was then declined in specific areas such as recycling, attention to the environment, sustainable tourism (the latter through a specialist intervention by a professor of Economic Geography with a lecture on this topic and a discussion with the participants), sustainable nutrition. Subsequently, the students were divided into two groups, and each of them chose a theme on which to build a social communication project. A group chose the sustainable tourism; a group the issue of sustainable food and healthy -sustainable diet, with a specific attention to Mediterranean Diet. Below are two posters drawn up by the students, with the iconic dimension and the structuring of the argumentative path.

THINK. FEEL. ACT. The poster created for encouraging a Sustainable Tourism among adult



Personal reflections and considerations upon the Course by ISIA students

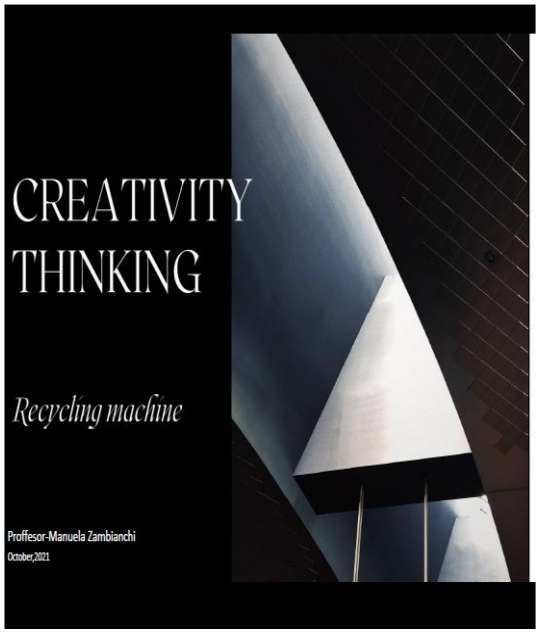
Nel complesso ritengo il workshop abbia creato numerosi spunti riflessivi su temi che non sempre metto al primo posto, e che talvolta ignoro. Motivo per cui ho deciso di entrare a far parte di questa esperienza collettiva. Sento nel complesso di aver sviluppato maggior senso critico riguardo alla sostenibilità ambientale. Overall, I believe the workshop has created numerous reflective ideas on issues that I do not always put in the first place, and that sometimes I ignore. Reason for which I decided to become part of this collective experience. Overall, I feel I have developed a greater critical sense of environmental sustainability (Valerio M. student at ISIA)

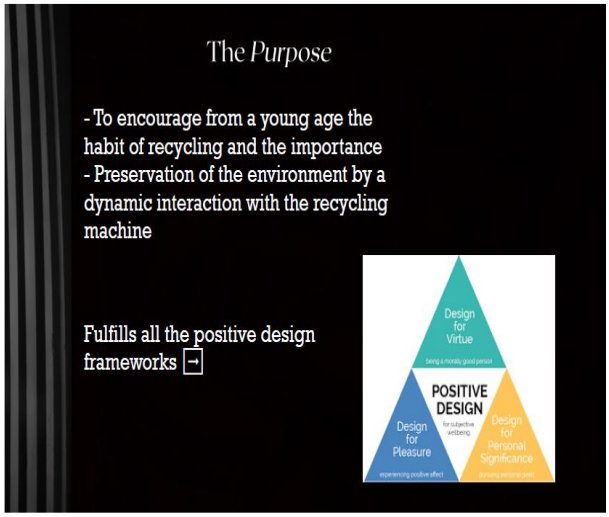
"Al giorno d'oggi un designer non può ignorare aspetti come la "sostenibilità ambientale" e la "responsabilità sociale" nei propri progetti, per questo è importante che questi concetti venganoappresi attraverso un corso incentrato sulla psicologia, in modo che il progettista prenda coscienza delle problematiche. Nowadays, a designer cannot ignore aspects such as "environmental sustainability" and social responsibility in their projects, so it is important that these concepts come learned through a course focused on psychology, so that the designer becomes aware of problems". (Andrea F. student at ISIA)

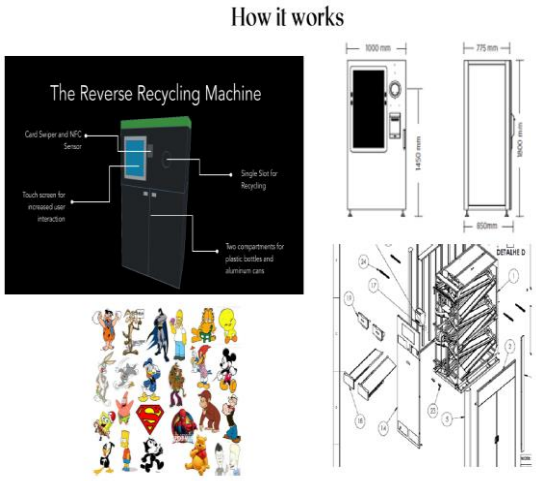
1-B The Creative Thinking Course at Obuda University.

The Course deepen the following areas of Psychology: The Positive Psychology and its relevance for Design; the Psychology of Sustainability and Social Responsibility; Positive Aging and Design (this issue was chosen do its growing relevance for all the societies); Creative processes (the course deepened the different logics of thinking and the detailed characteristics of divergent thinking style, with individual exercises); Psychology of Interpersonal Communication. The Course provided firstly a theoretical background and then the students enrolled were divided in two groups. A group choose the sustainability as area for the project (A Recycling Machine); the other group choose the interface between climate change (sustainability) and design for life-quality (The Multi-brella).

The Project of the Recycling Machine for children.







Personal reflections upon the Course by Obuda students

"In my personal opinion, the course has highlighted the importance of theory. It is important to stick to sometimes criteria and exanimate the circumstances and guidelines and not just focus on creativity. Focusing on the theory helped me to enlarge different aspects of design thinking, such as design principals and social participation. I believe that both the positive aging and creative thinking topic were very intriguing to explore. I have to say that they sparked several questions in my mind about implementing theoretical research into my future design studies" (Anna S., student at Obuda University)

"I have been working as a designer and a marketer. I though I had some experience in this field; however, the creative design course has not only taught me what it means to be a good designer, it taught me what it means to be a good communicator, a good team player. I have successfully integrated the communication theory lesson to my life and embraced myself not to be misunderstood by the meta-communication..My most favourite topics were intelligence and creativity comes from, and psychology of communication. I believe these topics give great step by step details in how to effectively and directly positively impact your life. As a person who works with many other colleague son marketing campaigns, on designs, and on products, I find fostering creativity as a team and as an individual, effectively communicating with them and not making them feel psychologically unsafe is the greatest lessons I could have learnt in any course" (Aria Z., student at Obuda University)

Conclusions

The courses held at ISIA and Obuda and the encouraging evaluation by the students indicate a path with potential for development at the didactic level and, for emerging contents, on the theoretical and application level. Meeting the challenges of contemporary society: Designers and Engineers can be seen as professionals who intervene to improve the quality of life of people, groups, communities and ecosystems.
The presence of skills (also) of a psychological nature enriches the training and professionalizing university path by offering both theoretical interpretations of reality useful for working in multi-professional teams, communication, critical and creative thinking skills, essential for interacting with others and creating methods of interventions, conception and explanations of innovative, or urgent, phenomena of reality.

References

[1] Seligman, M., & Csikszentmilhanyi, M. (2000). Positive Psychology. An introduction. *American Psychologist*, *1*, 5-14. DOI: 10.1037//0003-066X.55.1.5

[2] Kahneman D., Diener E., Schwarz N. (eds). (1999). *Well-Being: The Foundations of Hedonic Psychology.* New York, NY: Russell Sage Foundation.

[3] Ryff, C.D. (1989). Happiness is everything, or it is? Explorations on the meaning of psychological well-being. *Journal of Personality and Social Psychology, 57*, 1069, 1081.

[4] Ryff, C.D., & Singer, B.H. (2008). Know thyself and become who you are. A eudaimonic approach to psychological well-being. *Journal of Happiness Studie*s, *9*, 13-39. DOI 10.1007/s10902-006-9019-0

[5] Zambianchi, M. (2015).*Psicologia Positiva (Positive Psychology)*. Carocci Ed. Rome

[6] Keyes, C.L. M. (1998). Social Well-Being, *Social Psychology Quarterly,* 2, 121-140.

[7] Mc Millan, D., & Chavis, D. (1986). Sense of Community: A Definition and Theory. *Journal of Community Psychology*, 14, 6-23.

[8] Desmet, P. M. A., & Pohlmeyer, A. E. (2013). Positive design: An introduction to design for subjective well-being. *International Journal of Design,* 7(3), 5-19.

[9] Yoon et al., (2020). Design for Positive Emotions: Issues and Emerging Research Directions. *Design Journal*, 24, 2, 1-21.DOI:10.1080/14606925.2020.1845434

[10] Munari, B. (1998). *Good Design*. Ed. Corraini, Mantova.

[11] Di Fabio, A. (2017). The Psychology of Sustainability and Sustainable Development for Well-Being in Organizations. *Frontiers in Psychology*, 8, doi: 10.3389/fpsy.2017.01534

[12] Di Fabio, A., & Rosen, M. A. (2018). Opening the Black Box of Psychological Processes in the Science of Sustainable Development: A New Frontier. *European Journal of Sustainable Development Research,*2(4), 47. doi: 10.20897/ ejosdr/3933.

[13] Corral-Verdugo, V., & Frías-Armenta, M. (2016).The Sustainability of Positive Environments. *Environ. Development and Sustainability*18, 965–984. 10.1007/s10668-015-9701-7

[14] Engel, (1977). The need of a new medical model: a challenge for biomedicine. *Science*, 196 (4286), 129-136.

[15] Di Sivo, M., Leporelli, E., & Santi, G. (2021). Healthy City Management. Innovative Sustainable Perspectives in Architecture and Urban Space. *Counseling. Italian Journal of Research and Application,* 14, 2, doi: 10.14605/CS1422101

[16] Santi, G., & Leporelli, E. (2019). Architectural space and psychology of sustainability: A new paradigm for living place design. *Counseling. Italian Journal of Research and Application,* 12(*1*). doi: 10.14605/CS1211901

[17] Tamborrini, P. (2009). *Design Sostenibile (Sustainable Design).* Ed. Mondadori Electa.

[18] Baumann, Z. (2007). *Liquid Times. Living in an Age of Uncertainty.* Ed. Polity Press.

[19] Beck, U. (1992). *Risk Society: Towards a New Modernity*. London, Sage.

[20] Zambianchi, M. (2018). Time Perspective, coping styles, perceived efficacy on affect regulation and creative problem solving in adolescence and youth. *Psicologia Educativa (Educational Psychology*), 24, 1-6.

[21] Zambianchi, M. (2016). Proactive personality, Social well-being and civic participation in emerging adulthood. *Applied Psychology Bulletin, 276, 3-17.*

[22] Zambianchi, M. (2019). Time Perspective and Eudaimonic well-being in a sample of Italian Emerging Adults. *Counseling. Italian Journal of Research and Application, 3.*

[23] Bennett, N., & Lemoine, G.J. (2014). What a difference a word makes: Understanding threats to performance in a VUCA world. *Business Horizons,* 57, 311–317.

[24] Arnett, J.J. (2015). *Emerging Adulthood: the winding road from the late teens through the twenties*. New York: Oxford. II edition.

[25] WHO, (1994). *Life Skills education for children and adolescents at schools*. Division of Mental Health, Geneva.

[26] Robles, M.M. (2012). Executive perceptions of the top 10 soft skills needed in today's *workplace. Business Communication Quarterly*, 75(4), 453-465. DOI: 10.1177/1080569912460400

[27] von Bertalanffy, L. (2004). *Teoria Generale dei Sistemi, Fondamenti, Sviluppi, Applicazioni* (*General Theory of Systems, Foundations, Development, Applications*), Ed. ILI.

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THE EFFECT OF PACKAGING COLOR ON PRODUCT SALES

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Abstract

Packaging is an effective sales tool that directly affects the marketing of a product and allows the product to be transported, stored and used. A successful packaging, which ensures that the physical properties of the product are preserved until it reaches the consumer, acts as a silent seller by attracting attention in the retail environment in line with contemporary shopping habits. In addition, the form, the material, the way of use and the graphic elements on it and the packaging are a promotional item that reflects the product identity. Packaging shows structural and visual changes depending on the product type and marketing conditions. The images on the packaging create logical and emotional associations about the product, encouraging consumers to buy. Packaging directly affects purchasing behaviors. Different colors used in the packaging create different purchasing situations for people depending on the age, gender, mood and race of the person.

In this study, different packaging and designs in different colors were shown to a sample group of 100 people and the psychology of purchasing behavior (bitter, spicy, chocolate, death, clean, dirty, etc.) created in the group was examined. As a result, it was determined that the effect of color on purchasing varies between 80-100% for different products.

Keywords: *Packaging, Color, Purchase, Printing*

1. INTRODUCTION

Packaging with a general definition; it is the whole of the methods and measures that will increase the sale of the product, which is used for the purpose of protecting the product from the producer to the consumer, and after reaching the consumer, for the purpose of promoting the product it contains [1]. The task of the packaging is to reduce the transportation cost of the product, to extend its life, and to attract attention by competing with its counterparts in the sales channels where it will be presented to the consumer, thanks to its graphic and structural design qualities, and as a result, to sell the product [2-3]. In other words, the packaging not only protects the product and facilitates its distribution, but also fulfills very critical functions regarding the marketing of the product [4-5]. Consumers react to the form of packaging, the brand of the product, the colors and forms used in the packaging, and they instinctively imagine a shape in their minds. Therefore, the packaging element encourages the product to stand out from its competitors, to be recognized by the consumer, and accordingly, to try and re-purchase [6]. Packaging has basic and side functions. Basic functions are functions that must be performed unconditionally. Side functions are optional functions that do not have to be included in the package that can be dispensed with if desired. While carrier, protection and narrator are the basic functions of packaging, storage, advertising and marketing are secondary functions. The goals of a successful packaging;

- It should protect the product and keep contaminants away from the product.
- It should provide benefits during the transportation, distribution and marketing of the product.
- It should prevent the possibility of loss of the product.

- Packaging format, weight and dimensions should provide comfort to the consumer.
- Product packaging such as food should be protected from physical and chemical damages.
- It should be able to introduce the product, attract attention and present the necessary information for the correct use of the product.

1.1 Functions of Packaging

- Carrier Function

The intended carrier function in packaging is the function of transporting a product safely and easily from the place of production to the area of use with low transportation costs at the same time.

- Protective function

While the packaging protects the product from physical damage such as falling, impact, vibration, wetting, and injury, it should also protect the product quality.

a. Storage Function: The packaging must be systematically stacked on top of each other and designed to occupy a minimum of storage space.

b. Quantity function: Packaging depending on the condition of the product on a weight basis. It directly affects its size. The larger the packaging package, the lower the packaging cost per unit, but the larger the package, the more difficult it is for the consumer to transport and finish before the expiration date, which is not preferred.

- Narrative Function

This function provides a link between the consumer and the product. If the product of the packaging communicates correctly and quickly, the faster the product will be sold. While packaging gives introductory and instructive messages to the consumer, it should also appeal to the emotions thanks to its design.

a. Advertising function: With this function, the target is to attract the attention of the consumer to the product. Each of the graphic, image, text and color elements on the product can be presented as an advertisement. It is a silent salesperson who sells the packaging product to the consumer. The consumer first encounters the packaging and the purchasing movement is directed according to the packaging. While very good packaging may sell the bad product, bad packaging may cause not very good packaging to be sold. Nowadays, the advertising function of packaging is gaining more and more importance due to the requirements of fast consumption culture.

b. Marketing Function: It is the function of the packaging, which contains the advertising elements correctly, to present the product for sale correctly and on the spot. Today's marketers are aware that packaging plays a huge role in differentiation and marketing strategies and they try to use this function effectively [7].

Packaging design studies are usually carried out in line with certain marketing-oriented functions such as increasing sales, market enlargement, cost reduction, getting a quick reaction from the target audience and the market, or introducing new products. Among the packaging design elements, the color, the shape of the packaging, typography symbols and numbers that attract the attention of the consumer the most. Packages that use these four design elements effectively are successful.

The necessary features to make the packaging design successful can be summarized as follows.

- The packaging should catch the consumer's eyes directly, without searching, while walking between the shelves.
- Packaging should be constantly renewed and compatible with all times by tending to trends and fashion trends.
- Packaging should affect the consumer emotionally.
- It should have its own characteristics and be distinguishable from its competitors.
- The selected printing and production technique should be compatible with the packaging material. The print must be of good quality.

It is unlikely that a package will be adopted and liked by all target audiences at the same time. Target audiences often have different demographic and psychological characteristics. Categorizing target audiences is a logical approach for designers and manufacturers. Before the packaging design is made, the profile of the consumers in the market where the product will be presented, their expectations from the packaging and the sales environments should be thoroughly researched and analyzed. While determining the target audience in packaging design, groups can be made according to age, including young consumers, children and consumers over the age of fifty, while designs can be made according to gender (female/male) and geographical conditions.

The elements that make up the packaging design can be listed as structural design, graphic design and color. Within the scope of this study, the subject of color in packaging design has been emphasized. Colors that we can notice thanks to our sense of sight are formed by the perception of reflected light or direct light. Color is a visual language that we feel through our eyes and has the ability to create perception in our minds [8-9]. Color is a basic design element that emerges as a result of the impact of light on objects and surfaces. Colors make everything around us visible thanks to light. Light, surface, eye and brain provide this process of appearance. It is physiological for the light to reach our brain by hitting various places and refraction in the eye, but the perception of our brain is a psychological event. Colors with proven effects on people are used to evoke many emotions. Warm colors are often stimulating, while cool colors are relaxing and restful. Red has been used for centuries as a sign of nobility and wealth, while generally describing passion and danger. Color, which affects traditions and customs, has always included a meaning from the past to the present, even in ancient times. The Greeks have always cared and studied colors in the past and observed and researched what happens in the mixing of colors. Aristotle revealed that all colors between black and white are composed of the combination of light and black. In later times, Hippocrates said that there are 4 colors and they occur as white, red, black and yellow. Even religions had colors during the Middle Ages and the renaissance. Every color is a symbol. The 4 elements found in nature used to represent the 4 primary colors. These are listed as follows; Fire-Red, Earth-Black, Air-Blue, Water-Violet. When things were like this, colors had many meanings for people. Many of these meanings were mysterious. Blue represented heaven, red showed hell, purple meant cruelty, and white represented clarity. In the 15th century, purple was the color worn by the rich of the time in Europe, and these clothes were complemented by red caps. In Rome, people called senators usually wore red. Newton, on the other hand, came out in those years and said the 7 color theory.

There are general opinions and perceptions about colors in the minds of consumers and designers. For example, when it is said red, passion, blue sadness, yellow luxury feelings have been created by many people [10]. However, due to the complex structures of colors, they should not be contented with general judgment and should be examined in detail in terms of their use in the market and psychologically. While colors can have meanings individually, they can gain new meanings by interacting when used together.

Black color; it is the color of power, majesty, passion, solemnity and formality. It also means mourning in many western cultures. Being the darkest color, it is known to evoke pessimism, bad faith and melancholy, which are negative effects and feelings. The use of black color in packaging adds a serious image to the product and is a color that can attract the attention of the consumer. It shows the product quality and expensive by using it in the packaging.

Figure 1: Example of packaging in black color

Brown is the color of the earth, represents abundance, and is known to evoke feelings of hesitation and doubt. It has been determined that people move faster in brown-walled environments and start moving faster. The color of fast food restaurants is usually brown, as it is more unbearable to sit in brown environments compared to other colors. Brown is the color of mourning in India. It can be preferred because of the color of the brown product, which is preferred in chocolate packaging.

Figure 2: Example of packaging in brown color
(https://en.99designs.es/profiles/FredrickBalois/designs/1857638)

White is the color of cleanliness, innocence and purity. In many cultures, the fact that wedding dresses are white is due to the feeling of purity. In some Asian societies, white is the color of mourning. It uses the word

white in its advertising discourses for almost all detergent brands, as it creates a feeling of cleanliness. It is frequently preferred in milk, detergent, medicine and medical equipment packaging.

Figure 3: Example of packaging in white color (https://www.apple.com/tr/shop/bag)

Red is an extremely dynamic and powerful color. While it can motivate and encourage people, it also gives energy. It evokes warmth, enthusiasm, extroversion. It accelerates blood circulation and pulse, has the effect of increasing adrenaline. Red is the color of danger and caution by many cultures. This is why red is used on the safety buttons of weapons. Traffic signs are also used because of the attractiveness of red. In India, the color of the wedding dress is red, which means luck. Since the red flag evokes rebellion and revolution, many countries prefer this color in their flags. Since the red color is formed just behind the retina, we feel closer to ourselves. It is known that since the visibility of red on the shelves is higher than other colors, it attracts more attention and is frequently used in packaging. Red evokes an irresistible sense of reception in packaging design. Like strawberry, it is the color of the blackberry family and can be used in packaging to express them and spices. It is preferred by many food companies because it is known for its appetite.

Figure 4: Example of packaging in white color (https://www.johnsbyrne.com/blog/packaging-colors-say-brand/)

Yellow; The brightest color. Screams for attention; That's why yellow is preferred for warning lights. Also, taxis in the world are yellow because of their attractiveness. The dominant colors of autumn, yellow and yellow-orange, have a strong appeal that captures our emotions. It tells of happiness and joy. Yellow is also associated with wit, refinement, and practicality. There is a sense of social life and reflect work together. It is a symbol of impermanence. In all the sad beauty of autumn, it is possible to watch it in its dark tones. It is used in the meaning of reign and palace in Chinese culture. It is used in packaging to emphasize sourness,

lemon and freshness. It is generally used in oil and tea packaging to create a sense of wellness. Golden yellow adds expensiveness and prestige to the packaging.

Figure 5: Examples of packaging in yellow and golden yellow color (https://percept.com.au/work/packaging/lipton-yellow/ and https://www.designerpeople.com/blog/packaging-design-trends-2021/)

The dominant color of the world, blue is a timid color; describes relaxation and passivity. When used in dark tones or intensely, it creates a depressing and gloomy effect, when used in light tones or mixed with white, it creates a soothing and reassuring effect. It is a color that reflects the throat area in our body. Blue color is the symbol of sea, sky and wide horizons. It symbolizes limitlessness and farsightedness. It represents peace and calms. Arabs believe that blue slows down the blood flow, that's why the evil eye bead is blue. In the West, they paint the bridge piers blue to reduce suicides. It has been determined that children misbehave less in schools with blue walls. It is the color of immortality in Chinese culture. Blue colors evoke the feeling of moving away from us. It is generally used in blue color water packages, which creates an image of cleanliness, and in yoghurt packages because it creates a feeling of freshness.

Figure 6: Example of packaging in blue color (https://www.designerpeople.com/)

Green describes silence. It is thought that the heart organ, an organ that affects us the most emotionally, is in the energy field emitted by this color. It is the color of nature and spring. It is the color that gives confidence. Therefore, it is the dominant color in the logos of banks. Green stimulates creativity. That is why green is chosen on the kitchens of big restaurants. Green is also used in hospitals because of its relaxing properties. The green area is determined to take people less stomach discomfort. It is a color used in food packaging, in the packaging of mint-apple or sour products, and in places where it is desired to give the

impression of being beneficial to health because it evokes ideas such as recycling and renewal. It is used in the packaging of yoghurt and fresh plant flavored products due to the impression of health and naturalness.

Figure 7: Example of packaging in green color (https://www.dairyfoods.com/articles/91687-dairy-packaging-gets-a-makeover)

Orange is a color that makes us feel the comfort and brightness of the sun, has exciting, encouraging, cheerful and happy effects. It reinforces enthusiasm, cheerfulness and friendliness. It is used in spicy or fruity foods in food packaging. It is also frequently preferred in sun oil and creams.

Figure 8: Example of packaging in orange color (https://99designs.com/product-packaging-design/contests/create-packaging-design-fun-squeeze-jelly-treat-886656)

Pink is the color of togetherness, happiness and trust. It usually attracts the attention of girls. It is used in the cosmetics industry and in confectionery packaging.

Figure 9: Example of packaging in pink color (https://www.ateriet.com/pink-food-packaging-design/)

Purple is the color of wealth, luxury, royalty, nobility, self-confidence and headstrongness, intelligence and power. However, it also appears as a neurotic color. Intense use reveals feelings of fear and regret. Purple and blue tones can be used in detergent packaging as they create a feeling of microorganism killing. In food packaging, purple color is used to indicate the flavors of grapes and blueberries.

Figure 10: Example of packaging in purple color (https://www.pinterest.com/packagingexpert/purples-in-packaging/)

2. EXPERIMENTAL

In this section, various tests were carried out in order to understand the effects of colors on human psychology. In the literature researches, it has been determined that the green color evokes a sour feeling in people. In order to compare this result with the experimental group, three chips packages were designed. The designed chips packages are given in figure 11. As the experimental group, 100 students from Marmara University were used as a sample group.

Figure 11: Chips packaging designs shown to the sample group

In this experiment, people were shown these 3 pictures and asked which ones were seasonal greens, which were spicy, which were salty, and which were cheese.

Studies have shown that yellow/brown color evokes a sense of naturalness in people. In order to compare this result with the experimental group, 2 cracker packages were designed. The cracker packages designed are given below. In this experiment, these two pictures were shown and it was asked which one was natural and which one was synthetic.

Figure 12: The designed cracker packages in the study

In this research, a test was conducted to find out which color is the official color in people's eyes. In order to compare this result with the experimental group, three different colored cars are shown.

Figure 13: The three different colored cars shown to the experimental group

The pictures given above were shown to people and asked to rank these cars from civilian to official.

Studies have shown that red color is associated with chocolate. In order to compare this result with the experimental group, three different colored chocolate packages were designed. The chocolate packages designed are given below.

Figure 14: The three different colored chocolate packages shown to the experimental group

The pictures given above were shown to people and asked which one was a real chocolate package.

In the researches, it has been revealed that the color of death is different in European countries compared to Asian countries. It has been revealed that the color of death in European countries is black. In order to compare this result with the experimental group, black and white colors, which are the colors of death in two different cultures, were shown to the sample group and they were asked which one evoked death.

3. RESULTS

Within the scope of the experiment, chips packages were shown to the sample group. As a result, when the answers given by the experimental group students were examined, the green one of the chips packages in the pictures was associated with seasonal greens with a rate of 85%. The red one of the chips packets was associated with spicy with 80% rate. In the blue one of the chips packages, 50% associated with salty, but 50% associated with cheese.

As we can see from here, people think of sour and fresh flavors when they see the color green. That's why people associated the green color with seasonal greens with a sour taste. As the red color evokes things that are spicy in people's minds, people considered the red color appropriate for the spicy chips. In the blue color, unexpectedly, the blue color was associated with a low amount of salt.

In another example, cracker packs were shown to the sample group. As a result, when the answers given by the experimental group students were examined, the purple cracker packages in the pictures were associated with synthetic content with a rate of 80%. The yellow/brown cracker package was associated with 80% of the natural ingredients.

As we can see from here, when people see earth tones, they think of naturalness. When people see the color purple, they think of synthetic content, that is, artificial content, compared to earth tones.

In another example, cars of different colors were shown to the sample group. As a result, when the answers given by the experimental group students were examined, the black car in the pictures was associated with

the official car with a ratio of 95%. The gray one of the cars was associated with a medium official car with a rate of 85%. The white one is associated with the civilian car with a rate of 90%.

In another example, chocolate packages in different colors were shown to the sample group. As a result, when the answers given by the students in the experimental group were examined, the red packaged chocolate among the pictures was associated with the red packaged chocolate at a rate of 100%. The red color, which we know has a great effect on people, has also shown itself here.

In another example, black and white colors were shown to the sample group. As a result, when the answers given by the experimental group students were examined, the color black from the colors in the pictures was 90% people associated death with black. In 10%, people associated the color white with death.

4. CONCLUSIONS

In this study, the purchasing effect of colors was investigated. When the results are examined, it is seen that red color evokes a desire to buy and is associated with chocolate, green/brown colors make people feel that the product is natural, black color evokes death in the majority, also people associate black color with official institutions in the examination where cars are used, and finally, red reminds spicy tastes. It was concluded that green evokes fresh tastes. In the results obtained, the response distributions of the individuals are generally in a narrow area, that is, they are consistent. As a result, colors create certain emotions in people, which directly affects people's purchasing behavior.

5. REFERENCES

[1] Ozcan, A.: New approaches in smart packaging technologies, *Proceedings of the 10th International Symposium on Graphic Engineering and Design*, *GRID2020*, (Ed: Sandra Dedijer), (pp 21-37). Novi Sad, Serbia, (2020) https://doi.org/10.24867/grid-2020-p1

[2] Jobber, D.; Ellis-Chadwick, F.: *Principles and Practice of Marketing*, 9.E. Mcgraw-Hill. ISBN: 152684723x, e-book, (2019)

[3] Zelzele, Ö. B. et al: Ambalaj sektöründe kullanilan saf selüloz kağitlarin baskisinda optimum flekso baski parametrelerinin belirlenmesi. *Proceedings of the* International Congress on New Trends in Science, Engineering and Technology, (pp. 54-60). Barcelona, Spain (2017).

[4] Meyers, H. M.; Lubliner, M. J.: *Başarılı ambalaj Başarılı pazarlama*, (Çev: Zehra Üsdiken), Rota Yayınları, ISBN:9789758296644, İstanbul, Turkey, (2003).

[5] Majid, I. et al: Novel food packaging technologies: innovations and future prospective. *Journal of the Saudi Society of Agricultural Sciences*, **Vol.** 17 No. 4, pp. 454-462. (2018) https://doi.org/10.1016/j.jssas.2016.11.003

[6] Martinez, L. M. et al: True colors: consumers' packaging choices depend on the color of retail environment. *Journal of Retailing and Consumer Services*, **Vol.** 59, 102372, (2021), https://doi.org/10.1016/j.jretconser.2020.102372

[7] Ampuero, O.; Vila, N.: Consumer perceptions of product packaging, *Journal of Consumer Marketing*, **Vol.** 23 No. 2, pp. 100-112. (2006), https://doi.org/10.1108/07363760610655032

[8] Sara, R: Packaging as a retail marketing tool, *International Journal of Physical Distribution & Logistics Management*, **Vol.** 20 No. 8, pp. 29-30. (1990), https://doi.org/10.1108/eum0000000000372

[9] Baptista, I. et al: Effects of packaging color on expected flavor, texture, and liking of chocolate in Brazil and France. *International Journal of Gastronomy and Food Science*, *24*, 100340. (2021), https://doi.org/10.1016/j.ijgfs.2021.100340

[10] Holtzschue, L.: (Çev: Akdenizli, F.) *Rengi anlamak: tasarımcılar için kılavuz kitap*. Duvar Yayınları. İstanbul, Turkey, (2009).

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GCTW SESSION

THE DIFFERENCE BETWEEN SCRUM AND OTHER AGILE AND TRADITIONAL METHODOLOGIES

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Abstract:

SCRUM defines the systems development process as a loose set of activities that combines known, workable tools and techniques with the best that a development team can devise to build systems. In the recent years, software development organizations are striving to adopt agile software development methods and techniques. Successful agile adoption leads to producing higher quality software, enhances developers moral at a lower cost than the traditional waterfall model approach. It is necessary to know which methodology is the best for the appropriate project, considering that the projects differ according to the people in the team, the duration of the projects and the like. It is assumed that Scrum is the best methodologies, that it is most applied and should be compared with others in order to see the differences and to know which methodology is best used in the appropriate project because it is assumed that a methodology must be chosen to meet all project needs. This paper presents a review of Scrum Methodology, as well as the extent to which it is applied, and describe difference and advantages between SCRUM and other methodologies. It was concluded that Scrum is the most used, but that it is desirable to use the methodology that is best for the respective project since the projects differ.

Keywords:

Scrum, Waterfall, Kanban, agile methodologies

1. INTRODUCTION

Many new software development approaches were introduced to fit the new cultures of the software development companies. Most companies nowadays aim to produce valuable software in short time period with minimal costs. Customer requirements are frequently changing and making it even more difficult [1]. Traditional software development approaches have a potential to provide straightforward, systematic, and organized process in the software development. The traditional approaches have limitations such as adaptation to rapidly changing business requirements, a tendency to be over budget and behind schedule, a lack of dramatic improvements in productivity, reliability, and simplicity [2].

Software Development Life Cycle (SDLC) consists of few phases like planning, analysis, design and implementation [1][3][4]. Software Development Life Cycle Model is used as a process of creating and altering current existing system. SDLC can be thought of as a concept that used by many software development methodologies, which are currently available in market or software industry [4]. Many number of SDLC models have been created like Waterfall, Spiral and V-model etc. There are many number of new approaches, SCRUM (Agile methodology) is one of them. Agile consists of many methodologies but SCRUM is most famous and powerful methodology which provides benefit to companies. SCRUM is simple for managing difficult projects. It is used at many companies with success when compare to traditional SDLC model [1]. It was included in agile methodology since it contains the same concepts of agile. A SCRUM is a team pack, where everyone in the team acts together. It delivers the project within time and with minimal cost [1]. Scrum starts with the premise that software development is too complex and unpredictable to be planned exactly in advance [5].

Some of important development models are: Waterfall model, V model (verification and validation), Incremental model, RAD model (Rapid Application Development), Agile model, Iterative model, Spiral model [6]. In our comparative study, some agile and traditional methodologies will be discussed and the differences of the Scrum methodology in relation to other methodologies will be stated.

2. THEORETICAL CONSIDERATION

The difference between traditional methodologies and agile software development methodologies is that traditional methodologies are complicated, constant, sequential, oddest and highly mature level but agile methodologies had been adopted in many projects due to its ability to better cope with frequent changes in requirements. Agile methodologies are suitable when requirements change during each process. Keen observation of analysis shows that agile methodologies help us to acquire better outcome with high quality, more client satisfaction, efficiency and management within the specified time and expenses. Agile methodology encourages the developer team to meet with the customers on regular basis in order to validate and verify their requirements [3][7]. Hybrid Agile methods and their effectiveness under different environments are an interesting field of study in software processes [8].

2.1 Waterfall

The Waterfall model was introduced by Royce in 1970 [9][10][3][6][11]. The Waterfall model is one of the traditional SDLC model, it follows only the sequential order. It flows steadily downwards. This leads to face these problems - Customer will not get satisfaction, requirements will be in pending, no profit, waste of time [1]. The Waterfall model is the first applied software development strategy, resembling the designs that were used in other industries [12]. The Waterfall methodology was one of the first such defined system development processes [13]. After completing the first phase only we can proceed with next phase [1].

Some important features of the methodology are [1][10]
:

- Waterfall follows each step in a linear path.
- Plans all features for simultaneous implementation
- Designs all features
- Implements all features
- Tests all features
- Each phase of development proceeds in order without any overlapping.
- Each phase task to be completed within a specified time period
- The documentation and testing happens at the end of each phase, which helps in maintaining the quality of the project.
- In waterfall model the defect were found very late Figure 1 shows phases of Waterfall model.

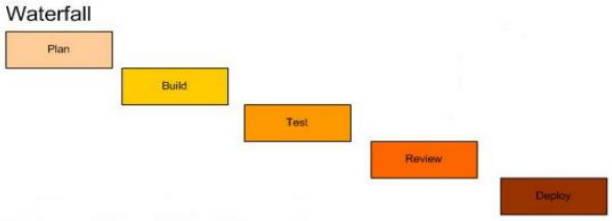

Figure 1. Waterfall method phases [1]

Waterfall model is easy to implement because it is sequential model. The amount of resources required to implement this model are minimal. Proper documentation is followed for the quality of the development. The problems with one phase are never solved completely during that phase and it leads to many problems. If client want the requirement to be changed, it will not implemented [1].

2.2 Scrum

Scrum was developed by Ken Schwaben and Jeff Sutherland in the early '90s [1] and is considered to be a framework for developing, delivering and sustaining complex products. Scrum is the most frequently used agile framework [14][15][16][17][18]. In order to define Scrum, all the roles, events, artefacts and rules have to be known and understood [19]. Weekly scrum-of-scrums considered very beneficial, since they distributed information between the teams and revealed possible problems early on[20]. Iterations in Scrum are called sprints. The length of one sprint in Scrum is normally four weeks, but can be also shorter or even longer [20]. Before starting each sprint a sprint planning meeting takes place[20]. Backlogs are lists of items to be developed. In the sprint planning meeting, a product owner with his or her team selects from the product backlog items to be developed during the next sprint to the sprint backlog [20][5]. Sprint planning meeting is conducted by the product owner, team member and the scrum master [21][22]. Product owner is responsible for prioritizing the items which is more important. Sprint planning meeting focusing on what to do and how to do. Changes will not accepted while in Sprint [1][5][23][10]. Daily Scrum implies: Scrum master and development team members report to each other and Daily meeting about 15 minutes [1][5][10]. Three questions are generated in this sprint: What they did yesterday? What they plan to do till next meeting? What difficulties are there in their way? [1][5]

A scrum retrospective meeting involves: talk about their experiences and the problems they face; talk about what to follow and what not further improvement followed and typically 15-30 minutes of the meeting. This will be done after each sprint[1][5]. Figure 2 shows scrum design.

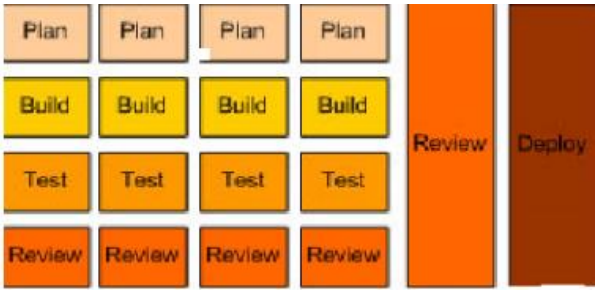

Figure 2. Scrum design [1]

Advantages are [1][13][4][7]:

- Scrum provides customer satisfaction by optimizing turnaround time and responsiveness to requests.
- Increase the quality
- Accept and expect the changes
- Provide better estimates while spending less time creating them
- Be more in control of the project schedule
- Scrum is ideal for rapidly changing, accumulating requirements. – Benefits to customer and project manager
- Scrum is fast, quick and can adapt changes easily
- Freezes schedule
- Short Sprint by short Sprint
- Estimates scope
- Top feature, then next feature – Never changes the schedule, or Sprint
- Adjusts the scope if needed to meet release dates
- Work estimates are much easier.
- Work proceeds and completes more logically.

Disadvantage are [1]:

- Documentation is very less
- Team members dedication is very important

- Team work is highly essential
- If team members does not cooperate well, the project will face failure.

The differences between Scrum and a waterfall are [1]:

- Different Roles
- Different Meetings
- Different Characteristics
- Different Artifacts
- Different Language

Table 1 shows the differences between a scrum and a waterfall.

TABLE 1. Comparison between Waterfall and SCRUM [1]

Waterfall	SCRUM
Deals with project	Deals with product
Traditional model consists of different phases	SCRUM methodology consists of different sprint
Does not expect changes	Expect changes and accept the changes
More documentation	Less documentation
Project cost determined during planning	Project cost set during project
Probability of success is low	Probability of success is high
Team flexibility and creativity is limited	Team flexibility and creativity is unlimited
Sequential	Overlapping

2.3 Spiral methodology

"The Spiral methodology "peels the onion", progressing through "layers" of the development process. A prototype lets users determine if the project is on track, should be sent back to prior phases, or should be ended [13]". The phases and phase processes are still linear. Requirements work is still performed in the requirements phase, design work in the design phase, and so forth, with each of the phases consisting of linear, explicitly defined processes[13]. Figure 3 shows spiral methodology.

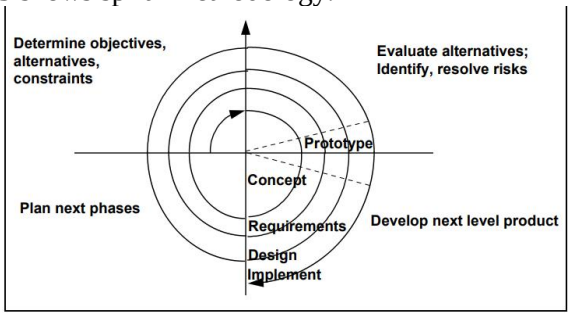

Figure 3. Spiral methodology [13]

2.4 Iterative methodology

"The Iterative methodology improves on the Spiral methodology. Each iteration consists of all of the standard Waterfall phases, but each iteration only addresses one set of parsed functionality. Using this approach, one can test the feasibility of a subsystem and technology in the initial iterations.[13]" Further iterations can add resources to the project while ramping up the speed of delivery. This approach improves cost control, ensures delivery of systems and improves overall flexibility. The Iterative approach still expects that the underlying development processes are defined and linear [13]. Table 2 presents a comparison of scrum with methodologies such as waterfall, spiral, iterative.

TABLE 2. Compares the primary SCRUM characteristics to those of other methodologies [13]

	Waterfall	Spiral	Iterative	SCRUM
Defined processes	Required	Required	Required	Planning & Closure only
Final product	Determined during planning	Determined during planning	Set during project	Set during project
Project cost	Determined during planning	Partially variable	Set during project	Set during project
Completion date	Determined during planning	Partially variable	Set during project	Set during project
Responsiveness to environment	Planning only	Planning primarily	At end of each iteration	**Throughout**
Team flexibility, creativity	Limited - cookbook approach	Limited - cookbook approach	Limited - cookbook approach	**Unlimited during iterations**
Knowledge transfer	Training prior to project	Training prior to project	Training prior to project	**Teamwork during project**
Probability of success	Low	Medium low	Medium	**High**

2.5 Kanban

Kanban (visual signal) was first used by workers in Toyota to track processes on their manufacturing system. Teams were able to communicate more effectively as this simple tool provided instance information on what needed to be worked on and when it is needed. Kanban is a scheduling system that provides information about what is needed, when to deliver, and how much to is needed. The entire value chain is controlled ideally by Kanban starting from the supplier to the customer [11].
Kanban is value optimization theory based agile framework for the transparency of work flow movement and limited work in-progress [24].
Kanban will allow teams and their members organize more freely [12].
From this point of view, the following differences will be considered during the research [12]:

- setting up roles in a team is not a requirement
- meetings are not restricted by time-boxed iterations (e.g. sprints)
- the board will be continuously updated and stories can be added anytime if they fit into the current workflow
- any member or team can be the owner of the board
- estimates for tasks are not needed (e.g. time, user points)

Choosing one of these methodologies will be a team decision, based on their style and on the type of project [12]. Table 3 shows the differences between s Scrum and Kanban.

TABLE 3. Scrum vs. Kanban - differences [6][19]

Scrum	Kanban
Team involved in a specific iteration	Optional involvement
Uses speed (velocity) as a measure for improving processes	Uses deadline / lead time as a measure for improving processes
Prescribed estimations	Optional estimations
One sprint backlog belongs to a team	Kanban-board may be shared
Involves using at least three roles (Product Owner / Scrum Master / Scrum Team)	Does not use roles
The Scrum-board is reset between sprints	The Kanban-board does not change, it is persistent
For each sprint, priorities are established on the sprint backlog	Establishing priorities is optional

2.6 Scrumban

"In Scrumban, development teams may adapt to production requirements and interests of the stakeholders, without being burdened by the project methodology. Scrumban inherits from Kanban the concept of elimination of elements that might lead to unwanted results, thus avoiding unnecessary processes [6]". Scrumban may optimize the teams' effort in order to achieve the quality standards assumed. Scrumban ensures a slow transition from Scrum to Kanban [6]. Table 4 shows the differences between Scrum, Kanban and Scrumban.
TABLE 4. Scrum vs. Kanban vs. Scrumban [6]

	Scrum	Kanban	Scrumban
Instruments	Scrum board, Burn-down charts, prioritized task lists	Kanban board	Working board for visualizing the workflow and the progress
Roles	Well defined (Product Owner, Scrum Master, Development Team)	No prescribed roles	Team and other needed roles
Planning meeting	Mandatory, Sprint Planning	If team wants and the flow is improved	If team wants and the flow is improved
Daily meeting	Mandatory, every day for 15 minutes	No meeting	Recommended, for continuous work on requirements and reduce idle time
Review/Retrospective meeting	Predefined meetings, activities and durations defined by the framework	Not prescribed	Can be done when needed for process improvement and feedback
Progress	Velocity (sprint content)	WIP (task limit for each step)	Controlled by workflow state
Product Backlog	List of prioritized and estimated stories, using story points	Task list, each task containing a signal card	Signal card/Time card
Iterations	2-4 weeks (Sprint)	Continuous flow	Continuous flow

2.7 Scrumbanfall

Scrumbanfall is an agile integration of Scrum and Kanban with Waterfall model using the mixture of traditional SDLC protocols with the empiricism, agility and workflow management. Scrum is on the base of Scrumbanfall, by keeping Kanban in the center of the Scrum and wrapping Waterfall prior to Scrum Sprints [24]. "A standalone framework Scrum or Kanban or Waterfall cannot provide complete solutions for all the challenges of Software Engineering Management processes. Scrum and Kanban are trending agile software project management frameworks while Waterfall is the first traditional SDLC and still in existence in some of the software development organizations, who have not yet adopted agile frameworks"[24]. Agile frameworks are very suitable for large or medium range of software project, where project requirement and its feasibility is changed frequently over the time, while Waterfall is suitable for the projects having small duration and clear requirement at the initial stage of project, it can be predicated that project requirement may not going to change during its life cycle until the final project delivery [24].

3. RELATED WORK

One of the earliest surveys on Agile was conducted by the Australian Shine Technologies in 2003. With the majority of the 131 survey participants referring to adoption of Extreme Programing (XP) and around 8% adopting Scrum, 49% stated that Agile reduced development costs, 93% that productivity was better, 83% that business satisfaction was better and 88% that the quality of the software improved. Although a rather early survey, when Agile experience had not been not gained yet, the results from the Agile use are generally in accordance with the outcome of our survey. In 2003 XP was more popular than Scrum [8].
Some survey showed that the most popular among heavyweight alternatives is, as expected, the waterfall model (36.5%) followed by the Spiral model (14.4%) and the Unified Process (12.2%), whereas enterprises tend to adopt also hybrid approaches or reject traditional methodologies completely heading directly for adaptive techniques (36.9%). In this study agile methodologies mostly used. Among Agile methodologies the big winner is Scrum (76.9% of the participants) followed by Extreme Programming (6.4%) and Feature Driven Development (3.8%), whereas Agile combinations were also indicated. Authors also tried to detect the percentage of projects that were considered successful. Agile projects are generally successful with 54% of the participants indicating an overall success rate over 81% for their projects [8]
The results some research indicate a significant increase in the adoption of Scrum in comparison to other Agile methodologies with many successful project. Nevertheless, continuous studies are necessary to follow its adoption progress and the emerging variants, especially its combination with other production methods, such as Kanban. [8].
In one study, it can be seen that the most popular methodology is Agile, using Scrum. The most popular methodology used by the candidates was Scrum, with 62.5% of them using Scrum at least once. 28.1% of them used Waterfall and only 25% used Kanban. Scrum reported as well the best overall satisfaction in terms of how much they enjoyed using the methodology. In conclusion, the methodology chosen depends on each team

and has to be picked specifically for that project, as no approach can satisfy all needs. The tendency is that Waterfall is used mostly by small teams for a small project that have well-defined requirements, while Agile is more flexible and preferred when continuous feedback is important [12].
Some authors are compared by means of simulation techniques an heavy and prescriptive approach, Waterfall, with two agile and less prescriptive process tools, Scrum and Lean-Kanban. Their study has been carried out on under some limiting assumptions, but it can be considered as a valid starting point for further studies. They described some strengths and weaknesses of three software process methods by modeling their environment with a continuous-time simulation tool. Although Lean-Kanban is well known in software development processes, it has not yet investigated in depth in research works. In their model, the Kanban workflow was managed through an effective control mechanism to limit the work in progress and minimize the lead time. One of the advantages of this approach is that the work is better controlled, so that the effects of errors is kept limited. On the contrary, in the Waterfall case often projects may fail to complete due to the difficulty to correct errors, including errors in requirements [9].

4. CONCLUSION

Following the results of the study, it can be concluded that each methodology has its strengths and weaknesses. As such, there is no solution for all types of projects. Various factors like the number of people in the team, how inclined to changes the requirements are or the duration of the project should be considered. SCRUM is best if the requirements frequently change. WATERFALL is best if there is no change in the requirements. Scrum and Kanban are trending agile methodologies for software project development and management. In conclusion, the methodology chosen depends on each team and has to be picked specifically for that project, as no approach can satisfy all needs. The tendency is that Waterfall is used mostly by small teams for a small project that have well-defined requirements, while Agile is more flexible and preferred when continuous feedback is important. Waterfall and Spiral methodologies set the context and deliverable definition at the start of a project. SCRUM and Iterative methodologies initially plan the context and broad deliverable definition, and then evolve the deliverable during the project based on the environment. SCRUM acknowledges that the underlying development processes are incompletely defined and uses control mechanisms to improve flexibility. The primary difference between the defined (waterfall, spiral and iterative) and empirical (SCRUM) approach is that The SCRUM approach assumes that the analysis, design, and development processes in the Sprint phase are unpredictable. A control mechanism is used to manage the unpredictability and control the risk. Flexibility, responsiveness, and reliability are the results. Certainly there is no “absolute best” agile development methodology, each project bringing its own goals and requirements. Still, emerging from the sphere of process control and industrial production, Scrum and Kanban methodologies have generated the Scrumban hybrid. Scrum, Kanban and Waterfall have generated the Scrumbanfall. Future research could relate to examining the extent to which the Scrumban and Scrumbanfall hybrid approaches are applied and whether it is better to apply multiple methodologies at the same time.

5. REFERENCES

[1]. Mahalakshmi, M., Sundararajan, M. Traditional SDLC vs scrum methodology–a comparative study. International Journal of Emerging Technology and Advanced Engineering, *3*(6), 192-196. (2013).
[2]. Flora, H. K., Chande, S. V. A systematic study on agile software development methodologies and practices. International Journal of Computer Science and Information Technologies, 5(3), 3626-3637. (2014).
[3]. Umbreen, M., Abbas, J., Shaheed, S. M. A Comparative Approach for SCRUM and FDD in Agile. International Journal of Computer Science and Innovation, 2, 79-87. (2015).
[4]. Amlani, R. D. Advantages and limitations of different SDLC models. International Journal of Computer Applications & Information Technology, 1(3), 6-11. (2012).
[5]. Mahnic, V., Drnovscek, S. Agile software project management with scrum. In *EUNIS 2005* Conference-Session papers and tutorial abstracts (p. 6). (2005).
[6]. Stoica, M., Ghilic-Micu, B., Mircea, M., Uscatu, C. Analyzing agile development-from waterfall style to Scrumban. Informatica Economica, *20*(4). (2016).
[7]. Azanha, A., Argoud, A. R. T. T., Camargo Junior, J. B. de, & Antoniolli, P. D. Agile project management with Scrum. International Journal of Managing Projects in Business, 10(1), 121–142. (2017).

[8]. Kapitsaki, G. M., Christou, M. Where is Scrum in the current Agile world?. In 2014 9th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE) (pp. 1-8). IEEE. (2014).

[9]. Cocco, L., Mannaro, K., Concas, G., Marchesi, M. Simulating kanban and scrum vs. waterfall with system dynamics. In International conference on agile software development (pp. 117-131). Springer, Berlin, Heidelberg. (2011).

[10]. Bannink, S. Challenges in the Transition from Waterfall to Scrum–a Casestudy at Portbase. In 20th Twente Student Conference on Information Technology (Vol. 182). (2014).

[11]. Zayat, W., Senvar, O. Framework study for agile software development via scrum and Kanban. International Journal of Innovation and Technology Management, 17(04), 2030002. (2020).

[12]. Andrei, B. A., Casu-Pop, A. C., Gheorghe, S. C., Boiangiu, C. A. A study on using waterfall and agile methods in software project management. Journal Of Information Systems & Operations Management, 125-135. (2019).

[13]. Schwaber, K. Scrum development process. In Business object design and implementation (pp. 117-134). Springer, London. (1997).

[14]. P. Diebold, J-P. Ostberg, S. Wagner and U. Zendler, "What Do Practitioners Vary in Using Scrum?", In International Conference on Agile Software Development, Springer, Cham, pp. 40-51, (2015).

[15]. L. S. Møller, F. B. Nyboe, T. B. Jørgensen, J. J. Broe, "A Scrum tool for improving Project Management", In Proceedings of fifth Student Interaction Design Research Conference, pp. 30-32, April, (2009).

[16]. V-P. Eloranta, K. Koskimies, T. Mikkonen, "Exploring ScrumBut—An empirical study of Scrum anti-patterns", In Information and Software Technology, vol. 74, pp. 194-203, (2016).

[17]. T. Gustavsson, "Benefits of Agile Project Management in a Non-Software Development Context: A Literature Review", In Project Management Development – Practice and Perspectives: Fifth International Scientific Conference on Project Management in the Baltic Countries, pp. 114-124, (2016).

[18]. Ereiz, and D. Mušić, "Scrum Without a Scrum Master", In 2019 IEEE International Conference on Computer Science and Educational Informatization (CSEI), pp. 325-328, (2019).

[19]. Mircea, E. Project management using Agile frameworks. Academy of Economic Studies. Economy Informatics, 19(1), 34-44. (2019).

[20]. Paasivaara, M., Durasiewicz, S.,Lassenius, C. (2009). Using scrum in distributed agile development: A multiple case study. In 2009 Fourth IEEE International Conference on Global Software Engineering (pp. 195-204). IEEE. (2009).

[21]. Ciurairu, C. Risu, "Usage of Scrum Methodology for Implementing Software Project", In Managing Innovation and Diversity in Knowledge Society Through Turbulent Time: Proceedings of the MakeLearn and TIIM Joint International Conference 2016, ToKnowPress, pp. 713-721, 2016. (2016).

[22]. H. Lei, F. Ganjeizadeh, P. K. Jayachandran, P. Ozcan, "A statistical analysis of the effects of Scrum and Kanban on software development projects", In Robotics and Computer-Integrated Manufacturing, vol. 43, pp. 59-67. (2017).

[23]. Nishijima, R. T., Dos Santos, J. G. The challenge of implementing scrum agile methodology in a traditional development environment. International Journal of Computers & Technology, 5(2), 98-108. (2013).

[24]. Bhavsar, K., Shah, V., Gopalan, S. Scrumbanfall: an agile integration of scrum and kanban with waterfall in software engineering. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 9(4), 2075-2084. (2020).

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THE USE OF DIFFERENT DEVICES FOR PRINT DIGITIZATION IN PRINT QUALITY ANALYSIS OF PRINT MOTTLE

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Abstract:

The goal of this paper was to find the best solution for digitization of print samples for Print Quality Analysis. A crucial step in this method for print quality control is a sampling of the area to be analyzed. The print could be acquired with various input devices, such as camera, microscope or scanner. In this study, we used the camera, two mobile devices, and two scanners. Samples used in the experiment were printed on digital printing machines, based on electrophotography. We also used various papers to obtain the largest possible number of different samples. Results showed that there is a huge difference depending on the device being used to digitize..

Keywords:

print sampling, print quality, scanner-based systems, camera-based systems

INTRODUCTION

There are developed various methods for print quality control, starting from densitometry until spectrophotometry. Recently, one new method has been also introduced for evaluating the print quality of lines, text, print uniformity, registration, etc. It is still underdeveloped but is certainly used for print quality control. The new method is called Image Quality Analysis by some authors [1] and it is based on an analysis of the acquired images (i.e., printed samples). We adjusted the name and called it the Print Quality Analysis (PQA) because it closely describes the quality control of the printed samples. Schematic representation of the method is presented in Figure 1. From the original to the numerical values, we need to go through few steps. The method can be incorporated in one device (such as *QEA Personal IAS or vipFLEX*), or the steps could be performed independently.

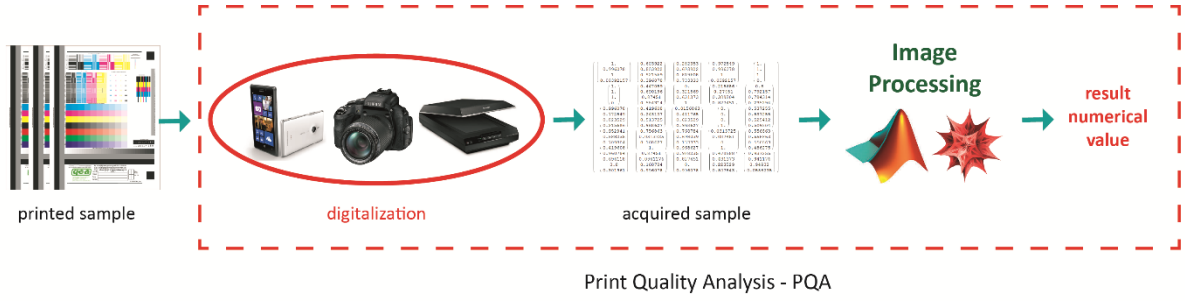

Figure 1: Schematic representation of Print Quality Analysis

The first international standard that defines procedures and methodology for quantifying basic print quality attributes is ISO 13660:2001 [2,3]. The standard is device independent; we can analyse digital, flexo, offset or any other prints [4]. According to the standard, the image to be analysed needs to be digitized using any input device as long as it is capable of sampling the image at a minimum resolution of 600 ppi [2]. Responding to the needs of the new standard, instrumentation manufacturers developed a class of devices called image analysers [1]. In such device, the print is acquired with camera and analysed (processed) to quantify attributes such as dot gain, line, and text quality, or print uniformity such as graininess and mottle. Beside image analyser,

that way of control could be accomplished by using several devices, which together form a system for quality control, called Image Analysis System [1]. We also adjust this name as Print Analysis System (PAS). PAS includes a light source and some kind of the photodetector in a defined geometric arrangement. In this case, photodetector could be CCD or CMOS sensor. Hence, PAS could be developed in two main styles: the camera-based or flatbed scanner-based system [1]. Each system has its advantages and disadvantages.

The advantages of the scanner-based system are low cost, and it can easily acquire the entire page area, which can facilitate many print quality analyses [1]. The scanner also has built-in illumination and we have the ability to define an area of interest during scanning, which reduces the time of later image processing. On the other hand, this system is time-consuming at high resolutions and it is a contact method, which leads to the unnaturalness of the scanned sample.

The camera-based system offers higher resolution and very accurate position measurement [1]. This type of system can be installed directly on the printing machine and provide inline control during printing. It also allows us to upgrade the system by adding other devices such as densitometers and colourimeters. The other strength of this system is the light source, which is away from the sample, so we get a more natural digital sample, as opposed to scanning. The light source is not embedded; therefore, this system is more expensive than the scanner-based one. In addition, the camera-based system typically captures only a small section of the printed page at a time, so we need some vacuum table for placing the sample. Using PQA, we can evaluate print quality according to a large number of attributes. One of the most frequently used attribute is print (non)uniformity [3,5–7]. In the reviewed literature [7–12], there are several different definitions of print (non)uniformity. General physical definition would be that the print nonuniformity is an unwanted variation of optical density (reflected light) from the print. Different types of print nonuniformity are presented in Figure 2. Two main groups are random and systematic nonuniformity.

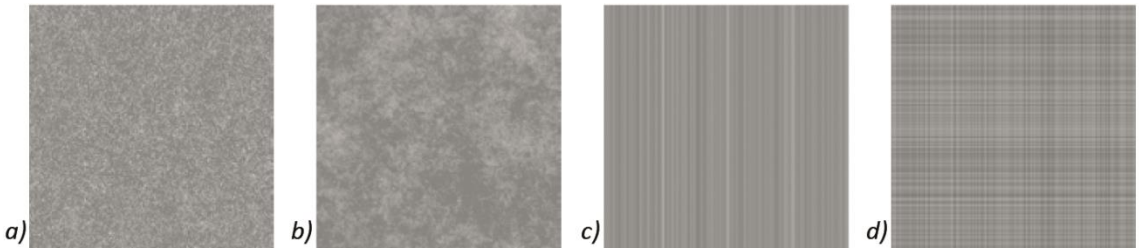

Figure 2: Different types of print nonuniformity: a) small-scale (graininess), b) large-scale (print mottle) random nonuniformity, c) stripes and d) wire mark texture – as systematic nonuniformity [8]

In this paper, we only analyzed one type od print nonuniformity – print mottle. Print mottle could be quantified using different methods: NU index [13], GLCM method [14,15], standard ISO 13660, method by [8], etc. Common to all methods is that they are based on the PQA method. All methods use digitized sample for obtaining the numerical value of a print quality attribute which is evaluated. The only difference between them is in the processing of digitized sample, some of them use gray level of pixels, some Fast Fourier Transform, etc.

In this paper, we used the method proposed by ISO standard 13660:2001. According to the standard, print mottle is ''aperiodic fluctuations of density at a spatial frequency less than 0,4 cycles per millimeter in all directions'' [2,p.11]. The patch for analyzing print mottle is divided into 100 equal tiles (as shown in Figure 3). Optical density is measured across each tile i several times and m_i is the average of density measurement. The measure of print mottle across the entire patch is the standard deviation of all m_i [11]:

$$ISO\_M = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(m_i - (\frac{1}{n}\sum_{i=1}^{n} m_i))^2} \quad (1)$$

where m_i is the average density measurement of tile i, n is the total number of tiles.

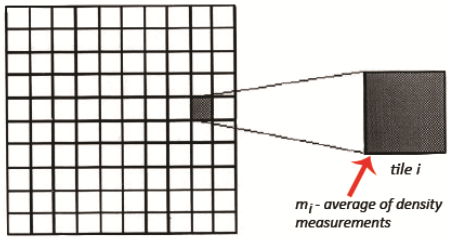

Figure 3: ROI divided into 100 equal parts (tiles), inside which is calculated optical density

The standard ISO 13660:2001 defines the procedures and methodology of various print quality attributes measurement, but has its drawbacks. One major drawback of this standard is the lack of reference values. There are no defined acceptance criteria; the user defines it. Once print quality measurements have been made, it is up to those involved to determine if the print quality is acceptable. In this study, we analyzed the effect of using different devices for digitizing prints on the final value of print quality, measuring only one parameter – print mottle. As it is shown in Figure 1, we can use the camera, scanner or any other device that has sufficiently high-quality image sensor, such as mobile device.

MATERIALS AND METHODS

This experiment included analysis of different devices for digitizing print samples. To obtain the largest possible number of different samples, we used various papers, coated and uncoated and two different digital printing machines. Test image used for the experiment contained patch (130 x 130 mm) with C: 65, M: 50, Y: 50 and K: 50%. FOGRA proposes that proportions of CMYK for evaluation of print mottle [16]. The test image was printed using two electrophotographic printing machines: Xerox 1000 based on dry toner and HP Indigo Press 1000 based on liquid toner.

Papers used in the experiment were characterized by optical properties (brightness, opacity, and tint) and geometrical characteristic of a surface (surface roughness R_a). For evaluation of the paper optical properties, we used software BabelColour CT&A (Whiteness Tool) and Eye-One (i1) spectrophotometer. The measurement setup was 45º/0º, standard illuminant D50 and standard observer 2º. Brightness is measured according to TAPPI T452/ASTM D985 and opacity is measured according to CGATS.5 / ISO 2471 [17]. During these measurements, we used appropriate white (required to measure brightness and opacity) and black backing (required to measure opacity). Surface roughness was measured with portable surface roughness tester TR200. The cut-off was set up according to the range of measured value. Other settings were: filter Gauss, measuring range +/- 20 µm, resolution 0.01 µm and head movement speed V_t = 0.5 mm/s. In Table 1 are presented papers used in the experiment. Papers are commercially available [18].

Table 1: Paper properties –brightness, opacity, tint and surface roughness

Samples	Paper name	Grammage [g/m^2]	Brightness	Opacity [%]	Tint	Surface roughness - Ra [µm]	Cut-off for Ra
1	**Gardapat/Kiara**	150	87,4	97,6	- 1,5	1,466	(0,8mm)

2	**Neobond**	200	84,8	91,6	- 0,16	4,913	(2,5mm)
3	**Options White**	220	97,5	99,5	- 0,51	2,962	(2,5mm)
4	**Revive 100 White Silk**	140	89,1	96,8	- 0,91	0,540	(0,8mm)
5	**Phoenixmotion Xantur**	115	88,1	95,5	- 0,22	0,802	(0,8mm)
6	**Phoenixmotion Xenox**	170	94,4	98,1	0,87	0,976	(0,8mm)

According to the results can be concluded that sample 6 is the brightest and sample 3 has the largest opacity. Most of the samples are neutral, except sample 1. Tint for that sample is quite moved from neutral (value of -1,5 indicate a reddish tint). Surface roughness is opposite to brightness. Sample with the smallest brightness has the largest roughness and vice versa. The influence of paper properties on print mottle was analyzed and presented in the previous work of the authors [19], so it isn't commented here because it isn't the main purpose of the experiment.

After printing, samples were digitized with one digital camera, two mobile phones, and two scanners. Input devices are presented in Table 2. There are their names and the most important technical parameters and adjustments. Depending on the sampling resolution, we obtained different sizes (in pixels) of the digital patch for the print mottle analysis, as it is emphasized in Table 2.

Table 2. Technical parameters and adjustments for used input devices

Device / Specification	**Canon EOS 550D**	**Nokia Lumia 925**	**Samsung S4 mini GT-I9195**	**Canon CanoScan 5600F**	**Epson V370 Perfection**
Type	**Digital camera**	**Mobile phone**	**Mobile phone**	**Flatbed scanner**	**Flatbed scanner**
Sensor	CMOS	BSI	CMOS	CCD	CCD
Resolution	72 ppi	72 ppi	72 ppi	1200 spi	1200 spi
Colour space	RGB	RGB	RGB	RGB	RGB
Image Format	JPEG	JPEG	JPEG	JPEG	JPEG

Patch dimensions for print mottle quantification	**2300 x 2300 px**	**1550 x 1550 px**	**1500 x 1550 px**	**3000 x 3000 px**	**3000 x 3000 px**
Other	No flash, auto white balance, F 4.0, focal length 24mm, 1/125, L image size	No flash, auto white balance, F 2.0, focal length 26mm	No flash, auto white balance, F 2.6	Light source: white LED	Light source: LED

Camera or mobile-based systems include a properly configured light source, optics, and an image sensor. Camera and mobile devices were placed at 21 cm from the samples, as shown in *Figure 4*. The devices were placed at that distance because in this case the entire printed patch was acquired at once. The lamps were mounted on both sides from the camera/mobile to achieve uniform illumination. We used Phillips fluorescent bulbs with 6500 K temperature (that corresponds to illuminant D65). In order to avoid the appearance of vignettes on the digitized samples for the analysis, we used only the central portion of the sample, cropped to the dimensions shown in *Table 2*.

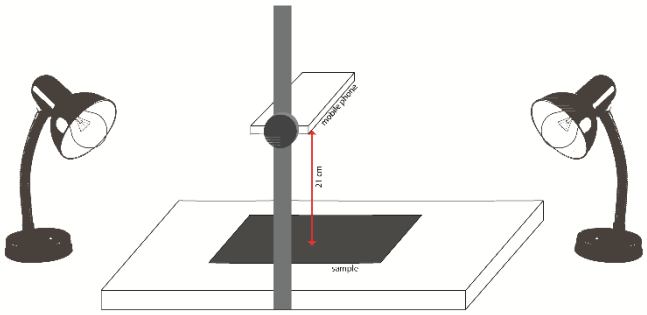

Figure 4: The camera/mobile-based system

In Introduction, we mentioned different methods for print mottle quantification and described procedure and methodology of ISO 13660 method, which was used in the experiment. For faster calculation, we made MATLAB add-in for quantifying print mottle based on the methodology described in the standard. The add-in contained following steps:

1. import of acquired patch (RGB image),
2. conversation into gray image using built-in Matlab function rgb2gray (*gray = 0.2989*R + 0.5870*G+0.1140*B*),
3. cropping the patch at 100 same tiles,
4. calculation of optical density into one tile (*optical density is calculated by the value of the gray level of each pixel) and*
5. calculation of print mottle according to standard ISO 13660.

RESULTS AND DISCUSSION

The results of print mottle when using different devices for print digitization are presented in *Table 3*. Based on the results it can be concluded that the utilization of the various devices for digitizing prints in the method of image analysis lead to different results. For the samples that were scanned with flatbed scanner 1 (CanoScan 5600F), we have obtained the highest values for print mottle. Much lower values were obtained when using the second scanner (Epson). All scanners have the same sensor (CCD), which means that other components of the capturing device (e.g. fluorescence lamps) could have also impact on the calculation of print mottle.

Table 3: Results of print mottle when using various input devices

Samples		**Digital Camera**	**Mobile phone 1**	**Mobile phone 2**	**Flatbed Scanner 1**	**Flatbed Scanner 2**
1	Gardapat - HP	20,8322	25,8076	30,6150	33,9248	24,3144
2	Neobond - HP	20,7623	25,8818	32,6713	36,0019	26,1865
3	Options White - HP	23,7341	25,4596	32,9147	37,2243	28,3820
4	Revive - HP	20,2122	24,9930	30,0338	32,6799	23,5789
5	Xantur - HP	22,1728	24,9190	30,2215	35,5388	25,6216
6	Xenox - HP	21,8880	25,4081	32,1302	35,2137	25,2374
7	Gardapat - Xerox	14,5762	23,5486	26,0533	26,7585	17,1841
8	Neobond - Xerox	16,2235	23,8174	29,3077	30,1154	20,3383
9	Options White - Xerox	16,9534	24,0788	28,0235	30,4541	20,5863
10	Revive - Xerox	16,0897	24,3488	28,1975	30,0127	19,4272
11	Xantur - Xerox	14,6349	23,2891	21,9535	27,0645	16,7282
12	Xenox - Xerox	16,0614	24,7201	27,0984	29,5280	19,2973

In Figure 5 is presented one sample (Xantur – HP) captured with different devices. The difference in captured image brightness is clearly visible. The sample is the brightest when it is digitized with the mobile phone 2 and flatbed scanner 1, which led to the highest values for the print mottle. The difference in the use of various cameras, digital or mobile device is also present, although the sample was illuminated with the same lamps. In this case, the different values of print mottle are influenced by the sensor devices.

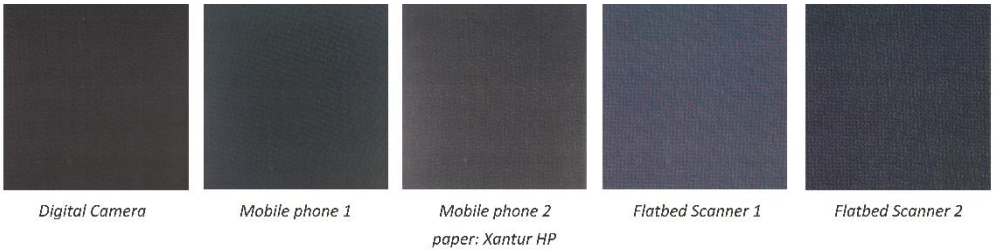

Figure 5: One sample (Xantur paper printed with HP printing machine) digitized with various devices

The relationship of the measured values of print mottle when using different input devices can be seen in Figures 6 and 7. In Figure 6 are presented values obtained for samples printed with HP printing machine. In Figure 7 are results obtained for samples printed with Xerox printing machine.

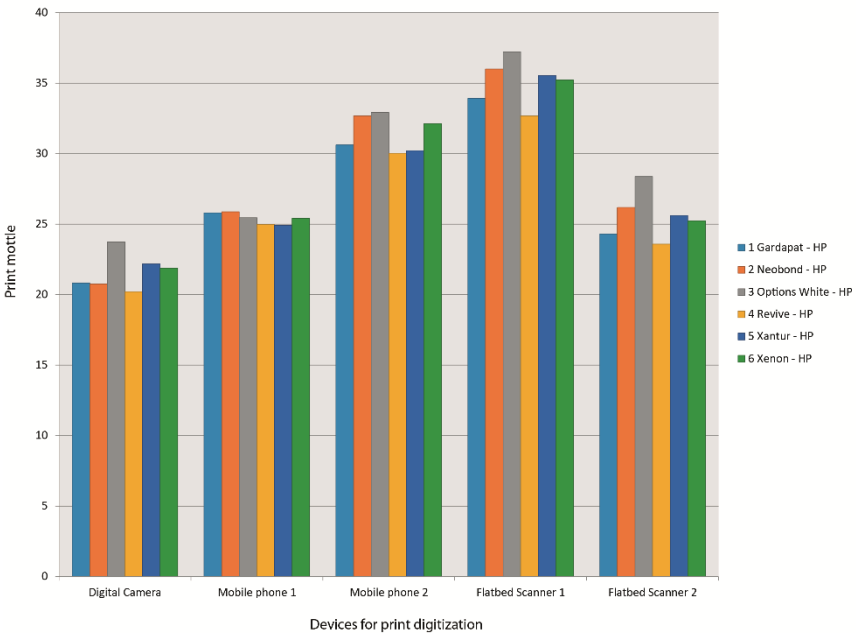

Figure 6: Print mottle for samples printed with HP printing machine and digitized with different input devices

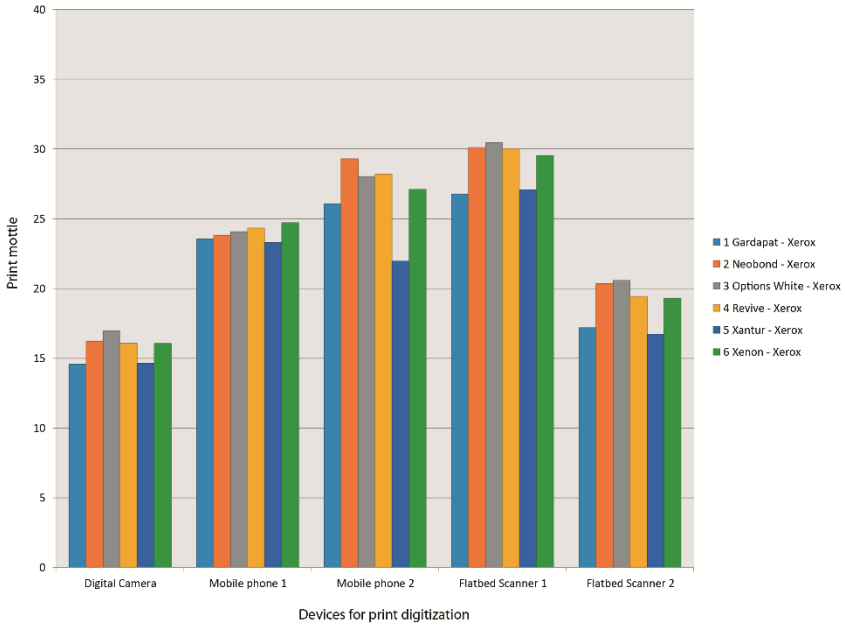

Figure 7: Print mottle for samples printed with Xerox printing machine and digitized with different input devices

As an additional conclusion of this research can be established that regardless of the used input device, we can see that the greater print mottle was obtained on samples printed with HP printing machine which uses liquid toners unlike the Xerox machine, which is based on dry toner. This was also the conclusion of the study [13].

According to the coefficient of variation (CV) presented in Table 4, we can conclude that any device could be used for digitization if we want to evaluate the quality of the print mottle between several prints. Variability is relatively low; it is between 17-23 % [17]. For example, if we want to check which sample will have the highest or smallest print mottle when using the same paper and different printing machines, we can choose any device for digitizing.

Table 4: Print mottle mean values for five different capturing devices, and the corresponding standard deviations and coefficient of variations

Samples		Average	St.dev.	CV [%]
1	Gardapat - HP	27,10	4,64	17
2	Neobond - HP	28,30	5,40	19
3	Options White - HP	29,54	4,94	17
4	Revive - HP	26,30	4,49	17
5	Xantur - HP	27,69	4,70	17
6	Xenox - HP	27,98	4,92	18
7	Gardapat - Xerox	21,62	4,88	23
8	Neobond - Xerox	23,96	5,28	22
9	Options White - Xerox	24,02	4,88	20
10	Revive - Xerox	23,62	5,23	22
11	Xantur - Xerox	20,73	4,50	22
12	Xenox - Xerox	23,34	4,97	21

But, if we would like to compare results of one sample with the reference values, then the device for digitizing has a tremendous impact. For example, print nonuniformity values for sample Gardapat - HP are 20.8322, 25.8076, 30.615, 33.9248 and 24.3144 when using different devices for digitization. The results are drastically different. Currently, the reference values are not defined, so that neither the results can't be compared to some standard.

CONCLUSIONS

A fundamental step in measuring print quality according to the PQA method is acquiring a digital image of the area (print) to be analyzed. We can use any input device such as camera, mobile phone or scanner, as long as they have minimal sampling resolution of 600 ppi. Comparing the results obtained for print mottle in this research, we can clearly see that there is a difference between results obtained when using different input device. Each device has its advantages and disadvantages, and since there are no reference values for print mottle, we can't now give the final conclusion which device is the best. Our goal of the further research is to define the optimal choice of an input device according to its structure, price and the need for the additional elements and also to define the reference values for print mottle when such device is used.

5. ACKNOWLEDGEMENTS

This research (paper) has been supported by the Ministry of Education, Science and Technological Development through the project no. 451-03-68/2020-14/200156: "Innovative scientific and artistic research from the FTS (activity) domain".

6. REFERENCES

[1] Briggs JC, Tse M-K. Objective Print Quality Analysis and The Portable Personal IAS Image Analysis System 2006;44.
[2] ISO13660. Information Technology - Office Equipment - Measurement of image quality attributes - Binary Monochrome text and graphic images 2001.
[3] Dhopade A. Image Quality Assessment According To ISO 13660 and ISO 19751. Test Target 2009;9:43–50.
[4] Briggs JC, Forrest DJ, Klein AH, Ming-Kai T. Living with ISO-13660: Pleasures and perils. Int Conf Digit Print Technol 1999:421–5.
[5] Lindberg S, Fahlcrantz CM. Perceptual assessment of simulated print noise with random and periodic structure. J Vis Commun Image Represent 2005;16:271–87. doi:10.1016/j.jvcir.2004.11.002.
[6] Dalal EN, Rasmussen DR, Nakaya F, Crean PA, Sato M, Corporation X. Evaluating the Overall Image Quality of Hardcopy Output 1998:169–73.
[7] Petersson J. A Review of Perceptual Image Quality. Linköpings Universitet, 2005.
[8] Christoffersson J. Evaluation of Systematic & Colour Print Mottle. Linkopings Universitet, Sweden, 2004.
[9] Fahlcrantz C-M. On the evaluation of print mottle. 2005.
[10] Sadovnikov A, Lensu L, Kälviäinen H. Automated Mottling Assessment of Colored Printed Areas. 15th Scand Conf SCIA 2007 2007;4522:621–30.
[11] Weingerl P. Objective methods for print inhomogeneity evaluation and their correlation with visual perception. Univerza v Ljubljani, 2014.
[12] Rasmussen DR, Donohue KD, Ng YS, Kress WC, Gaykema F, Zoltner S. ISO 19751 macro-uniformity. Proc SPIE 6059 2006;6059:60590K – 60590K – 12. doi:10.1117/12.648086.
[13] Rilovski I. Influence of paper surface properties and toner type on digital print mottle. Celul Si Hartie 2012;61:4–9.
[14] Hladnik A, Mihael L. Paper and board surface roughness characterization using laser profilometry and gray level cooccurrence matrix. Nord Pulp Pap Res J 2011;26:099–105. doi:10.3183/NPPRJ-2011-26-01-p099-105.
[15] Jurič I, Karlović I, Novaković D, Tomić I. Comparative study of different methods for the assessment of print mottle. Color Res Appl 2015. doi:10.1002/col.21984.
[16] Kraushaar A. Evaluation of within sheet uniformity by means of M-Score 2010:1–2.
[17] Pascale D. Color Translator & Analyzer help manual 2015:1–405. http://www.babelcolor.com/index_htm_files/CT&A_Help.pdf.
[18] Europapier. Business Areas 2015. https://www.europapier.com/portfolio/business-areas/.
[19] Jurič I, Ranđelović D, Karlović I, Tomić I. Influence of the surface roughness of coated and uncoated papers on the digital print mottle. J Graph Eng Des 2014;5:17–23.
[17] Papić, M. (n.d.) Poslovna statistika. http://www.oss.unist.hr/zg/rif/ kolegiji/20100301_pred_PSTA.pdf

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STANDARDIZATION POSSIBILITIES OF PREPRESS WORKS AND FLEXOPRINTING BY A UNIVERSAL TESTCHART

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Abstract:

This paper deals with the characterization and the standardization of flexo prepress works and printing process in general by a fingerprint test. According to our currently collected available information there doesn´t exist a broadly approved fingerprint test design, which would normalize and settle down the testing process of flexo printing. The scope of our research is to define parameters of a fingerprint design, which would help to build up a catalogue of elements for the print. We are defining the parameters characterizing the printing process and are suggesting elements, to research the specific field. We are in the first phase of our project, when the elements are almost ready and the test form design can be demonstrated. In the next phase we plan the realization of a survey to investigate the attitude of the Hungarian professional specialists. We plan to detect their overall rating of the elements and during the discussion we hope to discover further problems to be resolved, In the evaluation phase we will process the collected information and present a final fingerprinting form, which will be also produced and printed under real conditions. Our overall scope is to improve the available knowledge base for printing and prepress.

Keywords:

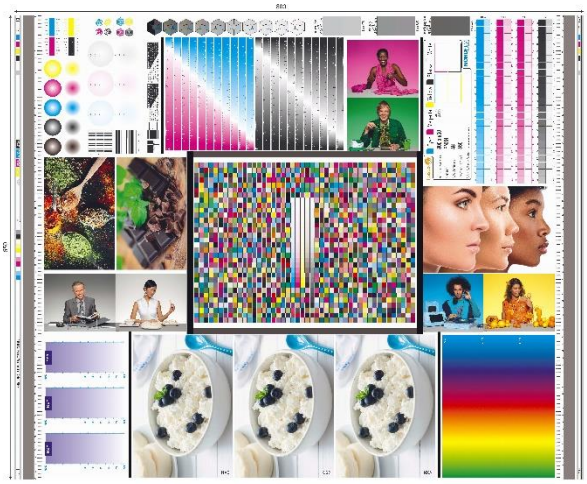
fingerprint, flexo, prepress, testing

INTRODUCTION

The virus crisis that is defining our days for the last almost two years does not spare any sector of the printing industry either, however the predictions about the recent and near future dominance of the flexographic printing between the printing processes have not changed. Many researchers and also the professionals in the printing industry agree that digital printing is evolving rapidly and gaining upon areas of use, but the dominance of traditional printing methods remains. Flexo printing is one of the most specific printing methods. There is a wide range of factors that affect the final print result. In the case of flexo technology no conclusions can be drawn about the expected quality or the operations required in prepress on the basis of one or two corresponding aspects, such as the same machine equipment manufacturer, the correspondence of the ink or ink transfer roller and the printing plates manufacturing technology, etc.

The printing conditions are different for each company, so each printing machine and substrate requires the creation of a unique printing and color profile. For creation of printing profiles a test print is required, which is called fingerprint (in English practice). Fingerprint is designed to assess the printing process and if we set our "questions" well, we will get a wide range of answers about the examined particular print. Thus, subsequent prepress and individual prints can be performed systematically and produce satisfactory results. To the best of our knowledge, there is currently no universally applicable fingerprint test form available in the European flexo sector. A huge number of test charts are circulating in practice, because the most technicians try to solve the fingerprints individually based on their own experience, information and tools. Test diagrams are given in cases where a special technology has to be set up, such as the test of surface structures for Esko Pixel + software technology for example. In this case, the software generates a test diagram for itself, as the goal is to set and optimize the production conditions. When, on the other hand, a general condition survey is required, participants in the printing process usually compile test diagrams based on their own imagination.

Two examples of a possible fingerprint test form compilation (Source: archives of Plastex Ltd.)



There is also the possibility that you can buy a license for a test chart from companies dealing with color management in general (f.e. GMG, EFI), but it is not certain that the test chart includes all the aspects to be assessed.

REPEATABILITY AND OPTIMIZATION IN FLEXOGRAPHIC PRINTING

What is optimization? Simply phrased, it is a printing test process that determines the printing parameters that result in the best print quality. Optimization is an extremely important basic requirement for print repeatability [2]. The goal of the optimization process is to identify the combination of the best print variables for the quality to be achieved in a given print process [1]. The test conditions must correspond to normal production conditions. The optimization process must be completed before creating the fingerprint. The process necessarily involves identifying the print variables from the perspective of the expected result. The U.S. literature distinguishes between two important groups of variables: press component variables and job-specific variables [1]. According to our experience the most flexo printing houses in Central Europe are looking for a generally suitable print setup. It occurs only infrequently that a high-volume job requires its own optimization and fingerprint process, normally it´s unprofitable for the printing house. When printing a general fingerprint, printers mostly rely on their printing experience to date.

Our research focuses on print and printing, so we do not deal with the optimization of printing conditions in this framework. We assume that the printing house has taken the appropriate steps to create the desired conditions, which is intended to assess the fingerprint, possibly correct it to some extent, and then evaluate it for standardization and repeatability.

RESULTS AND DISCUSSION

Just like the human fingerprint, each printing process is unique. Printing parameters such as speed, print pressure, dot distortion, etc. are different, however prints should be always accurate and consistent. Nowadays the primary focus in the printing industry is if the customer is satisfied with the print quality, price and other conditions, so printers cannot afford inconsistencies.

3.1 Fingerprint implementation

Optimization and standardization of the printing processes, saving time, cost and resources is a must. The base of this process is a printing form that helps to create a database of related parameters for each printing situation [3]. For each group of variables (printing machine, ink, substrate, etc.) we have to run a separate fingerprint, preparing to determine the largest possible number of combinations and to be able to predict the results of any change. The primary purpose of a fingerprint is to measure and record the characteristics of a particular printing process with specific settings and raw materials. The specific settings and substrates to be printed are determined by the requirements of the printing customers and the printer itself (substrate, ink, graphic design) and the printer's experience or optimization experiments (best anilox for each color separation, optimized ink setting, best adhesive, etc.) [1]. The fingerprint must contain the colors used for printing - typically CMYK, but seven-color printing is also becoming more common in some printing houses, but then the fingerprint must contain all seven colors (CMYKOGV). One of the keys to a successful fingerprint is the meticulous documentation of each step. The most important step to an appropriate test form and creating a multi-category, alternative printing element database is to define the parameters to be measured. These parameters can be divided into two groups, these are the

- process control parameters and a
- mechanical control parameters [1].

Process control parameters indicate the printing capability of a particular press considering the raw materials, settings, motifs, etc. to be printed. These test items map the quality capabilities of graphic design. The most commonly studied process control parameters are:

- tone colors,
- special / spot colors,
- grey balance,
- overprint and trap patches,
- raster scales,
- gradients,
- barcodes,
- line and text elements.

Mechanical control parameters include those variables that characterize the proper operation of the printing process from a technical point of view. These test items need to be placed in multiple places on the test form, as they are not necessarily balanced on every printing press at every single point. The most commonly studied mechanical control parameters are:

- impression and slur targets,
- registration targets,
- increase in tone value (dot gain / TVI).

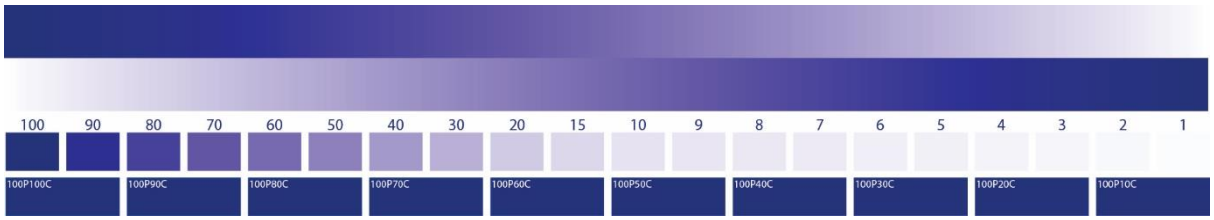
It is also important to pay attention to a balanced design when arranging the fingerprint to avoid possible printing vibrations. In the following part we deal with each parameter in detail and present the graphical elements we believe are suitable for assessing the discussed parameters.

3.2 Testing possibilities of the process control parameters

The four basic colors of the printing process — cyan, magenta, yellow, and black — are called process colors [4]. Examining the tonal values of these four primary colors is extremely important, because they represent fundamental points for the subsequent color reproduction process. The measurement fields can be examined from densitometric (density) and spectral (L *, a *, b * ,, C *, h °, ΔE value) angle [1]. If the basic parameters of the four base colors are correct, it is likely that the overprinting raster values of the colors will also show a standard result. It is enough to test tonal colors simply, even with just a 7x5 mm rectangle for each color, as this field is already sufficient to determine the density and spectral values for a photospectrometer. The visual of the graphic element is shown in Figure 2.

Graphic element for process tone values

If needed, the fingerprint may also contain spot colors. Using optimal print settings and ink, special spot colors can also be quantified by spectrophotometry (L *, a *, b *, C *, h °, ΔE) and visual evaluation. This type of test can be used to validate prints, create standards, and so on. Direct color should be tested in his tone values and raster scale too (see the Figure 3).



Graphic element for spot colors

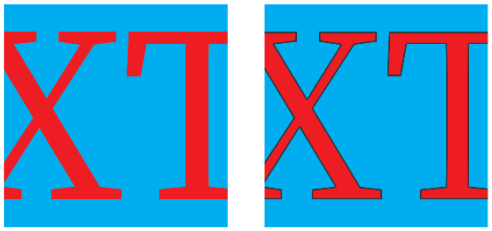
Grey balance is one of the visual elements which are easy to evaluate. Grey balance is the appropriate combination of cyan, magenta, and yellow inks to produce a neutral grey when measured with a densitometer or spectrophotometer. You can also use a photo element to measure it, but a vector element like on the figure 4 is definitely useful.

Graphic element for grey balance

The quarter-, mid- and three-quarter tones of the grey balance are defined by the ISO Standard 12647-2, which always has the highest cyan values, with magenta and yellow at slightly lower percentages for the best grey balance. Grey balance is affected by process color hue, density, dot gain / TVI, or ink trap [1]. This is one of the most sensitive parameters and even the slightest change or inaccuracy can upset the color balance.

Overprints and trapping are very important for prepress. Flexo technology may be characterized by the fact that the colors do not fit exactly at the meeting points of sharp contoured graphic elements due to printing inaccuracies. For this purpose, prepress operators use overprints to increase the size of the lighter element along its outlines to a certain extent, thus achieving a slight overlap between the two meeting colors during a multicolor printing. In this case, it is also easier for the printer to hold the register. Test elements for these purposes are shown on figures 5 and 6.

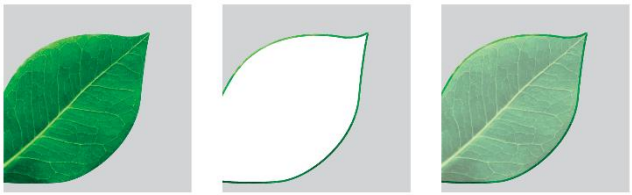
Graphic element for traps and overprinting 1.



Graphic element for traps and overprinting 2.

In the printing process may the white underprinting cause similar problems than the other printing colors however in a slightly different way. It can happen because of printing inaccuracies, but also is true, that the behavior of the white ink is different from the other colors. When printing on a transparent substrate, without a smooth and covering white a good print quality cannot be achieved.

From this reason, printers sometimes use high volume anilox rollers for white underprints, or possibly even add a little extra pressure to get better white coverage. In this case, the white underprint may “flows out” from under the printed design. That´s why the white underprint must be withdrawn around the edges. A possible testing element for this topic is shown on the figure 7.



Graphic element for white underprint

Raster scales are composed from patches of different percentages of each color, usually ranging from 1% to 98%, as we need to examine the properties of these raster patches. The result can also be used to measure dot gain / TVI, print contrast and density. Amongst others the raster scales can help us to choose the correct screen type for plate production (AM, stochastic, hybrid, etc.). Figure 8 shows a detailed example of a raster scale.

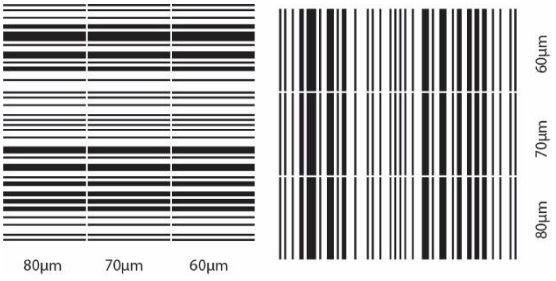
Graphic element for CMYK raster scale

A gradient scale is actually a gradient that goes smoothly from the full tone of a color to the minimal dots, which can be held on a plate. These scaletypes suit well for the definition of the screentypes and screensets used on the printing plates. It is advisable to examine each color separately (see Figure 9), however, gradients of overlapping colors may also be interesting, especially for the highlight dots (see Figure 10).

Graphic element for CMYK gradient raster scale 1.

Graphic element for CMYK gradient raster scale 2.

It may be surprising, but in the recent practice barcode is one of the most important graphic elements on a product packaging. An active, easy-to-read barcode is an essential part of the product, nobody would accept long queues in store due to manual barcode entering. For this reason, is it important to know how a barcode behaves in the printing process, for what to have respect while planning new future packaging materials. It is a common practice in flexographic prepress to use Barcode Width Reduction, which means that the “sticks” of the barcodes are reduced by a few microns by the prepress operator so that they can then thicken back and take on their original size during printing. During the fingerprint, you need to determine how much this take-back should be. Barcode printing is also affected by the printing direction, so it is recommended to test in both directions in a similar format as shown on Figure 11.

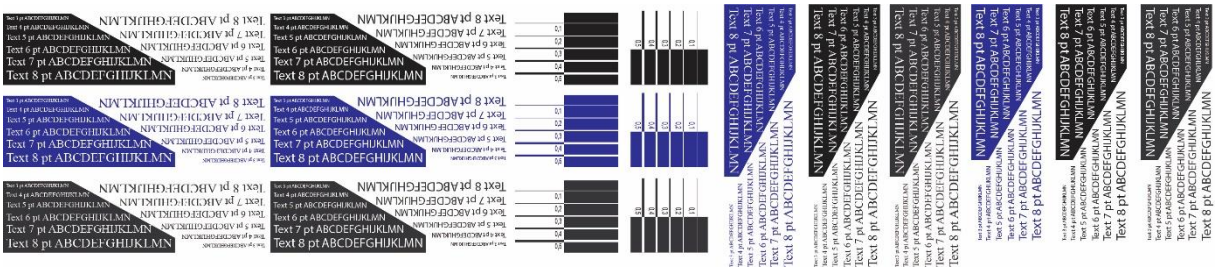


Graphic element for BWR

Line and text elements appear on every packaging. It is important to be focused on the dimensions of the texts and line thicknesses, the critical limit has to be found. It is worth to test the following points:

- Positive lines from one, two, possibly three colors
- Negative lines from one, two, possibly three colors
- Readability of positive text in one, two or even three colors
- Readability of negative text in one, two, possibly three colors

Figure 12 shows a possible way to test this.

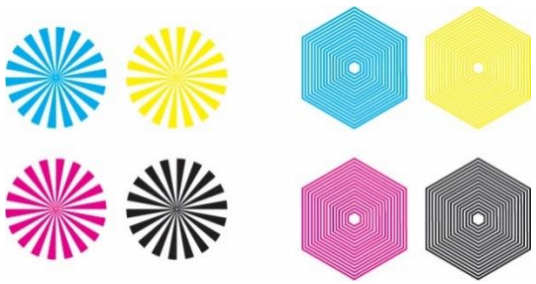


Graphic element for texts and lines

3.3 Testing possibilities of the process control parameters

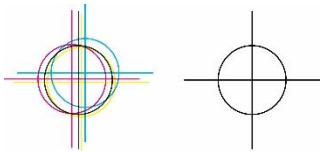
As we mentioned before, mechanical control parameters include impression and slur, register accuracy, and dot gain (TVI). Examining the technical parameters characterizes the printing process, if everything is working as it should. It is advisable to place the test elements of the mechanical control parameters in several places within the test form, as the machine may not print evenly at all points.

The impression and slur test elements characterize the adequacy of the press force applied between the printing plate and the substrate and the anilox roller and the printing plate, as well as the transferred ink amount and it´s drying. Slur effects blurred prints and usually occurs when the printing plate is moving or rotating at a different speed than the substrate or the anilox. These parameters are usually tested with two types of test elements - a hexagonal thin line element and a star / flower element. The hexagonal test element is logically composed of hexagonal, thin, concentric shapes. If there is an “hourglass effect” on the hexagon, it means too much impression was applied between the printing plate and the substrate. If, on the other hand, a “bow tie effect” is seen on the test element, there is too much impression between the anilox roller and the printing plate. This item can also indicate ink balance and ink drying problems. The star / flower test element consists of triangular shapes starting from the mddle and thickening outwards. The element is mainly intended to characterize the pressure between the ink transfer roller and the printing plate. If the printing plate gets too much pressure, the center of the “flower / star” element will be filled up with ink. If, on the other hand, the impression is too low, the middle of the flower will remain empty. The test elements for impression and slur are shown on the figure 13.



Graphic elements for impression and slur

To produce a high quality print is not possible without register accuracy, which is essential in all printing processes. By register accuracy we mean the exact matching of each printing color. There are several elements to assess registry accuracy, perhaps only limited by creativity. Classically used elements include the target cross used in Figure 14.



Graphic element fo register accuracy

The tone value incerase is a characteristic feature of flexographic printing. We use the terms “dot gain” and “TVI” (Tone Value Increase) in this topic. An accurate compensation curve can be generated from the values given by the fingerprint, it is essential for the accurate reproduction of the values set in the computer files. In fact, we can use raster scales with the same design as for process organization parameters, e.g. in figures 8 and 9.

3.4 Other elements on the fingerprint

In addition to the essential elements of a fingerprint belongs the testchart. They are designed to control the color management of the printing process. We are not dealing with this in more detail, as the development of test charts and their automatized evaluation, is handled by international software companies (such as GMG) who offer complex solutions for the whole color management process. However, it is also possible to compile a test chart manually and evaluate it manually, but this is an extremely time-consuming process. In an industrial environment, it is more appropriate to purchase a complete system that provides both - software and hardware, and the measurements can be partially or fully automated.

It’s important to mention that even the most professional printers will appreciate having something “eye-catching” on a test print. During the evaluation, it is very important to include elements in the fingerprint that are measurable, but in our experience, photographic parts are also needed. Photographic elements can serve different purposes: they can be included with the aim of showing the benefits of the technology - for example, if we want to convince the printing house about the advantages of a platemaking technology - it is not the test image that will enchant the printer. Or on the other side we can select pictures to show the limits of the technology.

Possible picture elements for a fingerprint (Source: Shutterstock)

CONCLUSION

The aim of our project is to develop a general test chart, which will be able to assess the conditions of a flexographic printing machine, the compatibility of the anilox rollers with the printing form, and the information necessary for the prepress. The research consists of the following phases.

1. Defining the specific properties of flexographic printing - specifying the phenomena to be assessed
2. Creation of the graphic elements of the printing form, digital execution of the printing form
3. Evaluation of the fingerprint design by professionals with the help of a questionnaire
4. Print tests

5. Evaluation protocol development to help interpret and document the results obtained.

Our research is currently in its second phase. Our plan is to further expand the range of applicable graphic elements and to continue the research between practical implementations. After the completion of the second phase, we plan to contact professional printers with a questionnaire. If the available resources will allow, we plan to print at least one fingerprint. As a final step, we plan to develop an evaluation protocol so that the results obtained can be interpreted and archived by all participants of the printing process.

Flexographic printing is a key technology in packaging production, our research is meant to help to meet the ever-increasing demands placed on packaging materials. Our goal is to facilitate, optimize and standardize the testing process.

The results of the first phase of our research were presented at the TAGA 71st conference in Minneapolis, which was also published in the conference publication (Horváth, Palova, 2019).

ACKNOWLEDGEMENTS

The publication and research are supported by the Ministry for Innovation and Technology, by the National Resarch, Development and Innovation Office and the ÚNKP Programme.

INNOVÁCIÓS ÉS TECHNOLÓGIAI MINISZTÉRIUM

NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION OFFICE HUNGARY

ÚNKP Új Nemzeti Kiválóság Program

REFERENCES

[1] Flexographic Technical Association, Inc., 2017. FIRST - Flexographic Image Reproduction Specifications & Tolerances. 6th ed. United States of America: Kindle Edition.

[2] Oetjen, S., 2017. An Introduction to the Importance of Press Optimization. [online] Packaging Impressions. Available at: <https://www.packagingimpressions.com/post/an-introduction-to-the-importance-of-press-optimization/> [Accessed 9 April 2021].

[3] Deamon, A., 2021. Best practices for press fingerprinting. [online] Carey Color Incorporated. Available at: <https://careyweb.com/press-fingerprinting-in-fta-oct-2013/> [Accessed 14 April 2021].

[4] Földvári, M., 2018. Színes nyomtatás. [online] Szinkommunikacio.hu. Available at: <http://www.szinkommunikacio.hu/13_12.htm> [Accessed 30 April 2021].

[5] GMG Color, 2021. GMG Open Color User Manual. [online] Sdla.webservice.gmgcolor.com. Available at: <https://sdla.webservice.gmgcolor.com/Knowledge%20Base/GMGOpenColor/GMG-OpenColor_Manual_en.pdf> [Accessed 1 May 2021].

[6] Horváth, Csaba ; Klaudia, Palova : Relationships Between the Surface Texture of Flexographic Printing Plates and Printability of Kraft Paper

[7] In: Proceedings of the 71th TAGA (Technical Association of the Graphic Arts) Annual International Technical Conference, March 17-20, 2019, Minneapolis, MN, United States (2019) pp. 176-188. , 13 p.

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INFLUENCE OF DIFFERENT APPLICATION METHODS OF SPECIAL INKS ON THERMOCHROMIC AND FLUORESCENCE EFFECT IN SCREEN PRINTING

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Abstract:

Printing inks with special effects are commonly utilized in graphic technology for the purposes of added value and anti-counterfeiting methods of printed products. Thermochromic liquid crystal-based inks (TLC) and ultraviolet (UV) visible (daylight invisible) fluorescent printing inks (UVF) can be used in smart packaging - as additional security features, indicators, markings, etc. In this research, TLC ink and UVF ink with red pigment have been applied on the printing substrate as a hybrid ink system, with the aim of obtaining a functional printed product with combined added value. Two suitable paper substrates were screen-printed using two methods: overlaying the prepared UVF ink on the printed TLC ink; and by mixing the UVF red pigment directly into the TLC ink before printing. Thickness, roughness, surface free energy and adhesion parameters of printed layers were analysed. Spectral reflectance of the UVF ink, as well as thermochromic effect of TLC ink were measured. Microscopy was used to display the visual colour play effect and the effect of luminescence. Results of the research have enabled the evaluation of hybrid TLC-UVF effect obtained by screen printing technique, using different ink application methods. Analysis of the properties of obtained prints can be used for the optimization and applicability recommendation of screen-printed TLC-UVF special inks.

Keywords:
Thermochromic liquid crystal-based inks, Colour play effect, Luminescence, Screen printing, Packaging

INTRODUCTION

Thermochromic liquid crystal-based (TLC) printing inks respond to a change in surrounding temperature. Active thermochromic liquid crystal material enables the colour change. This material must be protected from harmful environmental influence by microencapsulation [1,2]. Dynamic colour change of the TLC is defined by activation temperature T_A at which the colour change starts, and temperature activation region of the TLC ink. Inside this region, the reorientation of the molecules inside the TLC structure occurs with the change in temperature, causing the colour change, also called the colour play effect [3]. This effect implies that each colour in visible part of the spectrum occurs at a defined temperature [4]. The special colour play effect is observable only over black or grey substrate with optical density of at least 0.72 [5]. Thermochromic printing inks can be used in several different applications such as temperature indicators, intelligent packaging, security printing, textile, brand protection and marketing [6-9].

In order to produce a printed product with dual functional properties an ultraviolet (UV) visible (daylight invisible) fluorescent printing ink (UVF) with TLC printing ink was used. UVF printing inks belong to a group of a special effect inks and have the possibility of absorbing the UV radiation, and re-emitting of photons of a different radiation [10,11]. This phenomenon is called luminescence and gives UVF printing inks the possibility of their usage in a wide range of applications. They can be used in decorative and packaging industry, for different markings, signalling, and orientation purposes, in a document security application, etc. [12–14]. In printing processes, they can be used in form of a varnish in flexography, in offset printing and relief printing as well [15,16]. In screen printing process, they can be used as printing inks with special purposes or, most often, by mixing UV fluorescent pigments with the transparent base [17]. Printed UV fluorescent inks are usually invisible in a daylight or have a mild pastel tone.

The aim of the paper was to investigate the influence of printing substrate and different application methods on thermochromic and fluorescence effect of TLC and UVF printing inks, respectively. This knowledge could propose some new ideas for the application of TLC and UVF printing inks and their combination.

EXPERIMENTAL

Two types of hybrid TLC-UVF ink systems were used in this research; one of them is overlaying the prepared UVF ink on the printed TLC ink (denoted as HS1 – hybrid system 1), and the other is a mixture of UVF red pigment and TLC ink (denoted as HS2 - hybrid system 2). TLC and UVF printing inks used for hybrid ink systems had a water-based formulation. Both HS1 and HS2 were screen-printed, using a screen-printing plate with a mesh density of 43 lines cm^{-1}, on two types of black paper substrates: uncoated recycled cardboard (URC), 425 gm^{-2} and pressure sensitive label material (PSL), 120 gm^{-2}. URC has thickness of 0.617 mm and was pre-printed in black, while PSL is 0.293 mm thick and coloured in mass. Pressure sensitive label material (traditionaly known as selfadhesive label material) is in recent business and science literature named pressure sensitive as these types of label materials are coated with adhesive that is sensitive to pressure and needs a pressure for its activation. Activation is crucial as pressure ensures the process of adhering the label material to the substrate, from the initial adhesion (initial tack) to final adhesion. PSL material used in this paper is an alternative fibre, environmentally friendly material traditionally and commercially used in area of speciality and decorative labels. Uncoated recycled cardboard (URC) is a one side black, one side brown cartonboard made from recycled fibres. URC is specially developed as substitution for plastic packaging of food, particularly red colour fruit and vegetables, as black side of the board gives perfect contrast and ensures maximum eye-catching effect with the end user.

Caliper was measured with micrometer DGTB001 Thickness Gauge (Enrico Toniolo S.r.l.), according to ISO 534:2011.

Thickness of the printed layers was measured by means of a device working on the magnetic induction principle (SaluTron D4-Fe, Frechen, Germany). Surface roughness of substrates and samples was defined by profiling methods following ISO 11562, DIN 4777 and DIN 4762 standards. R_a roughness parameter was measured in order to define the arithmetic mean deviation of the profile (ISO 4287).

Surface free energy (SFE) and contact angles on samples were calculated using the Data Physics OCA 30 goniometer (DataPhysics Instruments GmbH, Germany). In order to define the strength of interactions between the materials in contact, the adhesion performance was calculated as well.

Temperature-dependent optical properties of both hybrid printing ink systems were measured in a temperature range from 21°C to 47°C, using fiber-based USB 2000+ portable spectrometer (Ocean Optics, USA). CIELAB L^*, a^*, b^* values were calculated using SpectraSuite software by Ocean Optics was used, with D50/2° settings. The printed samples were temperature controlled using the surface of a water block (EK Water Blocks; EKWB d.o.o., Slovenia) [11,18].

Images of printed samples was captured by means of an Olympus BX51 microscope (Tokyo, Japan).

RESULTS AND DISCUSSION

Thickness of the printed layers

Thickness of the printed layers was measured to identify the possible influence of the thickness on the visual response of printed layers. Results are presented in Figure 1.

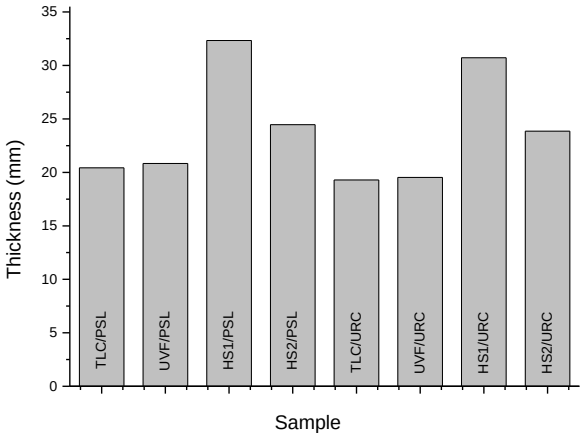


Figure 1. Thickness of the printed layers

One can see that the thickness of the TCL and UVF inks is relatively uniform, on both substrates. Substrate PSL gives slightly higher values of thickness, probably due to the better ink transfer during the printing process. One can see that HS1 layers have a significantly higher thickness on both substrates (32.333 μm on PSL and 30.714 μm on URC). This result was expected due to the application of double-layered ink system and possible interaction of the layers and drying process of the inks.

Surface roughness

R_a parameter was measured on the prints made by pure TLC ink, pure UVF ink and on the printed hybrid ink systems in order to define the substrates' surface structures and to observe the influence of surface roughness of the substrates on the optical properties of effects and on the adhesion performance of the materials in contact. Results are presented in Figure 2. It is visible that pressure sensitive label substrate (PSL) has significantly rougher surface in comparison to uncoated recycled cardboard (URC). R_a parameter amounts 6.940 μm on the PSL and 2.392 μm on URC substrate. By application of pure inks and proposed hybrid systems, one can see that the R_a parameter is decreased on almost all samples. One can assume that applied printing inks penetrate between the paper fibres causing the reduction of surface roughness. On the other hand, due to the usage of water-based printing inks, a certain amount of the ink is probably absorbed into the paper structure causing the reduction of roughness as well. R_a parameter measured on PSL and URC substrates has the smallest values on the prints made using UVF ink. Obviously, UVF ink layer, containing transparent base and UVF pigment, evenly overlays all depths and peaks in the surface structure, causing decreasing of surface irregularities. When observing the roughness values of hybrid ink systems one can say that printed layers cause a certain reduction of roughness. On PSL substrate higher value is detected on prints made using HS2 printing system (R_a = 4.881 μm) in comparison to HS1 (R_a = 3.984 μm). On URC substrate higher value of roughness is detected with HS1 system (R_a = 2.24 μm), in comparison to HS2 (R_a = 1.982 μm).

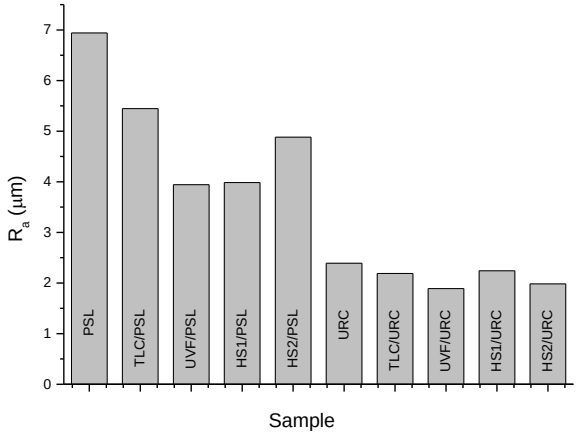


Figure 2. R_a roughness parameter measured on samples

Surface free energy and adhesion parameters

Results of the calculation of surface free energy (SFE) components of papers and printed ink layers are presented in Table 1.

Table 1. Surface free energy components of papers and printed ink layers

	Total SFE (mJ/m^2)	SD	Dispersive SFE (mJ/m^2)	SD	Polar SFE (mJ/m^2)	SD
PSL	53.86	1.28	44.16	1.00	9.71	0.79
TLC/PSL	53.20	2.88	18.58	1.58	34.62	2.41
UVF/PSL	28.00	1.39	27.46	1.36	0.54	0.28
HS2/PSL	48.65	2.29	19.57	1.29	29.08	1.89
UVF (HS1)/PSL	31.64	1.26	31.64	1.26	0.00	0.00
URC	37.71	1.47	36.94	1.43	0.77	0.35
TLC/URC	52.89	1.94	33.08	1.29	19.81	1.45
UVF/URC	29.53	0.78	29.48	0.78	0.06	0.02
HS2/URC	28.35	1.54	16.87	1.15	11.48	1.17
UVF (HS1)/URC	26.86	1.35	26.12	1.31	0.74	0.34

It is visible that paper substrates and UVF ink have a dominant dispersive component of SFE, while polar component is noticeably higher in ink systems with TLC ink. Additionally, polar SFE of the surface of pure TLC ink printed on PSL paper is higher (34.62 (mJ/m^2) than the polar SFE of the pure TLC ink printed on URC paper (19.81 (mJ/m^2). The same trend is visible for HS2 ink printed on two different paper substrates. This occurrence points to the different interactions between layers containing TLC ink and papers, resulting from different SFE components, roughness, and other paper parameters. Compared to the TLC printing ink, UVF ink printed on both papers as pure ink and as HS1 system, has a dominant dispersive component of SFE. The highest SFE values among the printed hybrid ink systems was measured on HS2/PSL sample (48.65 mJ/m^2). This could be related to the highest roughness parameters among the hybrid printed surfaces (Figure 2). The results of SFE calculations are in the accordance with previous research, where the properties of TLC

and UVF inks were analysed [17,19]. Since the SFE components significantly vary among the printed hybrid ink systems, the calculation of adhesion parameters was important for the assessment of the interactions between different papers and printed ink systems.

Results of the calculated adhesion parameters are presented in Figure 3a-c. All three parameters were taken into account when assessing the adhesion. Generally, for the optimal adhesion, work of adhesion

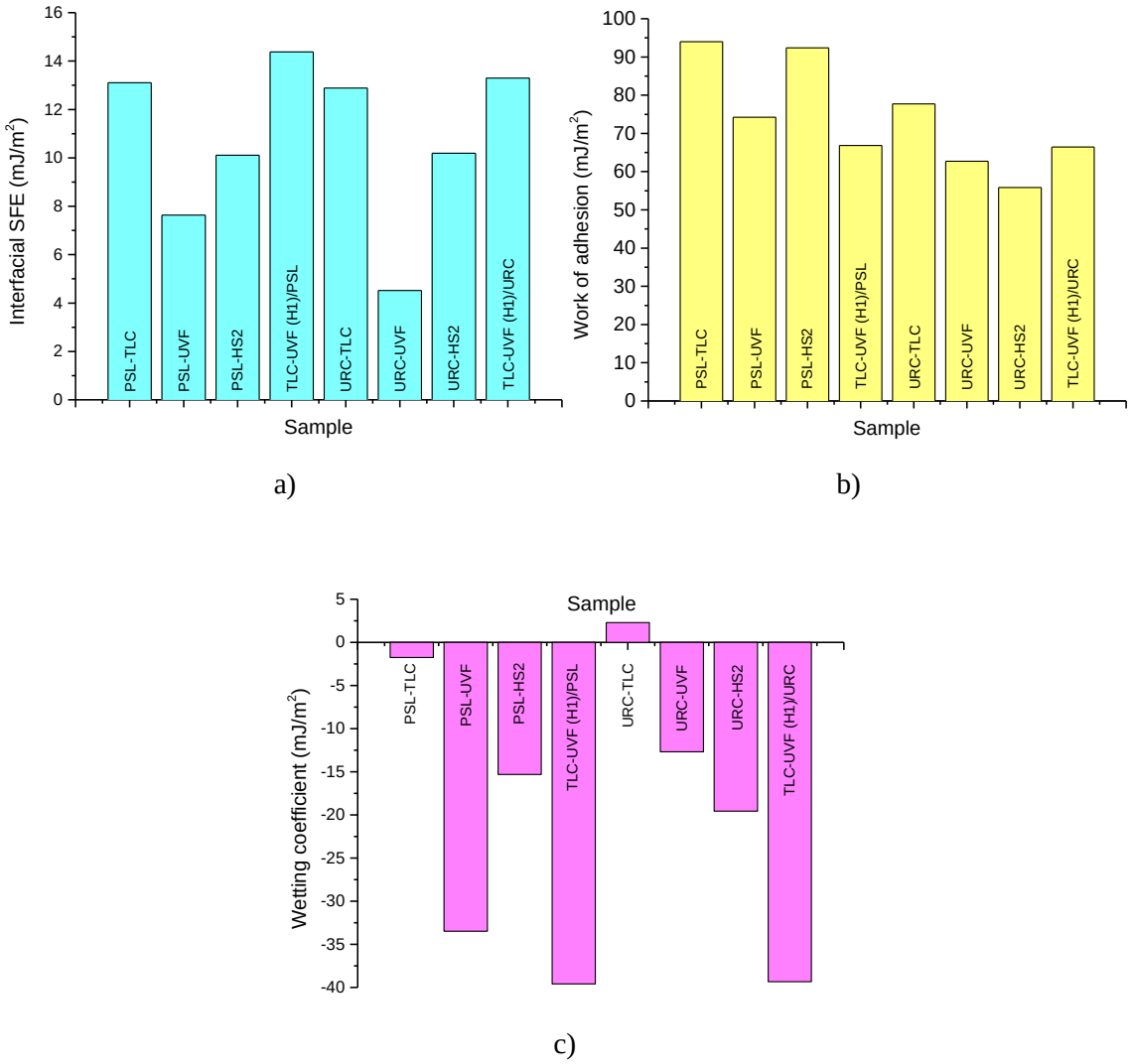


Figure 3. Adhesion parameters between the layers:
a) Interfacial SFE, b) Work of adhesion, c) Wetting coefficient

(W_{12}) should be as high as possible, interfacial tension (γ_{12}) should be close to zero, and wetting coefficient (S_{12}) should be positive or equal to zero. In Figure 3a one can see that the interfacial tension was positive for all samples. However, it was lower between the URC paper and UVF ink (4.52 mJ/m^2), than between PSL paper and UVF ink (7.63 mJ/m^2). When comparing the interfacial tension between different substrates and TLC or HS2 ink, as well as between UVF and TLC in HS1 system on different substrates, the difference of γ_{12} was not significant. Observing Figure 3b, it is visible that higher work of adhesion was obtained between PSL paper and TLC ink, compared to TLC ink printed on URC paper (93.96 mJ/m^2 vs. 77.72 mJ/m^2). In hybrid ink systems (HS1 and HS2), the highest work of adhesion was achieved between PSL paper and HS2 ink (92.4 mJ/m^2), while the lowest work of adhesion was achieved between the URC paper and HS2 ink (55.87 mJ/m^2). Wetting coefficient was not optimal between most analysed surfaces (Figure 3c). Since all wetting coefficients in the hybrid systems, as well as between UVF ink and paper substrates presented the negative values, it can be concluded that the wetting between the layers was not complete. This occurrence is not favourable in most

systems. However, in the printing process, negative wetting coefficient can decrease the mottling, resulting with the improved quality of the print [20].

To establish a possible relation between surface roughness and the adhesion, Pearson product-moment correlation coefficient *(r)* was calculated between R_a parameter of the prints, and the work of adhesion. Significant correlation (r = 0.81) was found. This points to the conclusion that the increased arithmetic mean deviation of the profile is directly related to the higher work of adhesion, i.e., higher work necessary to separate two layers. It can be concluded that the best adhesion in hybrid ink systems was achieved between the papers and HS2 ink. Compared to the HS2 ink, higher interfacial tension, lower work of adhesion and highly negative values of the wetting coefficient between TLC and UVF ink in HS1 system pointed to the weaker adhesion.

Colorimetric analysis was used to describe thermochromic colour play effect of the TLC component in both hybrid ink systems. The CIE *L**, *a**, *b** colour values of all samples printed on URC and PSL paper substrates were calculated from measured reflectance spectra. Both hybrid ink systems printed on URC and PSL show full colour play effect caused by the active material inside microcapsules of the TLC ink (Figure 4). The loop starts to form at T_A of the TLC ink, passes through red, yellow, green, blue and violet, ending at almost the same point at (*a**,*b**) graph, describing the thermochromic effect of the TLC component inside hybrid ink systems. HS2 on PSL results in the most intense colour play effect, forming the widest loop in (*a**,*b**) graph. Less diminished colour play effect within the same curve limits can be observed for HS1 on PSL. HS2 results in less intense colour play effect printed on URC paper substrate, than the ones on PSL.

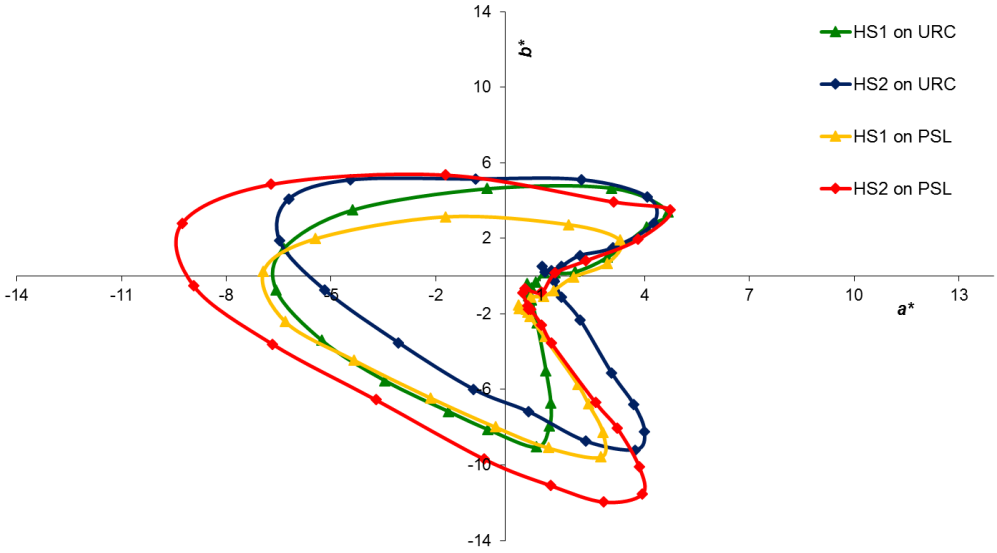


Figure 4. CIELAB colour values of the HS1 and HS2 printed on URC and PSL printing substrates, presented in (a, b*) diagram*

The values of lightness *L** measured at each individual temperature of the printed samples are shown in Figure 4, describing temperature-dependant properties of printed hybrid ink systems. The curve for each sample in *L**(T) graph extends from 21 to 47 °C, showing a single maximum inside temperature activation region of TLC ink. L^*_{max} occurs at almost the same temperature for all samples (Table 2), but the intensity of lightness ΔL^*_{max} is different for each sample. HS2 on PSL shows the highest intensity in lightness, confirming the results from (*a**, *b**) diagram (Figure 4). The same printing substrate results in second highest result of ΔL^*_{max} for HS1, then follows HS1 on URC and HS2 on URC.

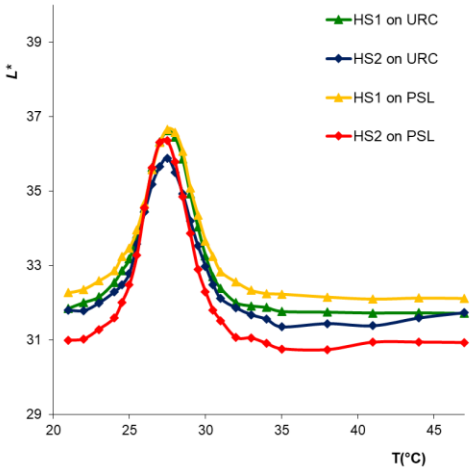


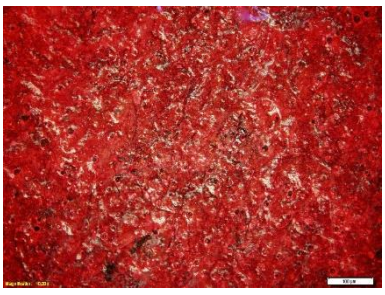
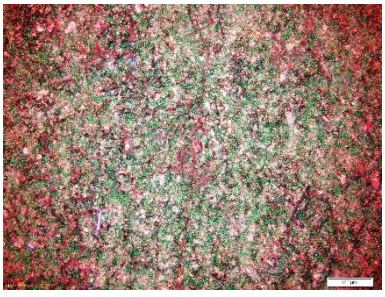
Figure 5. CIELAB colour values of the HS1 and HS2 printed on URC and PSL printing substrates, presented in L/T diagram*

Table 2. Properties of HS1 and HS2 printed on URC and PSL paper substrates: temperature at which the L(T) curve has its maximum is denoted by $T(L^*_{max})$, and its intensity by ΔL^*_{max}. See also Figure 5.*

Sample	$T(L^*_{max})$ (°C)	ΔL^*_{max}
HS1 on URC	27.5	4.82
HS2 on URC	27.5	4.09
HS1 on PSL	27.5	4.42
HS2 on PSL	27	5.49

Microscopy of printed layers

Microscopic images of the printed layers are presented in Figure 6. The images were taken at a room temperature of 25 ± 1 °C and 50–55 % relative humidity. Images present the surfaces of printed layers produced in hybrid printing ink systems captured when exposed to UV radiation to ensure the visibility of the fluorescence effect. Thermochromic effect of printed layers was proven by colorimetric analysis of prints. Observing the Figures 6a and 6c one can see that the fluorescence effect is clearly visible on both substrates. TLC layer with microcapsules is not visible since it is completely covered with UVF printing ink. On the other hand, when observing the HS2 system, containing UVF pigment mixed in the TCL ink, a complex structure with properly distributed thermochromic microcapsules and fluorescent pigments is visible (Figures 6b and 6d). One can say that fluorescence effect is visible, but it is more expressed in HS1 systems, in comparison to HS2 systems.

a)  b) 

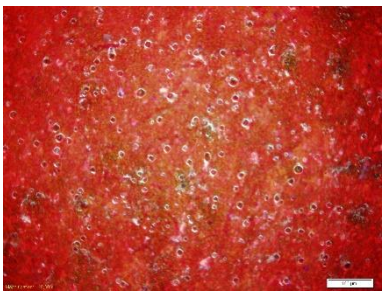
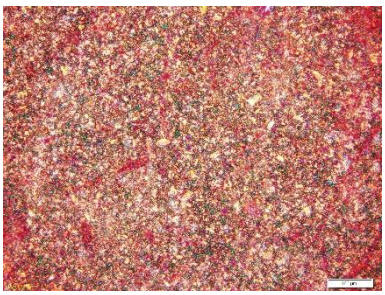
c)  d) 

Figure 6. Microscopic images exposed to UV radiation:
(a) HS1/PSL; (b) HS2/PSL; (c) HS1/URC; (d) HS2/URC (mag 100×).

CONCLUSIONS

The compatibility of the proposed hybrid ink systems and printing substrates is confirmed in this research. TLC and UVF printing inks are also mutually compatible and create a hybrid ink system, which was screen-printed on the substrates in individual layers (HS1), and as a mixture of UVF pigment and TLC ink (HS2). The highest SFE value among the printed hybrid ink systems was measured on HS2/PSL sample. This could be related to the highest roughness parameters among the printed hybrid surfaces. Lowest total SFE and lowest polar component of SFE were measured on the surfaces of UVF ink. Furthermore, higher work of adhesion was achieved between PSL paper and printed ink layers than between URC paper and printed layers. Specifically, in hybrid ink systems, the highest work of adhesion was achieved between PSL paper and HS2 ink. Correlation between R_a parameters of the printed layers and work of adhesion between the layers in contact presented correlation coefficient of 0.81. Both HS1 and HS2 resulted in full colour play effect of the TLCs and fluorescent effect of UVF pigment, on both substrates. However, there are some differences between the samples. Temperature-dependant colorimetric measurements showed PSL enables stronger thermocromic effect of the TLC component in hybrid ink systems, than URC. These results could be linked to the selective reflection of liquid crystals over printing substrate coloured in mass, where the colour of the backing has significant role in colour play effect. Resulting differences also may occur because of the moisture barrier inside URC paper substrate, since the hybrid ink systems are water-based and drying mechanism is absorption/penetration into the paper substrate. The proposed hybrid ink systems could be used in the development of applications considering functional packaging, monitoring systems, security printing and sustainable applications. Further research should include investigation of lightfastness properties and parameters of hybrid prints related to the product protection.

REFERENCES

[1] Seeboth, A. et al: THERMOCHROMIC POLYMER MATERIALS, *CHINESE JOURNAL OF POLYMER SCIENCE (ENGLISH EDITION)*, **VOL.** 25, PP. 123–135, ISSN 1439-6203

[2] Liquid Crystal Formulations (LCs), *AVAILABLE FROM* https://www.hallcrest.com/technology/liquid-crystal. *ACCESSED:* 2021-11-01

[3] Bamfield, P.: *CHROMIC PHENOMENA*, RSC PUBLISHING, ISBN 978-1-84755-868-8, LONDON, (2010)

[4] Christie, R.M., Bryant, I.D.: AN EVALUATION OF THERMOCHROMIC PRINTS BASED ON MICROENCAPSULATED LIQUID CRYSTALS USING VARIABLE TEMPERATURE COLOUR MEASUREMENT, *COLORATION TECHNOLOGY*, **VOL.** 121, PP. 187–192, ISSN 1478-4408

[5] Strižić Jakovljević M., Lozo, B. & Klanjšek Gunde M.: THE PROPERTIES OF PRINTING SUBSTRATES REQUIRED FOR THERMOCHROMIC LIQUIDCRYSTAL PRINTING INKS, *J. PRINT MEDIA TECHNOL. RES*, **VOL.** 4, PP. 165–170, ISSN 2414-6250

[6] Seeboth, A., Lötzsch, D.: *THERMOCHROMIC PHENOMENA IN POLYMERS*, SMITHERS RAPRA, ISBN 978-1-84735-112-8, SHRAWSBURY, (2008)
[7] Aitken, D. et al: TEXTILE APPLICATIONS OF THENNOCHROMIC SYSTEMS, *REVIEW OF PROGRESS IN COLORATION AND RELATED TOPICS*, **VOL.** 26, PP. 1–8, ISSN 0557-9325
[8] Sage I., THERMOCHROMIC LIQUID CRYSTALS, *AVAILABLE FROM* Https://Doi.Org/10.1080/02678292.2011.631302. *ACCESSED:* 2021-11-01
[9] Kerry J., Butler, P.: *SMART PACKAGING TECHNOLOGIES FOR FAST MOVING CONSUMER GOODS*, JOHN WILEY & SONS, ISBN:9780470028025, HOBOKEN, (2008)
[10] Jameson, D.M.: *INTRODUCTION TO FLUORESCENCE*, CRC PRESS, ISBN 9780429192890, BOCA RATON, (2014)
[11] Becidyan, A.N.: LUMINESCENT PIGMENTS IN SECURITY APPLICATIONS, *COLOR RESEARCH & APPLICATION*, **VOL.** 20, PP. 124–130, ISSN 1520-6378
[12] Bodenstein, C. et al: PRINTING PROCESS AND CHARACTERIZATION OF FULLY PAD PRINTED ELECTROLUMINESCENT PANELS ON CURVED SURFACES, *JOURNAL OF COATINGS TECHNOLOGY AND RESEARCH*, **VOL.** 16, PP. 1673–1681, ISSN 1547-0091
[13] Elenbaas, W.: FLUORESCENT LAMPS, *AVAILABLE FROM* https://books.google.hr/books?id=vVJdDwAAQBAJ. *ACCESSED:* 2021-11-01
[14] Yook, K.S., Lee, J.Y.: FABRICATION AND LUMINANCE SWITCHING OF FLEXIBLE ORGANIC BISTABLE LIGHT-EMITTING DIODES ON FLEXIBLE SUBSTRATE, *JOURNAL OF LUMINESCENCE*, **VOL.** 137, PP. 105–108, ISSN 0022-2313
[15] Bozhkova, T., Spiridonov, I. & Shterev, K.: OVERVIEW OF SECURITY PRINTING TYPES AND TRENDS IN ITS FUTURE DEVELOPMENT, *BULGARIAN CHEMICAL COMMUNICATIONS*, **VOL.** 49, PP. 195 -201, ISSN 0324-1130
[16] Talebnia, F., Nourmohammadian, F. & Bastani, S.: DEVELOPMENT OF NOVEL FLUORESCENT OFFSET INK BASED ON COUMARIN DYES: SYNTHESIS AND PROPERTIES, *PROGRESS IN ORGANIC COATINGS*, **VOL.** 77, PP. 1351–1359, ISSN 0033-0655
[17] Poljaček, S.M. et al: EFFECT OF SIO_2 AND TIO_2 NANOPARTICLES ON THE PERFORMANCE OF UV VISIBLE FLUORESCENT COATINGS, *COATINGS*, **VOL.** 11, PP. 928, ISSN 2079-6412
[18] Becidyan, A.N.: THE CHEMISTRY AND PHYSICS OF SPECIAL-EFFECT PIGMENTS AND COLORANTS FOR INKS AND COATINGS, *PAINT AND COATINGS INDUSTRY*, **VOL.** 19, PP. 65–76, ISSN 0884-3848
[19] Marošević Dolovski, A. et al: THERMOCHROMIC EFFECT AND ADHESION PARAMETERS OF LIQUID CRYSTAL-BASED PRINTING INK ON RECYCLED PRINTING SUBSTRATES, *PROCEEDINGS OF THE 2ND INTERNATIONAL CONFERENCE ON CIRCULAR PACKAGING*, Karlovits, I. (ED.), PP. 305–310, ISBN 978-961-90424-6-5, LJUBLJANA, OCTOBER 2021., PULP AND PAPER INSTITUTE, LJUBLJANA, (2021)
[20] Joshi, A. V., Bandyopadhyay, S.: EFFECT OF INK TRANSFER ON PRINT MOTTLE IN SHRINK FILMS, *JOURNAL OF COATINGS TECHNOLOGY AND RESEARCH*, **VOL.** 12, PP. 205–213, ISSN 1547-0091

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JAPANESE KNOTWEED, A USEFUL MATERIAL FOR GRAPHIC PRODUCTS

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Abstract:

Eco-design is an approach to designing products with special consideration for the environmental impacts of the product during its whole lifecycle. To design packaging, it is important to seek for new packaging materials, that are sustainable, recyclable and if possible also biodegradable. One of such materials is cardboard, made from fibers obtained from Japanese knotweed. The goal of our research was to make innovative graphic products from this material. First, the characteristics of cardboard were determined and afterwards sustainable graphic products were designed.

Keywords:

Cardboard, Eco-design, Packaging.

INTRODUCTION

Eco-design is an approach to designing products with special consideration for the environmental impacts of the product during its whole lifecycle and is becoming a core design concept in packaging [1]. The main purpose of packaging is to contain and protect the packed items from their point of production through to the point of use. The challenge is to do so by optimizing the use of materials, water and energy, minimizing waste and maximizing the recovery of used packaging [2]. The sustainable packaging design principles of effective, efficient, cyclic, and safe should be consider [3]. For packaging with short-life span is even more important to focus on material choice, to use materials from renewable sources, that are recyclable or compostable, and design for maximum sustainability and recoverability [1, 4].

The project »APPLAUSE – from harmful to useful with citizens' led activities« addresses unsolved questions with regard to invasive non-native plant species in terms of the zero-waste approach and circular economy. At present, these plants are composted or incinerated, though they could be utilized for other useful purposes, such as raw material for wooden products, paper and graphic products [5]. As invasive plant species represent a more or less rich source of cellulose fibers, in the project Applause, several plants were explored, among them Japanese knotweed. Just like other cities Ljubljana is also faced with significant Japanese knotweed overgrowth, a plant on the list of hundred most invasive non-native species worldwide [6]. It is a fast-growing and strong clump-forming perennial, with tall, dense annual stems. Stem growth is renewed each year from the stout, deeply-penetrating rhizomes in sum. In summer, dense stands of tall bamboo-like canes grow to 2.1 m tall (Fig. 1a) [7].

a b

Figure 1: Japanese knotweed (a) and harvested steam (b)

In the research program novel sustainable materials are used for production of more eco-friendly products. In our study we have analyzed some properties of cardboard made from the Japanese knotweed and designed a sustainable graphic products from it.

EXPERIMENTAL

2.1 Materials

The cardboard was made from a mixture of wood fibers (hardwood/softwood) and Japanese knotweed fibers, which were obtained from the stem of the plant (Fig. 1b) using a sulfate process of delignification (Fig. 2a). Pulp was prepared using a Hollander beater (Fig. 2b). Cardboard with a nominal grammage of 240 g/m^2 was produced on a pilot paper-making machine at the Pulp and Paper Institute in Ljubljana shown in Figure 2c.

a b c

Figure 2: Fiber preparation: delignification (a) beating (b) and paper-making (c)

2.2 Methods

Cardboard was tested under standard climate conditions (ISO 187). Among basic properties of cardboard, the basic weight (ISO 536), thickness and bulk (ISO 534) were determined. The surface roughness of cardboard was determined according to ISO 8791-2 with the Bendtsen tester measuring device. Determination of mechanical properties included determination of tensile strength, tensile strain and energy at break, modulus of elasticity (ISO 1924-2), busting strength (ISO 2759), tearing strength by Elmendorf method (ISO 1974), bending stiffness – L&W 15° (ISO 5628) and folding endurance (ISO 5626).

RESULTS AND DISCUSSION

3.1 Cardboard properties

In table 1 properties of carboard made from Japanese knotweed are presented. Analyzed cardboard has compared to commercial ones, higher roughness and natural brownish color with lot of darker specks seen, resulting from plant fiber residues. It is also less compact, more voluminous and less homogeneous, especially in the surface roughness, as indicated from a high coefficient of variation.

Table 1: Basic and mechanical properties of cardboard in mechanical (MD) and cross direction (CD): average value (av. val.) and coefficient of variation (CV%)

	MD av. val. *(CV%)*	CD av. val. *(CV%)*
Grammage (g/m^2)	229,8 *(1,2%)*	
Thickness (mm)	0,335 *(1,7%)*	
Density (g/cm^3)	685,9 *(2,6%)*	
Roughness (ml/min)	1480 *(18,4%)*	1639 *(18%)*
Tensile strength (kN/m)	10,5 *(10,4%)*	6,3 *(3,5%)*
Tensile index (Nm/g)	47,6 *(6,5%)*	28,5 *(2,9%)*
Tensile stress (MPa)	31,2 *(10,4%)*	18,7 *(3,5%)*
Stretch at break (%)	1,3 *(16,5%)*	4,9 *(7,9%)*
Modulus of elasticity (GPa)	3,9 *(9,9%)*	1,7 *(6,5%)*
Tensile energy absorption index (mJ/g)	74,1 *(15,4%)*	222,2 *(10,3%)*
Tear index (mNm^2/g)	10,9 *(4,1%)*	11,6 *(9,4%)*
Bending stiffness (mN m)	18,1 *(9,9%)*	9,3 *(19,3%)*
Folding endurance (double fold number)	1852 *(26,2%)*	215 *(38,2%)*
Bursting strength (kPa)	335,8 *(8,6%)*	
Bursting index (kPam^2/g)	1,5 *(8,6%)*	

Comparison with a commercial cardboard of the same nominal value of the grammage has shown that the mechanical properties of analysed cardboard are somewhat inferior, except of tearing strength and bending stiffness. Bursting strength, tensile strength, tensile stress and energy absorption are lower, though still within acceptable range. The most inferior characteristic of analysed cardboard is folding endurance, with only 215 double folds in cross direction, sugesting very high tendency to cracking and loss of strength at folding. These inferior characteristics must be consider by design of packaging.

3.2 Design of graphic products

3.2.1 Packaging

Sustainable packaging needs to be effective to provide functional requirements, efficient in its use of materials, energy and water, cyclic in its use of renewable materials and safe for people and the natural environment. Besides using recyclable, biodegradable printing substrate (cardboard from Japanese knotweed) packaging had to be fit for purpose, with optimizing the volume occupancy, considering the reduce of the use of graphic materials (glue), to design for recycling, reuse and apply eco-design at visual communication.

The construction of the packaging was made in the way to overcame the inferior mechanical properties of the cardboard and to achieve good stability of the box. With the sliding matchbox shape, in addition to simply opening it, we could reinforce the bottom of the box with a double layer (box and outside sleeve). With the interior fitment that was tide to box design we could stabilize the product and further strengthen the box.

For visual design only three colors were used, grey, pink and white, which are part of company's corporate identity. With the cut opening in outside sleeve, other three colors (purple, blue, orange) which are also part of the company's visual identity, and label design are meaningful incorporated. Opening in the sleeve, besides enabling the consumer to see the product, also saves material (cardboard and printing ink) and makes printing process more sustainable. A minimalist graphic design style was used, only elements are lines and concentric circles, the latter made by embossing, as seen from Figure 3.

Figure 3: Packaging made from Japanese knotweed

3.2.2 Bookmark

A bookmark is one of the least demanding graphic products. Modern bookmarks are available in a huge variety of materials in a multitude of designs and styles. Many are made of cardboard and are often used for promotional purposes. In our case the task was to create the bookmark that would promote the Applause project. Among different materials, we chose cardboard from Japanese knotweed, because its mechanical properties especially good tearing strength and bending stiffness, make this material a good choice for producing a bookmark. In graphic design a bilingual text in Slovene in English language, two logos and the graphic element reminiscent of a Japanes knotweed had to be included. A monocrome solution and design based on the steam and leaves of Japanese knotweed was suggested (Fig. 4).

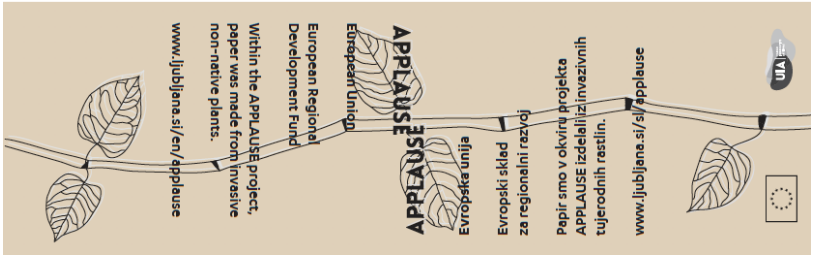

Figure 4: Bookmark made from Japanese knotweed

CONCLUSIONS

Japanese knotweed, one of the most invasive non-native plants in the world, represents a good source of papermaking fibers. With adding up to 40% of Japanese knotweed to wood fibers a natural looking cardboard can be produced. To some extant inferior mechanical properties of cardboard must be taken into account at the design of a graphic product. By aplying eco-design guidelines an uniq, sustainable graphic products can be obtained.

REFERENCES

Birkeland, J.: *DESIGN FOR SUSTAINABILITY*, ROUTHLEDGE, ISBN 9781853838972, LONDON, (2002)

Incpen & Envirowise: *PACKGUIDE: A GUIDE TO PACKAGING ECO-DESIGN*, ENVIROWISE, HARWELL/DIDCOT/OXFORDSHIRE, (2008)

Park, S-I.; Lee, D.S. & Han, J.H.: ECO-DESIGN FOR FOOD PACKAGING INNOVATIONS, IN *INNOVATIONS IN FOOD PACKAGING*, ELSEVIER, AMSTERDAM, ISBN 9780123946010, (2014), PP. 537-547

McDonough, W. & Braungart, M. *CRADLE TO CRADLE: REMAKING THE WAY WE MAKE THINGS*, MACMILAN PUBLISHERS, ISBN 9781429973847, LONDON, (2009)

PROJECT APPLAUSE, MUNCIPALITY OF LJUBLJANA, *AVAILABLE FROM* HTTPS://WWW.LJUBLJANA.SI/EN/APPLAUSE/ *ACCESSED:* 2021-10-17

PROCESSING JAPANESE KNOTWEED INTO PAPER, CITY OF LJUBLJANA, *AVAILABLE FROM* HTTPS://WWW.LJUBLJANA.SI/EN/LJUBLJANA-FOR-YOU/ENVIRONMENTAL-PROTECTION/TOWARDS-CIRCULAR-ECONOMY/EXAMPLES-OF-CIRCULAR-ECONOMY/PROCESSING-JAPANESE-KNOTWEED-INTO-PAPER/ *ACCESSED:* 2021-10-17

JAPANESE KNOTWEED, THE ROYAL HORTICULTURAL SOCIETY, LONDON, *AVAILABLE FROM* HTTPS://WWW.RHS.ORG.UK/ADVICE/PROFILE?PID=218 *ACCESSED:* 2021-10-17

Acknowledgement
This work was co-founded by the Slovenian Research Agency (Program P2-0213, Infrastructural Center RIC UL-NTF) and European Regional Development Fund (UIA02-228).

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THERMAL ANALYSIS OF CORRUGATED PACKAGING PAPER AND ITS COMPONENTS

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Abstract:

In the present work, thermal behavior of corrugated packaging paper and its components were investigated. The various pyrolytic processes appeared as overlapped endotherms on the heat flow curves and as non-separated mass loss steps on the mass loss (TG) and derivative thermogravimetric curves (DTG), as weell, which correspond to the thermal decomposition of the components of the investigated sample, such as cellulose, hemicellulose and lignin. The variable amount of these components appeared as peak height differences on the corresponding endothermic peaks, as well as variable peak heights and widths on the DTG curves. The mass loss curves were also somehow characteristic to the investigated sample, and it was found, that the the straw samples had the lowest thermal stability, while the cotton samples were more stable, their thermal degradation started at least 80 °C higher, compared to the straw samples. It was determined, that in the function of hemicellulose content of the sample, on the corresponding DTG curves smaller shoulders appeared on the lower temperature side (225 and 300 °C) of the main pyrolitic steps (between 225 and 400 °C), which could be used as an analytical markers of the hemicellulose content. The observed smaller endotherms between 400 and 450 °C could be the result of some reorganization in the carbonized remainder and it needs further investigations to clarify the ongoing processes in this temperature interval.

Keywords: TG-DSC, corrugated cardboard, pyrolysis, carbonization

7. INTRODUCTION

The thermal behaviour of the main constituents of the packaging paper were investigated with simultaneous thermogravimetric coupled with differential scanning calorimetric (TG-DSC) on various samples, such as NaOH treated cotton as primary source of alpha cellulose with its over 90 % content, three types of bleached sulphates, non-bleached sulphate, straw and an assorted basepaper type (namely the testliner). Testliner basepaper was also involved as a reference material for comparative purposes as a base of a future introduced analytical identification method. Using thermogravimetric analysis (TG) and differential scanning calorimetry (DSC), the characteristics of the energetic processes (endothermic or exothermic), marginal temperature peaks and the weight losses were measured during the tests. [1]

8. EXPERIMENTAL

2.1 Samples

In the present work, three types of bleached sulphates (bleached -sulphate poplar, - sulphate pine, - sulphate beech, - sulphate), a bleached straw, a non-bleached sulphate pine and NaOH treated cotton were investigated by thermal analysis. NaOH treated cotton was chosen to represent its high cellulose content (over 90% α-cellulose as a primary resource). The testliner sample used both fluting and cover layer for

normal cardboard paper production, consisted of mainly cellulose from secondary recycled source and great amount of incrust and filler materials, which can be classified as a complex chemical system among other samples. The bleached sulphates, bleached straw, the non-bleached sulphate and the NaOH treated cotton were provided by the Material Laboratory of Óbuda University, Hungary. Testliner samples were provided by Dunapack Kft., Hungary. All samples were provided in board form with the size of 210x297 mm. This preparation method has been proven suitable for preventing differences in moisture content, by the variable moisture absorption affinity of the various samples.

2.2 Thermal analysis

The thermal experiments were performed on a Setaram LabsysEvo TG-DSC system in flowing (80 mL/min) high purity (99.999%) argon. Suitable amount of samples were cut in approximately 1x5 mm pieces (Figure 1) and were placed in 100 microliter aluminium crucibles. The measurements were carried out in the 25 – 500 °C temperature range, with a heating rate of 10 °C/min. The dimensions of the samples were chosen to have the highest usable sample mass, with the highest possible surface to be in contact with the inert gas. The measurement results were blank corrected and evaluated with the thermal analyzer's software (Calisto v2.04).

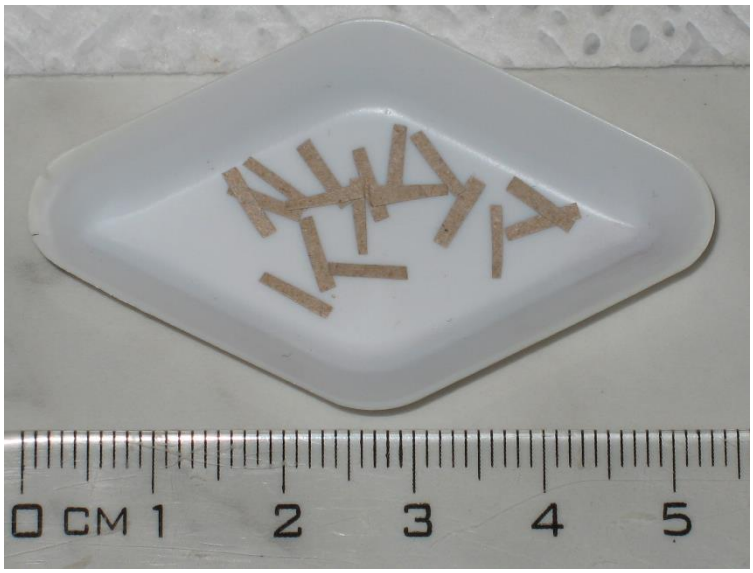

Figure 1. Dimensions of the samples used for thermal measurements

During the measurements, the pyrolytic processes were monitored by a plate type DSC rod, which provided information on the specific temperature (°C) peaks and energetic processes (endothermic, exothermic), which can refer to the characterisation of chemical changes taking place for each component.[10] The samples were analyzed from 30 °C to 500 °C under inert atmosphere (argon), at a heating rate of 10 K/min. This inert carrier gas was used to remove the gaseous and condensable products, thus minimizing any secondary vapor-phase interactions [9]. The energy changes (more specifically the heat flow curves) were recorded during the heating periods based on equation (1) [2-5]

$$dH\ dt = Cp\ dT\ dt + f(T, t) \qquad (1)$$

where dH/dt is DSC heat flow signal
Cp is a sample heat capacity (heat specific x weight);

dT/dt is the heating rate;
f (T,t) is heat flow that function of time at an absolute temperature (kinetic)

9. RESULTS AND DISCUSSION

On figures 2, 3 and 4 the mass loss (TG), derivative thermogravimetric (DTG) and heat flow (DSC) curves are plotted against temperature. Monitoring the chemical processes by TG and DSC taking place during the heating from 30 °C to 500 °C, four phases were identified (Δ1, Δ2, Δ3, Δ4) by the aid of the DTG curves. The temperature intervals of these phases are followings: Δ1 – between 25 and 150 °C; Δ2 – approximately between 150 and 225 °C; Δ3 – approximately between 225 and 400 °C and Δ4 – from 400 °C up to the end of the measurements (~ 500 °C). During the first phase, the physically bound water (moisture) evaporated. It was found, that in average 3-6% of mass loss occurred in this region. This is in agreement with the values described in the literature for conditioned and non conditioned samples [14].

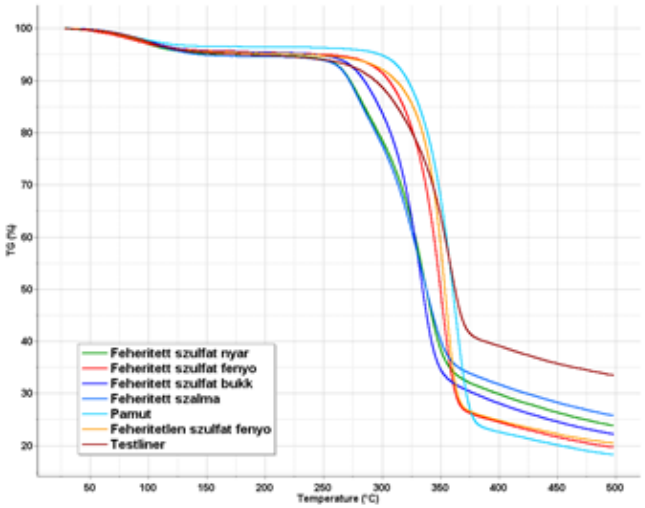

Figure 2. Mass loss (TG) curves of the blenched sulphates [poplar (green curve), beech (dark blue curve) and pinewood (red curve)] non-blenched sulphates (pinewood – orange curve) blenched straw (lighter blue), NaOH cotton (light blue) and testliner basepaper (brown curve)

In Δ2 phase from 150 °C to 225 °C no degradation processes took place in the samples, since there is practically no mass loss in this temperature interval, nor visible energetic processes are taking place in this temperature region. According to the literature, the depolymerization of the hemicellulose takes place usually between 180 and 250 °C, which could be seen as an endotherm on the heat flow signals. This process is not visible in our case, since the present measurements were optimized for best TG and DTG signal resolution and not for obtaining optimal heat flow (DSC) signals, the latter was recorded because of the combined nature (simultaneous TG-DSC) of the technique. Such measurements will be performed and presented later.

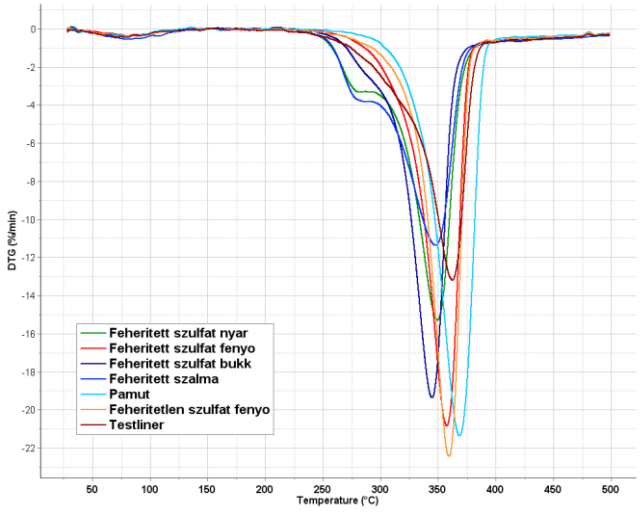

Figure 3. DTG traces of blenched sulphates [poplar (green curve), beech (dark blue curve) and pinewood (red curve)] non-blenched sulphates (pinewood – orange curve) blenched straw (lighter blue), NaOH cotton (light blue) and testliner basepaper (brown curve)

In Δ3 phase, the pyrolytic processes specific to the degradation of the paper's components are taking place, which appear as more or less overlapped peaks of the DTG curve (figure 3) and as endothermic peaks on the heat flow curves (figure 4). Hemicellulose is made up of low molecular weight polysaccharide units, including D-mannose, D-xylose, D-glucose, D-galactose, L-arabinose etc., which are linked together with β-1,4 glycosidic bonds and sometimes with β-1,3 glycosidic bonds. Because of their amorphous nature, short chains and the low molecular weight of sugar molecules,

are degrading at lower temperature. Usually the pyrolytic degradation of hemicellulose starts around 250 °C and is completed around 320 °C.[8,9,10] However, cellulose is a linear polymer that is composed of D-glucose units linked in conjunction with β-1,4 glycosidic bonds. These glucose units are linked together by hydrogen bonds and van der Waals forces to form long chain macromolecules. Therefore, cellulose has higher thermal stability than hemicellulose, and its pyrolysis takes place in the temperature range of approximately 320–400 °C. These processes appeared clearly in the 225 and 400 °C temperature region of the DTG curves, where a small shoulder is mainly visible on the lower temperature side of the large peaks, which based on the above described processes is characteristic to the pyrolytic decomposition of the already depolymerised hemicellulose. The large peaks between 310 and 400 °C are characteristic to the degradation of the cellulose [14, 15]. We have also observed, that the low temperature shoulders on the DTG curves are somehow characteristic markers of the hemicellulose content, as higher is its content, the more separated and visible these shoulders are. It can also be noted, that the determinant part of the mass loss takes place in this phase (Δ3). We have also noticed, that the peak minima on the DTG curves also shifts towards higher temperatures in the function of the cellulose content, as higher is the cellulose, the higher is the peak minima. Despite the fact, that these two degradations are two different processes, they do not appear as separate or overlapped peaks on the heat flow curve, which is not surprising, since –as described earlier- our measurements were optimized for optimal mass loss and not for the detection of the heat flow. [11,12,13]

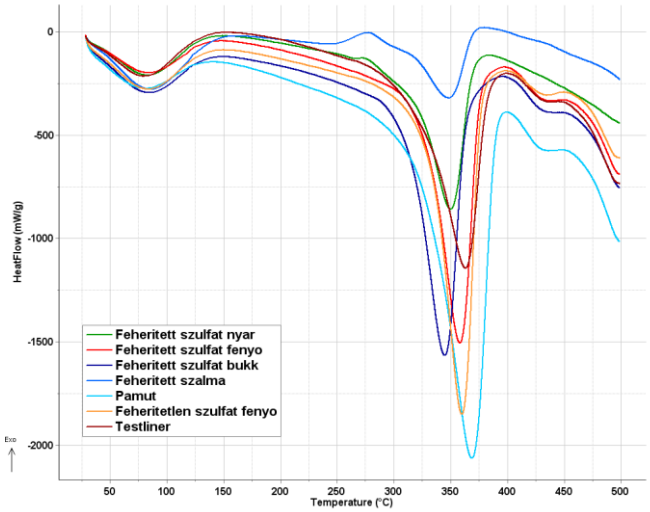

Figure 4. DSC measurement of blenched sulphates [poplar (green curve), beech (dark blue curve) and pinewood (red curve)] non-blenched sulphates (pinewood – orange curve) blenched straw (lighter blue), NaOH cotton (light blue) and testliner basepaper (brown curve)

In the last Δ4 phase, a far much smaller mass loss occurs in the case of all investigated samples, which is accompanied by a small and broad endotherm, which, based on the findings described in the literature, could be the result of the pyrolytic decomposition of lignin. Lignin is mainly an amorphous tridimensional polymer composed of three basic units, namely p-coumaryl (4-hydroxycinnamyl), coniferyl (3-methoxy 4-hydroxycinnamyl) and sinapyl (3,5-dimethoxy 4-hydroxycinnamyl) alcohols, which are also known as p-hydroxyphenyl (H), guaiacyl (G) and syringyl (S) units, respectively. The main difference in the three basic units is the number of methoxyl groups attached to an aromatic ring. The H, G and S units have none, one and two methoxyl groups, respectively. The proportion of H/G/S units in lignin largely depends on the biomass species. Softwood lignin has a high content of guaiacyl units, hardwood lignin presents a mixture of guaiacyl and syringyl units [16]. Since this small exotherm is also visible in the case of NaOH treated cotton, which does not contains lignin, it could arise from some internal rearrangement of the already pyrolized remainder. Further investigations will be performed in order to clarify the ongoing processes in this temperature interval.[6,7,8]

On figure 5, the quantitatively evaluated TG curve of the NaOH treated cotton is plotted against temperature, showing the characteristic mass losses fpr the previously determined Δ1 - Δ4 phases. Relevant mass loss values for each sample is given in table 1.

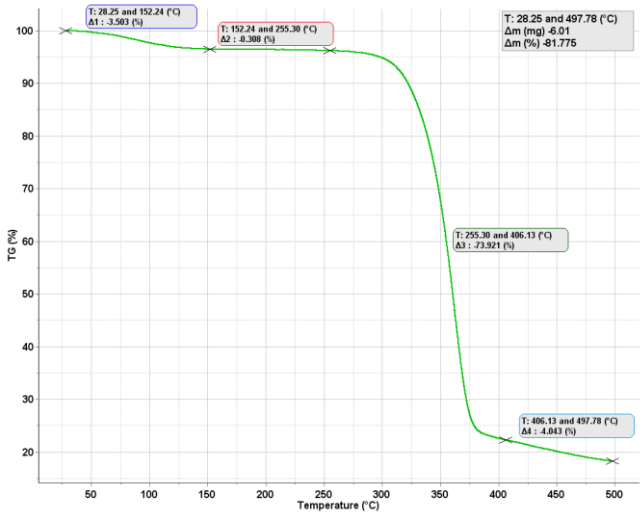

Figure 5. NaOH treated cotton's quantitatively evaluated TG curve (example)

Table 1: Mass loss values of blenched sulphates (poplar, bleech and pinewood) non-blenched sulphates (pinewood) blenched straw, NaOH cotton and testliner basepaper

Samples	Δ1 TG (%)	Δ2 TG (%)	Δ3 TG (%)	Δ4 TG (%)
Non- blenched sulphate pine	4.522	0.502	69.544	4.989
Blenched straw	5.223	0.327	61.837	6.848
Blenched sulphate beech	4.390	0.378	65.636	7.394
Blenched sulphate pine	4.149	0.738	70.215	5.228
Blenched sulphate poplar	4.906	0.435	64.328	6.495
NaOH treated cotton	3.503	0.308	73.921	4.043
Testliner	4.734	0.644	54.996	6.131

4. CONCLUSIONS

In this present research, thermal behaviour of corrugated packaging paper and itscomponents were investigated. It was found, that all samples contain a few percents of moisture, the depolymerization of the hemicellulose can not be observed under the used experimental conditions. At higher temperatures, the thermal decomposition of hemicellulose and cellulose takes place, which can be clearly separated and visible on the DTG curves. Additionally, the intensity of the shoulders (on the DTG curves) on the lower temperature side of the main decomposition process is characteristic to the lignin content of the sample. Above 400 °C up to the end of the measurements the degradations of the lignin are taking place, or some internal rearrangements in the pyrolized mass could also take place in this phase.

References

[11] Ball, R., McIntosh, A. C., & Brindley, J. (2004). Feedback processes in cellulose thermal decomposition: implications for fire-retarding strategies and treatments. Combust. Theor. Model. 8 (2): 281-291. doi:10.1088/1364-7830/8/2/005

[12] Böröcz, P., Pidl, R., Tóth, B. (2016). Thermo-Analytical Technique to Analize the Quality of Paper for Packaging. J. App. Packag. Res., 8(1): Article 6. 31-37. https://scholarworks.rit.edu/japr/vol8/iss1/6

[13] Ibrahim, S. F., El-Amoudy, E. S., Shady, K. E. (2011). Thermal analysis and characterization of some cellulosic fabrics dyed by a new natural dye and mordanted with different mordants. Int. J. o Chem., 3(2): 40-54. doi:10.5539/ijc.v3n2p40

[14] Mackenzie, R. C., Mitchell, B. D. (1962). Differential thermal analysis. A review. Analyst, 87 (1035): 420-434.

[15] Pöhler, T., Jetsu, P., Fougerón, A., Barraud, V. (2017) Use of papermaking pulps in foam-formed thermal insulation materials. Nord. Pulp Pap. Res. J. 32 (3):367–374. doi:10.3183/npprj-2017-32-03-p367-374.

[16] Raunio, J., Asikainen, T., Wilo, M., Kallio, E., Csóka, L. (2020). Affecting the bonding between PLA fibrils and kraft pulp for improving paper dry-strength. Nord. Pulp Pap. Res. J. 35 (2): 185-194. doi:10.1515/npprj-2019-0033

[17] Raveendran, K., Ganesh, A., Khilar, K. C. (1995). Influence of mineral matter on biomass pyrolysis characteristics. Fuel. 74 (12): 1812-1822. doi:10.1016/0016-2361(95)80013-8

[18] Soares, S., Camino, G., Levchik, S. (1995). Comparative study of the thermal decomposition of pure cellulose and pulp paper. Polym. Degrad. Stab. 49 (2): 275-283. oi: 10.1016/0141-3910(95)87009-1

[19] Stewart, J. M. (1966). The characterization of a peat profile by thermal methods. Agrochimica, 11, 92-104.

[20] Tsujiyama, S. I., Miyamori, A. (2000). Assignment of DSC thermograms of wood and its components. Thermochim. Acta, 351 (1-2): 177-181. doi:10.1016/ S0040-6031(00)00429-9

[21] Yang, H., Yan, R., Chen, H., Zheng, C., Lee, D. H.,Liang, D. T. (2006). In-depth investigation of biomass pyrolysis based on three major components: hemicellulose, cellulose and lignin. Energy Fuels, 20 (1): 388-393. doi:10.1021/ef0580117

[12] Nadežda Števulova, Viola Hospodárova, Adriana Eštoková STUDY OF THERMAL ANALYSIS OF SELECTED CELLULOSE FIBRES; Geoscience Engineering, Volume LXII (2016), No. 3 p. 18-21, ISSN 1802-5420

[13] V. Ramiah THERMOGRAVIMETRIC AND DIFFERENTIAL THERMAL ANALYSIS OF CELLULOSE, HEMICELLULOSE, AND LIGNIN, Journal of Applied Polymer Science vol. 14, pp. 1323-1337 (1970)

[14] Raj Kumar, Vishal Sharma, Neha Verma, Pawan Kumar Diwan, Vinay Kumar & Vijay Kumar, Analysis of writing/printing paper via Thermogravimetric Analysis: application in forensic science, Australian Journal of Forensic Sciences, DOI: 10.1080/00450618.2017.1310921.

[15] Nadežda ŠTEVULOVA, Viola HOSPODÁROVA, Adriana EŠTOKOVÁ,STUDY OF THERMAL ANALYSIS OF SELECTED CELLULOSE FIBRES, GeoScience Engineering Volume LXII (2016), No. 3, p. 18-21, ISSN 1802-5420, HTTP://GSE.VSB.CZ

[16] Shurong Wang, Gonxin Dai, Haiping Yang, Zhongyang Luo, Lignocellulosic biomass pyrolysis mechanism: A state-of-the-art review, Progress in Energy and Combustion Science, 62 (2017) 33-86, DOI: 10.1016/j.pecs.2017.05.004.

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DETERMINATION OF CHEMICAL MIGRATIONS OF PHOTOINITIATORS, WHICH ARE FREQUENTLY ENCOUNTERED IN UV-CURABLE INKS IN THE PRINTING INDUSTRY

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Abstract

Some photoinitiators used in inks, lacquers and print films are minor chemicals and have high chemical mobility. Since these substances are also harmful to human health, their use has been limited by some regulations by the European Union. In the printing industry, ITX, benzophenone, and Irgacure are among the most commonly used.

Within the scope of this study, equal amounts of different photoinitiators (ITX, benzophenone, and Irgacure) were added to the formulation of UV-cured ink with the same chemical content, and their chemical migrations were determined by the LC-Ms method with the help of Tanex LC–MS conditions for calibration experiments: Flow rate 0.4 mL pre-column, 50 wt.% ACN–50 wt.% water. First of all, the calibration curve of each photoinitiator was prepared and then the amount of photoinitiator passing through the square meter was calculated with the help of the calibration curve. As a result, it was determined that Irgacure had the lowest migration and ITX had the highest migration.

Keywords: *Migration, Ink, Printing, Lc-MS*

INTRODUCTION

The emergence of ITX in infant milk products in Italy in 2005 had an intriguing and alarming effect. As a result of the researches, it was found that the source of this chemical found in infant milk is the photoinitiator, which undergoes chemical migration from the printing of the packaging package. In the light of these developments, the European Food Safety Agency (EFSA) has published a declaration on the subject and has given an opinion on the use of all of Europe by determining the maximum amount of migration of some chemicals that can pass from the material to be printed, ink, lacquer, varnish or adhesive to food products. For this reason, the concept of low migration ink and varnish has come to our agenda.

Polymerization using UV light is a fast, easy and effective polymerization technique that has been used since the 1970s. It is frequently encountered in lacquers and varnishes, high speed printing, metal packaging, lamination and bonding, 3D printing processes in the printing industry [1-3]. Curing with UV has some advantages over other drying systems. These; It is fast, polymerization takes place at a high level and monomer residues are low, the liquid binder part takes a solid structure for a minimum time, it does not need an extra heating process, and there are almost no solvent residues with high mobility [4-7].

Photoinitiator is the substance that forms active particles and initiates photopolymerization when exposed to light in the UV curing process [8]. Photopolymerization is examined in 4 steps, these are

initiation, growth, chain transfer and termination steps. UV polymerization steps can be seen in Figure 1.

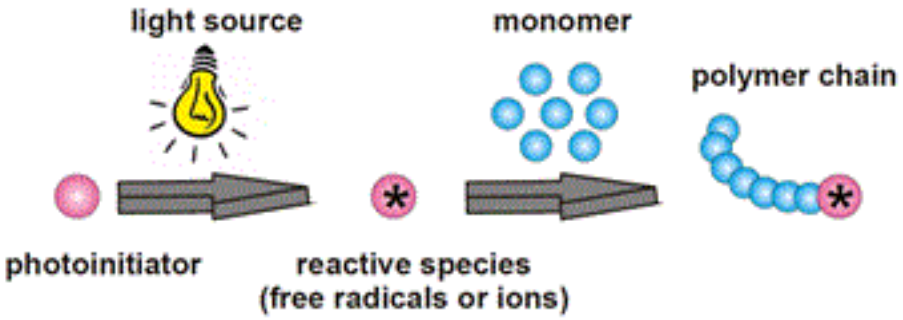


Figure 1: The scheme of UV polymerization

For UV-cured inks, the photoinitiator selection should be chosen by considering the structure of the ink film to be formed, the drying rate, and its value in terms of human health, depending on whether the by-product is harmful or not. The most commonly used photoinitiators in the printing industry are free radical photoinitiators and cationic photoinitiators. Free radical photoinitiators are the most widely used and common photoinitiators whose radical formation and curing stages are well known. Radical generation is of two main types; one-component (Type 1) and two-component (Type 2) foroinitiators that need a co-initiator. Cationic photoinitiators are a polymerization technique that has gained industrial importance in the last quarter century. The advantages of this technique include better adhesion, low oxygen termination, stable polymer dimensions, and homogeneous polymerization process [9-14].

In recent years, greener, cheaper, more effective photoinitiator research continues for the printing industry. In this context, longer-lasting light sources are used, photopolymerization time is shortened, inks curing even with natural light have been produced, and moreover, biodegredable monomers have begun to be researched.

The concept of low migration ink has emerged in order to meet regulatory compliance requirements. Photoinitiators are known to be smaller than 500 D when examining normal UV-curable inks, and their degradation products are even smaller. Small molecules are more prone to chemical migration because of their greater mobility. This poses a risk to human health. The easiest way to reduce migration is to enlarge the photoinitiator. The use of ‘multicomponent photoinitiating systems’ is another novel alternative Another solution to the problem is self-starting systems where the photoinitiator is not used. This is a property of the resin. however, it is not an effective method that can be processed industrially. Electron beam curing, a process that provides some advantages over UV curing such as: instantaneous complete curing, no requirement of photoinitiators, and the possibility of curing thick and pigmented coatings. Chemical migration occurs in two ways, from ink, varnish, lacquer, printing material or adhesive to food. These are direct migration or indirect migration. In direct migration, photoinitiators or other chemically migrated substances diffuse from the printed material to the food. In indirect migration, the migrant substance (photoinitiator or other migrants) is transmitted to the food by steam. Determining chemical migration is a very difficult task. because inks with very complex material content undergoing chemical migration also form by-products. This makes it difficult to determine the amount of migrant. The type in which all chemicals

transferred from a print to the food are determined is called the total migration, and the migration in which the presence and amount of only a single material is determined is called specific migration. While it is quite difficult to determine the total migration, the specific migration is comparatively easier. Analytical methods are used to indicate migration. the most common of these are HPLC, LC-MS, GC and GC-MS.

In this study, UV-curable inks were prepared with 3 photoinitiators (ITX, Irgacure and benzopenone), which are known to be widely used in inks, and the migration amounts of the prepared inks were determined. In addition, printed materials were compared in terms of color and their printability was compared.

EXPERIMENTAL

9.1. Material

Photoinitiators. isopropyl-9H-thioxanthen-9-one, benzophenone, 1-hydroxycyclohexyl-phenylketone (IRGACURE 184) were obtained from Sigma–Aldrich. Methyl alcohol, n-hexane, and ethyl acetate acetontryl solvents were supplied by Fluka. Laromer, the binder used in the ink preparation, was purchased from BASF. Deionized water was supplied from the Milli-Q SP Reagent Water System.

9.2. Methods

In the study, screen printing ink was prepared by using 3 photoinitiators (ITX, benzophenone, and Irgacure), which are frequently used in the printing industry. The formulation of the prepared ink is given in Table 1.

Table 1: The Formulation of prepared inks.

	Acrylate Prepolymer (%)	Triethyl amine (%)	Photoinitiator (%)	Colorant (%)
ITX-based ink	96.8	0.2	3	20
Benzophenone-based ink	96.8	0.2	3	20
Irgacure-based ink	96.8	0.2	3	20

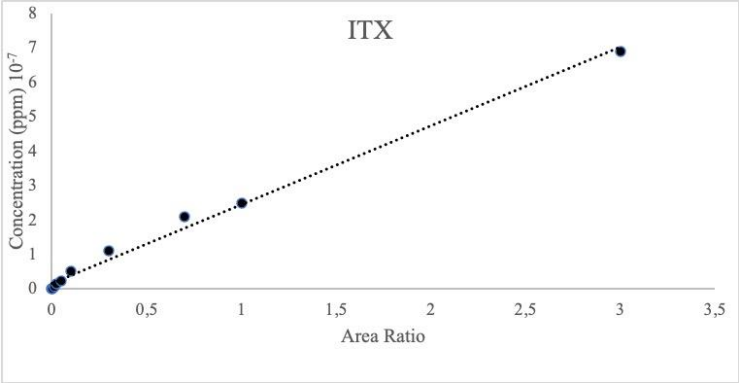
Viscosities of the inks were adjusted to 25 seconds with water. With the obtained inks with different photoinitiators, solid prints with a weaving density of 77 tpc, 75° scraping angle and 75° shore hardness by using an Arus semi-automatic screen printing were made on 80g/m2 uncoated paper. The prints obtained were dried with a laboratory type UV drying lamp. Color measurements were made with X-Rite exact spectrophotometer (Spectral Range 400 -700 nm, with D50 light, 2° observer angle, with polarized filter, 0/45-degree) spectrophotometer for three different inks. Color differences were calculated according to the CIELab (2000) technique.

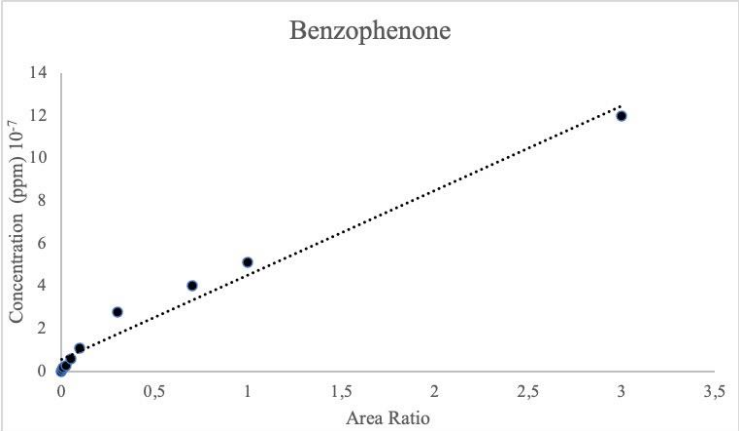
$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}} \qquad (1)$$

Gloss values were measured by BYK Gardner gloss meter at 60° according to TAPPI T480 OM-15. In chemical migration studies; calibration curves of all substances to be quantitatively analyzed were created. Eight concentrations from 0.5 ppb to 3 ppm were used to create the calibration curve. It was started to calculate the specific migration amounts of three different photoinitiators for which calibration curves were created. Solid prints made with an ink amount of 3 g/m^2 were left in room conditions for 24 hours by putting Tanex inside after leaving the UV curing lamp. Tanex obtained overnight was treated with dichloromethane. and the photoinitiators passing into the Tanex were taken to the organic phase. After evaporation of some of the dichloromethane in the organic phases, the samples were prepared by diluting the products with acetonitrile. LC-Ms analyzes were performed with water containing 50% (0.2% formic acid contained) water- 50% Acetonitrile mobile phase, flow rate 0.4 mL/min, pressure 80 bar, Kromasil 3 μm particle size 100 mm×4.6 mm C8 column conditions.

RESULTS

Calibration curves of three different photoinitiators were successfully prepared and analyzed by LC-MS for use in calculating the amount of migration. When the calibration curves are examined, it is seen that even a very small amount of photoinitiator can be determined. In addition, all calibration curves gave sensitive, fast and effective results. Regression value of each curve was calculated as 0.99. In other words, it was determined that the standard deviations in the calibration curve were very low.





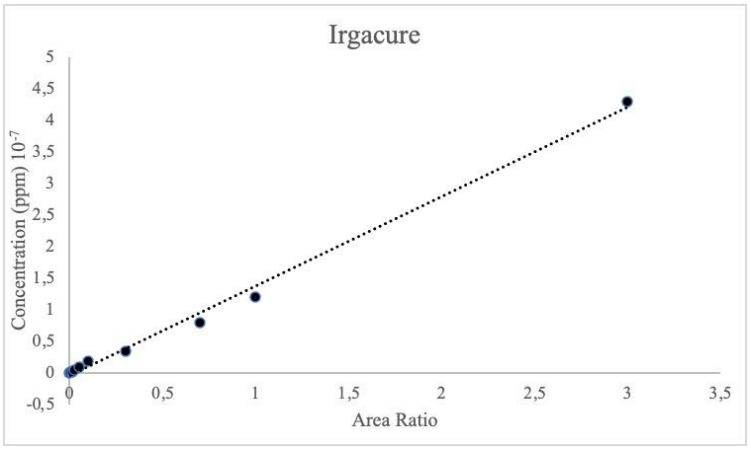


Figure 2: Calibration curves of ITX, Benzophenone and Irgacure.

The chemical migrations of three different photoinitiators used in the printing industry were determined by the LC-MS method, and the absorption values were replaced in the calibration curve and the migration amounts were found. Chemical migration amount of ITX was 0.1 mg/kg, chemical migration amount of benzophenone was 0.039 mg/kg, chemical migration amount of Irgacure was 0.016 mg/kg. When the results were examined, it was concluded that the photoinitiator with the lowest migration rate among the compared three photoinitiators, Irgacure had the lowest migration amount and ITX was the highest.

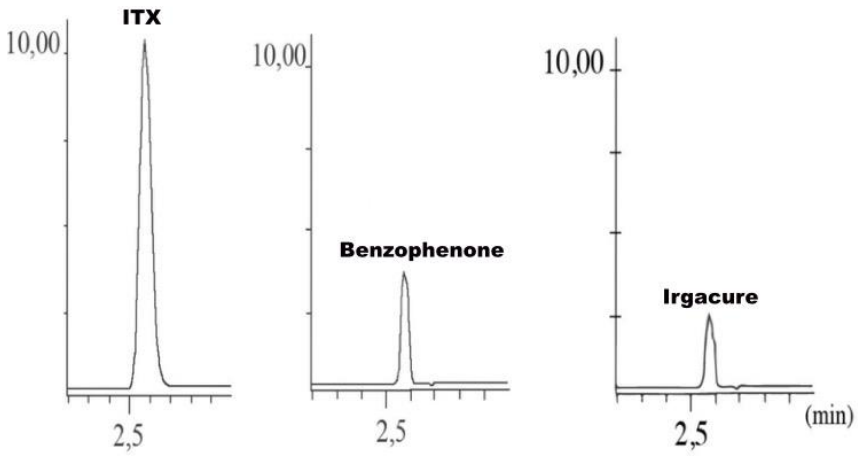


Figure 3: Migration amounts of ITX, Benzophenone and Irgacure based inks

When the color values of the prints were examined, it was determined that the deviation in the colors where the differences between the colors were very small, when the print made with ITX-containing ink was taken as reference, occurred at the L value the most. It was concluded that the inks changed in direct proportion to the drying time. The resulting color differences are within the ISO standard reference range, and the difference has a color difference that is difficult to detect by the human eye. When the gloss values were examined, it was determined that the gloss value of the ink containing Irgacure, where the glossier print was obtained with inks containing ITX and Benzophenone, was lower than these two inks. Drying times of ITX and benzophenone are shorter than Irgacure. In fact, non-drying problems were encountered during the drying process of inks containing Irgacure. For

this reason, the acrylic resin, which is in contact with the air before it dries, has undergone oxidation and a less glossy surface is formed. However, this difference is around 10%.

Table 2: The color and gloss values of prepared ink's prints

	L	a	b	ΔE_{00}	Gloss
ITX-based ink	72.5	82.9	-2.9	Ref	30.5
Benzophenone-based ink	72.4	81.6	-2.3	0.59	30.4
Irgacure-based ink	70.9	82.6	-2.6	1.2	27.3

CONCLUSIONS

Screen printing inks have been successfully prepared with three different photoinitiators, which are frequently used in the printing industry. Screen prints were made on the paper surface with the obtained inks. A fast, selective method has been developed for the photoinitiators used and calibration curves have been prepared. Photoinitiator migrations in prints using inks were calculated by means of calibration curves. When the three photoinitiator inks were compared, it was determined that the ink with the highest migration was the ink containing ITX, and the ink with the least migration was the ink containing Irgacure. In terms of color and printability, it has been determined that all colors comply with the ISO standard and the difference between the colors is too small to be distinguished by the eye. In terms of gloss, it was determined that inks containing Irgacure were more matte due to longer drying time. As a result, it was concluded that among these three photoinitiators used in the printing industry, Irgacure is more suitable for health, but the drying time should be extended.

REFERENCES

Allen, N. S.: Photoinitiators for UV and visible curing of coatings: mechanisms and properties. *Journal of Photochemistry and Photobiology a: Chemistry*, **Vol.** 100 No. (1-3), pp. 101-107. (1996) https://doi.org/10.1016/S1010-6030(96)04426-7

Decker, C.: Photoinitiated crosslinking polymerisation. *Progress in Polymer Science*, **Vol.** 21 No. 4, pp. 593-650. (1996) https://doi.org/10.1016/0079-6700(95)00027-5

Green, W. A.: *Industrial photoinitiators: A technical guide*. CRC Press. (2010).

Fouassier, J. P.: Photoinitiation, photopolymerization, and photocuring: fundamentals and applications. Hanser. (1995)

Decker, C.: Light-induced crosslinking polymerization. *Polymer International*, **Vol.** 51 No. 11, pp. 1141-1150. (2002) https://doi.org/10.1002/pi.821

Papilloud S.; Baudraz D.: Analysis of food packaging UV inks for chemicals with potential to migrate into food simulants. *Food Additives and Contaminants - Part A*, **Vol.** 19 pp. 168-175, (2002) https://doi.org/10.1080/02652030110084800

Rothenbacher, T. et al.: 2-isopropylthioxanthone (2-itx) in food and food packaging materials on the German market. *Food Additives and Contaminants - Part A*, **Vol.** 24 No. 4, pp. 438-444. (2007) https://doi.org/10.1080/02652030601182664

Arsu, N. et al: Photoinitiated radical vinyl polymerization (vol. 8, p. 141à204). CRC Press Taylor & Francis Group: New York. (2009).

Crivello J. Y.; Sangermano, M.: Visible and long wavelength photoinitiated cationic polymerization. *Journal of Polymer Science Part A Polymer Chemistry*. **Vol.** 39, pp. 343-356. (2001). https://doi.org/10.1002/1099-0518(20010201)39:3<343::aid-pola1001>3.0.co;2-j

Decker C. et al: Photoinitiated cationic polymerization of epoxides. *Polymer International*, **Vol.** 50, pp. 986-997. (2001).

Crivello J. V.; Jang, M.: Anthracene electron-transfer photosensitizers for oniumsalt induced cationic photopolymerizations. *Journal of Photochemistry and Photobiology A: Chemistry*, **Vol.** 159, pp. 173-188. (2003). https://doi.org/10.1016/s1010-6030(03)00182-5

Yagci Y.: Wavelength flexibility in photoinitated cationic polymerization. *Macromolecular Symposia*, **Vol.** 215 No. 1 pp. :267-280. (2004). https://doi.org/10.1002/masy.200451121

Aydogan B. et al: Wavelength tunability in photoinitated cationic polymerization. In: Photochemistry and UV curing: new trends. (Ed. Fouassier J.P.) ISBN: 81-308-0014-4, Research Signpost, (2006).

Yagci Y. et al: Photoinitiated polymerization: advances, challenges, and opportunities. *Macromolecules*. **Vol.** 43 pp. 6245-6260 (2006). https://doi.org/10.1021/ma1007545

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ANALYSIS OF THE MATT LACQUERING STRUCTURE OF FLEXIBLE-WALLED PACKAGING MATERIALS IN THE CASE OF FLEXOGRAPHIC PRINTING TECHNOLOGY

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Abstract:
Flexographic printing is one of the fastest growing sectors in the printing industry. Our related research project examined the potential of matte varnishing as surface finishing process. Various surface finishing processes, such as various safety varnishes, protective varnishes, barrier varnishes, and the types of matt varnish we have chosen, are playing an increasingly important role in the development of today's packaging material trend. In the course of the research, we tested the changes in the surface structure of the varnishing layer in the case of varying amounts of lacquer application, and we measured the gloss values in the case of the use of clichés with different surface patterns.
For the tests, we used a type of varnish developed by us, the critical required feature of which was a high degree of heat resistance, and in the development of which the biggest challenge was to achieve fingerprint resistance.
Three different cliché types and three differently applied anilox rollers were used for printing.
The effectiveness of the varnish application is influenced by a number of factors: the varnish uptake of the printing plate, the printing speed, the printing pressure, the temperature and the properties of the printing plate and the substrate.

Keywords:

flexographic printing, varnishing, surface structure,

1. INTRODUCTION

A number of factors have contributed to the importance of packaging and it is gaining strength nowadays. The most important of these is globalization and the resulting economic changes. Changes in the role of packaging are also affected by consumer and social changes, which are mainly due to demographic changes. Globally, the growing population is a challenge, which, in addition to the expanding supply of goods, is leading to an increase in the use of packaging. This process leads to a narrowing of packaging raw materials and, in parallel, an increase in their price, which often forces developers to innovate technologically [1].
In the last few years, many product demands have transformed. The main requirement for the production of packaging materials has become a constant supply, constant quality and simple workmanship, one of the basic pillars of which is varnishing. [2] Varnishes have always played a protective role, from which they developed into individual solutions. Today, most varnishes still play a significant role in mechanical protection, but processes have emerged that open up new opportunities for printers and also increase demand for their products. If the consumer sees a surface that seems interesting during a purchase, they will involuntarily step in to feel it. Just because the consumer grabs the products, he already evaluates them better they are more likely to buy them [3].

One of the leading trends today is the solution of highlighting logos or other important elements on products by treating the surface around them with matt lacquer, so that the brightly left area becomes dominant.

It is no coincidence that this technique has become popular, as the optical experience it provides has a really significant effect, directing the gaze to the right place the result will be clear but dynamic and special. In our

opinion, the use of matt lacquer still has many possibilities. We have built our present research to explore these and apply innovative application techniques.

2. METHOD OF RESEARCH

2.1 Stain resistance

The requirements for matte varnish are high heat resistance and fingerprint resistance, so that no traces remain on the surface treated with matt lacquer after touch. We launched developments for the latter, during which we developed and tested a special matte varnish. To achieve the desired effects, a mineral filler was used as the matting agent, the proportion of which was increased to 15% and thus the desired opacity and opacity value was achieved. The success of the development is indicated by the positive feedback from our partners, which was followed by a successful introduction in several areas.

2.2 Pattern design

The visual effect of segmental varnishing is becoming an increasingly desirable feature in the graphic industry. The initial usage of varnishing was to protect products. Today, almost every product, from commercial to personalized items, includes some type of varnishing. [4] In terms of design, varnish is applied to the majority of products to increase their value by enhancing their visibility or to personalize the product for a customer. Varnishing could be, to some extent, conducted with most printing techniques, including screen printing, flexography, standard offset printing, drip-off offset systems and inkjet digital printing. [5]

An important aspect is the level of gloss achieved on the matt lacquered surface after the matte varnish. One of the main elements of our research is to examine the range in which we can modify the gloss value of matte varnish even within a given print. This technique can allow different patterns to be displayed by changing the structure of the matte finish. In order to map the possibilities of matte varnishing, we need to examine the factors that can be used to influence the quality and quality of varnish application. 3 types of clichés and 3 different sizes of anilox rollers were used for the tests. For the test print, we used the test chart we compiled in Figure 1, which contained the 19 different surface patterns shown in Table 1.

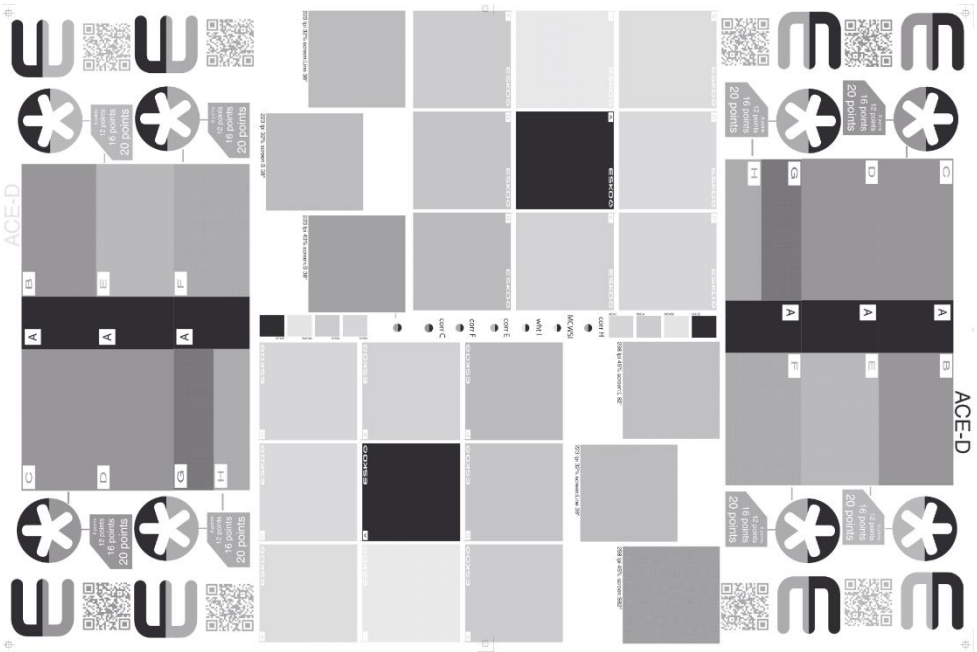

Figure 1: The applied test chart

Table 1: Applied surface pattern

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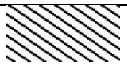
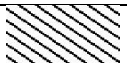
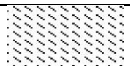
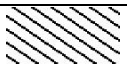
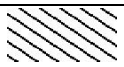
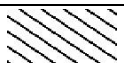
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
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Three types of anilox rollers with different ink volumes and screen line densities were used for printing:

- Anilox 1: 360 L / cm screen line density and 5.5 cm^3 / m^2 ink volume
- Anilox 2: 260 L / cm screen line density and 7 cm^3 / m^2 ink volume
- Anilox 3: 200 L / cm screen line density and 10 cm^3 / m^2 ink volume

The tests were performed using the following cliché types:
Flint ACE-D

- Standard digital cliché
- FLAT TOP: nitrogen chamber with UV-A illumination, surface pattern formation: during lasering
- Shore A hardness: 78 Sh A

Flint ACT-D

- Standard digital cliché.
- FLAT TOP: nitrogen chamber with UV-A illumination, surface pattern formation: during lasering.
- Shore A hardness: 74 Sh A.

MacDermid LUX ITP-60

- FLAT TOP cliché and surface pattern can be created during lasering.
- Shore A hardness: 78 Sh A.

After selecting the appropriate cliché and anilox rollers, the testing process began. Test printing was performed on a Soma Midi Flex 2 press on 0.012 mm thick polyester substrate.

Measurements were performed with a Biuged BGD515 / 3 gloss meter. Furthermore, we visually examined cliche surfaces and structural changes of matte varnished surfaces using a high-resolution microscope and Peret Flex Pro instruments.

3. RESULTS

We were the first to perform visual examinations using a high-resolution microscope and Peret Flex Pro. It is clear from the samples to what extent the structure of the location of the matting grains within a given varnished surface can be changed. In the second test cycle, the gloss values were measured in 19 different parts of the test chart. The measurement results are shown in Table 2.

Table 2: Gloss values

Anilox 360/5.5			
Samples	ITP-60	ACT-D	ACE-D
S1	32,7	40,7	36,5
S2	21,5	24,6	29,7
S3	32,7	27,3	32,8
S4	32,7	34,3	43,3
S5	28,1	33,2	46,3
S6	33,7	32,1	37,3
S7	33,5	35,4	38,2
S8	35,6	30,2	36,3
S9	57,6	54,3	71,8
S10	62,4	66,8	62,5
S11	33,8	35,9	38,6
S12	23,1	23,7	29,4
S13	32,3	29,2	38,3
S14	35,6	33,3	34,7
S15	39,2	35,5	49,3
S16	28,6	27,9	27,6
S17	34,3	41,8	49,8
S18	45,8	41,9	60,7
S19	63,8	46,5	68,1

Anilox 260/7			
Samples	ITP-60	ACT-D	ACE-D
S1	35,3	29,6	33,5
S2	26,7	25,6	22,1
S3	32,9	29,4	33,8
S4	35,7	37,8	42,1
S5	39,8	35,1	42,4
S6	32,0	32,1	35,1
S7	36,2	45,2	32,7
S8	36,1	36,2	39,5
S9	69,3	69,5	71,1
S10	55,4	64,9	54,1
S11	26,1	37,8	33,4
S12	31,1	22,1	25,3
S13	27,7	28,3	30,1
S14	32,2	32,8	33,7
S15	32,5	36,6	56,2
S16	19,8	26,6	29,0
S17	41,2	44,5	59,8
S18	49,8	48,8	59,9
S19	43,8	49,3	66,0

Anilox 200/10			
Samples	ITP-60	ACT-D	ACE-D
S1	16,3	12,8	15,1
S2	8,6	8,4	8,4
S3	8,9	8,6	9,8
S4	9,6	8,2	10,6
S5	10,5	7,3	9,2
S6	9,7	7,5	8,6
S7	13,7	12,4	18,7
S8	9,0	8,1	8,1
S9	47,4	19,8	63,1
S10	44,8	37,1	48,5
S11	16,1	17,1	19,8
S12	7,8	9,1	9,2
S13	7,7	8,2	9,4
S14	8,3	7,6	9,8
S15	10,6	9,5	10,5
S16	9,3	7,6	9,0
S17	13,1	10,4	14,0
S18	18,1	11,5	15,7
S19	18,2	10,6	17,3

4. DISCUSSION

By selecting the appropriate anilox roller, the available gloss range can be well defined as follows:

- gloss range: 8 - 50 200 L / cm screen line density and 10 cm^3 / m^2 ink volume
- gloss range: 20 - 70 260 L / cm screen line density and 7 cm^3 / m^2 ink volume
- gloss range: 25 - 70 360 L / cm line density and 5.5 cm^3 / m^2 ink volume

In all cases, the lowest gloss values were obtained with the Flint ACT-D clichés, from which it can be concluded that the matte appearance of the varnished surface can be increased by using softer clichés.

5. CONCLUSIONS

By evaluating the results, we determined the range over which the gloss of the varnished surface can be changed using different cliché surface structures. Within a printed test sheet, the maximum brightness difference from a minimum of 8.4 to a maximum of 63.1 can be achieved using Anilox 3 (200 L / cm screen line density, 10 cm^3 / m^2 ink volume) and Flint ACE-D cliché.

The most matte surfaces were obtained by the surface patterns with the geometry shown in Figure 2.

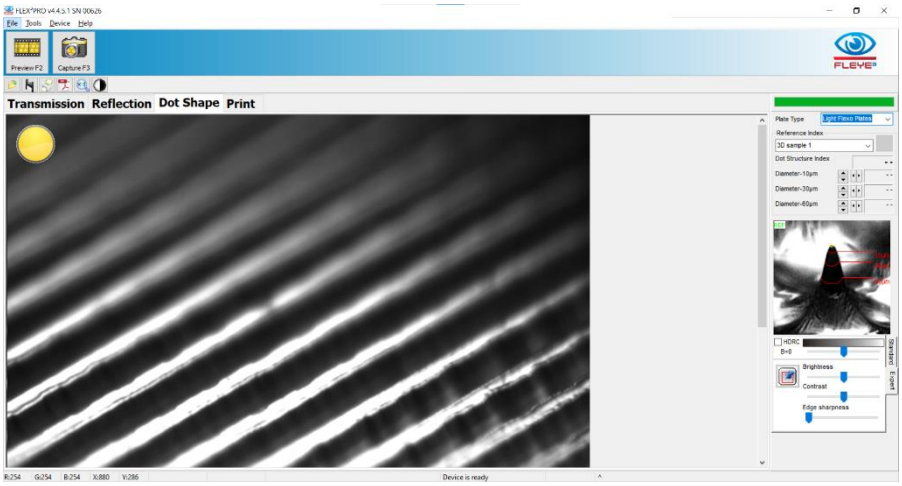

Figure 2: Surface pattern that formed the most matte surface

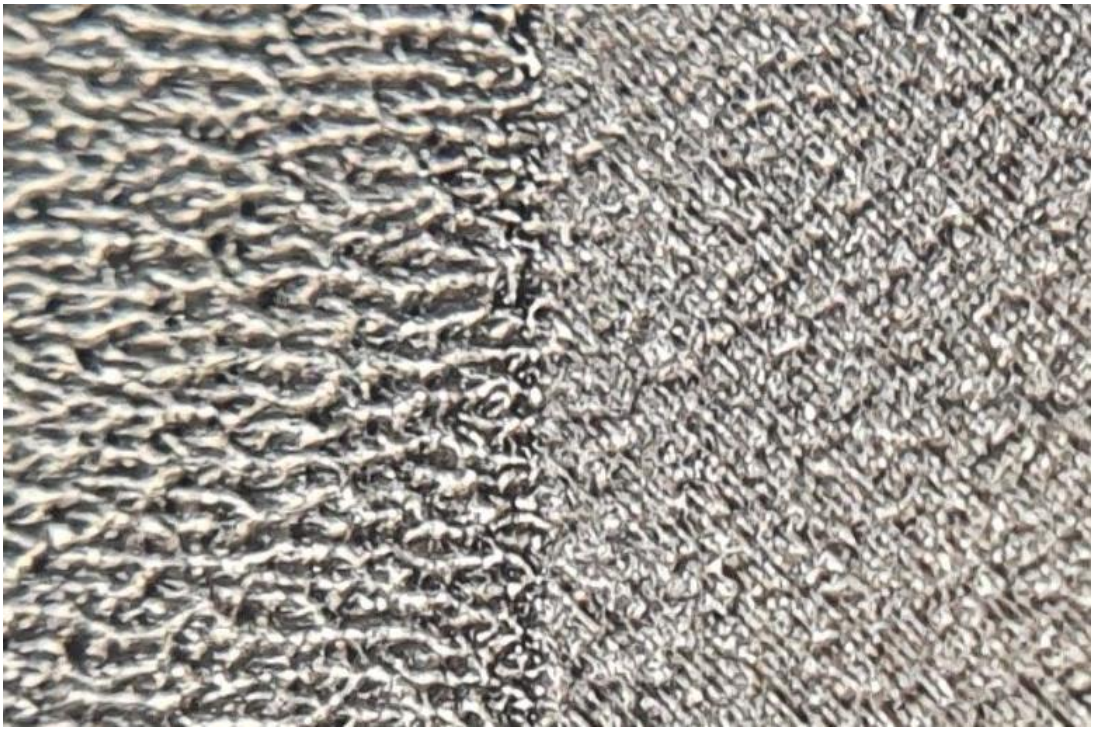

Figure 3: printed without pattern (left) and with pattern (right)

It can be seen in Figure 3 that we were able to change the structural surface of the lacquered parts with the microcellular patterns, without printing on the left side, with a line pattern on the right side.

The above test results, as a segment of the potential of flexo printing technology, can have a significant economic impact in terms of efficiency and economy, thus contributing to the protection of our environment. In addition to minimizing the amount of varnish used, production can be optimized with the most suitable surface pattern and the most efficient varnish type to use. With the help of the test results, we got a more accurate picture of the brightness values of the type of varnish developed by us when using clichés with different surface patterns, thus giving the opportunity to cover the widest possible range of applications.

Despite the sudden crisis of the past year, unlike many other sectors, the packaging industry, including the flexo line, has lost momentum surface pattern line density to achieve minimum brightness values.

6. REFERENCES

[1] Dörnyei K. R. : *CSOMAGOLÁS – MENEDZSMENT*, KOSSUTH KIADÓ, ISBN 978-963-09-9307-4 (2019)

[2] JR. Kovács T. CNI Kft.– Lakktrendek a nyomdaiparban; Magyar Grafika 2021/1

[3] Spence, C. & Gallance, A. 2011. Multisensory design: Reaching out to touch the consumer. Psychology & Marketing, 28(3): 267-308.

[4] Hudika T., Majnarić I., Cigula T.: Influence of the Varnishing "Surface" Coverage on Optical Print Characteristics; TECHNICAL JOURNAL 14, 4(2020), 428-433; ISSN 1846-6168 (Print), ISSN 1848-5588 (Online) Original scientific paper https://doi.org/10.31803/tg-20191129104559

[5] Kipphan, H. (2001). *HANDBOOK OF PRINT MEDIA*. Berlin, Germany: Springer-Verlag Berlin, 45-60. https://doi.org/10.1007/978-3-540-29900-4 [2]

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CHALLENGES AND ADVANTAGES OF ONLINE TEACHING DURING COVID-19 PANDEMIC

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Abstract:

In this work we were interested in how lecturers at the department of Graphic engineering and design perceived online teaching during Covid-19 pandemic, what they think are the main problems, advantages and disadvantages of online approach, and what were the biggest challenges they were facing in their work so far. Our colleagues filled a survey to answer all these questions, and to give us a better insight on how to improve the teaching process. The responses make it clear that the biggest challenge was to engage students and maintain their attention, as well as the lack of feedback during online classes. The problems our colleagues were facing were to adequately present practical processes, distractions from the members of their households, and technical issues mostly on the sides of students. In their opinion, the advantages of online teaching are the possibility to connect from any location and to adapt the environment to their own needs, as well as easier sharing of the material, while the biggest reported disadvantages were: difficulty to monitor students' progress and reactions, lack of socialization, too much screen time and prolonged class preparation time.

Keywords: *Covid-19, challenges, advantages, lecturers, e-learning*

INTRODUCTION

Covid-19 pandemic has brought a lot of challenges to educational institutions and had changed the way how educational content is structured and presented. The lecturers had to adapt to the new way of presenting, and find the best manner to engage the students and monitor their performance. This was by no means an easy task, and required a lot of energy an effort, as well as technical and social skills.

Different strategies were employed by educational institutions. Some opted for entirely online teaching with synchronous and/or asynchronous [1] courses. In this case, good results in some study fields were obtained with flipped classroom approach [2]. Other institutions used combined model, where classes were only partially presented online (the rest taught face-to-face). The choice of the best option depended on the epidemiological situation and the readiness of the institution to support online learning. The majority of teachers, at least at the beginning, had to improvise, which affected the quality of the teaching and even led to the proposal of a new term: "emergency remote teaching" [3].

Our home institution, Faculty of Technical sciences, as well as the University of Novi Sad were more than prepared for the transfer to online teaching. The necessity to create an online learning platform was recognized a long before the Covid-19 pandemic took place, so lecturers were having a head start when the transfer happened. The technical literacy played an important role in adapting to the new way of teaching. In case of our lecturers, all had some prior experience with online learning, creating the content for online platforms, and many even participated in development of software tools and online solutions for sharing the knowledge related to graphic arts industry [4-6]. Hence, we all adapted rather quickly to teaching over Zoom and, after the first semester, over Microsoft Teams. University of Novi Sad Moodle-based platform was used for sharing the material.

Despite the technical literacy, availability of adequate communication software, excellent technical support etc., online learning was not without problems and challenges. Especially if it is observed in time of global

social isolation and insecurity. Many issues were brought to light so far. Some authors [1, 7] mention that even though distance learning increase ICT skills, support work and education simultaneously and increase innovation, it raises the challenges such as digital divide, problems with communication and interaction, as well as plagiarism. The sense of isolation due to not having direct contact with students as well as too much screen time [8] also influence the motivation and effectiveness. The survey conducted by "The chronicle of higher education" [9] revealed that many professors feel stressed and overwhelmed, since they struggle not only to adapt their courses to the online form, but also to keep their students motivated.

Taking into account that the teaching content and the way of presenting it differs from one study field to another, we were curious to find out what were the main problems and challenges our colleagues from the department of Graphic engineering and design have faced in their work since the beginning of the pandemic, what they think are the main advantages and disadvantages of online teaching, and how they feel about the online teaching in the future. The goal was to share our experience so far and to pinpoint all the problematic aspects we can address in order to improve teaching process.

EXPERIMENTAL

To assess how our colleagues perceived online teaching, we formed an anonymous online survey that consisted of single-select and multi-select multiple choices questions. In most of the cases we allowed the possibility to add the answer that was missing, thus encouraging our colleagues to share their own thoughts. Predefined choices were determined on the basis of studies dealing with the effect of Covid-19 pandemic on higher education, overviews on e-learning [1, 7-10], and on authors' experience.

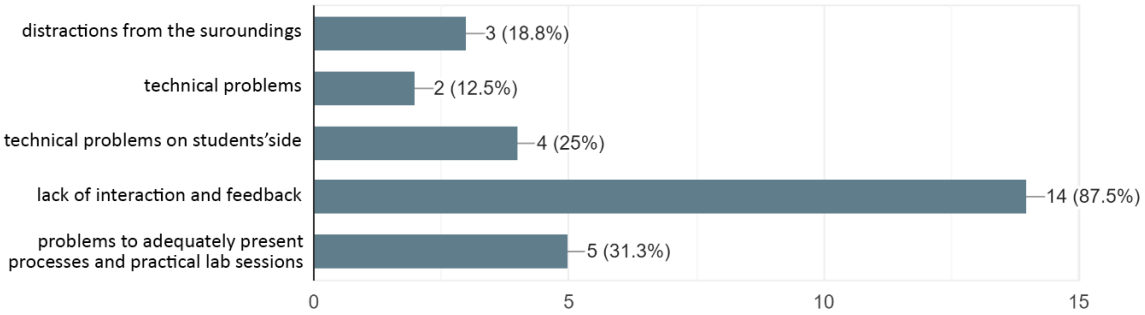
In the survey we asked about the problems and main distractors, advantages and disadvantages of online learning, but also about their experience in the efficiency of online teaching (if it had increased the students' performance and exams pass rate).

The big struggle the majority of us were facing was how to adapt the practical lab sessions to online form, so we also asked our colleagues on how did they solve this problem, and what was their preferred way of presenting online the processes/methods that were normally demonstrated face-to-face. In addition, we wanted to evaluate whether our lecturers would like to continue with online teaching (solely or in combination with traditional approach) and whether they think that it can replace the traditional forms of teaching in the future.

Sixteen lecturers from the Department of graphic engineering and design filled the survey. They were all aware of the purpose of the study, and all have prior experience with preparing content for online platforms.

RESULTS

For the lecturers in our department the biggest issue in online teaching was the lack of interaction/feedback from the students, followed by the problems to adequately present practical processes, technical issues both on the sides of students and their own, and the distractions from the members of their household (Figure 1).

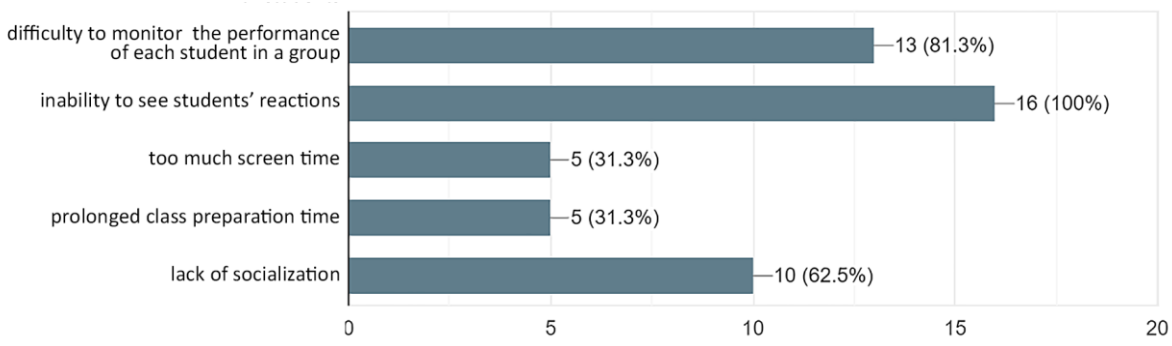


The main problems lecturers were facing in online teaching

The biggest challenges for our colleagues were: holding students' attention (56.3%), students' engagement (50%), lack of feedback during classes (50%), presenting the lab sessions (37.5%) and the lack of motivation and inspiration (6.3%).

Our lecturers think that the biggest advantages of online teaching in comparison to the traditional form are: the possibility to connect from any location (68.8%), possibility to adapt their surroundings to their own needs (56.3%), as well as the much easier sharing of the material (50%). Some also believe that the online mode enables more flexibility in teaching, since the content can be extended far from typical PPT slides. Sense of privacy was also mentioned by few.

The biggest drawbacks that were reported are mostly related to communication as seen in Figure 2. Lack of face-to-face communication, reflected as the inability to see students' reactions and monitor the performance of each and one of them, was the main drawback in comparison to traditional teaching. Also, lack of social interactions, as well as the prolonged class preparation time and too much screen time, were also noted as the disadvantages of online approach (Figure 2).



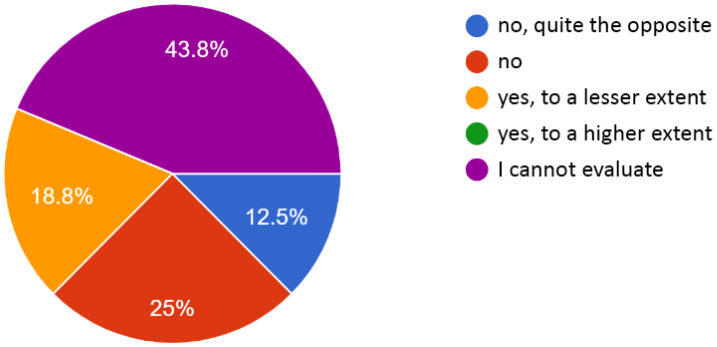
The main disadvantages of online teaching

Most of our colleagues opted to present their practical lab sessions in the form of static and video presentations, tutorials, and combination of the abovementioned. Also, 50% of them always turn on the camera, while 31.3% is doing it sporadically (turning the camera during lectures so that the students can see their facial expressions, but not during lab sessions in order not to increase the cognitive load). Both groups hope that turning the camera on during classes would encourage students to communicate more and provide them with the feeling of conventional classes.

The majority of our colleagues (68.8%) prefer Microsoft Teams over Zoom, 25% have no preference, while the rest gave their votes to Zoom. Microsoft Teams was chosen mostly due to all the options it provides – calendar, chat, possibility to store and share the files more easily, easier monitoring of the students' attendance and so on.

When asked if they would continue presenting their lectures online if given the opportunity, only one lecturer answered positively, while 68.8% gave the negative answer (the rest being undecisive). In case of computer labs, the situation is slightly different – 21.4% of respondents would continue presenting their labs online and 64.3% would go back to classic approach. For presenting practical sessions 92.3% of lecturers chose to go back to labs and 7.7% thinks that both approaches have their benefits.

Considering the exam pass rates, grades of the students in the last period, as well as the number of students who successfully submitted projects and other works required to pass the exams, more than the third of our lectures do not think that the online teaching have improved the students' performance (Figure 3).



Answers to the question whether the students' overall performance increased during online teaching

Also, 37.5% of the examined lecturers do not think that the students belonging to generation-Z find online learning more suitable to their needs, while 15.1% have an opposite opinion (to the higher or lesser extent).

As a conclusion, 56.3% of examinees do not think that the online teaching would ever replace traditional form, 25% thinks that it will eventually happen and to the higher extent, while 18.7% of lectures think that it will happen but to a lesser extent.

CONCLUSIONS

The online teaching is a demanding process, and it is even more so during Covid-19 pandemic. Lecturers faced not only the pressure to quickly adapt to the different way of presenting the content, but also the demand to engage the students, maintain their attention, and motivate them in a situation that was quite challenging for everyone. Lack of feedback during online classes together with the abovementioned were the main challenges lecturers at our home department faced in their work so far.

The biggest problems our colleagues reported were distractions from the members of their households and technical issues mostly on the sides of students. Also, they had problems to adequately present practical lab sessions. In case of later, some opted to record the processes in question, while others combine video recordings with static content.

Even though online teaching enabled us to connect from any location, to be more creative with how we present teaching material and how we share information with our students, it came with a price. Undoubtedly, the biggest disadvantages as seen by our lecturers were not being able to see the students and thus monitor their reactions and performance, lack of socialization, too much screen time and prolonged class preparation time. Some of the lecturers tried to overcome the lack of face-to-face communication by turning on their cameras during classes and encouraging the students to do the same.

It seems that the most of our lectures are eager to go back to aulas, since the majority prefer traditional way of teaching over online approach. Also, more than a half of the examinees do not think that the online teaching could ever replace face-to-face knowledge transfer. Even though it might look like that at this point, where we all miss social contact, it is evident that we would all have to adapt to this new way of knowledge sharing. In that sense, we believe it is essential to give our best to understand and improve the online teaching process, at least in those aspects that are under our control.

Acknowledgements

This research has been supported by the Ministry of Education, Science and Technological Development through the project no. 451-03-68/2020-14/200156: "Innovative scientific and artistic research from the FTS (activity) domain".

References

Arkorful, V. & Abaidoo, N.: THE ROLE OF E-LEARNING, ADVANTAGES AND DISADVANTAGES OF ITS ADOPTION IN HIGHER EDUCATION, *INTERNATIONAL JOURNAL OF EDUCATION AND RESEARCH*, VOL. 2 (2014) NO. 12, PP. 397-410. ISSN: 0883-0355.

Tang, T. el al.: EFFICIENCY OF FLIPPED CLASSROOM WITH ONLINE-BASED TEACHING UNDER COVID-19, *INTERACTIVE LEARNING ENVIRONMENTS* (2020) 1-12. DOI: https://doi.org/10.1080/10494820.2020.1817761.

Hodges, C. et al.: THE DIFFERENCE BETWEEN EMERGENCY REMOTE TEACHING AND ONLINE LEARNING, *EDUCAUSE REVIEW*, *AVAILABLE FROM* HTTPS://ER.EDUCAUSE.EDU/ARTICLES/2020/3/THE-DIFFERENCE-BETWEEN-EMERGENCY-REMOTE-TEACHING-AND-ONLINE-LEARNING *ACCESSED:* 2021-09-21

Pinćjer, I. et al.: INFORMATION DESIGN FOR THE GRAPHIC ENGINEERING E-LEARNING APPLICATION, *PROCEEDINGS OF WOOD, PULP & PAPER*, PP. 170 - 175, ISBN 978-80-89597-16-1, Bratislava, 13. - 14. NOV, (2014)

Vladić, G. et al.: IMPLEMENTATION OF MULTIMEDIA TECHNOLOGIES IN ELECTRONIC EDUCATION OF GRAPHIC ENGINEERS AND DESIGNERS, *PROCEEDINGS OF INTERNATIONAL CONFERENCE ON DESIGN & DIGITAL COMMUNICATION*, PP. 55 - 62, ISBN 978-989-99861-5-2, BARCELOS, (2017)

Pinćjer, I. & Tomić, I.: INTERACTIVE EDUCATIONAL TOOL FOR DIGITAL PRINTING SYSTEM, *PROCEEDINGS OF INNOVATIONS IN PUBLISHING, PRINTING AND MULTIMEDIA TECHNOLOGIES*, PP. 106 - 112, ISBN 2029-4638, KAUNAS, 19. - 20. APR, (2018)

El Rafae, G. A. et al.: DISTANCE LEARNING DURING COVID-19 PANDEMIC: SATISFACTION, OPPORTUNITIES AND CHALLENGES AS PERCEIVED BY FACULTY MEMBERS AND STUDENTS, *INTERACTIVE TECHNOLOGY AND SMART EDUCATION*, VOL. 18 (2021) NO. 3, PP. 298-318. ISSN: 1741-5659.

Gautam, P.: ADVANTAGES AND DISADVANTAGES OF ONLINE LEARNING, *ELEARNING INDUSTRY*, *AVAILABLE FROM* *HTTPS://ELEARNINGINDUSTRY.COM/ADVANTAGES-AND-DISADVANTAGES-ONLINE-LEARNING* *ACCESSED:* 2021-09-13

TUGEND, A.: "ON THE VERGE OF BURNOUT": COVID19'S IMPACT ON FACULTY WELL-BEING AND CAREER PLANS, THE CHRONICLE OF HIGHER EDUCATION SURVEY, *AVAILABLE FROM* *HTTPS://CONNECT.CHRONICLE.COM/RS/931-EKA-218/IMAGES/COVID%26FACULTYCAREERPATHS_FIDELITY_RESEARCHBRIEF_V3%20%281%29.PDF* *ACCESSED:* 2021-09-15

Panigrahi, R. et al.: ONLINE LEARNING: ADOPTION, CONTINUANCE, AND LEARNING OUTCOME—A REVIEW OF LITERATURE, *INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT*, Vol 43 (2018) PP. 1-14, ISSN 0268-4012.

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PREPARATION AND CHARACTERIZATION OF ZNO-CONTAINING UV-CURABLE ANTIBACTERIAL COATINGS

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Abstract:

Chitosan is a natural carbohydrate that is extracted from the shells of seafood, such as crabs and shrimp. Chitosan has antiviral, antibacterial and antifungal properties. Chitosan is advantageous in terms of its non-toxicity, biodegradability and biocompatibility. For this reason, chitosan is a natural biopolymer used in many industrial areas such as food, medicine, pharmaceuticals, cosmetics, agriculture. ZnO nanoparticles are nontoxic inorganic oxides that have been extensively used as antibacterial agents in the industry and academic studies. In this study, acrylate functionality was first added to chitosan, and then a control formulation was prepared by mixing it with other acrylate group containing monomers. Then the prepared ZnO nanoparticles were included in the control formulation. The prepared formulation was applied to the polycarbonate surface by spraying method and left to dry for 3 minutes under UV rays. The structural, thermal and antibacterial properties of the obtained biocompatible coating were examined and it was observed that the coating showed antibacterial properties.

Keywords: *Antibacterial coating, ZnO nanoparticles, chitosan, UV-curable*

INTRODUCTION

Chitosan is a linear aminopolysaccharide obtained by deacetylation of chitin. Chitin, on the other hand, is a natural biopolymer that is abundant in the shells of shellfish and is the most abundant on earth after cellulose [1-3]. Chitosan has excellent chemical and biological properties. The biocompatibility, biodegradability, non-allergy, film-forming capacity and antibacterial activity are the most attractive properties of chitosan. Therefore, chitosan can be used in many fields such as food, cosmetics, water treatment, membranes, environmental protection material development, biomedicine, tissue engineering and packaging [1,4-8]. Nanocomposites have unique properties and wide application potential in various fields. Therefore, there has been a significant increase in the number of academic articles on nanocomposites in recent years [9-12].

In this study, ZnO nanoparticle was synthesized as relevant literature and chitosan is modified with 2-isocyanatoethylmethacrylate. we investigate the antimicrobial activity of the prepared coating.

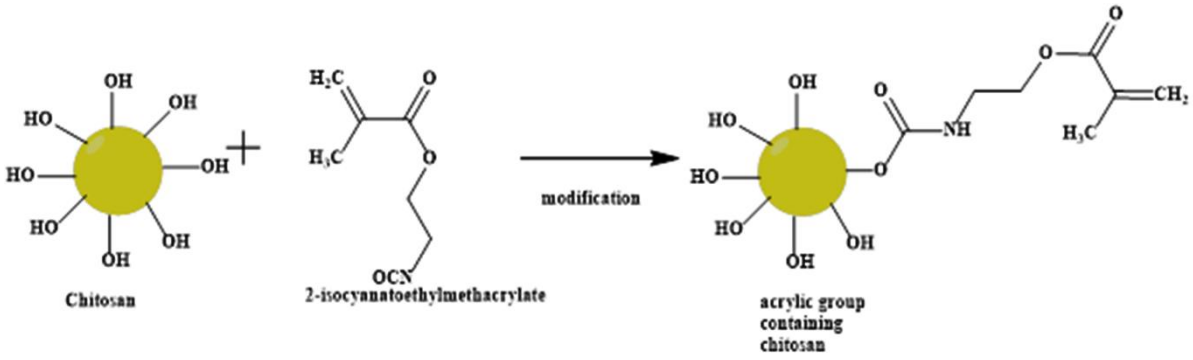
EXPERIMENTAL

2.1. The synthesis of ZnO particles

ZnO nanoparticles was synthesized as indicated in the relevant literature.[13,14] 4.5 g of zinc acetate and 1.5 gram hexamethylenetetramine were dissolved in 100 ml of destilled water and pH of the solution was adjusted. The mixture was stirred for 30 minutes. The mixture at about 100 °C was refluxed for 24 h and then filtered. The precipitate was heated at 450°C. ZnO nanoparticles were solidly obtained.

2.2. The modification of chitosan

1 g chitosan were dissolved in 100 ml destilled water and then added 5 mL 2-isocyanatoethyl methacrylate and refluxed at 100 °C for 12 h. The mixture was recrystallised using sodium hydroxide solution and then washing with distilled water several times. Modification route to chitosan is given in Figure 1.



Modification route to chitosan

2.3. The preparation of the coatings

The formulation table of the prepared coating was given in table 1.

Table 1: Formulation Table

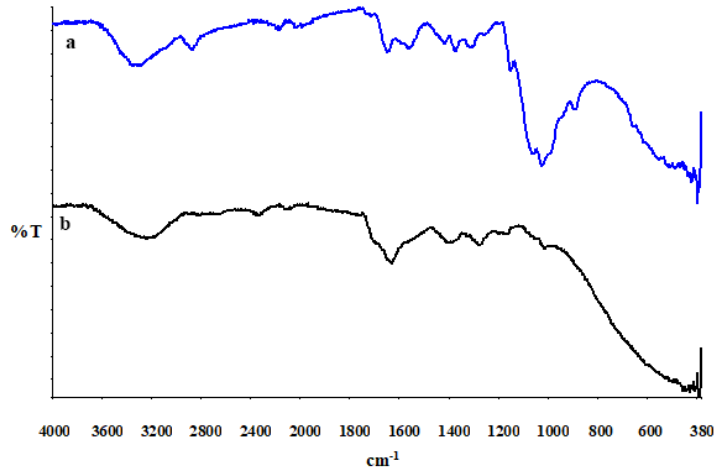
	Modified chitosan (g)	ZnO Nanoparticles (g)
F0	1	-
F1	1	0,03

RESULTS AND DISCUSSION

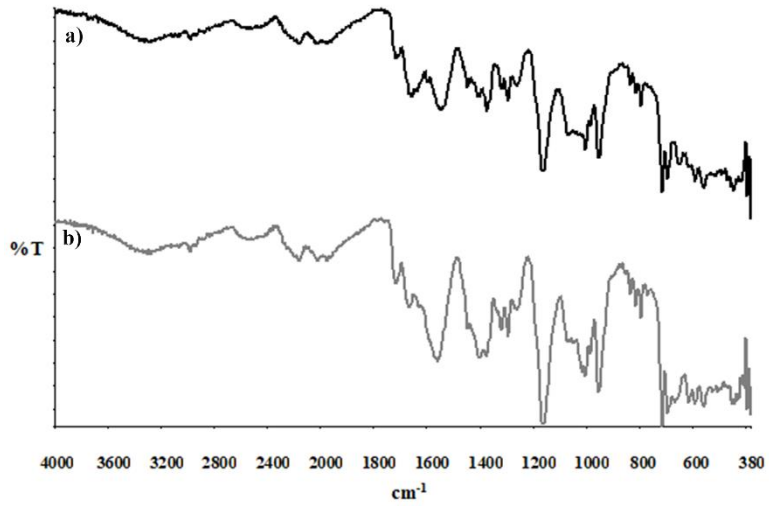
3.1. FTIR analysis

FT-IR spectra of chitosan, modified chitosan and the prepared coatings in the range of 4000-400 cm^{-1} were obtained using Perkin Elmer ATR FT-IR spectrophotometer. FTIR spectra of the prepared coatings, chitosan and modified chitosan are given in Figure 2 and 3. In the FT-IR spectrum of chitosan, a wide band of -OH group is seen at 3353 cm^{-1}. At 1648 cm^{-1} stretching vibration band of amide C=O bond is seen. In addition, -N-H at 1560 cm^{-1} and $–CH_3$ wagging at 1377 cm^{-1} are seen [15]. The FTIR spectra of chitosan and modified chitosan in this study are similar to previous literature [15,16]. FT-IR spectrum of modified chitosan is seen -C==C- band that should be seen at 1630 cm^{-1} so that chitosan with 2-isocyanatoethyl methacrylate is succesfully modified. FTIR spectra of the prepared coating has not observed -C==C- band that should be seen

at 1630 cm^{-1} which is characteristic for acrylates, This result demonstrates that the coatings is successfully prepared.



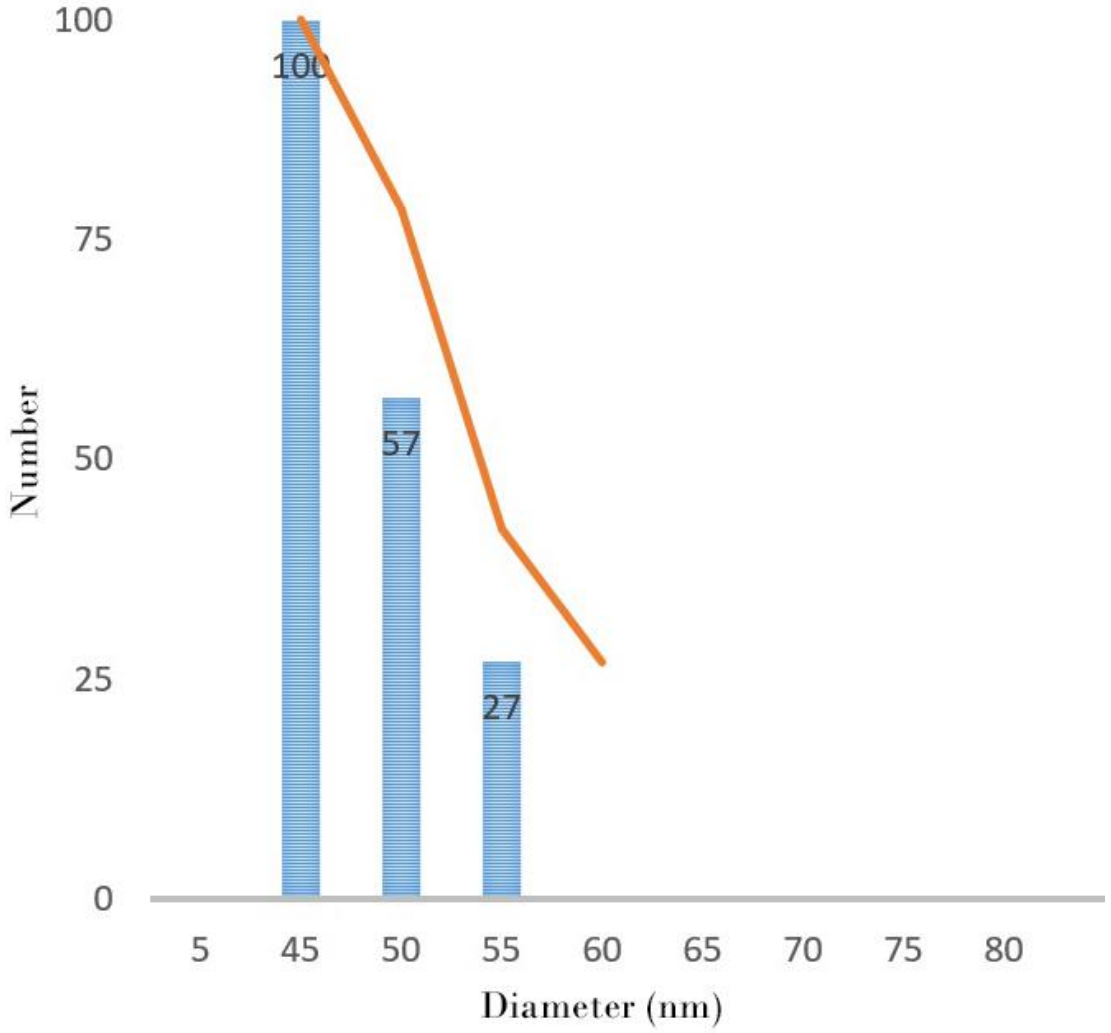
FTIR spectra of a) chitosan and b) modified chitosan



FTIR spectra of a) F0 and b) F1

3.2. Size distribution

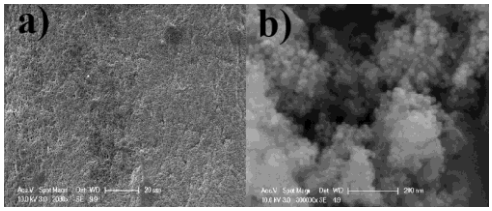
The size distribution of ZnO nanoparticle was in the range of 43.9 and 54.7 nm and the mean diameters measured with the zeta-sizer were 48.4 nm. The results are similar to previous literature [13,14]. Size distribution of the obtained ZnO nanoparticles is given Figure 4.



Size distribution of ZnO nanoparticles

3.3. SEM analysis

SEM images of prepared coatings are given Figure 5. As seen Figure 5, Results are consistent with the literature [17].



SEM images a) F0 coating and b) F1 coating

3.4. Antibacterial activity

Antimicrobial activity of prepared coatings against S. aureus, Gram-positive pathogen bacteria and E. coli, Gram-negative pathogen bacteria is shown in Tables 2 Both F0 sample and F1 sample were observed to have inhibitory effects against E. coli and S. aureus. Because chitosan and ZnO nanoparticles have antimicrobial activities.

Table 2: Antimicrobial activity (inhibition zone diameter in centimeter)

Sample	*E. coli*	*S. aureus*
F0	0.9	0.6
F1	1.1	0.9

CONCLUSIONS

ZnO nanoparticles and acrylic group containing chitosan were successfully synthesized. The synthesized ZnO nanoparticles had an average size of 48.4 nm. The synthesized acrylic group containing chitosan was characterized by FTIR spectroscopy. The prepared coatings show anti-bacterial activity. Therefore it is thought the obtained coatings can use food packaging.

References

Yassue-Cordeiro, P.H.; Severino, P.; Souto, E.B.; Gomes, E.L.; Yoshida, C.M.P.; De Moraes, M.A., Da Silva, C.F.: CHITOSAN-BASED NANOCOMPOSITES FOR DRUG DELIVERY *APPLICATIONS OF NANOCOMPOSITE MATERIALS IN DRUG DELIVERY WOODHEAD PUBLISHING SERIES IN BIOMATERIALS* (2018) 1-26.

Biswas, S.; Ahmed, T.; Islam Md.M.; Islam, Md.M.; Rahman, M.M.: BIOMEDICAL APPLICATIONS CARBOXYMETHYL CHITOSANS, *HANDBOOK OF CHITIN AND CHITOSAN VOLUME 3: CHITIN AND CHITOSAN BASED POLYMER MATERIALS FOR VARIOUS APPLICATIONS,* **3**.(2020), 433-470.

Tian, Y.; Sun, Y.; Wang, X., Kasparis, G., Mao, S.: CHITOSAN AND ITS DERIVATIVES-BASED NANO-FORMULATIONS IN DRUG DELIVERY, *NANOBIOMATERIALS IN DRUG DELIVERY*, **9** (2016), 515-572.

SONG, E.H.; SHANG, J.; RATNER, D.M:. POLYSACCHARIDES, *POLYMER SCIENCE: A COMPREHENSIVE REFERENCE*, **9** (2012), 137-155.

Yoshinori, K.; Hiraku, O.; Yoshiharu, M.: APPLICATION OF CHITIN AND CHITOSAN DERIVATIVES IN THE PHARMACEUTICAL FIELD, *CURRENT PHARMACEUTICAL BIOTECHNOLOGY*, **4** (2003), 303-309.

Zhao, D.; Yu, S.; Sun, B.; Gao, S.; Guo, S.; Zhao, K.: BIOMEDICAL APPLICATIONS OF CHITOSAN AND ITS DERIVATIVE NANOPARTICLES, *POLYMERS (BASEL).* **10** (2018), 462-479.

Aider, M.: CHITOSAN APPLICATION FOR ACTIVE BIO-BASED FILMS PRODUCTION AND POTENTIAL IN THE FOOD INDUSTRY: REVIEW, *LWT - FOOD SCIENCE AND TECHNOLOGY*, **43** (2010), 837-842.

Kas, H.S.: CHITOSAN: PROPERTIES, PREPARATIONS AND APPLICATION TO MICROPARTICULATE SYSTEMS, *JOURNAL OF MICROENCAPSULATION, MICRO AND NANO CARRIERS*, **14** (1997), 689-711.

Bogue, R.: NANOCOMPOSITES: A REVIEW OF TECHNOLOGY AND APPLICATIONS, *ASSEMBLY AUTOMATION*, **31** (2011), 106-112. https://doi.org/10.1108/01445151111117683

Fischer, H: POLYMER NANOCOMPOSITES: FROM FUNDAMENTAL RESEARCH TO SPECIFIC APPLICATIONS, *MATERIALS SCIENCE AND ENGINEERING: C*, **23** (2003), 763-772.

De Azeredo, H.M.C.: NANOCOMPOSITES FOR FOOD PACKAGING APPLICATIONS, *FOOD RESEARCH INTERNATIONAL*, **42** (2009), 1240-1253.

Zou, H.; Wu, S.; Shen J.: POLYMER/SILICA NANOCOMPOSITES: PREPARATION, CHARACTERIZATION, PROPERTIES, AND APPLICATIONS, *ACS CHEMICAL REVIEWS*, **108** (2008), 3893-3957.

Kandirmaz, E.A.: PRINTING OF UV-CURABLE TRANSPARENT CONDUCTIVE POLYMER COMPOSITE, *JOURNAL OF MACROMOLECULAR SCIENCE, PART A PURE AND APPLIED CHEMISTRY*, **57** (2020), 139-144.

La, D.D.; Nguyen-Tri, P.; Le, K.H.; Nguyen, P.T.M.; Nguyen, M.D.; Vo, A.T.K.; Nguyen M.T.H.; Chang, S.W.; Tran, L.D.; Chung, W.J.; Nguyen, D.D: EFFECTS OF ANTIBACTERIAL ZNO NANOPARTICLES ON THE PERFORMANCE OF A CHITOSAN/GUM ARABIC EDIBLE COATING

FOR POST-HARVEST BANANA PRESERVATION, *PROGRESS IN ORGANIC CHEMISTRY* **151** (2021) 106057-106065.

Varma, R.; Vasudevan, S.: EXTRACTION, CHARACTERIZATION AND ANTIMICROBIAL ACTIVITY OF CHITOSAN FROM HORSE MUSSEL MODIOLUS MODIOLUS, *ACS OMEGA*, **5** (2020), 20224-20230.

Esquivel, R.; Juárez, J.; Almada, M., Ibarra, J., Valdez, M.A.: SYNTHESIS AND CHARACTERIZATION OF NEW THIOLATED CHITOSAN NANOPARTICLES OBTAINED BY IONIC GELATION METHOD, *INTERNATIONAL JOURNAL OF POLYMER SCIENCE*, **7** (2015), 1-18.

Dhillon, G.S; Kaur, S.; Brar, S.K.: FACILE FABRICATION AND CHARACTERIZATION OF CHITOSAN-BASED ZINC OXIDE NANOPARTICLES AND EVALUATION OF THEIR ANTIMICROBIAL AND ANTIBIOFILM ACTIVITY, *INT NANO LETTER*, **4** (2014) 107-117.

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PRODUCTION OF ANTIMICROBIAL PAPER WITH NATAMYCIN AND METHYLCELLULOSE AND EVALUATION OF ITS PRINTABILITY

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Abstract:

Food preservation has become one of the important research topics due to developing technology and decreasing resources. One of the methods used to increase the shelf life of food is to make antimicrobial packaging. A package should both promote the product well and protect it. For this reason, the production of printable and antimicrobial packaging paper was investigated within the scope of this study.

In this study, methyl cellulose biopolymer containing natamycin in different amounts (0;2,5;5;7.5;10) to produce antimicrobial paper was successfully coated on office paper in a laboratory paper coating device and its antimicrobial properties were measured by disc diffusion method. The gloss and color values of the obtained papers were determined and offset test prints were made with IGT C1. Color and gloss properties of printed papers were measured. As a result, an effective antimicrobial paper was produced with natamycin. The antimicrobial properties of the produced papers increased due to the increased amount of natamycin. In addition, it has been found that the produced papers are suitable for offset printing.

Keywords: *Natamycin, Biopolymer, Paper coating, Antimicrobial, Printing*

INTRODUCTION

In recent years, we have been encountering more and more researches on increasing food quality and safety of food both in cultivation and during transportation and storage due to reasons such as increasing food need and population, awareness of people. Contaminations that occur after the production of food until it reaches the end consumer and the deterioration of food as a result of the growth of microorganisms lead to serious diseases in humans or economic losses resulting from the disposal of food without consumption [1].

The chemical changes in the structure of the food and the growing microorganisms during the transportation, storage and sale of the food cause the food to deteriorate and reduce the quality [2]. Unsuitable conditions and poor packaging can be counted among the main causes of these deteriorations in the storage and transportation of foods. These food spoilages increase the risk of diseases such as poisoning [3]. Contamination of foods by microorganisms poses great effect on the shelf life and sensory properties of the foods and also causes significant health and economic concerns.

Antimicrobial substances can be applied directly on the food in order to prevent the microorganisms that reproduce in the food under these unsuitable conditions. In these applications, dipping, spreading with spray, coating methods can be used. However, direct application of antimicrobial agents to food may cause some adverse effects in food. While researches for safer food processing continue, it is seen that there are different chemicals in the literature that prevent the growth of microorganisms. Among them, organic acids and their salts, ammonium compounds, amines and sulfites appear [4]. Because of people's health concerns, consumers do not want to use antimicrobial agents in direct contact with food. However, excessive use of antimicrobial

agents causes problems by making microorganisms resistant [5]. Today, due to increasing health concerns, antimicrobial materials produced from natural substances such as milk and plants attract attention. Such materials are of edible origin. The use of naturally sourced antimicrobial packaging materials eliminates many environmental and health concerns [5] [6].

Biopolymers that can be used in smart packaging materials not only act as carriers against the antimicrobial agents used, but also add moisture and oxygen barrier properties to the packaging material [7] [8].

Cellulose is the most abundant biopolymer of natural origin. It is found in almost all plants. It is a polymer formed by the combination of many cellulose units with beta1,4 glycosic bonds. Cellulose in its unprocessed form is insoluble in water due to its polymeric arrangement [9]. However, some derivatives of cellulose become soluble by etherification through the hydroxyl groups on them [10]. Examples of water-soluble cellulose derivatives are methyl cellulose and hydroxypropyl cellulose. Thus, cellulosic films can be formed. These films from cellulose derivatives are generally transparent and have good barrier properties [11].

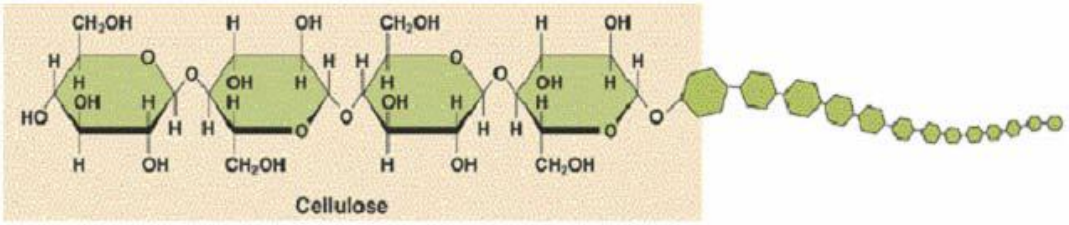

Figure 1: Structural of cellulose

Methyl cellulose is a water-soluble cellulose derivative. The synthesis of methyl cellulose is carried out by combining cellulose with methyl chloride at the appropriate pressure and temperature [10] [12]. The shape of methyl cellulose is given in figure 2. The films and coatings of methyl cellulose are transparent, flexible and have good barrier properties [11] [12].

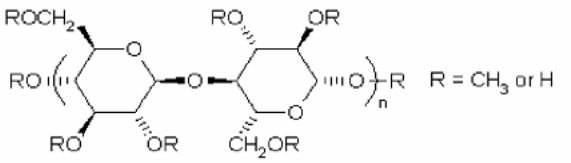

Figure 2: Chemical structure of Methyl Cellulose

The use of coatings formed with edible polymers and naturally sourced antimicrobial materials as active packaging material in the food industry attracts attention in terms of health and sustainability. Examples of naturally derived antimicrobial agents added to edible biopolymer are oils produced from plants (rosemary, mint, lavender), food additives nisin etc and some enzymes can be given [13].

Natamycin is a good antibiotic produced from Streptomyces natalensis and is used as a growth inhibitor in fungi and molds. (Stark 2003). The reason why natamycin is used in the food industry is that it has no negative effects on health and visibly reduces reproduction even in low amounts. Another reason for use is that it does

not cause a change in taste and color in delicatessen products consumed in daily life. The fact that it does not inhibit the growth of good bacteria does not affect the ripening process in processed foods [14].

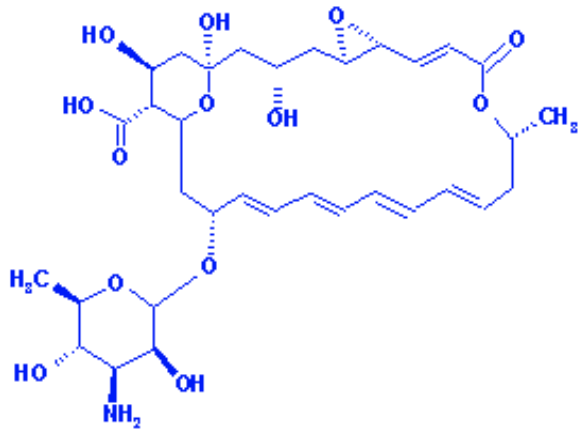

Figure 3: Chemical structure of natamycin

In this study, edible bio based polymer Methyl cellulose and Natamycin antimicrobial additive used to produced for active packaging applications. Natamycin was added to methyl cellulose at different rates as a solid additive and the resulting coated papers were treated with two different bacterial species and two fungi species. In addition, color and gloss of the obtained papers were evaluated. In addition, some printability properties that are absolutely necessary for packaging have been determined.

2. MATERIAL AND METHOD

In the first part of the study, coating formulations with biopolymer methyl cellulose binder and natamycin antimicrobial agent were prepared according to Table 1. The paper sample described as F0 is an untreated 80 g/m2 office paper. It was used as a control group.

Table 1: Paper coating formulations

Formulation Number	Methyl Cellulose (gram)	Water (gram)	Ethanol	Natamycin (gram)
F1	10	45	45	0
F2	10	45	45	2.5
F3	10	45	45	5
F4	10	45	45	7.5

F5	10	45	45	10

Before starting the coating process, the papers to be used were conditioned for 48 hours under laboratory conditions. In the preparation of coating formulations, a 10 % methyl cellulose / distilled water:ethanol mixture was first prepared. And while the mixture was stirred at 750 rpm with a magnetic stirrer, it was heated to 80 degrees Celsius and stirred at this temperature for about 10 minutes. Thus, the biopolymer fibers were separated from each other and F1 was obtained. This mixture was cooled to room temperature and the amount of antibacterial agent in Table 1 was added and mixed at 500 rpm and coating formulations were obtained. All the formulations obtained were coated with a laboratory type K303 model Multi-coater (RK Print Coat Instruments Ltd, United Kingdom) using Mayer Rod 2 at a speed of 2 m/min at a rate of 0.1 g/m^2 on one side of 80 g/m^2 paper at room temperature. The average thickness of the coatings was set at 3 micrometers. The obtained coatings were dried at 25 degrees Celsius for 24 hours at 65% relative humidity. The chemical structure, color, gloss and surface morphology of the obtained coatings were determined by Perkin-Elmer ATR-FTIR, X-Rite eXact spectrophotometer and BYK Gardner glossmeter and Leica optical microscope, respectively.

In the second part of the study; Antibacterial test was performed for untreated paper (F0), surface sized paper (F1), surface coated papers (F2, F3, F4, F5). The antimicrobial activity of the surfaces was determined by the zone of inhibition method (disk diffusion method). Each bacterial culture was activated by inoculation in Tryptic Soy Broth (TSB) for 24 hours at 37 °C. The inoculum (0.1 mL) was spread on the surface of Mueller-Hinton (MH) agar petri dishes using the spread plate technique, then 6 mm diameter films cut from the prepared coated papers were placed on the petri dishes. Petri dishes were incubated at 37 °C for 24 hours. After incubation, petri dishes were checked for bacterial growth, inhibition zones around disc films were evaluated qualitatively and quantitatively. Quantitative evaluation was made according to the preventive zone diameter. The regions around the disc films were evaluated as an indicator of inhibition of bacterial growth. The paper coating, which produces a large zone of inhibition, is thought to exhibit a high antimicrobial activity.

In the third part of the study, background prints were made on uncoated, only surface sized and different coated papers using an equal amount of process magenta ink (DIN ISO 2846-1) with an IGT C1 offset printability test printing machine. The printing parameters were set as 300 N printing pressure, 0.2 m/s printing speed. The ink film thickness of all printed samples was measured as 8 μm. Color measurements of prints made on papers with different coatings were made using the CIE L*a*b* method according to ISO 12647-2:2013 standard using X-Rite eXact spectrophotometer. The measurement conditions of the spectrophotometer were determined with a D50 light source in the 400-700 nm range, with an observer angle of 2° and an open polarization filter in 0°/45° geometry. The difference between the colors of different prints is calculated according to formula 1 according to the CIE ΔE* 1976 ISO 13655 standard.

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

L* black (0) to white (100); a * denotes green (-) to red (+) and b * denotes blue (-) to yellow (+).

The gloss measurements of the coated papers were carried out in accordance with the ISO 8254-1: 2009 standard, with BYK Gardner GmbH micro gloss 75º geometry, and the gloss measurements of the prints were carried out with BYK Gardner GmbH micro Tri-gloss 60º geometry in accordance with the ISO 2813: 2014 standard.

3. RESULTS

Coating formulations were prepared using natamycin and methyl cellulose and coated on the paper surface under laboratory conditions. The chemical structures of the obtained coated papers were elucidated with ATR-FTIR. Figure 4 shows the ATR-FTIR spectra of F1, F2, F3, F4, and F5.

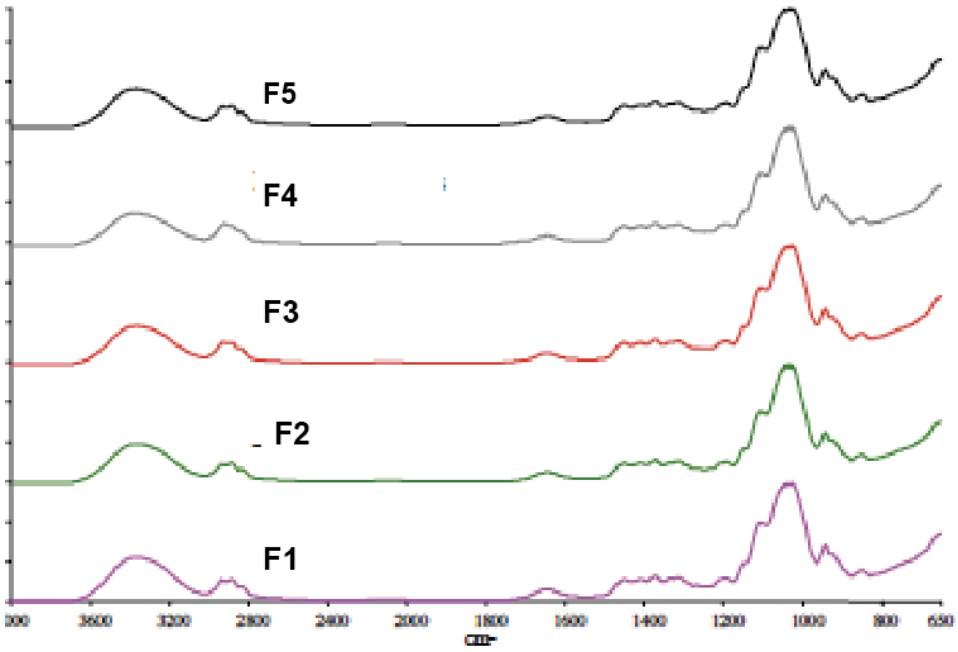

Figure 4: ATR-FTIR spectra of F1, F2, F3, F4, and F5

When the FTIR spectrum of methyl cellulose is examined, the hydroxyl vibration band at 3400 cm^{-1}, the carbon hydrogen vibration band at 2800-2900 cm^{-1}, the stress of carbon oxygen at 1650 cm^{-1} the vibrations of carbon hydrogen around 1450 cm^{-1}, the carbon oxygen carbon vibration at 1050 cm^{-1}clearly reveals. The results are consistent with the literature [15]. FTIR spectra of all natamycin added coatings gave the same result as pure methyl cellulose. This shows that the added natamycin does not react with methyl cellulose [16].

Table 2: Color and gloss values of coatings

Formulation number	L*	a*	b*	ΔE	Gloss
Base paper	95.46	2.91	-10.21	Standart	5.2
F1	91.98	3.6	-11.25	3.7	21.6
F2	91.70	3.7	-10.74	3.89	17.4
F3	90.94	3.6	-10.69	4.6	15.8
F4	90.98	3.7	-10.52	4.5	13.7
F5	90.43	3.5	-10.41	5.1	13.1

CIE L*a*b* color, gloss and color differences of the coatings are given in Table 2. When the colors of the samples are examined, it is seen that the color of the base paper slightly shifted to blue with the addition of surface sizing and natamycin. When the ΔE color differences were compared, it was determined that the surface sized was made compared to the uncoated paper and the coatings with natamycin added were within acceptable limits according to ISO12647-2. In addition, the gloss value of the coatings is given in Table 2. In the surface sizing process applied on the base paper, it was determined that the gloss increased 4 times. The gloss has also increased in natamycin added coatings, but this is less than the residual surface sizing process. Because natamycin did not react with methyl cellulose and created some roughness on the surface, which scattered the light and reduced the brightness a little. In the printing industry, gloss is required for attractiveness. In F1, the paper fibers are filled only with methyl cellulose and the surface is smoothed. Thus, diffuse reflection is reduced and full reflection is approached. This also increased the gloss. With the addition of natamycin to the coating formulation, the gloss decreased at first glance as the roughness would increase [17]. However, this decline has not been so drastic, due to the distinctive brilliance of natamycin.

Table 3: Antibacterial activity of coatings

Formulation number	**Inhibition diameter S. aureus (mm)**	**Inhibition diameter E. coli (mm)**	**Inhibition diameter A. niger (mm)**	**Inhibition diameter P.roquefortii (mm**
F0	0	0	0	0
F1	0	0	5	5
F2	0	0	7.5	18
F3	0	0	18	22
F4	0	0	23	29
F5	0	0	27	34

The antimicrobial activity of the prepared paper coatings was tested against both gram positive (S. aureus) and gram negative (E. coli) bacteria as well as A. niger and P. roguefortii fungi. The diameter of the inhibition

zone of the samples is shown in Table 3. In the control samples, it was observed that all bacteria and fungi grew homogeneously in all parts of the petri dishes. It was determined that both S. aureus and E. coli did not produce any radius of inhibition, that is, natamycin did not have any effect against bacteria. Since there is no antimicrobial agent in F0, any inhibition diameter did not occur as expected. Some antifungal activity was seen in the F1 formulation. This showed that methyl cellulose was slightly inhibitory in fungi. It was found that natamycin had inhibitory effects against A. niger and P. roguefortii in all coatings containing natamycin. However, the best antifungal effect was seen in P.roguefortii. In addition, it was determined that active packaging was more effective against fungi with increasing natamycin amount.

The surface morphology of the coated paper containing the most natamycin belonging to F5 was examined by scanning electron microscopy. Figure 5 shows that the additives in the coatings are homogeneously distributed on the paper surface and the surface is regular and smooth.

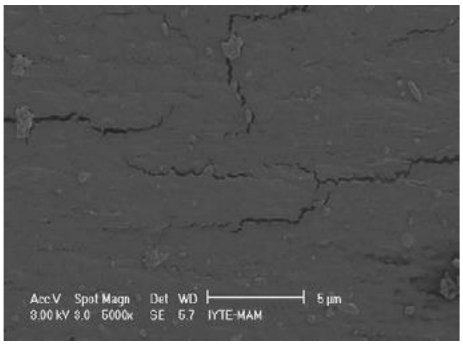

Figure 5: SEM image of F5

Offset test prints were made with IGT C1 on the surface of all coated papers. CIE L*a*b* color, gloss and color differences of the prints obtained are given in Table 4.

Table 4: Color and gloss values of prints

Formulation No	L*	b*	b*	ΔE	Gloss
Base Paper	47.68	74.20	-3.48	Standart	1.6
F1	44.26	74.93	-4.39	3.6	15.7
F2	44.13	74.89	-4.26	3.7	13.2
F3	44.18	74.91	-4.14	3.6	12.6
F4	43.99	74.80	-4.06	3.8	12.2
F5	43.56	74.79	-4.01	4.2	11.7

When Table 4 is examined, it is seen that natamycin tends the color slightly towards blue in printing, as in the colors of the coatings. The ΔE color difference in the coatings has decreased. This shows that the magenta tone of the ink tolerates the color difference. The reason for the decrease in the gloss of all prints is that the pigment

in the ink scatters the light to some extent. Thus, the surface roughness and diffuse reflection increased and the brightness decreased.

4. CONCLUSIONS

In this study, natural antimicrobial agents added methyl cellulose binder paper coatings were produced that would not adversely affect human health even if migrated, and it was aimed to investigate the printability parameters.

Paper coating formulations were prepared using antibacterial agents such as natamycin and successfully coated on the paper surface. The chemical structures of the obtained coated papers were elucidated with ATR-FTIR. When the color values of the coatings were examined, it was concluded that while natamycin did not cause a great change in color, it increased the gloss approximately three times. According to these results, it was found that the natamycin added coating was better than the uncoated papers in terms of printability. When the antimicrobial effect was examined, it was found that natamycin antimicrobial agent did not have any effect on gram positive and gram negative bacteria, but inhibited two different types of fungi and had a protective feature in delicatessen product packages such as cheese and salami.

Offset prints were made on coated papers containing natamycin, and it is determined that natamycin tends the color slightly towards blue in printing, as in the colors of the coatings. The ΔE color difference in the printings has decreased. This shows that the magenta tone of the ink tolerates the color difference. The gloss value of the coated papers in the printed samples was higher than the reference paper. However, it is inferior to unprinted papers. Because the pigments in the ink caused the light to scatter and reduced the gloss.

5. REFERENCES

Eswaranandam, S., Hettıarachchy, N.S., Johnson, M.G.: ANTIMICROBIAL ACTIVITY OF CITRIC, LACTIC, MALIC, OR TARTARIC ACIDS AND NISIN-INCORPORATED SOY PROTEIN FILM AGAINST LISTERIA MONOCYTOGENS, ESCHERICHIA COLI O157:H7, SALMONELLA GAMINARA, *JOURNAL OF FOOD SCIENCE*, 69(3)., 79-84, 2004.

Lee, C.H., An, D.S., Lee, S.C., Park, H.J., Lee, D.S.: A COATING FOR USE AS AN ANTIMICROBIAL AND ANTIOXIDATIVE PACKAGING MATERIAL INCORPORATING NISIN AND A-TOCOPHEROL, *JOURNAL OF FOOD ENGINEERING,* 62(4)., 323-329, 2004.

Kristo, E., Koutsoumanis, K.P., Biliaderis, C.G.: THERMAL, MECHANICAL AND WATER VAPOR BARRIER PROPERTIES OF SODIUM CASEINATE FILMS CONTAINING ANTIMICROBIALS AND THIER INHIBITORY ACTION ON LISTERIA MONOCYTOGENES, *FOOD HYDROCOLLOIDS,* 22(3)., 373-386, (2007)

Appendini, P., Hotchkiss, H. J.: REVIEW OF ANTIMICROBIAL FOOD PACKAGING *INNOVATIVE FOOD SCIENCE & EMERGING TECHNOLOGIES*, 3(2)., 113-126, (2002)

Souza, E., Stamfrod,T., Lima, E., Trajano, V., Filho, J.: ANTIMICROBIAL EFFECTIVENESS OF SPICES: AN APPROACH FOR USE IN FOOD CONSERVATION SYSTEMS, *BRAZILIAN ARCHIVES OF BIOLOGY AND TECHNOLOGY*, 48(4)., 549-558, (2005)

Coma, V., Gros, A.M., Garreau, S., Copinet, A., Salin, F., Deschamps, A.: EDIBLE ANTIMICROBIAL FILMS BASED ON CHITOSAN MATRIX, *JOURNAL OF FOOD SCIENCE*, 67(3)., 1162-1169, (2002)

Ustunol, Z., Mert , B.: WATER SOLUBILITY, MECHANICAL, BARRIER AND THERMAL PROPERTIES OF CROSS-LINKED WHEY PROTEIN ISOLATE –BASED FILMS, *JOURNAL OF FOOD SCIENCE*, 69(3)., 129-133. (2004)

Sebti, I., Martial –Gros, A., Carnet –Pantiez, A., Grelier, S., Coma, V. CHITOSAN POLYMER AS BIOACTIVE COATING AND FILM AGAINST ASPERGILLUS NIGER CONTAMINATION, *JOURNAL OF FOOD SCIENCE*, 70(2)., 100-104, (2005)

Ruckenstein, E., Park, J.S.: VISCOELASTIC PROPERTIES OF PLASTICIZED METHYLCELLULOSE AND CHEMICALLY CROSSLINKED METHYLCELLULOSE, *CARBOHYDRATE POLYMERS*, 46(4)., 373-381. (2001)

Gennadios, A., Hanna, M.A., Kurth, L.B.: APPLICATION OF EDIBLE COATINGS ON MEATS, POULTRY AND SEAFOODS: A REVIEW, *LEBENSM.-WISS.U.-TECHNOL*, 30(4)., 337- 350, (1997)

Erdohan, Z.Ö., Turhan, K.N.: BARRIER AND MECHANICAL PROPERTIES OF METHYLCELLULOSE–WHEY PROTEIN FILMS, *PACKAGING TECHNOLOGY AND SCIENCE: AN INTERNATIONAL JOURNAL*, *18*(6),. 295-302. (2005)

Krochta, J.M., Baldwin, E.A., Nisperos-Carriedo, M. *EDIBLE COATING AND FILMS TO IMPROVE FOOD QUALITY, ISBN* 9781420059663, CRC PRESS, USA, (1994)

Arman, E. K.: NİSİN VE SODYUM ALJİNAT İÇEREN KAĞIT KAPLAMALARININ HAZIRLANMASI VE ANTİMİKROBİYAL ÖZELLİKLERİNİN İNCELENMESİ, *BARTIN ORMAN FAKÜLTESİ DERGİSİ*, 22(1), 114-122, (2020)

Stark, J.: NATAMYCIN: AN EFFECTIVE FUNGICIDE FOR FOOD AND BEVERAGES. IN S. ROLLER, *NATURAL ANTIMICROBIALS FOR THE MINIMAL PROCESSING OF FOODS*, WOODHEAD PUBLISHING, ISBN 1855736691, CAMBRIDGE, GBR, (2003) 82-97

Zaccaron, C., Oliveira, R., Guiotoku, M., Pires, A., & Soldi, V. (2005). BLENDS OF HYDROXYPROPYL METHYLCELLULOSE AND POLY (1-VINYLPYRROLIDONECO-VINYL ACETATE): MISCIBILITY AND THERMAL STABILITY, *POLYMER DEGRADATION AND STABILITY,* 90 (1), 21-27, (2005)

Pranoto, Y., Rakshit, S. K., Salokhe, V. M.: ENHANCING ANTIMICROBIAL ACTIVITY OF CHITOSAN FILMS BY INCORPORATING GARLIC OIL, POTASSIUM SORBATE AND NISIN, *LWT-FOOD SCIENCE AND TECHNOLOGY*, 38(8), 859-865, (2005)

Ural, E.; Kandirmaz, E. A.: POTENTIAL OF FISH SCALES AS A FILLING MATERIAL IN SURFACE COATING OF CELLULOSIC PAPER, *JOURNAL OF APPLIED BIOMATERIALS & FUNCTIONAL MATERIALS*, 16(1), 23-27, (2018)

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THE INVESTIGATION OF EFFECT OF PIGMENT RATIO IN INK ON COLOR GAMUT

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Abstract:

*Color printing is important for every printing method in the Printing Industry. When it comes to obtaining the right colors, visual beauty and cost factors comes into prominence. In order to reduce the printing cost, it is necessary to obtain the maximum possible number of colors from the mixture of these colors by using less colors and plates. For this purpose, it is tried to reach the widest color gamut that can be reached in printing by interfering with the L*a*b* values of standard CMYK colors or by using additional colors. In the study, offset printing CMYK inks were prepared using mono pigments. Then, the ink pigment ratios were increased by 25% and the obtained inks were printed on 135 g/m^2 glossy coated paper. The density values, L*a*b* values of the prints were measured and the ΔE_{00} differences were calculated. By measuring the color values of the prints, the effect of the inks on the color universe was examined. It has been determined that increasing the pigment ratio has a positive effect on the color gamut.*

Keywords: *Offset printing, ink, pigment, color gamut*

INTRODUCTION

Print media is still a part of everyone's daily life and remains very important for everyone. Offset printing system is one of the most used printing techniques. Offset printing system is a preferred printing system in terms of keeping up with the developing technology and printing quality. [1-2] The development of printing materials manufacturers and the great developments in ink and paper production have increased the print quality day by day. [3-4]

One of the most important reasons for the increase in print quality today is the use of inks with high dyeing properties. [5] The layer thickness of these inks used during printing should be 2 μm or less. The critical point is that the thickness of the ink directly affects the print quality and color space. Absorption of ink by the paper and drying are other factors [6]. In every printing process, the interaction between the paper surface and the colorant or pigment is an important factor in determining print quality. [7]

Ink-paper interactions, including ink transfer, setting and drying processes, play an important role in print production as they affect both print quality and runnability. Sheet-fed offset ink is made of three main ingredients: Pigment, Vehicle and Modifiers, it also contains catalytic desiccants, antioxidants, wax particles and other additives [8].

If we want to improve the print quality, one of the main ways is to develop new highly pigmented inks that have a better ability to coating the substrate, unlike the inks used so far.[6]

When using a standard ink, it may be necessary to create a higher ink thickness to cover the paper surface. This can be over 2 microns, which is the standard printing thickness of the ink. However, when using highly pigmented inks, a better dyeing can be achieved with the thickness of the standard ink layer. For this reason, in this study, the effect on printing parameters was investigated by creating inks with high pigment content.

EXPERIMENTAL PART

Materials and Methods

In the study; Oil-based offset printing inks are used. Inks; It was prepared by using mono pigments by increasing the standard pigment ratio and 25% pigment ratio. (The reason for using a precise ratio of 25% in pigmentation is planned to have a direct effect on the test result) Test prints were made on 135 g/m^2 coated glossy paper. Test prints were made in accordance with the ISO 12647-2 standard. X-Rite manufacturing standards are used for all spectrophotometric and densitometric measurements (according to 0/45º geometry with 2º observer angle with D50 light source in the range of 400-700 nm and 23°C +/- 1°C temperature, 40-60% RH). The difference between the colors of the prints is calculated according to the formula (1) (according to the CIEDE 2000 standard, ISO 13655). Chromix ColorThink Pro 3.0 Color Gamut Volume Measurement Software was used to calculate color gamut volumes.

$$\Delta E^* = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}} \qquad (1)$$

RESULTS AND DISCUSSION

As a result of the studies, all printing parameters were examined. The density values and CIE L a*b* values of the prints made with Standard Pigment Ratio ink, Pigment Ratio +25% ink and ISO 12647-2 Standard were measured and compared with each other. Delta-E values were calculated according to the CIE L a*b* values. The dot gain values were compared for each color separately. The results of color gamut and color gamut volumes were calculated. All results are shown below in tables and graphics.

Solid Density Values

	ISO 12647-2 Standard	Standard Pigment Ratio ink	Pigment Ratio +%25 ink
Cyan	1,55	1,48	1,58
Magenta	1,5	1,42	1,46
Yellow	1,45	1,43	1,42
Black	1,8	1,81	1,8

When Table 1. is examined, it is seen that the solid density values of the prints are within the standard values.

*Table 2: CIE L a*b* values for ISO 12647-2 Standard and all printed papers*

ISO 12647-2 Standard	L	a*	b*	Standard Pigment Ratio ink	L	a*	b*	Pigment Ratio +%25 ink	L*	a*	b*
Cyan	55	-37	-50	**Cyan**	58.4	-35.31	-50.12	**Cyan**	55.87	-34.73	-51.28

Magenta	48	74	-3	**Magenta**	51.08	73.02	-5.41	**Magenta**	46.91	73.68	0.05
Yellow	89	-5	93	**Yellow**	89.94	-4.89	93.41	**Yellow**	89.05	-4.41	95.92
Black	16	0	0	**Black**	16.48	1.Feb	0.52	**Black**	18.03	-1.02	0.9
Red	47	68	48	**Red**	49.32	65.29	48.13	**Red**	46.34	68.2	47.05
Green	50	-68	25	**Green**	50.19	-64.34	29.45	**Green**	49.11	-63.69	30.63
Blue	24	17	-46	**Blue**	25.43	19.39	-44.19	**Blue**	22.73	23.58	-40.59
White Paper	95	0	-2	**White Paper**	94.66	0.73	-4.75	**White Paper**	94.97	0.72	-5

Table 3: Density and ΔE values

	Cyan	Magenta	Yellow	Black
Standart Pigment Ratio ink	3,2	4,8	0,9	1,2
Pigment Ratio +%25 ink	2,7	3,3	3	2,7

When the Delta-E values of all printed papers are examined, it has been determined that the ink values with both pigment ratios are in the acceptable range, that is, below 5.

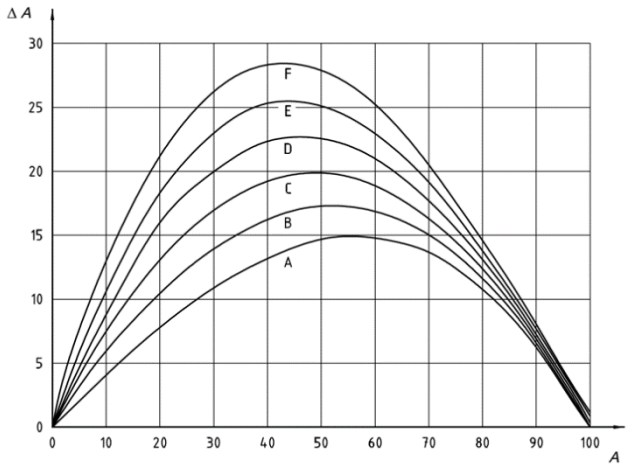

Figure 1: Tone value increase according to Process Standard Offset-ISO 12647-2 [9]

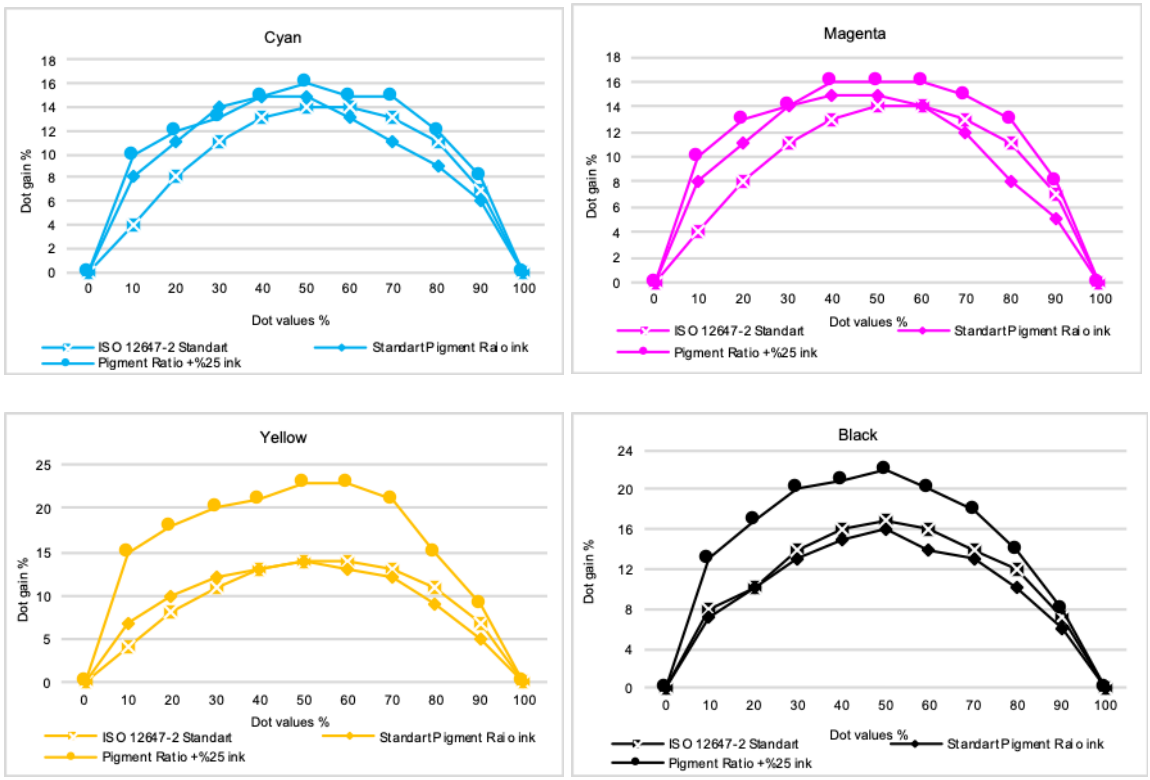

Figure 2: Tone value increase for all printed papers

When the dot gain values are compared, it is seen that the dot gain values in Cyan and Magenta colors are within the standard values. It was determined that the Pigment Ratio +25% values in black and yellow colors were higher than the standard values.

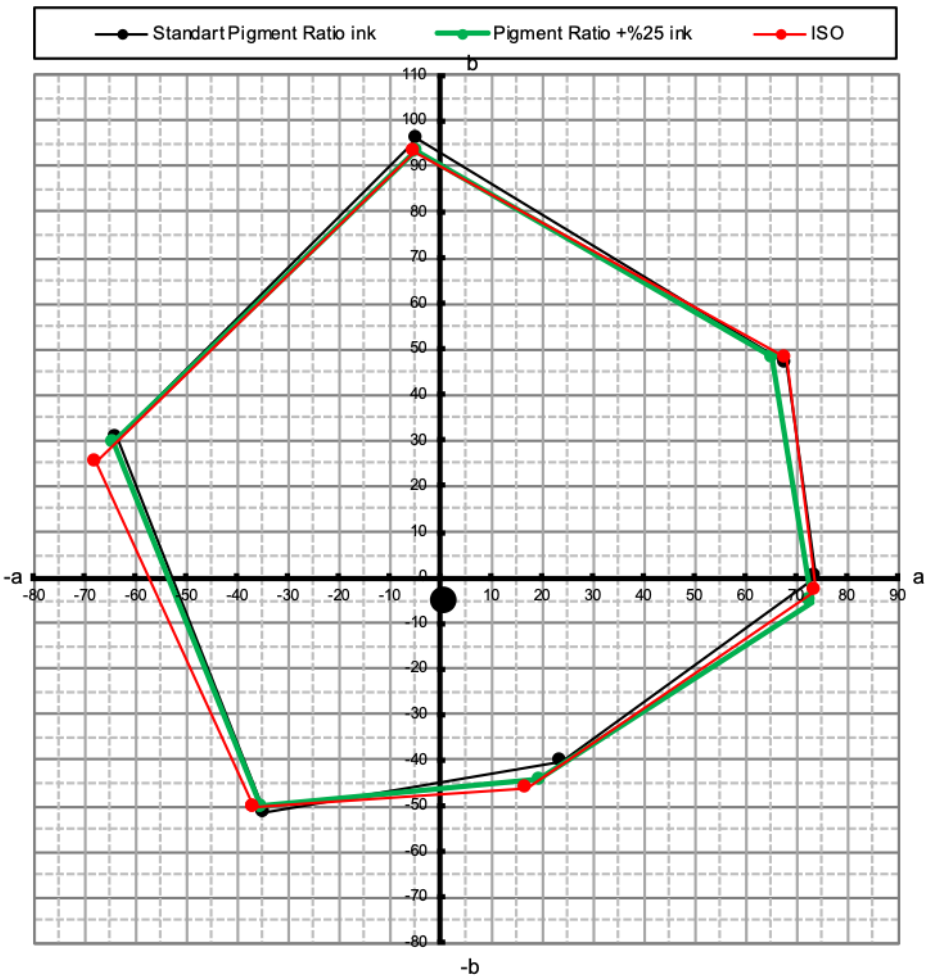

Figure 3: Color gamut diagram for all printed papers

When we look at the color gamut diagram, it is seen that the color gamut obtained with both Standard Pigment Raio ink and Pigment Ratio +25% ink values is narrower in the light blue-light green regions and red regions compared to the ISO 12647-2 Standard value color gamut.

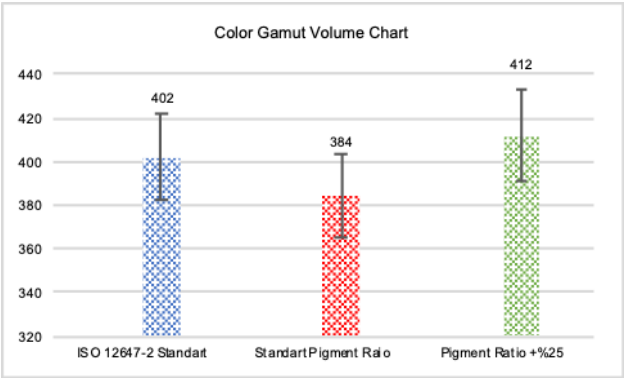

Figure 2: Color gamut volues for all printed papers

Color gamut volume values show that Pigment Ratio +%25 ink values have the highest values among all values. Although the Pigment Ratio +25% ink color gamut diagram appears narrower in the color universe

diagram, the Color gamut volume value was found to be 7.29% higher compared to the Standard Pigment Raio ink, and 2.48% higher when compared to the ISO 12647-2 Standard value.

CONCLUSIONS

In order to obtain print quality and a wider color gamut, offset printing ink with increased pigment ratio has been prepared. Prepared inks are printed on glossy coated paper. The printing parameters of all printed inks were examined. No expansion has been achieved in the two-dimensional color universe diagram.

However, when the color gamut volumes are compared, it has been determined that Pigment Ratio +25% ink has a volume of 7.29% more than the Standard Pigment Ratio ink value. When compared to the ISO 12647-2 Standard color gamut volume, it has been found to have a 2.48% wider color gamut. This has led to the conclusion that the Pigment Ratio +25% ink is more successful in half tone values than the others.

REFERENCES

Joost, R.; & Salomon, R.: HIGH QUALITY OFFSET PRINTING: AN EVOLUTIONARY APPROACH. *IN PROCEEDINGS OF THE 9TH ANNUAL CONFERENCE ON GENETIC AND EVOLUTIONARY COMPUTATION* (2007) PP. 2053-2058

Tutak, D.: COMPARING THE COLOR GAMUTS OF DIFFERENT PAPERBOARD SURFACES USED IN PACKAGE PRINTING. *AJIT-E*, 5(17), (2014) 57-66 E-ISSN: 1309-1581

Kipphan, H.: *"HANDBOOK OF PRINT MEDIA",* SPRINGER, ISBN 3-540-67326-1, BERLIN, (2001)

Shankar, N. G.; et al.: A REAL-TIME PRINT-DEFECT DETECTION SYSTEM FOR WEB OFFSET PRINTING, *MEASURMENT*, 42, (2009), PP. 645-652, ISSN 0263-2241

Leach, R. H.; Pierce, R. J.: THE PRINTING INK MANUAL", 5TH ED. SOCIETY OF BRITISH PRINTING INK, ISBN-13:978-94-011-7099-4, LONDON, (1993),

Zjakić, I.; et al.: A STUDY OF DOT GAIN AND GAMUT FOR PRINTS MADE WITH HIGHLY PIGMENTED INKS. *TECHNICAL GAZETTE*, *18*(2), (2011), PP. 227-235, ISSN 1330-3651

Karademir, A.; et al.: PRINTABILITY OF PAPERS RECYCLED FROM TONER AND INKJET-PRINTED PAPERS AFTER DEINKING AND RECYCLING PROCESSES. *JOURNAL OF APPLIED BIOMATERIALS & FUNCTIONAL MATERIALS*, *16*(2), (2018), PP. 76-82, ISSN: 2280-8000

Pykönen, M.; et al.: INFLUENCE OF PLASMA ACTİVATION ON ABSORPTION OF OFFSET INK COMPONENTS INTO PIGMENT-COATED PAPER. *NORDIC PULP & PAPER RESEARCH JOURNAL*, *25*(1), (2010), PP. 93-99, ISSN: 0283-2631

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ISDIT SESSION

THE DEGRADATION EVIDENCE OF NATURAL AND SYNTHETIC FIBERS

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Abstract:

Based on their chemical composition, fibres belong to two main groups: the natural cellulose-, and protein-based materials; and the natural-based and synthetic-based artificial textile materials. The physical and chemical properties of the fibres determine their future behaviour in a different environment. Their damage results from the physical, chemical, and biological interactions between the fabric and its surroundings. There is clear evidence of the degradation of the several hundred years old natural fibres. Still, at the same time, the twentieth-century objects are often said to be "time bombs" waiting to explore in museum collections. It is becoming evident that these modern materials show signs of breakdown, sometimes dramatically and rapidly. Since they are only barely a hundred years old, there is not enough data concerning their long-term future behaviour. However, there is a burning need in conservation to examine the deterioration factors of the different artificial threads to preserve them as much as possible for posterity.

Future work will be based on the aging tests of artificial textiles to predict their future behaviour and determine their optimal environmental limits for preventive conservation. In this paper, we will try to give a short overview of the most important damage factors and their effects on textiles that should be considered during storage and exhibition.

Keywords:

natural fibres, synthetic fibres, degradation, artificial aging tests

1. INTRODUCTION

All organic objects, but especially objects made of textile, are very sensitive to their environment. They can be damaged easily, and therefore special care has to be provided for their preservation. Textile objects stored in museum collections need more protection since these objects, in most cases, have already suffered light degradation or other types of damage before being acquired by the museum and therefore more sensitive to environmental effects. Maintaining proper and stable relative humidity, temperature, and illumination; providing air filtration; dust, vibration and shock protection; establishing handling protocols and integrated pest management are crucial for the long-term preservation of these objects. Different factors have to be taken into account during storage, transport and exhibition. The various sources of damage intensify each other, and the effects are multiplied. Still, deterioration can be significantly reduced or minimalized by applying the proper environmental conditions, proper materials, techniques and equipment. In this paper, we will try to give a short overview of the most important damage factors and their effects on textiles that should be considered during storage and exhibition.

2. DAMAGE FACTORS OF DEGRADATION

The word "environment" refers to a series of conditions surrounding an object, the sum of "forces" created by nature and humans that can slow or accelerate the physical and chemical changes of the material. These changes are reflected both in the mechanical or chemical properties of the material and in the aesthetic appearance of the artefact. The destruction of textile fibers is caused by many damage factors that interact closely, in parallel and in competition with each other. They are divided into three major groups according to their appearance (not origin): biological, physical (mechanical) and chemical factors. Let me present these harmful factors from the visible to the microscopic size in order.

2.1. Biological factors

A major issue in collection management is establishing effective defense against insects and fungi, the two main types of pests. Since textiles are themselves organic materials and are also often combined with other organic materials like leather, paper, organic paints, animal glue, starch, different kinds of adhesives, etc., they are all exposed to almost all types of pests. It is impossible to list all of them, but textiles are most susceptible to moth- and mould infections (Figure 1).

There are approximately 160,000 species of moths, but only two species consider the textiles as a source of food: the case-making clothes moth (Tinea pellionella) and the webbing clothes moth (Tineola bisselliella). Both are about only 1 cm long and yellow or greyish. What causes specific damage is that they eat the object itself from mm to mm. All obvious signs of the infestation should be brushed or vacuumed away as soon as possible. Fumigation should be employed multiple times as fumes can only kill a live grub or a developed insect (the eggs are immune).

Figure 1: Moth infection on a textile upholstered armchair

Live mould can be recognised by the musty smell and the three-dimensional nature of the surface growth. Many types of mould can cause staining, weakening, or complete destruction of fibres. Moulds feed by digesting the substrate on which they grow. Cellulosic fibres such as cotton, linen, and rayon are particularly vulnerable, but proteins such as wool and silk can also be affected. Mould will even grow on synthetic fibres such as nylon and polyester if they are soiled or have finishes that provide food for the organism [1]. Spores of fungi can hide in the material for a very long time, even years, as long as the ambient humidity is not adequate for the spores to regenerate. Most fungi need at least 70% relative humidity to exert their vital activity. The optimum temperature for fungi is between 20 and 30 °C, but species developing at lower temperatures can also occur (Figure 2).

Nevertheless, mould is very harmful to humans as well: it can be allergens (substances that can cause an allergic reaction), irritants and, sometimes, toxic substances. Inhaling or touching mould spores may cause an allergic reaction, such as sneezing, a runny nose, red eyes and skin rash. Moulds can also cause asthma attacks. There are stringent protocols on how to disinfect and treat a mouldy object [2].

Figure 2: Mould infection on metal-thread decoration

To avoid these dangerous biological factors, the combination of the following main steps of pest management is carried out in museums:

(1) maintaining low temperature and heat treatment,
(2) carrying out pesticide treatment every year,
(3) adjusting insect and small animal (rodent) traps
(4) adhering the isolation protocol
(5) applying carbon dioxide, nitrogen treatment and gas fumigation (e.g. ethylene oxide) in case of need.

2.2. Physical factors

No matter how surprising, most injuries to textile objects (be they costumes or flat textiles) occur due to mishandling. The source of damage can be ourselves by accidental physical impacts or by vibrations caused by the rolling mechanism of a mobile shelving system, for example. Vibration is a common phenomenon in an urban environment. The sources can be diverse like traffic, subway or a construction site near the storage building or the museum.

The improper moving of the object or sometimes even a little moving causes mechanical stress. This tension in polymers creates so-called "activated bonds" in the artefact that can be broken even by low kinetic energy (e.g., light punch). "Activated bonds" require less photo or thermal energy to participate in various chemical degradation processes than non-activated ones. The radicals formed by the bond break immediately and undergo spontaneous chemical reactions that can cause their degradation [3]. This explains, for example, why previously patched fabric breaks down sooner than unsawn ones. It means in real life that the threads become extremely fragile, and the textile seems to be worn-out, shabby, threadbare, dingy, aged. In conservation, these physical lesions are detected thoroughly: condition assessment drawings are made of each part of the object on which the locations and the nature of the injuries are precisely marked. Figure 3 - the condition assessment of a right sleeve of a tailcoat from the end of the 18th century - clearly shows how fragile an artefact can be even if it is stored under proper conditions. Another striking aging - caused by mechanical stresses - can be observed on painted canvas, where the different layers (stretched canvas, primer, painted layer, lacquer layer,

etc.) all behave differently due to changes in temperature and relative humidity. This results in splitting, warping of the layers, or scaling of the painted layers (Figure 4.)

Figure 3: The condition assessment of a right sleeve of a tailcoat from the end of the 18th century

The restoration of an artefact is intended to reinforce its structure and to maintain its condition. Nevertheless, it is crucial to physically protect an object even after conservation and not only ensure the optimal climate control. Foams, cloths, padding materials without harmful off-gassing can be used for effective protection. Objects are stored on open shelves but need to be covered or wrapped into VOC-free (Volatile Organic Compound) materials, like unbleached and undyed cotton or polyethylene film, bags, boxes. Tyvek (non-woven, soft, polyethylene-based material with antistatic coating), Hollytex (non-woven, acid-free wrapping material made of 100% polyester) or acid-free, unbuffered tissue paper are also good choices.

Figure 4: The bad condition of a painted canvas

2.3. Chemical factors

Whether from natural or synthetic sources, all fibres and dyes are organic, which in chemical terms means that the chemistry of carbon compounds is the branch of sciences with which the conservator is most concerned. The speed with which a compound breaks down depends on many factors, particularly stability in the presence of light, humidity, other gases in the atmosphere, heat, acids and alkalis. These factors exert an influence not only individually but also through complicated interactions [4].

The appropriate environmental conditions for the safe, long-term preservation of an artefact may differ from object to object depending on the environmental circumstances under which the object came from. The general guidelines for storage in Western collections are the following:

- Relative humidity: 45-55 %
- Temperature: 18-22 ^{0}C
- Light: 0 Lux in storage, max. 50 Lux in exhibition
- UV: 0 µW/lumen

2.3.1. Humidity

According to experts, the most versatile cause of the decomposition of organic materials is the relative humidity. The relative humidity (RH) is used to express the accurate humidity of the environment in relation to the saturation value achievable at the given temperature. The RH-induced changes in organic structures are classified into three major groups: 1) shape and size change, 2) chemical reaction occurrence and 3) biodegradation. In organic polymers, water acts as a “plasticizer”, thereby providing flexibility and elasticity to the material. If the RH is low, the textiles that have lost structural water will be stiff and brittle (Figure 5), while if the RH is too high, the fibres will swell, and harmful deformation may occur, e.g. dyed textiles will separate and crack. Furthermore, swollen materials are more permeable to degrading chemical reagents because vapor is good for atmospheric impurities. The growth of fungi and bacteria is favoured by humidity above 65%, while organic materials dry out below 40% RH.

Figure 5. The very brittle state of a damask fabric as a consequence of low humidity

What is most damaging for textiles is the fluctuation of RH. This alternation causes the material to swell and shrink constantly. The associated "stress" causes tension and deformation. At the same time, the sensitivity of the substance to chemical degradation also increases. It can therefore be concluded that the relative humidity of 45-55% is generally suitable for the conservation of organic materials, including a stable climate as sudden changes in humidity pose a greater risk than a relative humidity within a given but constant range even if it is not the optimum [3].

Providing the proper and stable humidity for textile objects is crucial for their long-term preservation. There are several ways for the maintenance of optimal RH levels. HVAC (Heating, ventilation and air conditioning) systems are used to provide an airflow that prevents indoor air stagnation, completed with air filtration, humidity and temperature control, using fresh air from outdoors. Using local sensors, the humidity can be controlled appropriately with this central system. Portable humidifiers can maintain a stable level of humidity in buildings without central humidity control. Built-in dehumidifiers can effectively reduce the moisture content of the air. Reduction of relative humidity is indispensable in humid storage buildings where the risk of mould formation is high.

2.3.2. Temperature

Thermodynamically, heat is defined as the energy that migrates from one place to another due to a temperature difference. Heat transfer can take place by heat flow, heat conduction or heat radiation. As an energy source, heat occurring in museum conditions can only cause the decomposition of very low energy bonds in organic compounds. However, it can trigger the disruption of activated bonds (activated bonds only need very little energy to break their bond). Heat also causes the movement of molecules in materials. The higher the temperature, the faster the molecule movement is. The rate of chemical reactions usually doubles with each temperature rise of 10°C. Many organic materials expand and soften at higher temperatures, thereby increasing their ability to absorb or bind chemical degradants. The solubility or dissociation of the substances involved in the reaction increases, facilitating the initiation and accelerating the course of chemical reactions.

As with relative humidity, temperature fluctuations are most dangerous. In general, the materials expand on heating and contract on cooling. Significant temperature fluctuations can cause stress in organic compounds and usually force them to rearrange physically. Ambient temperature determines the uptake and release of humidity of the organic compounds. An increase in temperature favours water uptake for some time, but the amount of moisture absorbed from the air generally decreases at high temperatures [3].

Overall, it can be stated that higher temperature accelerates degradation processes in the artefact and can cause alteration of original and restoration materials in the long run.

The HVAC system mentioned above and/or central heating system is used for regulating temperature in museum buildings in general. The location of the shelving system has to be carefully selected in storage because serious damage like shrinkage, cracking, flaking, or discoloration can occur if the objects are placed close to a heating unit. Portable air conditioners can help reduce the temperature in overheated areas, which is extremely important, especially in the summer season. The location of the devices has to be planned carefully because the cool airflow must not hit the objects directly.

2.3.3. Light

All forms of light are damaging to textiles. Photochemical reactions initiated by light energy can lead to the deterioration of the principally organic textile components. The damage to fabric by visible and invisible radiation is cumulative and irreversible. Although the wavelengths of the solar radiation start well below 200 nm, due to the presence of oxygen, nitrogen-dioxide, water vapor, and ozone occurring in the higher air layers, most rays below 286 nm do not penetrate the air. Although UV radiation between 286 nm and 400 nm, which reaches the surface, is in fact only 5% of the total radiation emitted by the sun, it is abundant enough to break down chemical bonds in organic materials [5]. Therefore, UV has to be eliminated. The shorter the wavelength, the more significant the damage. Photo-degradation of organic objects accelerates under wavelength 400 nm.

The UV and visible range of electromagnetic radiation can cause photolysis of organic materials (breaking of chemical bonds) and photochemical breakdown (chemical reactions using the energy of the radiation absorbed by the material). One of the most harmful degradation processes is photo-oxidation which results in the yellowing of the textile, changes of colours (Figure 6.) and the decrease in mechanical strength. These do not always appear on the fabric immediately because the process is an autocatalytic radical chain reaction that continues in the material even if the irradiation is stopped. Often, damage to organic material due to UV radiation or light only appears at the end of the exhibition or a few months afterward [3]. In addition, infrared radiation, which represents thermal energy, can cause thermal decomposition of the material and thermochemical reactions.

Figure 6: Discoloration of cotton fabric due to photo-oxidation

Light is the most harmful degradation factor for textiles because it can permanently degrade textile fibres. Therefore, light exposure should be kept to a minimum in storage areas. During work, handling, packing, general lighting shouldn't be more than 150 Lux. More intensive light sources are used for examination and research purposes but have to be restricted to a limited timeframe. Objects should be covered, kept in drawers or mobile shelving systems for protection against light.

2.3.4. Air pollutants

In addition to temperature, humidity and light, the concentration of air pollutants is another essential consideration. There are various sources of pollutants, namely:

(1) Ambient air pollutants from traffic and combustion, fine dust, human emissions (NO_X, SO_2, hydrocarbons, ozone, soot, dust and other aerosols);
(2) Emissions of surrounding exhibition installations and storage materials (furniture, shelves, flooring, packaging materials);
(3) Emissions of the objects themselves (volatile organic compounds (VOCs), in particular, acetic and formic acids, hydrogen sulfide, etc.).

All the contaminants mentioned above accelerate degradation significantly.

In particular contemporary objects made of synthetic fabric are very sensitive to air pollutants, as the surfaces of these objects are often electrostatically attracting dust and dirt. The attracted dust particles and the leaked and sticky plasticizers together form a layer of dirt that is very difficult to remove. Due to this type of pollution, many objects lose their aesthetic appearance and significance.

The most common VOCs are NOx, Ozone, PM (particulate matter), SO_2, H_2S, Carbon compounds, Chlorides, Ammonia. These pollutants are always present in lower or higher concentrations in an urban environment, but special weather conditions can cause their accumulation. Dust is also a kind of air pollutant concentration in the urban environment and can cause several indirect damages to objects. It is a fine, dry, airborne particle with a large specific surface, capable of adsorbing gases, solid or liquid particles or biological substances. Therefore, it can initialize damages, providing surface contact for these harmful materials.

As mentioned above, storage construction materials can also have harmful VOC off-gassing. Therefore we have to avoid using them in storage areas if possible. Chipboard, particleboard, MDF (medium-density fibreboard), plywood is often used for making cupboards, drawers or stands. They contain different synthetic glues like carbamide-formaldehyde, phenol-formaldehyde, melamine-formaldehyde resins. Natural woods like oak, beech, pine are off-gassing different acids, like acetic acid, formic acid, propionic and butyric acid. Safe shelving systems should be made of powder-coated steel or anodized aluminium.

The VOCs mentioned above have a wide range of direct and indirect harmful effects, which we have to eliminate from the environment of the objects. Air filtration can be effective by installing filter modules in HVAC systems, but mobile air purification units can complete the function of central systems or provide clean air in specific spaces. The damage caused by VOCs can be avoided by applying VCIs (Volatile Corrosion Inhibitor). The technology is based on materials that can vaporize or sublimate. The molecules condense on the object's surface, creating a barrier film that protects from acidic components, reactive corrosive gases, etc.

3. A CLOSE LOOK OF DEGRADED FIBERS

To demonstrate the combined effect of all the degradation factors mentioned above, a closer look at deteriorated silk threads could be a good example as silk is the most sensitive natural fibre to environmental effects. The thousand-times magnified shot of black silk fibres (Figure 7.) clearly shows the fibres' highly damaged and deteriorated state. The rapid degradation is due to its high level of tyrosine and tryptophan content. Tyrosine and tryptophan in the protein chain are easily oxidized by UV radiation. They are then converted to chromophore groups of yellow/brown colour while the peptide bonds of proteins are dissolved [3]. The level of degradation caused by electromagnetic radiation highly depends on the pH level. Due to the dissolution of the peptide bonds and the shortening of the chain-discharge, the fabric becomes stiff, brittle, rigid, fragile and discoloured [3].

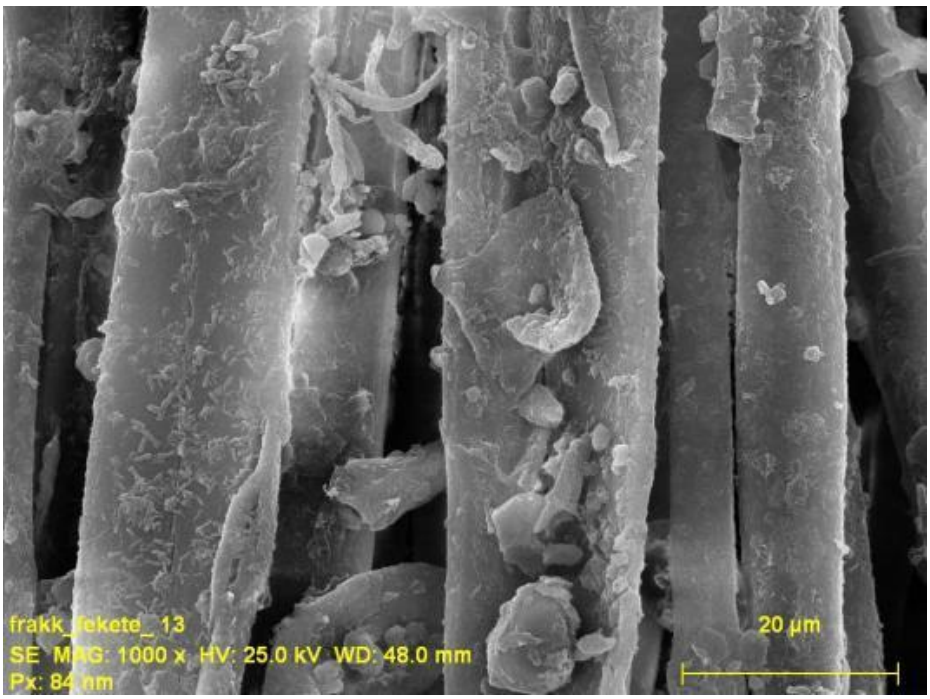

Fig.7. The deteriorated black silk fibres under thousand magnification using an electron-beam microscope

4. CONCLUSIONS

The physical and chemical properties of fibres, whether natural or synthetic, determine their behaviour in different environments. Their damage results from the physical, chemical and biological interactions between the objects and their surroundings. There is numerous scientific research to show the aging factors of natural fibres, but there is clear evidence of synthetic fibres' aging as well. The twentieth-century objects are often said to be “time bombs” waiting to explore in museum collections. It is becoming evident that these modern materials show signs of breakdown, sometimes dramatically and rapidly. Since they are only barely a hundred years old, there is only some practical experience on their behaviour, but not enough scientific data concerning their long-term future behaviour. However, there is a burning need in conservation to examine the deterioration factors of the different artificial threads to preserve them as much as possible for posterity. Future work will be based on the aging tests of artificial textiles to predict their future behaviour and determine their optimal environmental limits for preventive conservation.

Nevertheless, we must consider that keeping the environmental parameters (temperature, humidity, lighting, pest protection) at an optimal limit is not enough. There is no use to keep the temperature and relative humidity of a storage room on an optimal level if the condition of the building is poor (nitrous and mouldy walls, no insulation at the windows, no UV protection foil on the windows, etc.), there is no use to protect objects from pests if the textiles are stored on free shelves, stacked on top of each other without any protection/packaging materials.

5. REFERENCES

[1] https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/mould-growth-textiles.html, downloaded: September 12. 2021

[2] Canadian Conservation Institute, Technical Bulletin Nº 26 Mould Prevention and Collection Recovery: Guidelines for Heritage Collections

[3] Tímárné Balázsy, Ágnes: *MŰTÁRGYAK SZERVES ANYAGAINAK FELÉPÍTÉSE ÉS LEBOMLÁSA*, MNM NYOMDA, BUDAPEST, (1993), P.58.

[4] Landi, Sheila: *THE TEXTILE CONSERVATOR'S MANUAL,* ROUTLEDGE; 2ND EDITION (AUGUST 1, 2016), P.19.

[5] Hon, D.N-S.: *„* YELLOWING OF MODERN PAPERS „PRESERVATION OF PAPER AND TEXTILES OF HISTORICAL AND ARTISTIC VALUES II., IN *ADVANCES IN CHEMISTRY SERIES 193*, AMERICAN CHEMICAL SOCIETY, (1981), PP.120-138.

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ADVANCED LUBRICATION SYSTEMS FOR INDUSTRIAL SEWING MACHINES

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Abstract:

The article describes lubrication systems used by advanced industrial sewing machines. The most part of the sewing machines use to be lubricated in automated way. The automated and centralized lubrication system delivers controlled and minimal amount of a liquid lubricant to multiple wear locations in a machine while the machine is operating. To avoid oil leakage and contamination of the workpiece with the lubricant, the machines use to have a sealed needle bars which close the space between stationary and moving components of the machine. Some parts of the machine can be self-lubricating. There are made from metals: bronze, iron or plastic with high porosity and impregnated with a lubricant. The lubricant use to be: oil, graphite, Teflon (PTFE), Diamond Like Carbon (DLC). Many companies are developing so called minimal lubrication machines, semi-dry head and dry head sewing machines. The minimal lubrication machines use a sealed needle bar and a sealed type oil tank. For the hook section of the machine, the standard lubrication method is employed. The needle bar mechanism of the semi-dry machine is dry type and does not require any lubrication. It is coated with diamond-like carbon or Teflon. The hook lubrication of the machine is performed automatically. The most part of the available advanced sewing machines are semi-dry head and minimal lubrication machines. The mechanisms of a dry head sewing machine does not require any lubrication - they can work fully dry.

Keywords:

industrial sewing machines, lubrication, self-lubricating components, sealed needle bar, semi-dry sewing machines

1. INTRODUCTION

The article is developed to describe lubrication systems used by advanced industrial sewing machines. All industrial sewing machines require regular basic maintenance - cleaning and lubrication. The lubrication is the application of oily or greasy substances, to moving surfaces of the machine to reduce their friction and wear [1]. Avoiding direct metal-to-metal contact, the components are protected against wear and can last longer. Beyond friction reduction, lubricants also protect metal parts from corrosion, provide heat and contamination control [2].

Manual lubrication is traditional lubrication method used in sewing factories. However, this method has several serious disadvantages: it increases machine downtime and maintenance costs, as well as, cannot ensure perfect dozing of the lubricant. The uneven lubrication use to lead to serious problems. Insufficient lubrication is the reason of premature wear and contamination of the mechanisms. Too much lubricant applied increases production costs and can contaminate the manufactured textile products. Manual lubrication is not consistent with today's cost efficiency challenges and pro-active maintenance strategies [3].

Automatic/centralized lubrication is an advanced system that delivers controlled and minimal amount of lubricant to multiple wear locations (metal/metal, metal/brass, ball bearing or metal/plastic) in a machine while

the machine is operating. Automatic lubrication forms a constant thin layer between moving machine parts to avoid these parts scraping against each other [3].

2. SEWING MACHINE LUBRICANTS

Oil is a traditional sewing machine lubricant. As oil has syrup-like fluid consistence, it is good for dozing and delivery to different mechanisms of the machine from a common oil source [4]. Separate parts of the machine can be lubricated with grease (see Fig.1).

Figure 1. Grease (a) sewing machine parts lubricated with the grease (b)

The grease is oil with thickener added to be in semi-fluid or solid structure. Using the grease as a lubricant it is easier to avoid its leakage and to provide seals against contaminants. The grease can remain in an equipment longer and tolerate different conditions. New technologies use also solid lubricants, such as graphite, Teflon, Diamond Like Carbon to coat separate components of the machine and with it make them lubrication free [1].

3. AUTOMATIC LUBRICATION SYSTEMS

Sewing machines with automatic lubrication system use oil as a lubricant because of its fluid consistence [5]. The oil lubricant flows through special channels/pipes to the mechanisms subjected to abrasion. Special computerized system determines the frequency and the volume of lubricant needed. In automatic lubrication systems the oil use to be distributed by help of:

- ***gravity*** (***drip feed system)*** - consist of a loosely covered cup or manifold of oil, placed above the lubricated components that meters out the oil at a set intervals,
- ***wicks*** - machines are equipped with oil sumps or felt oil pads. The oil is distribute by help of cotton wicks (cords/ropes), (see Fig.2).

Figure 2. Felt oil pad and cotton wicks to distribute the oil

- ***splash*** - the oil externally splashes on the certain machine's parts. It is shielded by a frame, oil recovery mechanism and automatic oil circulation mechanism;
- ***pressure(force)*** - an external oil pump is added to the machines. The flow or splash of oil is seen through the special windows or bubbles which indicate a good oil pressure in the machine.

The most often the oil use to be distributed by help of an external oil pump which is added to the machine. The flow or splash of oil is seen through the special *sight window or bubble* on the top of the machines (see Fig.3). It indicates good oil pressure in the machine.

Figure 3. Sight window to see a flow or splash of oil

The system may also incorporate a suction/vacuum oil return system, operated by the same pump and a filter system to clean used oil and return for use again.

To improve lubrication of machines moving parts and avoid fabric contamination because of accidental oil leakage, advanced machines use sealed parts of the machine, self-lubricating components or specially coated components.

3.1. Sealed parts of the sewing machine

Sewing machines use to have a ***sealed needle bar*** to close the space between machine's stationary and moving components and avoid oil leakage (see Fig.4). The minimal amount of oil is locked inside the fully closed/covered needle bar mechanism. By help of vacuum oil return system the oil is delivered to the needle bar and return to the machine's lubrication system during the work process [6].

To prevent contamination of oil in the lubrication system, instead of traditional oil sump advanced machines use to be equipped with ***sealed (dry) oil pan/tank*** - a small closed container for oil storage integrated into the machine's head. The sealed oil pan avoid oil leakage and its mixing with ambient dust, as well as, ensures lower oil consumption.

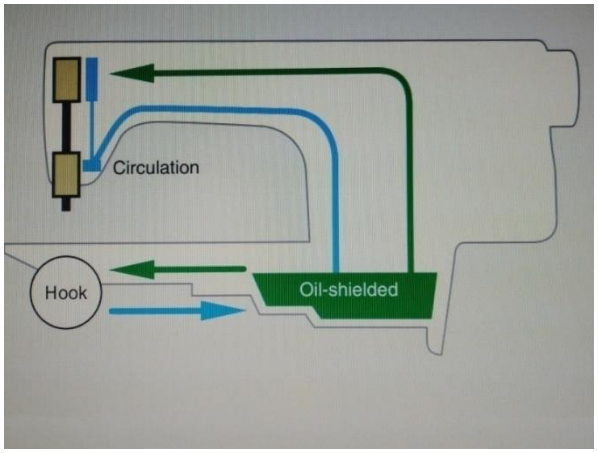

Figure 4. Lubrication system of lockstitch machine JUKI DDL-900A with a sealed needle bar and a sealed oil pan

3.2.Dry head of a machine

Many companies are developing so called "semi dry head" and "dry head" sewing machines. It means that the most important drive units of the machine's head - a needle bar, a presser foot bar, bearings do not require lubrication - they can work dry. To reduce friction not using external lubrication, special surface treatments are applied to the major drive units of the machines.

3.3. Self-lubricating components

The self-lubricating components (such as, bushes in bearings) are made from metals: bronze, or iron with high porosity (20-25% in volume) or plastic impregnated with a lubricant. The lubricant provides a constant lubrication where metal/metal, metal/brass, ball bearing or metal/plastic meet in the machine. The system does not need any additional external lubricants certain period of time - from the warranty period of the machine up to its guaranteed lifetime (15 years).

Different liquid or solid lubricants are used to manufacture *self-lubricating components*:

- ***oil*** - the porous metal component is soaked in lightweight oil. The oil gets drawn to the component pores and surface. During the work process of a sewing machine the oil creates a lubricating layer between two surfaces which use to make friction. The oil impregnation can be used also for plastic, such as, nylon components. After this treatment the surface becomes slippery and have low friction coefficient;

- ***graphite*** - graphite as a solid lubricant is used to treat bronze components. Solid plugs of graphite are inserted into pores of the bronze. The graphite provides lubrication as long as it remains;
- ***teflon*** *(PTFE - polytetrafluoroethylene*) - teflon can be used to coat the metal surface in several ways. It can be dusted onto the bearing as a powder, added to a mixture and sprayed onto bearings where it adheres, or it can be part of a liquid or grease compound applied to bearings. By help of these methods a thin layer of Teflon is created on a the component surface;
- ***Diamond Like Carbon (DLC)*** - components coated with DLC become very durable and their surfaces needs much less lubrication - only ~10% of oil used for conventionally manufactured components.

Oil and grease are traditional lubricants. Solid lubricants are used in circumstances where oil and grease are unsuitable. Advanced sewing machines use to have: bearings soaked with oil or grease, needle bars, presser foot bars, hooks coated with DLC, hooks coated with PTFE (see Fig. 5).

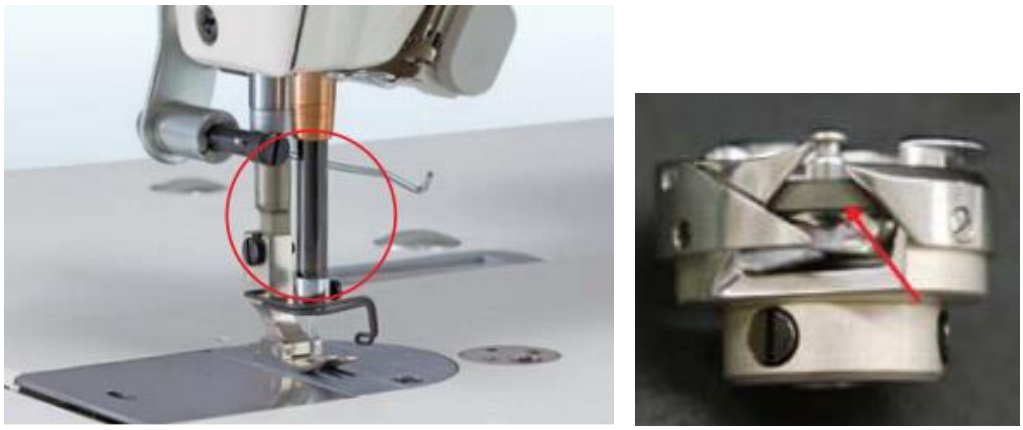

Figure 5. Needle bar finished with a special surface treatment (a), and a hook with a lace from special plastic (b) on Juki DDL-9000

Depending on lubrication principles and specially treated components, sewing machines use to be promoted as: *machines with minimal lubrication, semi-dry head machines, dry head machines*.

3.4. Minimal lubrication

The needle bar and thread take-up components are lubricated with the minimum required quantity of oil. The machine can have the sealed needle bar and a sealed type oil pan/ tank. For the machine's hook section, the standard lubrication method is employed. The closed and shortened lubrication system use to be divided in two sections: first section lubricates hook, second section lubricates other moving parts which need the lubricant (see Fig. 6).

Minimal lubrication system prevents oil from being dispersed on sewing area and with it fabric staining during sewing, as well as, reduces oil consumption.

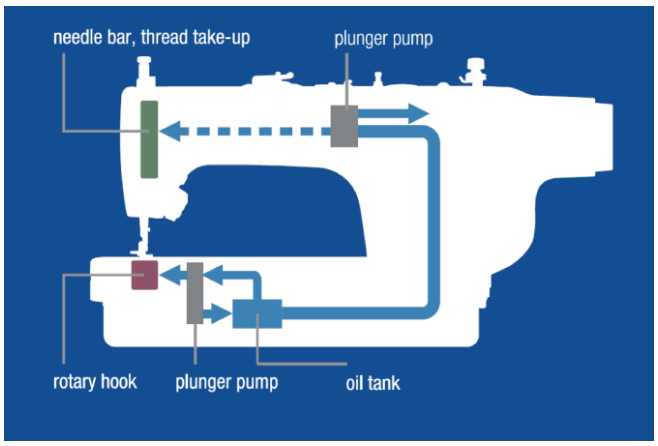

Figure 6. Minimal lubrication system on Brother S-7100A

3.5. Semi-dry head

The needle bar mechanism is "*dry type*" and does not require any lubrication. It is coated with diamond-like carbon (DLC) or teflon (PTFE). The machine can also use sealed and maintenance free bearings. The hook lubrication is performed automatically.

The machine may be equipped with oil filtration system. Then the oil dropped from the hook into the under-cover is filtered to remove dirt and dust and is then returned to the oil tank (see Fig.7).

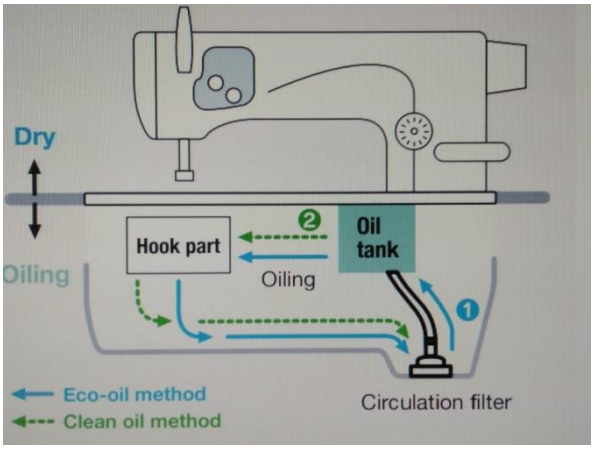

Figure 7. Semi-dry head machine with oil filtration system - eco oil method offered by Juki

3.5. Fully dry head

The section around a needle bar, a thread take-up lever and a hook does not need to be lubricated (se Fig.8). Grease-filled bearings with long non-service period are used for the sections requiring bearings.

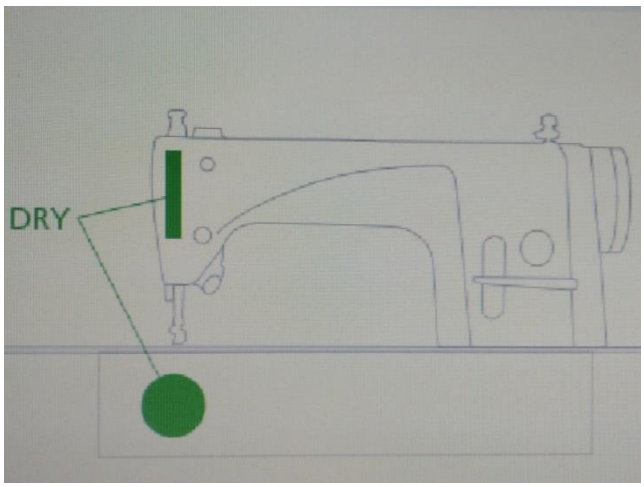

Figure 8. Dry head system sewing machine by Juki

Till now only JUKI DDL-9000BDS is announced as a fully dry head lockstitch sewing machine [7]. All other machines with improved wear parts are promoted as minimal lubrication or semi-dry head machines. There is also no strict border in between meanings a *minimal lubrication machine* and a *semi-dry head machine*. In different brand websites the machines with the same or similar lubrication principles use to be added to one or another group.

Have to be added that all advanced treatment methods which are currently used to get lubrication free parts of the machine (impregnation with a lubricant, coating with DLC) cannot create so called fully maintenance free, or lubed for life components:

- The oil dissipates and ages over time. It has to be replenished or new components fixed in the machine.
- The graphite and Teflon wear out before the end of operational life of the metal components and the machine in which they are used.

By help of these new technologies: machine's lubrication is minimized or simplified; contamination of processed fabric with the lubricant is avoided; non service time of wear parts of the machine is increased.

4. CONCLUSIONS

The manual lubrication cannot ensure qualitative oiling of the moving part of the sewing machine and efficient work process in a sewing line. Often processed textile goods get contaminated with the too much oil applied. The automatic lubrication systems have replaced traditionally many decades used manual lubrication methods. In nowadays all type of advanced high speed industrial sewing machines use automatic lubrication systems. They can delivery correct amount of oil to all moving parts of the sewing machine in automated way. They help to reduce sewing machine dowtime, extended sewing machine life, reduce consumption of the lubricant, reduce maintenance costs, create healthier work conditions to the workers, ensure environmental improvements. The most part of advanced sewing machines are minimal lubrication or semi-dry type machine. They are equipped with sealed or specially coated components. The development of fully dry head sewing machines are still technology of the future. Advanced treatment methods which are currently used to get lubrication free parts of the machine cannot create fully maintenance free, or lubed for life components.

5. REFERENCES

1. Gresham R. M., Totten G. E.: *LUBRICATION AND MAINTENANCE OF INDUSTRY MACHINERY*, TAYLOR & FRANCIS, LONDON, 2008
2. Corporation N.: LUBRICATION BASICS, *AVAILABLE FROM:* https://www.machinerylubrication.com/Read/24100/lubrication-basics
3. WHAT IS LUBRICATION AND WHY IT IS IMPORTANT, *AVAILABLE FROM:* https://www.graco.com/gb/en/vehicle-service/solutions/articles/what-is-lubrication-and-why-is-it-important.html
4. R. LANSDOWN R.: LUBRICATION: A PRACTICAL GUIDE TO LUBRICANT SELECTION, PERGAMON PRESS, UK, 2011.
5. M. ISLAM, A. M. KHAN, M. R. KHAN: MINIMIZATION OF REWORKS IN QUALITY AND PRODUCTIVITY IMPROVEMENT IN THE APPAREL INDUSTRY, *INTERNATIONAL JOURNAL OF ENGENEERING AND APPLIED SCIENCES*, VOL.1 NO.4, ISSN 2305-8269, 2013
6. P. Jana: DOES YOUR SEWING MACHINE HAVE THE RIGHT COMPONENTS FOR HIGHER PRODUCTION, *AVAILABLE FROM:* https://apparelresources.com/technology-news/manufacturing-tech/evolution-of- technology-sewing/
7. DIRECT-DRIVE, HIGH SPEED, 1-NEEDLE, LOCKSTITCH MACHINE DDL-900B AVAILABLE FROM: https://smartmrt.com/product/direct-drive-high-speed-1-needle-lockstitch-machine-ddl-9000b/

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THE IMPACT OF RAW COMPOSITION, KNITTED FABRIC PARAMETERS AND FINISHING OF 1X1 RIB KNITWEAR ON WATER VAPOR RESISTANCE

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Abstract:

Clothing comfort is very important feature which is considered as a result of different process of heat exchange between human body, clothing and environment. The purpose of this paper is to analyze the impact of raw composition, knitted fabric parameters and finishing on the heat water vapor resistance. The measurements was carried out on commercially 1x1 RIB knitted fabrics used for the production of next -to-skin shirts. The one group of samples are made from 100% cotton yarn and another with 96% cotton and 4% Lycra. It is noticed that knitted material composition affected the change in water vapor resistance. Also, this paper presents and verifies the correlation between the measured values of water vapor resistance (Ret) and the knitwear thickness (d_{pl}), mass per unit area (m_{pl}) the tightness factor (K), the porosity (ε) and the surface coefficient (δ_p). Based on these results, a mathematical model for calculating water vapor resistance is proposed. Comparing the results obtained with the proposed equation and the measured results, we can see that the deviations are minimal. The lowest deviation for sample CP3 is less than 0.0008%, while the largest deviation for sample CL1 is 0.023%.

Key words: *thermo physiological comfort, porosity, tightness factor, surface coefficient*

1. INTRODUCTION

The development of science and technology, as well as the improvement of social standards, moved the requirements of customers who prefer garments that provide a satisfactory level of comfort to a higher level. Today, many people are exposed to different atmospheric influences from heat to cold and frequent weathering factors, which is depended by nature of their work [1]. Therefore the clothing with appropriate protective properties as well as satisfactory level of comfort has a huge importance and it represent one of the key factors during the clothes selection, and a decisive factor in the evaluation of the clothing quality [1]. The garments can be seen as a heat exchange layer between the body and its environment. Thermo physiological comfort is directly related to physiological processes of human body and is the result of the balanced process of heat exchange between the human body, the clothing system and the environment. [2]

The thermal properties of clothing that demonstrate the ability to transfer heat and moisture from the surface of the human body to the environment are the dominant determinants of the thermal comfort of clothing. The measuring values that are related to the ability to evaluate the heat exchange of the human body with the environment, and are related with the human perception of comfort are thermal resistance or thermal insulation (Rct) and resistance to water vapor flow on clothing (Ret). The impact of clothing and air trapped in clothing and around the body can be assessed by thermal comfort properties, which provide the ability to assess the effect of clothing on thermal balance in a particular environment [2,3].

The speed of water vapor flow from the skin surface trough the layers of clothing into the environment is an important parameter that defined the usable characteristic of clothing. During the sweating of human body, sweat is taken to the environment through clothes.
The speed at which the evaporated sweat will be removed largely depends on the type of clothing, i.e. parameters of the material and the raw material composition. This means that it is possible to balance the rate of sweat evaporation by choosing the right clothes [4,5].

The aim of this paper is to investigate the influence of structural characteristics (knitwear's thickness, mass per unit area porosity, tightness factor and surface coefficient) on the water vapor resistance of Ret in ribbed 1x1 knitwear. The effect of incorporation of elastane fibers into the knit structure on water vapor resistance was also analyzed. For this purpose ribbed 1x1 knitwear are made with four different linear densities of yarn made from 100% cotton and from a mixture of cotton/elastane yarns.

2. WATER VAPOR RESISTANCE (RET)

The measuring device KES FB 7 - Thermo Labo II (Figure 1) was used to test the water vapor resistance of knitted samples. In the wind tunnel of the device, there is a measuring body that simulates the skin temperature and it is heated to 35°C. There is a constant air flow of 1 ms^{-1} and a constant air temperature of 20° C $\pm$ 2 in the wind tunnel. Water vapor resistance was determined only by the contact method, where the sample is placed directly on the hot plate because the knitwear i.e. T-shirts were used for the experiment, intended for carrying next to the body.

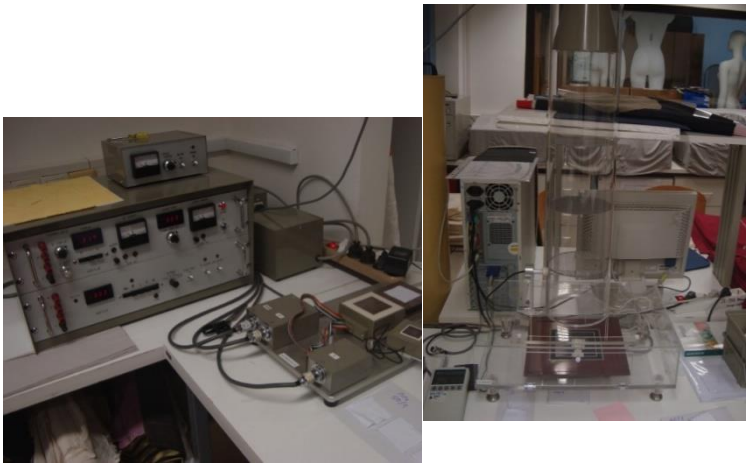

Figure 1. KES FB 7 - Thermo Labo II

Water vapor resistance Ret was determined according to the following equation :

$$R_{et} = \frac{(p_s - p_a) \cdot A}{H_{et}} \qquad (1)$$

Where is: $R_{et} - water\ vapor\ resistance\ [Pa\ m^2\ W^{-1}]$, H_{et} – evaporated heat flow $[W]$, p_s- partial pressure on the surface of plate $[Pa]$,p_a- partial air pressure in wind tunnel $[Pa]$, A – plate surface $[m^2]$ [5].

3. MATERIALS AND METHODS

Experimental part of this paper was carried out using the knitwear that is commercially used for the production of clothes of next-to-skin-wear. This kind of clothes are worn either as one-layer summer wear or as the first layer that is in contact with human skin in cooler season of the year. The knitwear samples are produced with 1x1 RIB structure. Samples are made of 100% CO yarns and CO yarns in combination with Lycra (96% CO / 4 % LY). Linear density of Lycra which was used is 44dtex. CO yarn was used in four linear densities: 20 tex, 17, 14 and 12 tex. Samples in the bleached state and stained samples were examined (table 1).

Table 1: Basic characteristics of analyzed knitwear's samples

Sample	Structure	Fiber composition	Yarn linear density (tex/dtex)	Yarn twists (m-1)	Knitwear finishing
BP_1	1x1 RIB	100% CO	20	780	bleached
BP_2	1x1 RIB	100% CO	17	804	bleached
BP_3	1x1 RIB	100% CO	14	929	bleached
BP_4	1x1 RIB	100% CO	12	977	bleached
BL_1	1x1 RIB	96% CO / 4% LY	20/44	780/-	bleached
BL_2	1x1 RIB	96% CO / 4% LY	17/44	804/-	bleached
BL_3	1x1 RIB	96% CO / 4% LY	14/44	929/-	bleached
BL_4	1x1 RIB	96% CO / 4% LY	12/44	977/-	bleached
CP_1	1x1 RIB	100% CO	20	780	dyed
CP_2	1x1 RIB	100% CO	17	804	dyed
CP_3	1x1 RIB	100% CO	14	929	dyed
CP_4	1x1 RIB	100% CO	12	977	dyed
CL_1	1x1 RIB	96% CO / 4% LY	20/44	780/-	dyed
CL_2	1x1 RIB	96% CO / 4% LY	17/44	804/-	dyed
CL_3	1x1 RIB	96% CO / 4% LY	14/44	929/-	dyed
CL_4	1x1 RIB	96% CO / 4% LY	12/44	977/-	dyed

Knitwear are made on a circular knitting machine type Fv 2.0 of company Mayer & Cie. Characteristics of the machine are as follows: cylinder diameter 19 "(inch), the gauge is E18 and with 40 feeders, the knitting speed is 1.7 m / s. All of the samples are knitted under the same conditions on the same machine. A measuring device used to test the thermal characteristics of knitwear samples was KES FB 7 - Thermo Labo II.

The correlation analysis is used to compare the relation between the resulting values of water vapor resistance (R_{et}) and the resulting values of knitwear thickness (d_{pl}), porosity (ε), surface coefficient (δ_p) and tightness factor (K).The correlation coefficients present the strength of the association between two variables. The coefficient of determination (R^2), was used to measure the strength of the linear association between variables. The value of coefficient of determinations ranges between -1 and 1. The positive value of coefficient of determination means that the values obtained with two methods are proportionally linear. If the coefficient of determination is +1 this presents the maximum of positive correlation. If the correlation coefficient is zero, this means zero correlation.

4. RESULTS AND DISCUSSION

Experimentally obtained results of knitwear thickness, porosity, surface and volume coefficients, tightness factor, and water vapor resistance are presented in table 2.

Table 2:

EEXPERIMENTALLY OBTAINED RESULTS OF KNITWEAR THICKNESS, POROSITY, SURFACE COEFFICIENT, TIGHTNESS FACTOR, VOLUME COEFFICIENT AND WATER VAPOR RESISTANCE						
Sample	**Mass per unit area (m_{pl})**	**Knitwear thickness (d_{pl})**	**Porosity (ε)**	**Surface coefficient (δ_p)**	**Tightness factor (K)**	**Water Vapor resistance (R_{et})**
	($g\ m^{-2}$)	(mm)	-	-	($tex^{1/2}cm^{-1}$)	(m^2PaW^1)
BP_1	194,71	1,073	0,88	1,16	15,8	8,5187
BP_2	178,55	1,062	0,89	1,23	14,4	8,4723
BP_3	140,25	0,965	0,91	1,32	13,4	8,4192
BP_4	115,44	0,914	0,92	1,40	12,4	8,3981

BL_1	279,44	1,217	0,85	0,84	15,9	8,9018
BL_2	243,43	1,171	0,86	0,90	14,6	8,8234
BL_3	207,14	1,205	0,89	0,92	13,2	8,5311
BL_4	189,94	1,164	0,89	0,96	12,2	8,4377
CP_1	206,89	1,116	0,87	1,16	15,7	8,9007
CP_2	177,99	1,036	0,89	1,11	14,4	8,3381
CP_3	146,41	1,002	0,91	1,31	13,5	8,1727
CP_4	129,16	0,920	0,91	1,38	12,5	8,2102
CL_1	279,48	1,225	0,85	0,86	15,9	8,6172
CL_2	255,54	1,228	0,87	0,86	14,5	8,8424
CL_3	211,37	1,196	0,88	0,93	13,0	8,7758
CL_4	188,81	1,158	0,89	0,96	12,1	8,4776

The correlation between the water vapor resistance and knitwear thickness, surface coefficient, porosity and tightness factor are shown in figures 2-11.

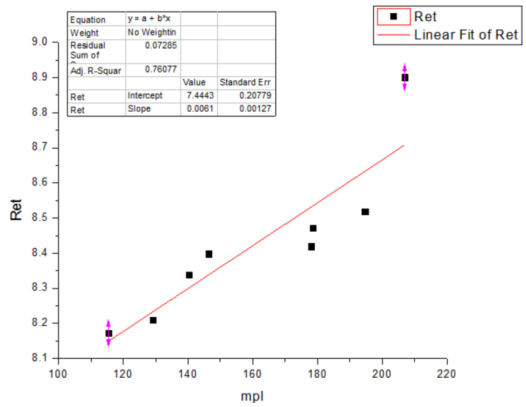

Figure 2: Relationship between R_{et} and m_{pl} in 100%Co bleached and dyed knitwear, R^2=0,7607

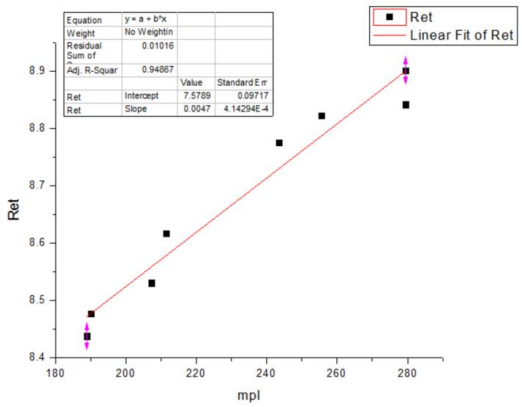

Figure 3: Relationship between R_{et} and m_{pl} in in 96%Co /4%Ly bleached and dyed knitwear, R^2=0,9486

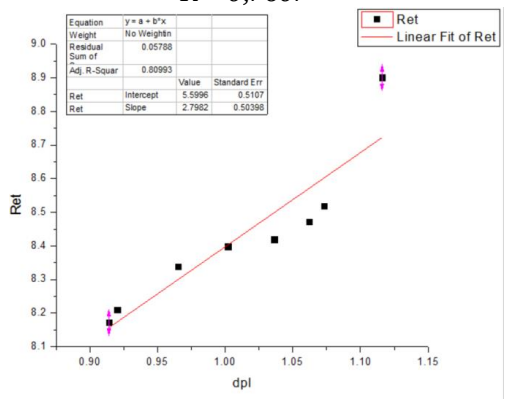

Figure 4: Relationship between R_{et} and d_{pl} in 100%Co bleached and dyed knitwear, R^2=0,8099

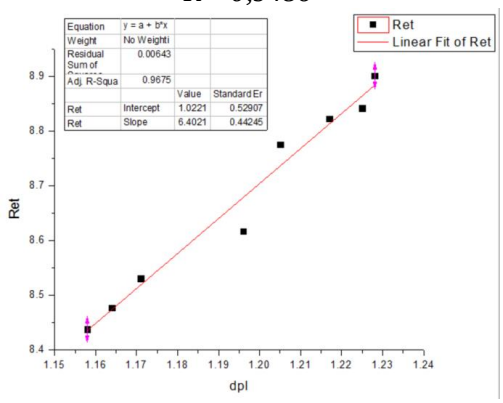

Figure 5: Relationship between R_{et} and d_{pl} in 96%Co /4%Ly bleached and dyed knitwear, R^2=0,9675

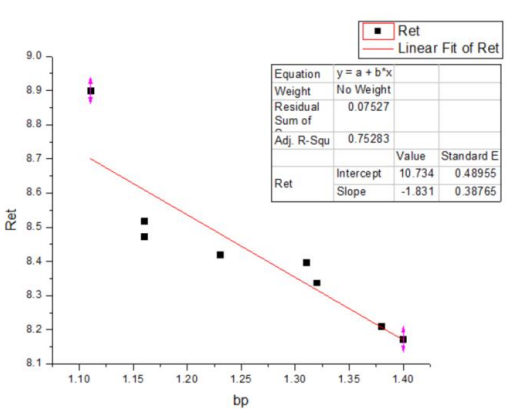

Figure 6: Relationship between R_{et} and δ_p in 100%Co bleached and dyed knitwear, R^2=0,75283

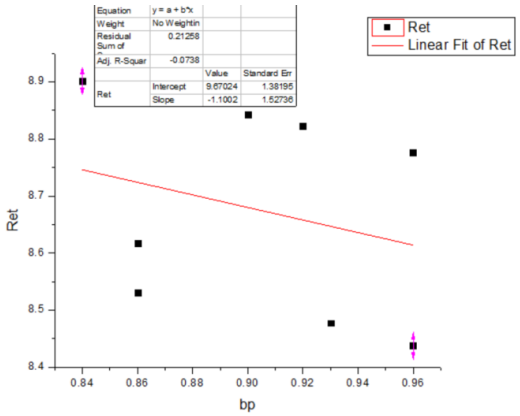

Figure 7: Relationship between R_{et} and δ_p in 96%Co /4%Ly bleached and dyed knitwear, R^2=-0,0738

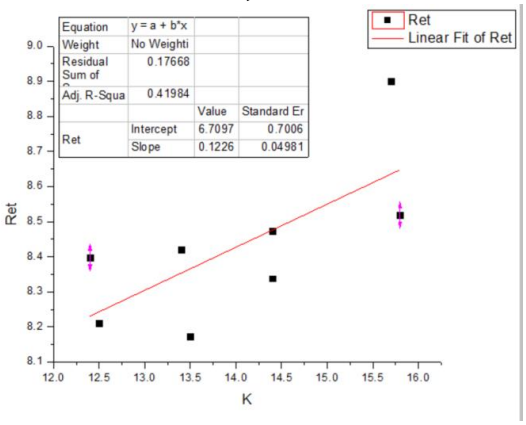

Figure 8: Relationship between R_{et} and K in 100%Co bleached and dyed knitwear, R^2=0,41984

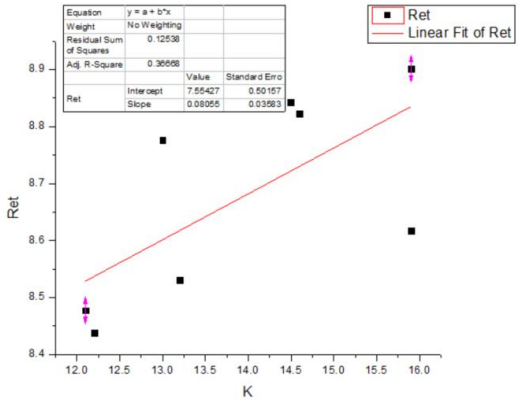

Figure 9: Relationship between R_{et} and K in 96%Co /4%Ly bleached and dyed knitwear, R^2=0,36668

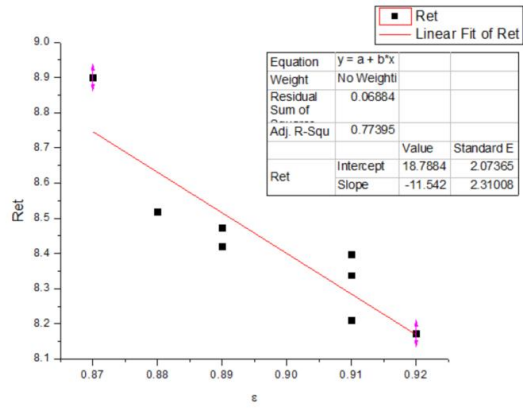

Figure 10: Relationship between R_{et} and ε in 100%Co bleached and dyed knitwear, R^2=0,77395

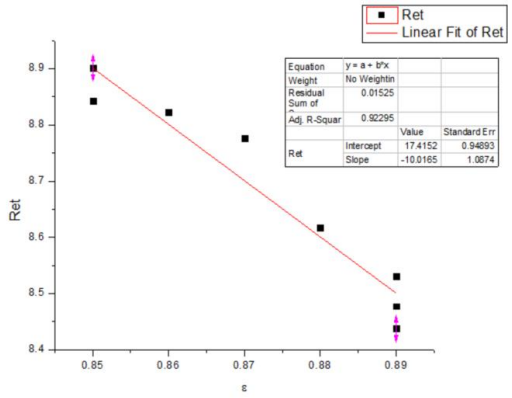

Figure 11: Relationship between R_{et} and ε in 96%Co /4%Ly bleached and dyed knitwear, R^2=0,92295.

From the previous considerations it can be seen that there is a correlation between the parameters of knitwear and the water vapor resistance of the same knitwear. Therefore, it is proposed a suitable mathematical model in order to calculate the Ret values of the 1x1 rib knitwear samples tested, based on the experimentally measured values of knit thickness (dpl), tightness factor (K), surface coefficient

(δ_p) and porosity (ε). The coefficients for the proposed formula are shown in Table 3 and they are given separately for 100% cotton bleached ribbed knitwear made from cotton yarns with linear densities of 20, 17, 14 and 12 tex, for 100% cotton ribbed colored knitwear made from cotton yarns 20, 17. 14 and 12 tex, for ribbed bleached knitwear of 96% cotton and 4% Lycra made from cotton yarns linear densities 20, 17, 14 and 12 tex and for ribbed dyed fabrics of 96% cotton and 4% Lycra made from cotton yarn linear densities 20 , 17, 14 and 12 tex.

The mathematical model for calculating the value of R_{et} has the following form:

$$R_{et} = c_1 * d_{pl} + c_2 * K + c_3 * \delta_v + c_4 * \varepsilon \qquad (2)$$

where c_1, c_2, c_3, c_4 are coefficients, d_{pl} is knitwear thickness, K is tightness factor, δ_p is surface coefficient, ε is knitwear porosity.
The coefficients for the proposed formula (2) are shown in Table 3 and they are given separately for 100% cotton bleached ribbed knitwear made from cotton yarns with linear densities of 20, 17, 14 and 12 tex (BP1-BP4), for 100% cotton ribbed colored knitwear made from cotton yarns 20, 17. 14 and 12 tex (CP1-CP4), for ribbed bleached knitwear of 96% cotton and 4% lycra made from cotton yarns linear densities 20, 17, 14 and 12 tex (BL1-BL4) and for ribbed dyed fabrics of 96% cotton and 4% lycra made from cotton yarn linear densities 20 , 17, 14 and 12 tex (CL1-CL4)."
Graphical representation of the deviations between calculated and measured values of Ret using the equation 3 are shown in Figure 11.

Table 3: Values of coefficients c_1, c_2, c_3, c_4 used for calculating Ret belached and dyed RIB 1x1 knitwear

Sample	Finishing	Coefficient c_1	Coefficient c_2	Coefficient c_3	Coefficient c_4
BP1-BP4	bleached	-0,0017	0,2990	0,2654	1,9562
CP1-CP4	colored	0,0403	-0,5189	0,3977	5,6841
BL1-BL4	bleached	-0,00073	-1,4085	-3,5746	68,924
CL1-CL4	colored	-0,0347	-0,253	-2,6753	46,279

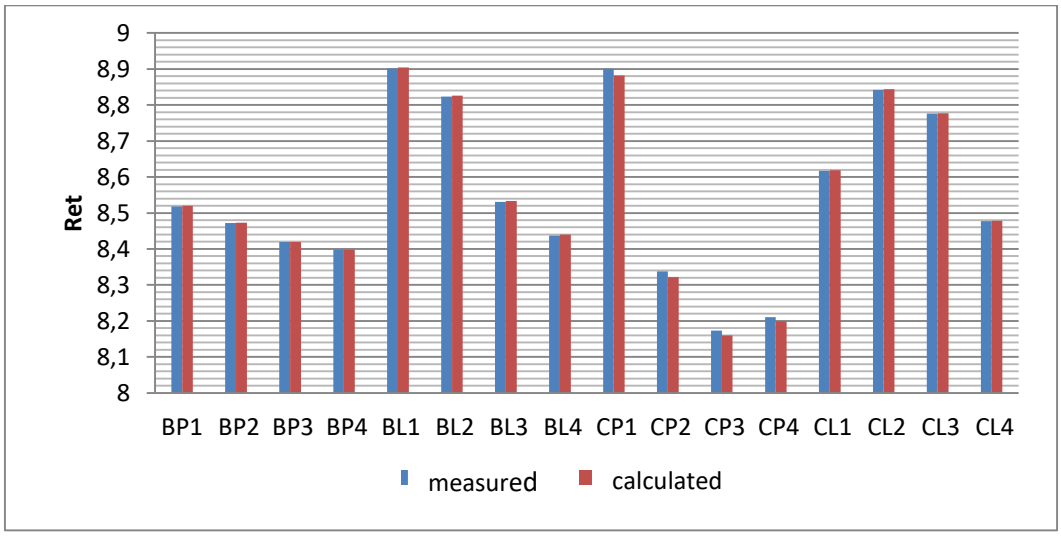

Figure 11: Graphical representation of the deviations between calculated and measured values of Ret

On figures 8 and 9 we can see that tightness factor (K) have a small coefficient of correlation for both raw compositions with water vapor resistance (R_{et}). Therefore it is replaced in mathematical model with mass per unit area (m_{pl}). Mass per unit area (m_{pl}) is in a strong correlation with water vapor resistance (R_{et}). Then the mathematical model will have a new form:

$$R_{et} = c_1 * d_{pl} + c_2 * m_{pl} + c_3 * \delta_v + c_4 * \varepsilon \qquad (3)$$

The coefficients for the proposed formula (3) are shown in Table 4 and they are given separately for sample groups BP1-BP4, CP1-CP4, BL1-BL4 and CL1-CL4. Graphical representation of the deviations between calculated and measured values of Ret using the equation 3 are shown in Figure 12.

Table 4: Values of coefficients c_1, c_2, c_3, c_4 used for calculating Ret belached and dyed RIB 1x1 knitwear

Sample	**Finishing**	**Coefficient c_1**	**Coefficient c_2**	**Coefficient c_3**	**Coefficient c_4**
BP1-BP4	bleached	0,1076	1,6001	1,4683	3,8389
CP1-CP4	colored	0,4191	-2,0477	6,4140	-0,78
BL1-BL4	bleached	1,8114	-21,8164	0,5115	4,8344
CL1-CL4	colored	-03292	16,5734	5,2720	-12,982

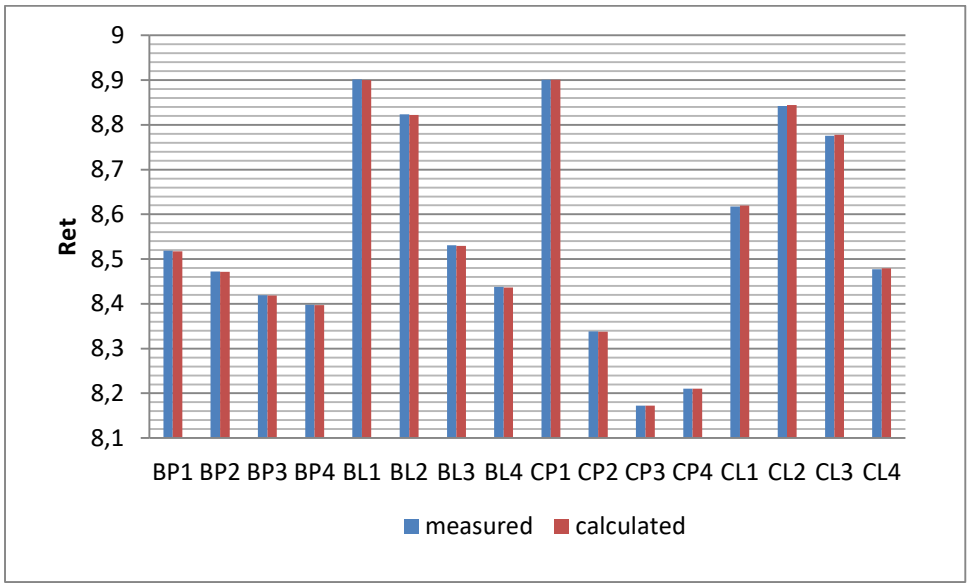

Figure 12: Graphical representation of the deviations between calculated and measured values of Ret using the equation (3)

5. CONCLUSIONS

According to the conducted research of the impact of yarn thickness and raw material composition, i.e. the influence of Lycra on thermal resistance in ribbed knitwear, following can be concluded:

- knitwear that, beside cotton yarn, has Lycra in their composition, are more compact and therefore water vapor resistance increases with these samples.
- with a change of linear density of the cotton yarn i.e. with a decrease in the thickness of cotton yarn and water vapor resistance decreases by 1,5% in cotton yarn knitwear and up to 8% in knitwear with Lycra in its composition.

From the obtained results we can conclude that in knitwear made from 100% cotton yarn, and linear density of 12tex shows the lowest water vapor resistance. While the highest water vapors resistance is observed in knitwear that has Lycra and cotton yarns linear density of 20tex in their composition.

Also, this paper presents and verifies the correlation between the measured values of water vapor resistance (R_{et}) and the knitwear thickness (d_{pl}), mass per unit area (m_{pl}), the porosity of the twists (ε) and the surface coefficient (δ_p). It is noticed that the tightness factor has a small correlation with water vapor resistance. Based on these results, a mathematical model for calculating water vapor resistance is proposed. Comparing the results obtained with the proposed equation and the measured results, we can see that the deviations are minimal. The lowest deviation for sample CP3 is less than 0.0008%, while the largest deviation for sample CL1 is 0.023%.

Based on the results obtained, we can conclude that knitwear intended for wearing to the body are made of 100% cotton yarn have lower values of water vapor resistance and are recommended for wearing in warmer weather, while knitwear with Lycra is recommended for wearing to the body in colder weather due to higher thermal insulation results.

ACKNOLEDGEMENTS

This paper is a part of the research project titled: Development of knitted textile materials for products of increased thermo physiological comfort, financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

6. REFERENCES

[1] I. Salopek Cubric, Z. Skenderi, G. Havenith : IMPACT OF RAW MATERIAL, YARN AND FABRIC PARAMETERS, AND FINISHING ON WATER VAPOR RESISTANCE, *TEXTILE RESEARCH JOURNAL*, 83 (12), 2013: 1215-1228.

[2]H.Shen, K. Xie, H. Shi, X. Yan, L. Tu, Y. Xu, J. Wang: ANALYSIS OF HEAT TRANSFER CHARACTERISTICS IN TEXTILES AND FACTORS AFFECTING THERMAL PROPERTIES BY MODELING, *TEXTILE RESEARCH JOURNAL*, vol 89, 2019.

[3] B. Mijovic, I. Salopek, Z. Skenderi : MEASUREMENT OF THERMAL PARAMETERS OF SKIN – FABRIC – ENVIRONMENT, *PERIODICUM BILOGORUM*, Vol.112, No.1, 69-73, 2010.

[4] S.Kawabata, Kawabata's Evaluation System for Fabric, Manual. Kyoto: KATO TECH CO. Ltd, 1972.

[5] K.C. Parsosn: Human thermal environments; THE EFFECTS OF HOT, MODERATE, AND COLD ENVIRONMENTS ON HUMAN HEALTH, COMFORT AND PERFORMANCE, *TAYLOR AND FRANCIS, LONDON*, 2003

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CRADLE TO CRADLE® DESIGN INNOVATIONS

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Abstract:

The Cradle to Cradle® concept defines and develops the reuse of products. Compared to traditional recycling, it maintains the same level of quality of raw materials through the life cycles of several products, and only safe chemicals are used. Products are developed in accordance with the principle of maintaining the quality of raw materials over several life cycles, even if we take into account the use, production processes and reuse. This means: no waste, since all ingredients are treated as nutrients for the next cycle. The right materials are included in certain cycles (metabolism) at the right time and in the right place. The approach of a circular economy analyzes the recycling economy in the value chain, which leads to the generation of revenue from recycled materials. Cradle to Cradle® defines quality preservation as well as the cost-effectiveness of the value-added chain. Re-use materials from Cradle to Cradle® products allow the cost of materials to be as close as possible to the cost of materials. Even if additional costs arise due to processing or cleaning, they are still lower than the market price of the material. The Cradle to Cradle® model transposes the principle "quality is equal to quantity" to industrial systems. The flow of materials is designed to be useful and useful for the restoration and conservation of biological and technical resources. This approach stems from the tendency to slow down and reduce the negative impacts on the environment. Breakthrough projects and innovations of Wolford, DyStar, Napapijri, Sanko and Calida will be presented.

Keywords: *Cradle To Cradle, Sustainable Development, Innovations, Certification*

INTRODUCTION

Cradle to Cradle Design opens the perspective of an industrial society where processes of production and use are designed by transfer of principles of Nature. Nature knows material flows, but Nature does not know waste, avoidance, constriction and restriction **[**1]. Nature is simply involving right materials at the right place and at the right time. In the case of textiles treated with chemicals innovation is needed to develop only chemicals which are safe for biological cycles.

In regard to differentiation to conventional recycling the quality level of the raw materials remains throughout multipleproduct lifecycles and only purely “assessed safe chemicals” are used.

The products are developed according the model to maintain the quality of raw materials over multiple life cycles taking the production processes, the use and the reutilization into account **[**2].

This means: No waste, all ingredients are considered as nutrients. The right materials are integrated in defined cycles (metabolism) at the right time and place.

The 3 Cradle to Cradle® Design Principles:

- Waste = Food
- Energy: use of renewable resources
- Diversity

Nature as a model reflects ongoing developments in a Cradle to Cradle® product: Flourishing trees in spring are only apparently redundant. From a few blossoms new trees are growing. All blossoms not used for growth, fall to the ground and become nutrients.

Cradle to Cradle® Products reach a new quality dimension and distinguish themselves through high economic value as well as modest, ideally with no environmental damage **[**3].They achieve high consumer friendliness and are credentials of a paradigm change towards consumer behavior and in the industrial production. Cradle to Cradle® Design defines not only form, functionality and ingredients of a product. The goal is to strive for a new dimension in quality and safety in endless cycles.

Cradle to Cradle® Design transmits the principle "Quality equal Quantity" to industrial systems. Materials together with material flows are designed to be beneficial and useful for the regeneration and conservation of biological and technical resources. This approach liberates from the present obligation to diminish, reduce or slow down the need to negative environmental impacts **[**4].

2. BREAKTHROUGH INNOVATIONS in TEXTILE INDUSTRY

2.1 Wolford

Austrian textile company Wolford is located in Bregenz in Austria and in Murska Sobota in Slovenia. It's opening a new story in direction of circular economy. That's breakthrough on textile and clothing area. After five years of team working in cooperation of 15 companies they made it to certify a biological cycle decomposition over industrial composting as tehnical cycle throught the decomposition of textiles. Both certification are in performance on GOLD Level Cradle to Cradle Certified ™ and appearance is luxurious.

Figure 1: Certification line of premium textile Wolford

2.2 DyStar

The DyStar Group is a leading dyestuff & chemical manufacturer and solution provider, offering customers across the globe a broad portfolio of colorants, specialty chemicals, and services. With a heritage of more than a century in product development and innovation for the textile industry, DyStar also caters to multiple sectors including the paints, coatings, paper and packaging industries. Its expansion into the food & beverages and personal care sectors reinforces the company's position as a specialty chemical manufacturer. DyStar's global presence offers customers reliable access to experts from offices, competence centers, agencies and production plants spanning over 50 countries.

The assessed Dystar Textile Dyes have achieved a Material Health Certificate on the Gold level. They include VAT Dyes, Reactive Dyes, Disperse Dyes, Indigo Dyes and a Reactive Dye for wool. The DyStar Group has offices, competence centers, agencies and production plants in over 50 countries to ensure the availability of expertise in all important markets.

With a heritage of more than a century of product development and innovation for the textile and leather industry, DyStar has developed into new markets and now in addition serves the paper, plastic and many other specialty chemical industries.

Approved for use: 39 dyes are available and the full collection is displayed in the table below.

2.3

#	VAT Dyes	Reactive Dyes	Disperse Dyes	Reactive Dye for wool
1	Indanthren® Brilliant Orange GR Coll	Levafix® Amber CA-N	Dianix® Blue XF	Realan Black MF-PV
2	Indanthren® Red FBB Coll	Levafix® Brilliant Yellow CA	Dianix® Yellow AM-SLR 200%	
3	Indanthren® Brilliant Green FFB Coll	Levafix® ECO Forest	Dianix® Yellow S-3G	
4	Indanthren® Olive Green B Coll	Levafix® ECO Black	Dianix® Yellow Brown XF2	
5	Indanthren® Scarlet GG Coll	Levafix® Fast Red CA	Dianix® Yellow XF2	
6		Remazol® Brilliant Blue RN	Dianix® Orange AM-SLR	
7		Remazol® Brilliant Red F3B	Dianix® Turquoise S-BG	
8		Remazol® Brilliant Yellow GL 150%	Dianix® Blue S-BG	
9		Remazol® Yellow GR 133%	Dianix® Brilliant Violet R	
10		Remazol® Luminous Yellow FL 150%	Dianix® Red AM-SLR	
11		Remazol® Golden Yellow RGB	Dianix® Red XF2	
12		Remazol® MAP Black NN	Dianix® Rubin XF2	
13		Remazol® Navy RGB 150 %	Dianix® ECO Black HF	
14		Remazol® Red RGB		
15		Remazol® Ultra Carmine RGB		
16		Remazol® Ultra Orange RGB		
17		Remazol® Ultra Orange RGBN		
18		Remazol® Ultra Rubine RGB		
19		Remazol® Ultra Navy Blue RGB		

Napapijri

Their trailblazing Circular Series of fully recyclable jackets has been recognised with the prestigious Cradle to Cradle Certified® Gold certification, the World's most advanced standard for safe, circular and responsible materials and products. This is how they want to play their part.

This is how they choose future. With outstanding results that change the game not just for them, but for the fashion industry as a whole: this certification sets an important precedent as no previous brand has succeeded to develop a fully circular system in just fourteen months, and effectively involving,

reviewing and innovating of all the tiers of their Circular. Series' technical cycle.
Sounds complicated? Let's have a look at what this means in practice on picture.

Figure 2: Napapijri Circular Series is Cradle to Cradle Certified® Gold

2.4 Sanko Textiles

Sanko Textiles combines the deep heritage from the past with the dreams of the future - the possible with the impossible. And the result is something that benefits not just Sanko and its customers, but the people and planet in which we all live.

Knit fabrics that are fully vertically integrated, from spinning, knitting, dyeing and finishing and driven by innovation for major brands.

Circular Knit Fabrics Future include:
Interlock, Interlock with Elastane, Single Jersey, Single Jersey with Elastane, Rib, Rib with Elastane, Fleece with Elastane, Towel, Pique with Elastane, Collar, Cuff

Figure 3: Certificate Cradle to Cradle Certified® issued for Sanko Textile

2.5 Calida

CALIDA looked to nature for inspiration when it designed its "I love nature" collection.

At CALIDA have more than 75 years of experience designing and manufacturing underwear – and they want to get even better. Their aim is to offer underwear suitable for every day, every taste and every situation. And top priority is always durability, quality and attention to detail – from design and fit, developing the best materials, through to the workmanship of the final product.

With the I LOVE NATURE range, CALIDA has created a true innovation in the field of sustainability; soft against the skin, temperature-regulating, fast-drying and odour-minimising

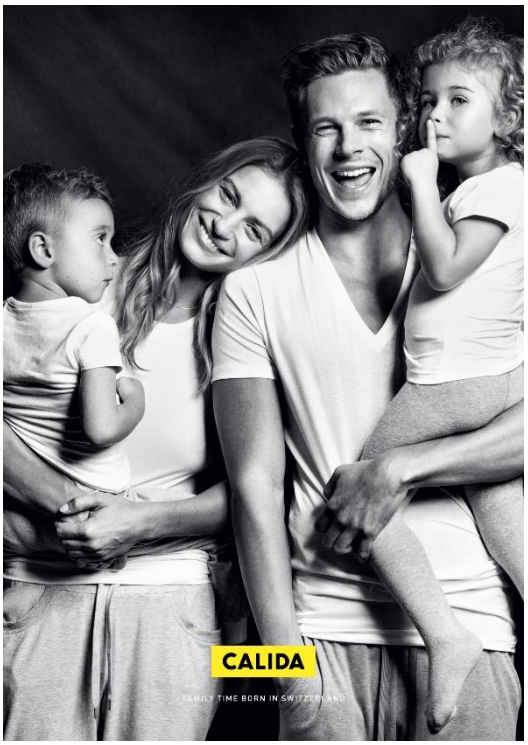

*Figure 4: Calida "I love nature***"**

3. Conclusion

The Cradle to Cradle® concept improves the economy in the entire value cycle of a product. Related risks within the supply chain and the production achieve higher transparency. The cost of the economy, the environment and the social aspects become predictable and profitable.

All substances and materials along the entire supply chain are being considered from raw materials to products within the Cradle to Cradle® Design Concept. This results in a product of unmatched quality. Therefore, a continuous raw material use is practice without restrictions.

1. Braungart, 1992 An Intelligent Product System to Replace Waste Management Braungart, Engelfried Fresnius Envir

2. Braungart, 1992 Criteria for Sustainable Development of Products and Production Braungart, Engelfried, Mulhall

3. Fresnius Envir Bull 2:70-77 (1993) Birkhäuser Verlag Basel Switzerland 1018-4619/93/020070-08 S 1.50+0.20/

4. „Cradle to Cradle“, Remaking the way we make things. McDonough, Braungart. New York, North Point Press 2002

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DEVELOPING A SUSTAINABLE DENIM COLLECTION: VIEWS, ASPIRATIONS & METHODS OF ETHICAL DENIM

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Abstract:

The article introduces the fundamental principles of sustainability in fashion and textiles and presents the critical factors of ethical denim by analyzing waste, water usage, chemical treatments, and recycling management. It introduces some of the latest literature and research dealing with these issues. It announces the aspirations of denim designers and their influence on fashion trends. It analyses some of the brands' developments and their implementation's global economic impact, social outcome, and environmental benefit. The article presents the latest innovative technologies applied in the denim industry over the last decade, analyzing the development in fabric composition, cotton/recycled cotton/organic cotton, and synthetic fibers. In this part, the most prominent literature and references available on this topic will be analyzed. The methodology of developing a sustainable denim collection is introduced in functional models. The method will be discussed on the example of developing sustainable designer brand and denim collection IKONIKA. The article presents the latest principles of developing a sustainable denim collection, compressively analyzing the innovative views, aspirations, methods, and technologies applied in the denim industry over the last decade. It introduces the model comprising some denim designers and brands' methodology, comparing them to the vision, technology, and form experiments used to develop an autonomous brand collection.

Keywords: *design, denim garments, environmental sustainability, ethical denim*

INTRODUCTION

Fashion changed much during the past years. The overall sustainability pushed specific sectors of the fashion industry backstage. Simultaneously, the mainstream of active and healthy lifestyles promoted sectors, such as intelligent textiles, sportswear, or functional garments. Denim, the omnipresent fabric, also known to be one of the most polluting sectors in the textile and fashion industry, is considered to change. [1] Making the blue jeans' lifespan more sustainable is a new spirit driving all the denim industry innovators, inspiring them to join the forces that present innovative, new sustainable denim manufacturing and finishing methods almost daily. [2] [3] Designers and manufacturers are introducing new methods and techniques resulting from worldwide programs, collaboration, and interaction of denim mills, producers, technologists, and designers. The core goal is to meet new corporate social responsibility standards, environment, and chemical usage, which will meet the renewed criteria of the sustainable denim policy. Last years, increased social and environmental responsibility has been present in the denim sector, and the industry actors are striving to focus on the new requirements of the denim supply chain. This mainstream results in a different aesthetical and technical approach to creating a classical pair of jeans and developing a denim collection.

CRITICAL ISSUES OF SUSTAINABILITY IN DENIM

Critical sustainability issues, often mentioned in connection with the textile and fashion industry, are very prominently and explicitly present in the denim industry and the ethical ones. The fundamental principles of sustainability applied today in the fashion and textile industry are also present in the denim industry. [4] [5] [6] Then: *What is wrong with the denim industry?* The denim industry became open to discussing the following matters to integrate the good practices in its system.

Environmental impacts of jeans production: water consumption and toxic pollution

The denim industry has a catastrophic impact on the environment. The jeans industry is the most polluting sector of the fashion industry – the second largest polluting industry globally. The jeans go through a particularly energy- and water-intensive dyeing and finishing process, starting with what gives the fabric its distinctive indigo color. After dyeing, the clothes are treated and washed with various chemicals, such as bleach, to soften, fade, or texturize the fabric. Most of our favorite shades and styles (acid washed or distressed) require additional treatments and chemicals. Overall, producing a single pair of jeans requires vast water and energy and causes significant pollution. The ecological damage is rising as the industry grows and the denim market emerges.

Denim is made primarily with cotton; however, it is often blended with synthetic polyester or elastin. Cotton is a very water-demanding crop: production of 1 kilogram of cotton can require up to nearly 20 000 litters of water. Until approximately 750 million people in the world do not have access to drinking water until about 1.5 trillion liters of water are used by the fashion industry every year. At the same time, 200 tons of fresh water are needed to dye one ton of fabric. [1] (Fig 1)

Visualization of facts about the water consumption of the fashion industry

The denim washing industry is considered the major industrial waste generator; the wastewater from the wash goes untreated, primarily into the rivers. [2] Wastewater of denim production contains toxic substances such as lead, mercury, and arsenic, among others. The contamination also reaches the sea and eventually spreads around the globe. According to a study that deals with the environmental impact of effluents released by denim garment washing factories in Bangladesh, only 40% showed evidence of improved filtration systems and produced clear wastewater. The study exposes the technical limitations of effluent treatment practices of the examined denim garment washing factories. [3] 20% of industrial water pollution comes from textile treatment and dying especially denim. 200 000 tons of dyes ate lost

to effluents every year, while 90% of wastewaters in developing countries are discharged into rivers without treatment. [1] (Fig 2)

Visualization of the facts about the wastewater pollution

Cotton crops grown today consume a lot of chemicals: 16 percent of all insecticides are used on the plant, and many of these pose significant health risks to farmers and those living in the area. Today, large amounts of petroleum and toxic substances such as formaldehyde and cyanide are used to produce the fashionable colors of Blue Denim. These compounds are washed out in the washing phase of denim clothing resulting in a significant ecological impact on the surrounding environment; vast amounts of wastewater generated by the manufacturers are drained into the rivers without proper treatment. The environmental issues and the consequences of washing denim clothing are growing, which poses a challenge to the sustainability of the denim industry. Vast amounts of waste from jeans laundries must be treated appropriately; otherwise, the actual impact will be more severe and critical for the environment. Many denim producers are still unable to maintain environmental safety. Consequently, strict regulation, valuable frameworks, and monitoring systems, a strategic action plan with measurable outcomes are needed to ensure sustainable denim production in terms of finishing. In this regard, the government, consumers, and industry professionals need to act more responsibly wherever necessary. [3] The ground-breaking documentary RIVERBLUE examines the destruction of our rivers, its impact on humanity, and the prospect of a sustainable future. The film draws attention to the destruction of one of the world's most important rivers by manufacturing our clothing. It also demands a significant change in the textile industry from the best fashion brands that can make a difference. [4] (Fig 3)

Intro image of the Riverblue project

Further sustainability and ethical issues to be put on the scales

Additional matters to be placed on the scales are:

- **The importance of soil pollution matters:** The agricultural system and local vegetation are affected by wastewater, which causes chronic health problems as the soil becomes contaminated upon contact with the wastewater.
- **Low wages and unethical treatment of the workers:** The issue of unethical treatment of the workers and bed working conditions. The worldwide introduction of fashion requires fashion companies to apply fair and equitable living wages to their employees as a global standard.
- **Fabric waste management and vast quantities of unsold goods cause global impact:** Better waste management, application of new solutions, better stock management, and production planning can solve the current problem.
- **Lack of transparency in the supply chain:** Many fashion companies acknowledged that a lousy reputation costs more than investments. Transparency of the textile supply chains should become a universal objective maintained by highly detailed sustainability reporting. In achieving this goal, training, education, networking, and associations play a crucial role.

NOVEL ASPIRATIONS ON DENIM AND RENEWED TECHNOLOGIES

Making the blue jeans' lifespan more sustainable is a new spirit driving all the denim industry innovators, inspiring them to join the forces that present innovative, new sustainable denim manufacturing and finishing methods almost daily. Designers and manufacturers are introducing new methods and techniques resulting from worldwide programs, collaboration, and interaction of denim mills, producers, technologists, and designers. [7] [8] Wide environmental awareness has made companies aware that reputation, transparency, and environmentally friendly manufacturing are the new "state-of-art" of the industry. Consumers encourage brands to make a change in how they manufacture their clothing and are aware of choosing:

- Clothes made in countries with stricter environmental regulations for factories
- Organic and natural fibers that do not require for their production
- Products created under conscious and sustainable manufacturing processes
- Extended producer responsibility
- Transparent supply chain

Manufacturers, brands, and designers collaborate to deliver industry-wide sustainable solutions. Some companies are introducing new technologies that significantly reduce water use, while others strive for sustainability by supplying their factories with renewable energy and recycling water.

Levi's: Better Clothes and Better Choices For Better Planet

The world's iconic denim producer, Levi's, focuses on the innovations that make jeans as durable as ever. Materials are crafted with thoughtful quality from sourcing to finishing. With innovations in *Cottonized Hemp, Levi's® WellThread, Water<Less®* technology, the company uses fewer resources and makes less waste. The Levi's® products *made to be worn and designed to get better with age* on philosophy that durability extends beyond just everyday use. (Fig 4, next page)

Levi's campaign images 2021

The company has sustainable practices and methods that help make their products stand the test of time, and everything they make is rigorously tested for durability. They have a Tailor Shop can for repairing or redesigning clothing on demand. They also introduced their *SecondHand project* in 2020 to further demonstrate their commitment to longevity by extending the life of their products even further and offering customers the vintage styles they love. [5]

Everlane: The world's cleanest denim factory

Saitex is a game-changing denim factory located in Vietnam. Unlike typical manufacturers, their LEED-certified facility recycles 98% of its water, relies on alternative energy sources, and repurposes by products to create premium jeans minus the waste. 98% of the recycled water is clean enough to drink! Until standard denim manufacturers waste thousands of gallons of water in the washing process, Saitex's unique closed system recycles 98% of all water used. When it comes out the other side, it is so clean that it is drinkable. Thus they advertise themselves as the world's cleaned denim factory. (Fig 5)

Banner image from the company website: the super-efficient jet washing machine

While 1500 liters of water are used in the standard production process of a single pair of jeans until Saitex produces the garment using 0.4 liters of water after recycling. The new technology allows a more efficient wash process, avoiding using the "belly" washing machines still widely used by standard denim manufacturers. Thanks to a closed water system and super-efficient jet washing machines, only 0.4 liters of water are lost due to natural evaporation. [6]

This denim manufacturer has reduced its energy usage by 5.3 million kilowatt-hours of power per year and reduced CO2 emissions by nearly 80% through its commitment to renewable energy resources like solar power. The factory's energy-saving production process is highlighted by 85% of air-dried products using air recycled from hot factory machinery. After drying on the conveyor, every pair of jeans is briefly finished in a commercial machine. (Fig 6)

Air drying method for the denim products using air recycled from hot factory machinery

The goal of the denim industry is to create a closed-loop in the Sustainable Circular Economy system. This goal is satisfied by the company brick by brick by the production of bricks. Since all denim makes a toxic product called sludge, the company extracts and ships it to a nearby brick factory; when mixed with concrete, the poisonous the substance can no longer leach into the environment. The bricks are used to build inexpensive homes; so far, the factory has built ten. (Fig 7)

Bricks created by mixing the sludge, the toxic waste of the denim process

The methodology applied by the denim supplier proves that it is possible to produce exceptional quality within a supply chain of ethical factories, maintaining radical transparency of all the actors.

Developments in Fabric Composition: Traditional Cotton vs. Recycled, Organic, and Synthetic Fibres, and Advanced Dyeing Technologies

In the denim industry, developments in fabric composition, new fibers, and structures such as recycled cotton, organic cotton, hemp, and recycled synthetic fibers are the most advanced field. The industry has continually renewed perspectives. Biotech firm Tinctorium (US) is one of the companies working to replace harsh chemicals with bioengineered organisms. [7] Instead of using petroleum as the raw material, some other processes use renewable carbon, such as agricultural waste transformed by micro-organisms instead of corrosive chemicals. The future is open for biodegradable paints; the denim industry strives to create beautiful colors without toxic chemicals. [8] Most garment suppliers today apply recycled cotton or polyester in their product range. Often, all the cotton used in the product range should be recycled or sustainably sourced. Organic cotton, recycled cotton, or cotton are sourced through the Better Cotton Initiative (BCI). Another critical trend is moving away from cotton and looking into new ways to incorporate recycled fibers as a substitute for cotton. [9]

IKONIKA: ASPIRATIONS AND METHODS FOR MAKING ETHICAL DENIM

Implementation of above mentioned is aspirations and methods highlights the work of fashion designers. Remarkable tendencies widespread in fashion most of the time spread from independent research, influencing the art of contemporary designers. Such experiments co-occurring would boost global trends; when the same motivation inspires many designers simultaneously, shortly, a movement will arise from the separate and isolated trend germs. Such simultaneously occurring individual manifests created the basis of denim's sustainable and ethical trend and made an identifiable shift to a new paradigm in the last decade.

Developing a Sustainable Denim Collection

The autonomous denim brand IKONIKA has been created to embody the spirit of the arising trends. After its introduction in 2016, a limited series collection was born in eco-design, drawing attention to a particular matter inspiring sustainable fashion. The collections and the artworks manifested the ideas that arose from them. The first in the series was the IKONIKA ORGANIKA (2016) collection, which aimed to join and draw attention to the rising organic trend. Selected items of global brands were remade into crafted, hand-painted pieces. (Fig 9)

A piece from series IKONIKA ORGANIKA – Mini skirt remade from a Cheap Monday jeans

Book of organic denim-flax collection IKONIKA SS17 (2016) was followed by collection IKONIKA HERMETIKA (2017). Both in the series were inspired by esoteric traditions, integrating symbolic and

hermetic details for design inspiration. These were followed by the collection CBJ IKONIKA (2018), a collection made in international cooperation of 3 designers and three companies from 2 countries. The collection aimed to integrate the trend of international collaboration of brands and designers by involving a Serbian denim manufacturer, a small Serbian enterprise, and a Hungarian design company in an integrated project.

Runway images of the CBJ IKONIKA SS18 collection (selection) – Edit Csanák (2017)

The CBJ IKONIKA SS18 (2017) project attempted to integrate expertise in the region as an international multi-brand trend: products were created in collaboration with Eastern European family-run companies. The CBJ IKONIKA SS18 denim collection satisfied the emerging trend of sustainable denim. The products using quality raw materials from traceable sources were made in combination with customized pieces made from unsellable denim stock and waste. They were treated by environmentally friendly manufacturing technologies. The limited series collection met the customer demand for stylish designer products different from mass-produced items. The pieces in the collection were produced in a limited series, keeping in mind the ethical and sustainability guidelines of the fashion market trends of our time, and were sold concerning fair trade. A manifest IKONIKA DENIFESTO: THE BLACK BOX (2019) followed it. The installation was made of 61 disassembled and destroyed trousers returned to the manufacturer as an example of the speculative methods applied in the fashion industry. The Black Box that was part of the installation contained the removed trademarks of an unethical brand. The protest was worded as a sonnet. Both projects strived to draw attention to sustainability and ethical issues in the denim industry and the emerging trends that arose from the matters concerned.

Semi Couture category, urban-denim style, thematic capsule collection IKONIKA LUMENIKA (2020) was inspired by György Kepes' gnostic view of the world and the timeless and obsessed passion for the lights of the Universe. Outfits were carried out in advanced trends of redesign and eco-design from recycled fabrics. The collection was exhibited at Kepes Institute in Eger (Hungary). (Fig 10, next page)

Sustainable, recycled denim collection IKONIKA LUMENIKA – Edit Csanák (2020)

The mural textile artwork carpet (wall textile) IKONIKA FLUIDIKA (2021) was carried out under theme “Flow” (from the Hungarian word "sodrás") for Hungary's VII International Triennial of Textile Art. The monumental mural "Blue Drift" portrays drifting with jeans as a specialty and art. The wall textile weaves together fragments and textures, memories of the twenty years of designing and work for sustainable and ethical denim manufacturing into one giant wave. (Fig 11)

IKONIKA FLUIDIKA: BLUE DRIFT (160 x 13 cm, details) – Edit Csanák (2021)

CONCLUSION

The article presented some aspects of sustainability and ethical behavior in the farm sector and the innovative methods and renewed technologies used in the farm industry in recent years. The social results and environmental benefits of their implementation were analyzed. The article analyzed the development of the use of fabric composition, cotton / recycled cotton / organic cotton and synthetic fibers, and presented an example of the possibility of recycling by-products from the manufacture of jeans. The methodology of developing a sustainable jeans collection is presented in the examples of the

collections of the IKONIKA designer brand. It sought answers to what methods have gained ground in the last decade to make the women's sector of the fashion industry sustainable, and what aspirations are currently driving the ethical farmers sector, and how these are inspiring individual artistic aspirations.

REFERENCES

[1] M. Charpail, „Fashion's Environmental Impact," 2017. [Online]. Available: https://www.sustainyourstyle.org/old-environmental-impacts#anchor-link-wastes. [Hozzáférés dátuma: 2 November 2021].

[2] M. A. Hossain, "Waste Water Production in Fabric Processing in Bangladesh," *European Online Journal of Natural and Social Sciences,* vol. 8, no. 3, pp. 558-563., 2019.

[3] a. a. Md Shamsuzzaman, „Quantifying environmental sustainability of denim garments washing factories through effluent analysis: A case study in Bangladesh," *Journal of Cleaner Production,* %1. kötetVolume 290, %1. szám125740, 2021.

[4] „Riverblue," Paddle Production Inc., 2021. [Online]. Available: https://www.watchriverblue.eco/about/. [Hozzáférés dátuma: 26. Október 2021.].

[5] Levi Strauss, „We're on the mission to change clothing industry. For good.," 2021.. [Online]. Available: https://www.levi.com/US/en_US/features/sustainability. [Hozzáférés dátuma: 2. November 2021.].

[6] Saitex, "Everlane," 2021. [Online]. Available: https://www.everlane.com/denim-factory. [Accessed 3. November 2021.].

[7] E. Woollacott, "Making beautiful colours without toxic chemicals," 30 January 2020. [Online]. Available: https://www.bbc.com/news/business-51007426. [Accessed 3 november 2021].

[8] E. Woollacott, "Making beautiful colours without toxic chemicals," 31. January 2020.. [Online]. Available: https://www.bbc.com/news/business-51007426. [Accessed 3. November 2021.].

[9] M. Wheeler, "The Future of Denim, Part #1: How the humble jean is redefining sustainable style.," 2019. [Online]. Available: https://www.fashionrevolution.org/the-future-of-denim-part-1-how-the-humble-jean-is-redefining-sustainable-style/. [Accessed 2021].

[10] E. Csanák, "'Denimized': Fashion, Passion and Innovation," in *University of Zagreb*, Zagreb, 2016.

[11] K. Roshitsh, "Short Takes: Saitex's New L.A. Denim Factory, Mass Appeal of Sustainability," 10 March 2021. [Online]. Available: https://wwd.com/sustainability/business/saitex-clean-sustainable-jeans-denim-mass-market-1234775048/. [Accessed 11 March 2021].

[12] L. Insights, "Dutch sustainable denim initiative uses blockchain for cotton traceability," 8 March 2021. [Online]. Available: https://www.ledgerinsights.com/dutch-sustainable-denim-deal-initiative-blockchain-for-cotton-traceability/. [Accessed 9 March 2021].

[13] T. Little, The Future of Fashion: Understanding Sustainability in the Fashion Industry, New Degree Press, 2018.

[14] L. D. Burns, Sustainability and Social Change in Fashion, London: Fairchild Books, 2019.

[15] S. S. Muthu, Sustainability in Denim, Cambridge: Woodhead Publishing, 2017.

[16] P. Szmydke-Cacciapalle, Making Jeans Green: Linking Sustainability, Business and Fashion, New York: Routledge, 2018.

[17] Greenpeace International, „Toxic Threads: Putting Pollution on Parade," Greenpeace International, Amsterdam, 2012.

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LIFELONG KINDERGARTEN: THE PAST AND PRESENT OF FRIEDRICH FRÖBEL'S TEACHING PHILOSOPHY IN CULTIVATING CREATIVITY

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Abstract:

The title is borrowed from a book written by Mitchel Resnick (1956) who is the Director of the Lifelong Kindergarten group at the Massachusetts Institute of Technology Media Lab. His position already suggests that the kindergarten is way more than a day-care institution where children may spend time in a safe and loving environment.

This paper seeks to explore the main motives that led Friedrich Fröbel (1782-1852) to the establishment of his series of experimental pre-schools from the early 19th century onward, that distinguished them from the already existing similar social institutions. It will be shown that despite the challenges the kindergarten and their founders themselves have been witnessing since the very beginnings, the firm foundations of its philosophy allow it to survive and to revive itself and become a major component in any progressive-creative endeavour.

The author of the present paper brings examples for the manifestations of the Fröbelian pedagogy both in the work of modern artists and architects, and its multi-layered connection to the Bauhaus school. The main focus is to provide an overview of the present creative enterprises that draw heavily on the kindergarten philosophy – Professor Resnick's research group and how they transformed it into a methodology that boosts (childhood) creativity in the 21st century.

Keywords:

Friedrich Fröbel, kindergarten, Bauhaus, MIT

INTRODUCTION: KINDERGARTEN AT MIT MEDIA LAB

"My nomination for the greatest invention of the previous thousand years? Kindergarten" – writes Mitchel Resnick (1956) in his award-winning book *Lifelong Kindergarten Cultivating Creativity through Projects, Passion, Peers and Play* [1]. As a LEGO Papert Professor of Learning Research at the MIT Media Lab which focuses on designing learning experience that is engaging and fun through new technologies and activities, Resnick is not the first who takes Friedrich Fröbel's brainchild, the kindergarten to be a point of reference in reforming our attitude towards learning and knowledge. Fröbel, through his unconventional life experience in educating himself and finding his life-mission proved to be an enduring legacy in preparing individuals for an active role in society in an age which deprived its population from a sense of integration and belonging coming from shared values and knowledge.

FRIEDRICH FRÖBEL (1782-1852) AND THE INVENTION OF THE KINDERGARTEN

2.1 Childhood experience and the finding of his vocation

From the onset Fröbel was heated by idealistic goals. After and amidst of war-ridden history, he wanted to contribute to the birth of a humanity that lived in harmony with nature and with each other which set him on a long quest. Son of a Lutheran pastor, he lost his mother before the age of one. Due to his movement coordination challenges, during his first years he was practically locked into his father's house, where he received little attention. The unhappy boy was taken under the patronage of his uncle, who was also a pastor. While staying with him, he experienced the beneficial effects of playing outside in nature, which came to be the cornerstone of his later pedagogy.

Because of his passion for nature and introverted figure, he first studied forestry and later opted for architecture after various careers in science. Due to his constant financial difficulties, he undertook various tutoring posts; at the beginning of his architectural studies in Frankfurt at a school headed by Dr. Anton Gruner, one of the patrons of Johann Heinrich Pestalozzi (1746-1827), the pioneer of "natural teaching" in Switzerland. This encounter prompted Fröbel to abandon his original plans in order to become an apprentice at Pestalozzi's Swiss institution.

Pestalozzi's school in Yverdon was a practical test of the educational principles described in Jean-Jaques Rousseau's (1712-1778) work *Emile* (1762), which informed Fröbel's thinking as well. Rousseau's suggestion is that the engine of learning is the child's curiosity that teachers only gently direct. Children develop during active pursuits that involve physical experience; their "curriculum" moves from the simple to the complex – the educators include learning stages into their rather free daily program. The real means of education are not books, but various (natural) objects. Pestalozzi also constructed an experimental ABC that decomposed the letters into a combination of squares and curves enclosed in a square grid. Composing with basic geometric shapes that can be arranged in a square grid later became an important element not only of Fröbel's method but also of modern architecture and typography.

Fröbel encountered the geometric structure of nature in his earlier studies in botany and crystallography, which experience he deepened during his position at the University of Berlin – a reward for his participation in the Napoleonic Wars – where he organized the crystal collection under the professional guidance of his revered professor, Christian Samuel Weiss (1780-1856) who was the founder of the crystal classification method he employed. During the two years thus spent, he became thoroughly acquainted with the laws of crystal growth, discovering the stages of development of all forms of creation, and considered it to be the best means of acquainting children with the harmony created by a higher power in the universe. [2]

2.2 The kindergarten philosophy

In 1817, in recognition of his professional excellence, Fröbel was offered a professorship at Stockholm University, but he decided to set up his own educational institution instead, where he was involved not only with the education of pre-schoolers but also with the development and teaching of his methodology. His scarce philosophical writing, which did not provide a systematic theoretical basis during his three decades of pedagogical activity, recalls the ideals of the Neoplatonist-pantheist characteristic of German Mysticism and Romanticism by the Lutheran pastor Jacob Böhme (1575-1624) and Friedrich

Schleiermacher (1768-1834) but more importantly, is based on his lived experience coming from the physical manipulation of objects.

The essence of the Fröbel method was its philosophy that geometric rules prevailed behind the manifested universe, which became tangible to children as they played with the simple geometric devices he invented. Fröbel did not expect, as later criticized by child psychologists, that at this age these connections would be intellectually perceptible; rather, he tried to tune children's sensitivity to these laws and thus to the harmony of the universe. Simple geometric forms were personified as people, animals, plants in the improvised tales that accompanied active play. Few kindergarten educators had such extensive scientific knowledge as Fröbel, thus it was precisely this metaphysical content that declined during the spread of the kindergarten movement in the promotional literature written by his followers and in the kindergarten teacher courses they organized.

2.3 The kindergarten pedagogy in modern art, architecture and the Bauhaus

Friedrich Fröbel is best known to designers today through Frank Lloyd Wright (1867-1959), who in his autobiographies traced his very first attempts in architecture to his childhood preoccupation with the fröbelian teaching devices, the so called Fröbel gifts. Wright grew up in one of the late 19th century "progressive" middle-class families among which the kindergarten teaching method was well known.

This popularity was not only because the fröbelian ideal was an alternative to mainstream education streamlined for rote learning, but also because it offered a status for mothers who, completing kindergarten teaching courses addressed directly for them, could act as trained educators for their children. Citizens of leading industrial nations value efficiency and the idea that everything would be better if experts identified problems and fixed them – probably this view supported the desirability of the specialization of women to become professional mothers. Thus, while her visit to the 1876 Philadelphia World Fair, Anna Wright decided upon purchasing maple wood building blocks and a kindergarten teachers' course for herself to ensure her son's successful career as an architect.

In addition to Wright, a whole generation of artists and grew up in kindergarten institutions: among others, Georges Braque (1882-1963), Paul Klee (1879 -1940), Piet Mondrian (1872-1947), Wassily Kandinsky (1866-1944), Le Corbusier (1887-1965) Richard Buckminster Fuller (1895-1983) and Johannes Itten (1888-1967). The latter also had a kindergarten educator qualification, and he employed the method during his teaching years in the Bauhaus, which also influenced the pedagogical work of Klee (*Pedagogical Sketchbook* 1925) and Kandinsky (*Point and Line to Plane*, 1926). [3]

The kindergarten movement, together with the Bauhaus, became one of the strongest trends in German pedagogical reform movements in the 1920s, influencing each other's development beyond the educational methodology. Walter Gropius (1883-1969) was in charge of designing the 'Friedrich Fröbel House' in 1924 which was to be built in Bad Liebenstein, Thuringia. The briefing and the spatial organization of this institution, which eventually was not realized due to a lack of financial resources, inspired the design of the Dessau Bauhaus School buildings – the similarities of the two concepts are very apparent from the surviving plans and drawings. [4]

There is an even more striking resemblance between compositions that can be assembled from Fröbel gifts and many modern paintings and buildings. Although these works prove Fröbel's contentions that childhood experiences shape the future outlook on the world of the individual, it took a similarly unconventional and influential individual and those inspired by his tenets to provide psychological underpinning and practical evidence about the potentials of active learning. [5]

Paper weaving, unknown kindergarten creation and Piet Mondrian's New York City III unfinished composition (1941-42)

THE ENCOUNTER OF CHILD PSYCHLOGY AND COMPUTER SCIENCE

3.1 Jean Piaget (1896-1980) and Seymour Aubrey Papert (1928-2016)

Contemporary with the Bauhaus movement, in the early 1920s, Jean Piaget conducted research in human cognition that corroborated the Gestalt psychological principles widely applied in modern art. Like Fröbel, Piaget placed great significance on the education of early childhood and proposed a later much-debated theory on the cognitive development of children where he differentiates 4 major stages through which our perception of the world and the internal we construct upon them develop and published his results of extensive testing in his foundational treatise *The Child's Conception of the World* in 1929. [6]

While many in his intellectual circles – including Albert Einstein – left their homeland with the rise of Nazism, Piaget remained stationed in the neutral Switzerland, where, working at the University of Geneva has met his student, the South African-born Seymour Aubrey Papert, who was a mathematician and computer scientist with whom they worked together from 1958 to 1963. Their collaboration is well expressed in Piaget appreciation of Papert's sensitivity "no one understands my ideas as well as Papert". [7]

In 1963 Papert took up a position at MIT as a pioneer in artificial intelligence studies co-directing the Artificial Intelligence Lab and spent all his active life there as a researcher and an educator until 1981. Drawing on Piaget's cognitive development theories, often called as constructivism, he proposed his own take on the idea which made him the founder of the constructionism movement in education. Its prime tenet was that the most efficient learning takes place when real, tangible object are created during the learning process. Papert advocated a systems-approach so that students start from their own experiences and within a project-framework they discover new ideas through making connections between various elements of that system.

3.2 Mindstorms, the collaboration between Papert and the LEGO group

Papert was particularly intrigued by the potentials new technologies may open in the field of learning, specifically in school education. For this purpose, he created the Epistemology and Learning Research Group at the MIT, the forerunner of the present Media Lab where from the late 1960s onwards he developed the first programming language for children, Logo, to enhance their problem-solving approach using modern computing technology. In applying his constructionist principles, he paid particular attention to the development of the learning environment and came up with the playful idea that children were to program the movements of a friendly creature, a turtle which was either a physically built small robot, the 'Logo Turtle' or a graphic image on the computer screen.

Papert was not a technocrat who wished to introduce modern technology in a very young age through which children end up losing their ability to create intimacy with their immediate surrounding. In his ground-breaking book, *Mindstorms: Children, Computers and Powerful Ideas* published in 1980, he unfolds his view that it was the responsibility of science to ingrain children with a sense of mastery over technology to avoid an undesirable outcome, when technology holds a grip on them when reaching adulthood. His words echo the idealism of Fröbel*:* "the child programs the computer and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building." [8]

In 1985, Papert established a company with his colleagues Mitchel Resnick and Stephen Ocko which they named Microworlds, with the aim to surpass the limitation the turtle shape imposed on the Logo programming project. Their idea was to open up the design of the programmable object to children and to develop a construction kit that facilitated the creation of such self-made robots. The Logo Turtle was already a popular item that was documented in popular science media; the Danish television screened a documentary of Papert's pedagogy in action, which Kjeld Kirk Kristiansen (1947), the then owner of the Lego Group happened to watch. He immediately contacted Papert as LEGO's education division shared very similar goals with that of the Microworlds company.

The collaboration was quickly agreed upon and was moved back to the MIT Media Lab where research was sponsored by the LEGO Group. The Lab was both developing the technology and was responsible for its testing it by children. This initiative was so ahead of time that LEGO had to wait for a while until personal computers came to be common household items and the production parts needed for mass manufacturing of the intelligent bricks were affordable. This was the foundation of the LEGO

Mindstorms product line which began in 1996 under the development of the home-learning division of LEGO Education.

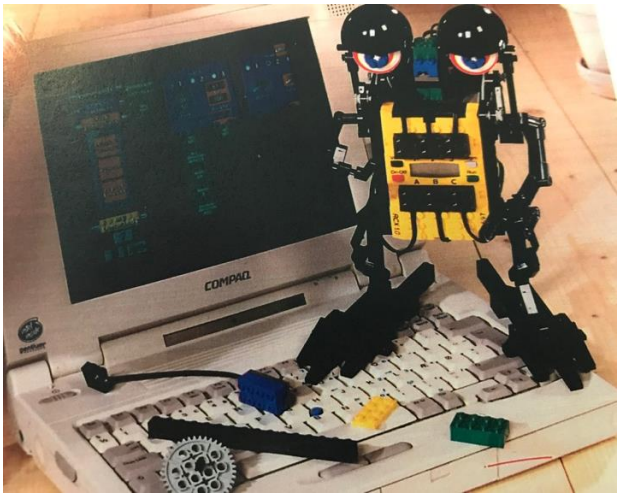

Figure 2: LEGO Mindstorms model from 1996

3.3 The Lifelong Kindergarten Group

Mitchel Resnick is a former student and long-time collaborator of Papert, who succeeded him as a LEGO Professor and is the head of MIT Media Lab's Lifelong Kindergarten research group. Following Papert's footsteps the group maintained the collaboration with the LEGO Company and participated in the development of the LEGO WeDo Robotics Kit. They also extended Papert's passion towards children programming software and introduced 'Scratch' around which a global online free community has been centred since its public launch in 2007.

According to their recent statistics the Scratch website that is being translated into over 70 languages connects 74 million users who keep in touch not exclusively in the online space, but also in self-organized public events where the 'Scratchers' may meet in person. Scratch, as a free product is not only a user-friendly programming language, but with time, its extensions came to be available, both software and hardware-based, including the above-mentioned LEGO WeDo kits, thus following the Logo Turtle 'tradition'. Although Scratch is mainly targeted at children, users include educators and parents, a trend intended by the creators of the software.

This type of community dynamics was borrowed from Resnick's other major co-initiative, the Computer Clubhouse Network founded in 1993 and sponsored primarily by Intel. This non-for-profit organization targets children of underserved communities who meet afterschool and interact in person with their mentors who assist them in their development as creative users of advanced technology that build their confidence and perspective. Whereas Scratch relies on the users' own resources, the Clubhouse initiative provides today 25,000 youth with access to resources, skills and experiences to assist them succeed in their careers and serving back to their communities.

Figure 3: Scratch logo

CONCLUSIONS

The very foundation of both Fröbel's and Resnick's kindergarten concept is the same – to create an ideal society. They both believe that the earliest possible exposure to a 'true' knowledge is the key for the realization of such an ideal. However, Fröbel, contrary to Papert or Resnick was not a social reformer, he spoke solely for the development of the human soul, which unintentionally made him a proponent of social ideals he was not wishing to address. It is probably his troubled, sensory-deprived childhood that made him a Platonic adorer of women and a proponent of the role of sensory experiences during the discovery process of the world.

Although in Petalozzi's institution Fröbel worked with orphans, his vision was broader than aiming to elevate youth of underserviced communities to a desired social standard. Fröbel was willing to avoid clashes with the political mainstream of his age as his primary goal was to lay the foundation of early childhood education and leave a legacy so that his followers could take on his initiative. Unfortunately, life brought about that kindergarten pedagogy was mistaken for a revolutionary movement with political overtones, due to the involvement of such social circles and activities of Fröbel's nephew, whom he brought up as his own child – this controversy led to the official closing down of his pre-schools and eventually to his depression and death.

Together with other contemporary educational reformers, Papert and Resnick's explicit aim is to reform education as a whole through which to arrive at a "creative society". Papert presents the underlying reasons of his choice for developing a children programming language as follows: "The computer is the Proteus of machines. Its essence is its universality, its power to simulate. Because it can take on a thousand forms and can serve a thousand functions, it can appeal to a thousand tastes." (Papert 1980, p. viii) Here, he refers to his early childhood fascination with differential gears, and how this deep impression served him later in enabling him to think in complex mathematical terms. But, as he reckons, differential gears do not possess the potential to become universal inspiration for mathematical thinking, as opposed to computers.

It remains debatable whether the computer can be considered such a universally successful device which is capable to kindle every single child's fantasy and interest. Professor Resnick's claim: "We need to develop better technologies, activities and strategies for engaging children in creative learning activities" (Resnick, p. 181) suggests a technological bias that is more explicit in the failed One Laptop per Child (OLPC) initiative, a joint project of Papert, Resnick and other professionals from the MIT Tech Lab. The program, which was launched in 2005 aimed to provide children in developing countries with access to computer literacy. The major means in achieving this goal was identified with the development of a very basic laptop and software, the so called OLPC XO, which was to be mass-distributed in the countries of the Global South.

The positive aspect of this project was the development of a (1) low cost and low power computer, (2) the general recognition of the importance of computer literacy's role in primary education (3) the development of an interface that did not require literacy in any language. However, the project was criticized for its blindness to the real challenges that children were exposed to in developing countries, for the little attention paid for the maintainability of the devices and for the training of software-use which resulted in the shutting down of the initiative in 2014, acknowledging its failure.

Undoubtedly, utopia and realism intermingle in all the above introduced stories, as it does in every idealistic endeavour of humanity. A one-size-fits -to-all approach is more likely to fail especially when the one-problem-of-all does not exist. It remains an enigma, whether Fröbel would embrace contemporary technology to the extent MIT professionals do today and whether the benefits of technology would make him to rank direct experience in nature behind the use of technical devises. Without being able to answer this question, the lost sense of community and belonging that was brought about the Industrial Revolution seems to find its remedy in the noble ambitions of the Lifelong Kindergarten group.

REFERENCES

Resnick, M.: *LIFELONG KINDERGARTEN, CULTIVATING CREATIVITY THROUGH PROJECTS, PASSION, PEERS, AND PLAY*, MIT PRESS., ISBN 978-0262037297, CAMBRIDGE, MA., (2017)

Elkind, D.: *GIANTS IN THE NURSERY, A BIOGRAPHICAL HISTORY OF DEVELOPMENTALLY APPROPRIATE PRACTICE*, REDLEAF PRESS, ISBN 978-1605543703, ST. PAUL, (2015)

Brosterman, N.: *INVENTING KINDERGARTEN*, HARRY N. ABRAMS, ISBN 0-8109-3526-0, NEW YORK, (1997)

MacCarthy, F.: *GROPIUS, VISONARY FOUNDER OF THE BAUHAUS*, FABER & FABER, ISBN 978-0571295142, LONDON, (2020)

Kinchin, D.; O'Connor, A.: *CENTURY OF THE CHILD, GROWING BY DESIGN 1900-2000*, THE MUSEUM OF MODERN ART, ISBN 978-0870708268, NEW YORK, (2012)

Gamwell, l.: *MATHEMATICS AND ART, A CULTURAL HISTORY*, PRINCETON UNIVERSITY PRESS., ISBN 978-0-691-16528-8, PRINCETON, (2016)

Thornburg, D.: *FROM THE CAMPFIRE TO THE HOLODECK, CREATING ENGAGING AND POWERFUL 21ST CENTURY LEARNING ENVIRONMENTS*, JOSSEY-BASS, ISBN 978-1118633939, SAN FRANCISCO, (2013)

Papert, S.: *MINDSTORMS, CHILDREN, COMPUTERS AND POWERFUL IDEAS*, BASIC BOOKS INC., ISBN 0-465-04627-4, NEW YORK, (1980)

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ISBN: 978-963-449-262-7

2021