# ICSD 2021

## 7TH INTERNATIONAL CONFERENCE ON SUSTAINABLE DEVELOPMENT

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# *WELCOME TO ICSD 2021*

*On behalf of the organizing committee, we are pleased to announce that the 4th International Conference on Sustainable Development (ICSD-2021) is held from October 13-17, 2021 in Istanbul, Turkey (Hybrid Conference). ICSD 2021 provides an ideal academic platform for researchers to present the latest research findings and describe emerging technologies, and directions in Sustainable Development issues. The conference seeks to contribute to presenting novel research results in all aspects of Sustainable Development. The conference aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results about all aspects of Sustainable Development. It also provides the premier interdisciplinary forum for scientists, engineers, and practitioners to present their latest research results, ideas, developments, and applications in all areas of Engineering and Natural Sciences. The conference will bring together leading academic scientists, researchers and scholars in the domain of interest from around the world. ICSD 2021 is the oncoming event of the successful conference series focusing on Sustainable Development. The scientific program focuses on current advances in the research, production and use of Engineering and Natural Sciences with particular focus on their role in maintaining academic level in Engineering and Applied Sciences and elevating the science level. The conference's goals are to provide a scientific forum for all international prestige scholars around the world and enable the interactive exchange of state-of-the-art knowledge. The conference will focus on evidence-based benefits proven in clinical trials and scientific experiments.*

***Best regards,***

***Prof. Dr. Özer ÇINAR***

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# The behavior of irreversible thermochromic inks in the paper recycling process

***Marina Vukoje*[1*]*, Ivana Bolanča Mirković*[1]*, Rahela Kulčar*[1]*, Renato Glibo*[1]**

***Abstract***

*Thermochromic printing inks are special chromogenic inks that change their color by exposure at a certain temperature, which is usually called the activation temperature (TA). The color change can be irreversible or reversible. The property of irreversible color change in relation to temperature exposure over time, allows the development of numerous indicators. As such, they can be used to monitor the storage and transportation of temperature-sensitive products, such as refrigerated and frozen foods, drugs, temperature-sensitive chemicals, or biological materials, etc. Since the ink formulation is an important factor in the deinking process, the aim of this research is to determine the recycling efficiency of irreversible thermochromic prints. Thermochromic inks differ from conventional printing inks in formulation and pigment size due to the presence of microcapsules that are much larger than conventional pigment particles. For this study, two irreversible thermochromic printing inks are printed by screen printing in full tone, on one printing substrate. To explain the behavior of these inks in the recycling process, the hydrophobicity of the sample surface was examined, as one significant factor in the flotation process using the contact angle of water. Recycling of prints was carried out in laboratory conditions, by chemical deinking flotation in alkaline conditions. Sheets were made for each sample before and after flotation. Optical properties of the recycled samples show that these inks are difficult to recycle. The deinking flotation method is not entirely the best method for recycling of irreversible thermochromic inks because slight differences in the optical properties of the laboratory paper samples before and after flotation are achieved. Future research should go in the direction of new techniques such as adsorption and enzymatic deinking.*

**Keywords:** thermochromic inks, paper recycling, optical properties, surface properties

## 1. INTRODUCTION

The waste paper recycling process and its use to produce new product reduces the number of trees that are cut down, as well as water and energy consumption conserving natural resources [1]. In order to obtain recycled fibers suitable for the production of recycled paper, the printing ink and other impurities must be separated to the greatest extent from the pulp suspension. The amount of residual ink in the suspension affects the final optical properties of the recycled paper. Therefore, a process for removal of printing ink is required. Deinking flotation is the most common process used for the separation of ink from the pulp suspension by means of air bubbles performed in a flotation cell. Inside the cell, the device blows out hydrophobic air bubbles that mix with the suspension and the hydrophobic ink particles cling to them and go towards the surface, while removable flotation foam (froth) forms on the surface [2]–[4]. Flotation can be aided by the use of different chemicals that increase the hydrophobicity property of the ink particles. Flotation efficiency is affected by various parameters such as the ability of the ink to bind to the air bubble, the ink to collide with the bubble, and the removal of flotation froth from the surface of the suspension during flotation [2], [4]. The brightness of the

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pulp is very often a measure of the efficiency of the flotation process since the removal of printing ink from the system affects the pulp's brightness [5], [6].

Smart materials are often discussed as materials that feel some stimulus from the external environment and create a useful response. Perhaps it is better to think of the answer, often called "smart behavior", which occurs when the environment reacts in a useful and reliable way, without affecting the material itself. Thermochromism is the specific ability of a substance, atomic group, or material to change its optical state. Materials that, within their complex structure, have a dynamic mechanism of color change due to the change in temperature that affects the complex formation, introduce an innovation to the market while offering improved product information transfer. Thermochromic mechanisms are divided according to the criterion of duration into reversible (multiple and temporary color change) and irreversible (single and permanent color change). Thermochromism in the printing industry is widely used precisely because of the new channel of information communication to the end user. Therefore, the thermochromic mechanism finds its benefits in terms of smart packaging, security printing, a multitude of promotional and marketing visuals. Thermochromic inks are composed of thermochromic pigments and vehicle. Thermochromic pigments are mainly encapsulated leuco dye-developer-solvent systems. Leuco dyes are colorless or weakly colored compounds which in reaction with a developer transform into a colored state [7].

Nowdays, more and more products on the market, precisely because of their competitiveness, strive to develop new functional properties that will attract consumers. Each new formulation will have a different effect on the environment, so it is necessary to determine the environmental impact of all new components, *i.e.* materials [8]. When it comes to reversible thermochromic printing inks, the research on their potential environmental and safety risks are limited. Thermochromic offset printing inks are very difficult to recycle by means of chemical deinking flotation method, while biodegradability studies showed that polymerized ink vehicle (vegetable oil + resin) in thermochromic offset ink is more stable than the polymer resin present in UV curable screen printing thermochromic ink (polyurethane acrylate) [9]–[11]. Additionally, another potential problem with thermochromic inks is the presence of bisphenol A (BPA) as one of the main compounds and its potential migration from the surface of the thermochromic print to artificial sweat solutions [12], [13], as well as the presence of BPA recycled paper made from thermochromic prints [14].

Thus, the aim of this study is to examine the possibility of thermochromic irreversible ink recycling and ink behavior in recycling process.

## 2. EXPERIMENTAL PART

### *2.1. Materials*

In the preparation of experiment, two irreversible thermochromic printing inks were used, Kromagen Magenta MB60-NH (hereinafter 60MG), with an activation temperature of 60° C, and Termosil Red 75/80 (hereinafter 120MG) with an activation temperature of 75-80° C. Both printing inks were screen printed using semi-automatic screen-printing device (Holzschuher K.G., Wuppertal), employing 62/64 mesh for 60MG thermochromic ink, and 120 mesh for 120MG TC ink, on uncoated paper (120 $g/m^2$). All prints were made in full tone. The printing inks when exposed to activation temperature change color permanently, 60MG changes color from light pink to purple, while 120MG changes color from colorless to magenta.

### *2.2. Methods*

### *2.3. Evaluation of surface wettability*

The evaluation of surface wettability of paper and prints (inactivated and activated) were carried out by water contact angle measurements on DataPhysics OCA 30 Goniometer, using the Sessile Drop method. Measurements were performed at room temperature 23.0 ± 0.2ºC. The volume of water droplet was 1 µl. Contact angle was captured by CCD camera and measured 1–2 s after the droplet was formed. Average values of ten drops on different places of the same sample were taken and presented as mean±SD.

### *2.4. Paper recycling process*

Printed paper samples were recycled by means of chemical deinking flotation under laboratory conditions defined by standard procedures described in ISO 21993:2020 [15], as presented in Figure 1. Unprinted paper and irreversible thermochromic prints were disintegrated in Enrico Toniolo disintegrator, while the flotation process was performed in the laboratory flotation cell. A certain amount of pulp suspension was separated after disintegration process before flotation (BF) and after flotation process (F) to prepare laboratory sheets of 45 $g/m^2$, using automatic sheet-forming device Rapid-Kothen Sheet, PTI.

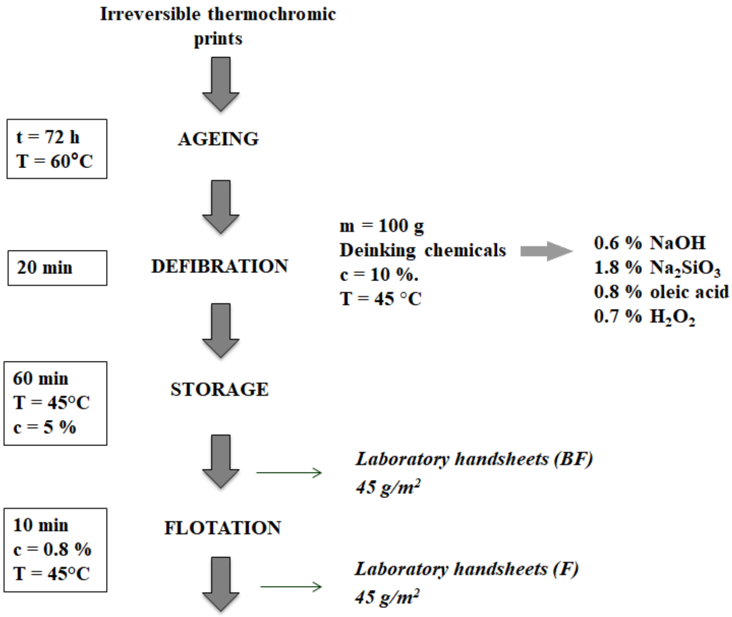


*Figure 1.Shematic view of samples recycling process*

### *2.4.1. Deinkability evaluation*

The efficiency of recycling process was evaluated by measuring optical properties of laboratory handsheets made from undeinked pulp (BF) and deinked pulp (F). Evaluation of optical parameters was conducted according to standard methods: ISO Brightness (ISO 2470), CIE whiteness and colorimetric properties (ISO 11475) and ISO Opacity (ISO 2471) using Technydine Colour Touch 2 Spectrophotometer.

## 3. RESULTS AND DISCUSSION

In order to explain the behavior of the irreversible TC inks used in paper recycling, surface wettability of prints was determined. The contact angle of the water droplet on the substrate surface greater than 90° indicates that the substrate surface is hydrophobic while contact angle smaller than 90° indicates that surface is hydrophilic. Surface hydrophobicity can play a significant role in the deinking flotation process i.e., hydrophobic particles should be easier to remove from the pulp suspension.

The results of the contact angle measurements show that the unprinted paper substrate and the 120MG prints in the activated and inactivated state are hydrophobic (the water contact angle is greater than 90°) (Table 1). The results of the 60MG sample show that in the activated and inactivated state the print surface is hydrophilic with a water contact angle smaller than 90°. It is possible that this phenomenon occurs because the thermochromic inks composition. The components in printing ink binder can contain compounds with functional groups which give hydrophilic/hydrophobic character of the print. For example, vegetable oil in which the ester groups are present increase the hydrophilic character of the prints [16].

*Table 1. Contact angle (θ) of unprinted paper and thermochromic printed surfaces*

| | Unprinted substrate | 60MG | $60MG_{activated}$ | 120MG | $120MG_{activated}$ |
|---|---|---|---|---|---|
| θ / ° | 96.65±1.03 | 85.3±1.07 | 86.51±1.37 | 112.02±1.14 | 103.39±0.67 |

To determine the efficiency of the recycling process, laboratory paper handsheets (45g/m$^2$) made before (BF) and after flotation (F) process were examined for their optical properties in the terms of ISO Brightness, CIE whiteness and colorimetric properties and ISO Opacity.

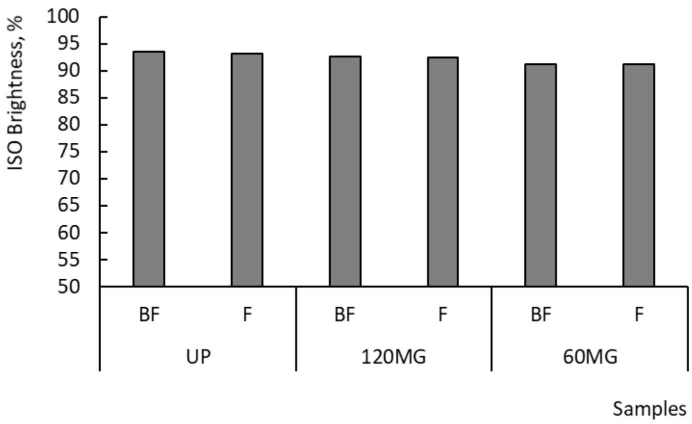


*Figure 2. ISO Brightness of recycled fibres*

The ISO brightness values of all samples are quite the same (Figure 2), with the highest value for the samples made of unprinted paper (93%), followed by the samples made from 120MG (92%) and the lowest for the 60MG sample (91%). The flotation process had no effect on the ISO brightness change for all samples (Figure). The lowest ISO brightness value is obtained for the 60MG sample, probably due to the hydrophilicity of the printed surface (Table 1).

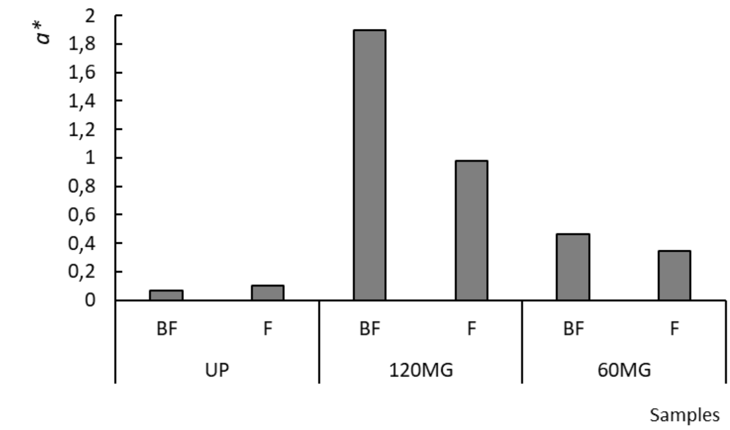


*Figure 3. Colorimetric parameter CIE a* of recycled fibers*

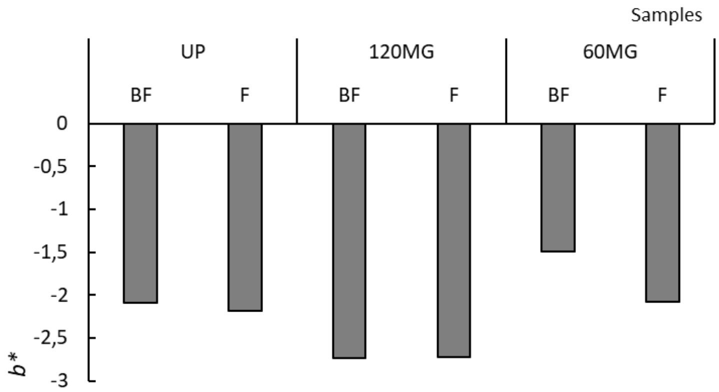


*Figure 4. Colorimetric parameter CIE b* of recycled fibers*

The values of the colorimetric parameter *a** (Figure 3) are highest for paper samples obtained by recycling of irreversible 120MG thermochromic prints, followed by recycled papers made from 60MG. The values on these samples are higher before flotation, which means that the ink particles are partially removed by flotation. A value of *a** indicates a shift to the red area, indicating a slight coloration of the laboratory paper handsheets.

Although the higher hydrophilicity of the 60MG thermochromic print surface was expected to result in a higher ink residue in the pulp suspension, this was not obtained in this study. The value of the colorimetric parameter *a** indicates that the more hydrophobic TC ink (120MG) remained in higher share in the pulp, while the hydrophilic TC ink showed lower *a** value, i.e., has smaller residue in pulp suspension.

The results of the colorimetric parameter *b** (Figure 4) for the recycled paper (before and after flotation process) made from unprinted paper and 120MG thermochromic prints are quite the same, i.e., the flotation process does not affect the *b** values. while after the flotation process they give higher values (Figure 11). The results of the paper obtained by recycling the samples printed with thermochromic ink 60MG show the lowest values of b *, which indicates a smaller shift to the blue area compared to other tested samples.

Larger changes in CIE whiteness values occur after flotation in all samples (Figure 4), but these changes are very small. For recycled papers made from unprinted paper samples, the whiteness value before and after flotation is almost identical.

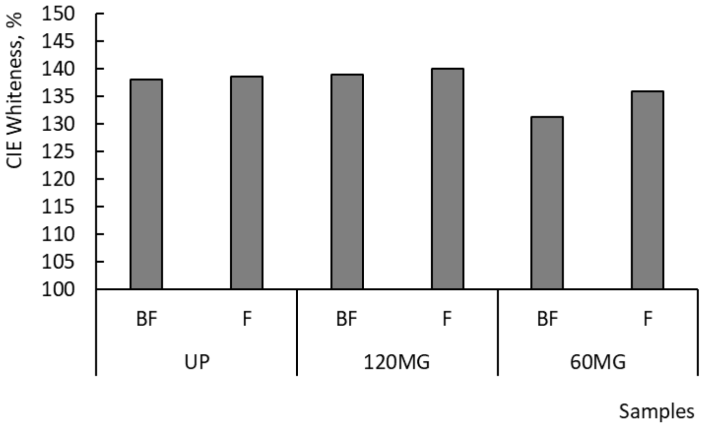


*Figure 5. CIE Whiteness values of recycled fibers depending*

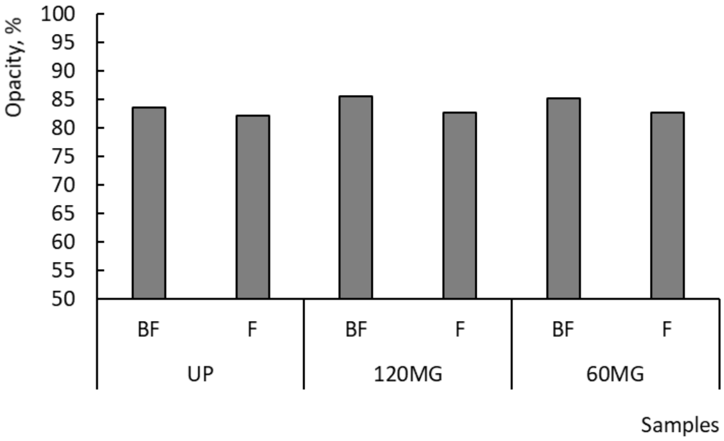


*Figure 6. ISO opacity of recycled fibers*

The opacity values of all samples are approximately the same (Figure 5). The results show that flotation process causes the loss of the fillers in the paper and the loss of them reduces the paper opacity. In samples obtained by recycling of unprinted paper, a decrease in opacity after flotation by about 1.37% is visible, while in samples obtained by recycling irreversible TC prints, a decrease in opacity is about 3.38% for 120MG and 2.95% for the 60MG sample, respectively. From this it could be concluded that the TC ink itself contributes to the loss of fillers, i.e., in some way it probably causes the filler particles to stick together resulting in higher removal in the flotation foam.

## 4. CONCLUSIONS

Despite the fact that the consumption of these kinds of printing inks is still limited, due to a Precautionary Principle it is necessar to examine thir possible impact on paper recycling process. The results of the optical properties of the recycled laboratory paper show that used irreversible thermochromic inks are difficult to recycle, although some changes were obtained by flotation, but the differences obtained are insignificant, i.e., very small. Also, the flotation process reduces the opacity of recycled paper because flotation causes the removal of the fillers that serves as a substitute between cellulose fibers and paper. In addition, it can be assumed that a loss of optical brighteners occurred as well, especially in the TC ink sample which shows more hydrophilic character of the print surface. The deinking flotation method is not entirely the best method for recycling of irreversible thermochromic prints because slight differences in the optical properties of the recycled laboratory paper (obtained before and after flotation) are achieved. Also, the colorimetric parameters indicate a slight coloration of the sheets of paper which may point to the release of colorants into the pulp suspension. Future research should be focused on new processes and/or chemicals research, such as adsorption or enzymatic deinking, which in other studies have proven to be successful methods for removal of poorly deinkable inks like water-based inks.

## ACKNOWLEDGMENT

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***Biography***: Marina Vukoje was born in 1987, Slavonski Brod, Croatia. She graduated from the University of Zagreb Faculty of Chemical Engineering and Technology, study course of Environmental Engineering in 2011. In October 2012 she was employed as an assistant at the Department of Environmental Protection, Faculty of

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# Durability Examination of the UHF RFID Labels with Respect to Environmental Changes in Terms of Elevated Temperature and UV radiation

***Katarina Itrić Ivanda[1], Marina Vukoje[1], Dorotea Kovačević[1], Rahela Kulčar[1]***

***Abstract***

*One of the key points of interest of sustainability is the preservation of products in order to make full use of their predicted lifespan. In that sense UHF RFID labels are no different. UHF RFID labels have replaced traditional labels in a wide range of products, from unique luxury products to commercial packaging. The reason lies primarily in economy. Namely, tagged products are easy to track throughout the entire production and supply chain. The question arises as to what extent the quality of the label is affected by exposure to different environmental conditions within production and distribution chain process. To this end, durability of the UHF RFID labels with respect to environmental changes were examined. Samples were exposed to electromagnetic radiation (artificial aging for 48h and 96h) and elevated temperatures (50 °C and 60 °C). Changes in the conductivity and read range frequency of the UHF RFID label antennas were determined. In order to get an insight into the degree of degradation, image analysis of the samples was performed with the Personal IAS imaging device.*

**Keywords:** degradation, imaging, UHF RFID labels

## 1. INTRODUCTION

One of the key points of interest of sustainability is the preservation of products in order to make full use of their predicted lifespan. In that sense UHF RFID labels are no different. RFID labels are more and more present in the everyday life and have a wide range of applications that include manufacturing (inventory control, inventory management), different transport processes (shipping, vehicle tracking, supply chain logistics and distribution, livestock tracking), healthcare (equipment tracking, medication tracking), security systems, retail sales etc. Different areas of use imply the need for certain characteristics of labels primarily in relation to their durability caused by different ways of storage and transport of labeled products.

In order to address the durability and longlivity of UHF RFID tags we must first get acquainted with the basic concepts of RFID technology. RFID tag is constructed from two elementary parts (the chip and the antenna). If we want to simplify things, we can say that the chip is a miniature computer, while the antenna is a way of communicating between the chip and the reader. Two types of tags can be distinguished, active tags (having their own energy source) and passive tags (communicating when put in an electromagnetic field). The simplest way of explaining how the RFID communicates with the reader is when the reader emits an electromagnetic wave of a specific frequency it interacts with the RFID which in the end results in the back scattering at a frequency that carries information about the chip [1]-[3]. RFID tags come in various shapes and forms.

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In our work we concentrated on the influence of environmental conditions on the longlivety of the UHF RFID tags used for labeling in one of the major sporting goods retailers-Decathlon. Decathlon sells more than 600 million individual products every year through a network of more than 1500 stores in Europe, Africa, South America and Asia [4].

Decathlon integrated their RFID solution in each step within their supply chain allowing enormous benefits of this strategy in their factories, distribution centers and stores. They started tagging all of their own branded products at the manufacturing plants already in 2013. The procedure included placement of RFID labels on items during the manufacturing process. Each RFID label was encoded with a unique identification number stored in the retailer's database.

Decathlon suppliers use handheld RFID readers inside their factories to record and track the transport of products to the distribution centers. The main advantage of RFID identification lies in the ability of making the tracking process easier and faster which in turn reduces the risk of error. Upon the arrival at a distribution center the products' ID is read from the RFID tag and recorded using fixed RFID readers, after which the products are stored for the picking process. Products that are not made by Decathlon and were not tagged at the factory are tagged with an RFID label at the distribution center. In total, more than 85% of products are RFID tagged [5].

Regarding the operation of RFID labels, they are printed and afterwards encoded with a unique identification number. Once the products that were tagged during production are received and the other branded products have been RFID tagged, several types of RFID systems, including mobile readers and RFID reading tunnels, are used to perform cycle counts and shipping control. Decathlon can ensure that the right products are shipped to the right stores.

Upon the arrival at the store, the products are placed on display shelves ready and available for consumers. Store personnel use an RFID handheld reader connected by bluetooth to a smartphone in order to execute efficient shelf inventories which are almost five times faster than with the former systems and technologies. Decathlon keeps up with the wishes of the consumers by installing RFID based check-out systems in order to make the payment process quicker and easier. The system consists of an RFID reader embedded into the check-out table. When a customer wishes to check-out, the cashier simply passes the products across the top of the table to read the product RFID ID encoded into the label without having to use a traditional barcode system [5]. The retailer also installed EAS-RFID gates at the stores entrance as a security measure. Namely, when passing through the gates, RFID tags are detected, so the system can check if the products have been purchased or not, and then alert the security staff.

Storage conditions were the RFID labeled products are held can very drastically with respect to the geographical location of the store, quality of the storage building as well as unexpected extreme conditions during transport. In that sense the question arises in what way the environmental changes, especially elevated temperature and UV radiation impact the quality of the UHF RFID label

## 2. MATERIALS AND METHODS

In our research we will examine passive UHF RFID tags. Namely, Decathlon uses the Tageos 100% paper-based passive UHF RFID tags. The labels have been specifically designed for Decathlon in order to match the various types and sizes of product items to be tagged. Two types of tags were analyzed. For simplicity, we will label them as Tag 1 and Tag 2. They come in a specific format as a double sticker. General characteristcs are the same for both tags. They operate in ETSI 865–868 MHz frequency under EPC Class 1 Gen 2 protocol. Antenna is made out of aluminum. Front face material is white printable paper while the adhesive used is solvent-free permanent acrylic adhesive [6,7].

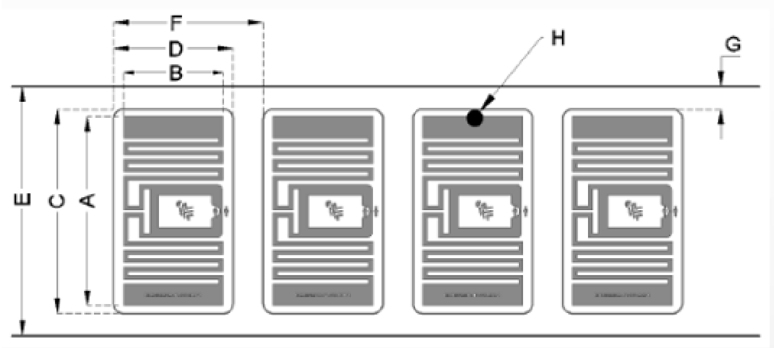


*Figure 7. Tag 1[6]*

*Table 1.Dimensions of tag 1[6]*

| Dimensions | A x B | C x D | E | F | G | H |
|---|---|---|---|---|---|---|
| Description | Antenna size | Label size | Web width | Pitch | Die-cut to web edge | Bad mark |
| Metric/mm | 38 x 20 | 41 x 24 | 50 | 30 ± 0.5 | 4.5 | 4 |

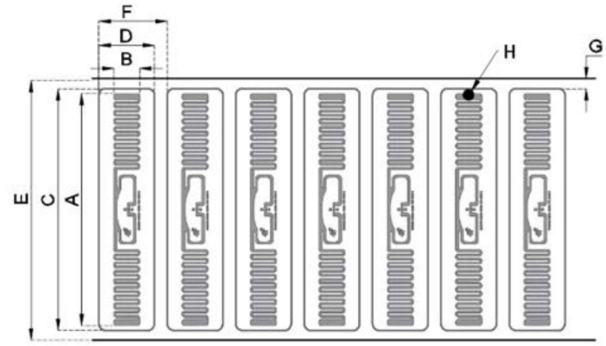


*Figure 2. A sample line graph using colors which contrast well both on screen and on a black-and-white hardcopy[7]*

*Table 2.Dimensions of tag 2[7]*

| Dimensions | A x B | C x D | E | F | G | H |
|---|---|---|---|---|---|---|
| Description | Antenna size | Label size | Web width | Pitch | Die-cut to web edge | Bad mark |
| Metric/mm | 71 x 8 | 74 x 17 | 80 | 21 ± 0.5 | 3 | 4 |

Samples were exposed to electromagnetic radiation in Cofomegra Solarbox 3000 Xenon Test Chamber. (artificial aging for 48h and 96h) according to ISO standard. Also, given the very high temperatures in which the labels/products are stored and transported, we also tested the effect of the elevated temperature, 50 °C and 60 °C, respectively, by exposing the samples in the "Kottermann" air chamber Type 2306 for 48 h and 96 h at 40% relative humidity.¸

Changes in the conductivity and read range frequency of the UHF RFID label antennas were determined according to the research presented in [2].

From the measurements conductivity was computed according to

$$\sigma = \frac{l}{R \cdot t \cdot w} \qquad (1)$$

where $l$ stands for length, $w$ width, $t$ depicts thickness and $R$ is the resistance obtained from current voltage measurement.

In order to get an insight into the degree of degradation, image analysis of the samples was performed with the Personal IAS imaging device. It consists of a measurement head housing a high performance digital camera and an optical modules. The justification for using an analysis device has been discussed earlier in numerous articles [8,9]. The standard optical arrangement is 45/0 geometry, typical for reflective, densitometric measurements. PIAS-II analysis results are displayed in both numerical and graphical form. The user can display contours, bounding boxes, center marks, and ROIs for the image features analyzed.

## 3. RESULTS AND DISCUSSION

Exposure of the tags to elevated temperatures and UV radiation had no impact on the read range regardless of the tag type. Also, no change in the conductivity of the antennas in both tag types were detected. Mean value of the conductivity of all tags, before and after the experiment, corresponds to $\sigma=(3.3\pm0.2)\cdot10^{7}$ $S\cdot m^{-1}$ indicating electric stability of UHF RFID tags.

Even though the tags showed great electric stability, image analysis indicated changes related to degradation of front face material which is white printable paper and the adhesion of the tags solvent-free permanent acrylic adhesive. In Fig. 3. pictures of Tag 1 after exposure to UV radiation for 48 h and 96 h are given. Degradation of the adhesive is evident, resulting in exposed antenna.

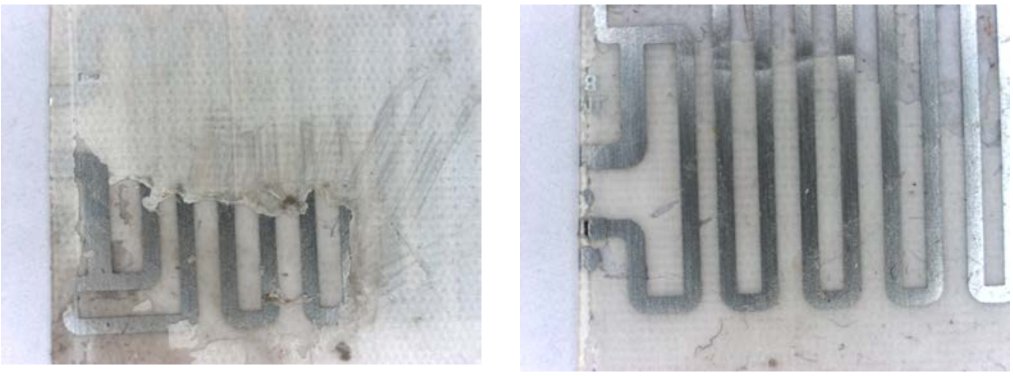

*Figure 8. (a) Tag 1 after exposure to UV radiation for 48h* *(b) Tag 1 after exposure to UV radiation for 96h*

Table 3. Summary of the results obtained by Pias for Tag 1 after exposure to UV radiation for 48h

| Line Summary | Mean | Min | Max | Stdv |
|---|---|---|---|---|
| Width / mm | 0.713 | 0.645 | 0.781 | 0.03 |
| Min width/mm | 0.62 | 0.403 | 0.756 | 0.123 |
| Max width / mm | 0.87 | 0.832 | 0.928 | 0.033 |
| Std Dev Width / mm | 0.053 | 0.018 | 0.114 | 0.033 |
| Fill | 0.973 | 0.971 | 0.975 | 0.03 |
| Contrast | 0.502 | 0.429 | 0.554 | 0.052 |
| Density | 0.475 | 0.43 | 0.504 | 0.027 |
| Reflectance | 0.336 | 0.313 | 0.372 | 0.021 |

If we compare the summary of the results obtained by Pias for Tag 1 given it tables 3 and 4 it can be seen that the mean line width corresponds to 0.71 mm in both cases. Line fill, contrast and density dropped slightly, while the reflectance increased all of which corresponds to the removal of the adhesive layer from the label. The lack of the adhesive may eventually cause the label to drop from the product which means that products should be handled with care in case of any increased exposure to UV radiation in transport and storage.

Tag 2 showed less pronounced changes in the appereance in respect to the exposure to elevated temperatures (Fig. 5. And Fig. 6.) that can occur during the transportation process. The level of degradation to the adhesion layer and paper substrate was significitally lower compared to degradation caused by UV radiation which means that the products are relatively well protected in closed dark compartments during the transport process. Degradation of the paper base and the adhesive, although undeniably present, are not the cause for concern when considering label decay.

Table 4. Summary of the results obtained by Pias for Tag 1 after exposure to UV radiation for 96h

| **Line Summary** | **Mean** | **Min** | **Max** | **Stdv** |
|---|---|---|---|---|
| Width / mm | 0.712 | 0.641 | 0.783 | 0.153 |
| Min width/mm | 0.023 | 0 | 0.047 | 0.014 |
| Max width / mm | 1.002 | 0.709 | 1.589 | 0.245 |
| Std Dev Width / mm | 0.188 | 0.122 | 0.354 | 0.067 |
| Fill | 0.963 | 0.908 | 0.987 | 0.028 |
| Contrast | 0.489 | 0.295 | 0.589 | 0.107 |
| Density | 0.427 | 0.274 | 0.519 | 0.092 |
| Reflectance | 0.383 | 0.302 | 0.532 | 0.085 |

*Figure 4. (a) Tag 2 after exposure to 50˚C* *(b) Tag 2 after exposure to 60˚C*

If the data obtained by Pias for Tag 2 (Table 5 and Table 6) are closely inspected, it can be seen that the values for fill and contrast decrease for 3 % and 6 % when the temperature is increased from 50˚C to 60˚C. At the same time the value of density dropped for 11 % while the reflectance increased for 11 %.

Table 5. Summary of the results obtained by Pias for Tag 2 after exposure to 50˚C

| **Line Summary** | **Mean** | **Min** | **Max** | **Stdv** |
|---|---|---|---|---|
| Width / mm | 0.276 | 0.231 | 0.31 | 0.028 |
| Min width/mm | 0.059 | 0.015 | 0.135 | 0.04 |
| Max width / mm | 0.511 | 0.331 | 0.7 | 0.146 |

| | | | | |
|---|---|---|---|---|
| Std Dev Width / mm | 0.104 | 0.08 | 0.14 | 0.019 |
| Fill | 0.973 | 0.925 | 1 | 0.029 |
| Contrast | 0.502 | 0.453 | 0.588 | 0.044 |
| Density | 0.479 | 0.402 | 0.554 | 0.051 |
| Reflectance | 0.334 | 0.279 | 0.396 | 0.039 |

Table 6. Summary of the results obtained by Pias for Tag 2 after exposure to 60˚C

| Line Summary | Mean | Min | Max | Stdv |
|---|---|---|---|---|
| Width / mm | 0.262 | 0.212 | 0.284 | 0.024 |
| Min width/mm | 0.077 | 0.026 | 0.187 | 0.052 |
| Max width / mm | 0.356 | 0.324 | 0.405 | 0.027 |
| Std Dev Width / mm | 0.084 | 0.033 | 0.108 | 0.025 |
| Fill | 0.948 | 0.829 | 1 | 0.06 |
| Contrast | 0.436 | 0.282 | 0.558 | 0.102 |
| Density | 0.366 | 0.234 | 0.492 | 0.094 |
| Reflectance | 0.44 | 0.322 | 0.583 | 0.096 |

Although the layer of paper has largely remained fixed to the antenna it is obvious that this inequality in surface coverage in respect of the amount of adhesive and paper affects the changes in density and reflectance.

## 4. CONCLUSION

In our research we examined the influence of UV radiation and elevated temperature on two types of UHF RFID labels commercially used in one of the worldwide present sporting products retailers. Our results showed that the exposure of RFID UHF labels to electromagnetic radiation had no influence on the read range and conductivity of the UHF RFID tags. At the same time image analysis showed the decrease in the longlivity of the adhesion between the RFID tag and the substrate. UHF RFID tags show satisfactory quality in regard to their electrical properties, but there is a place for improvement in the substrate/adhesion materials.

It is evident that there are multiple advantages and benefits of using RFID tags as labels. One of the key points are the upgrades in inventory tracking in connection much faster and more efficient inventory. No less important, timely procurement and redistribution of products from distribution centers to stores was made timely. Thanks to the RFID tagging of every product, a full store inventory can be performed as often as necessary with a rather small number of personnel. Any improvements in the quality of the adhesive and tag substrate will only improve this process even more as it will mean a smaller amount of destroyed / damaged labels.

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# UI GreenMetric Ranking Performance Analysis of Universities in Turkey: Suggestions Towards to Becoming Green Campuses

***Kadriye Elif Macin*** [1]

**_Abstract_**

*There is growing attention to UI GreenMetric from all over the world since it was established in 2010. Turkey totally have 207 universities and 43 of them was applied to UI GreenMetric in 2019. The aim of this study is to analyse UI GreenMetric ranking performance of universities in Turkey and giving suggestions towards to becoming green campuses. The data used in the study were taken from the UI GreenMetric's official website. According to the results; the most successful category was transportation (TR) while the unsuccessful categories were "energy and climate (EC)" and "water (WR)" in Turkey. In addition, 72% of the applicant universities have not ranked in the first 300. The rankings of universities in Turkey have been decreased according to the general ranking results. The major problems are lack of sustainability offices and inability to provide instutional data for the application. Institutional data keeping, monitoring system and targeting global indicator such as Sustainable Development Goals were suggested in order to become green campuses.*

**Keywords:** *Green campus, Higher Education Institutions (HEIs), Sustainable Development Goals (SDGs), Sustainability, UI GreenMetric.*

## 1. INTRODUCTION

The importance of education, especially universities to reach Sustainable Development Goals (SDGs) have been discussing since last four decades [1]. Universities are an impartial and reliable stakeholder in society. Hence, universities have the capacity and responsibility to guide SDGs at local, national and international level through dialogue and partnerships [1]. The relationship between the education sector and sustainability officially started with the Stockholm Declaration in 1972. Later, universities have made a commitment to address this issue more comprehensively with the Talloires Declaration. Universities stated that they would take measures to reduce the damage to the environment [2]. After the 1992 United Nations conference, the concepts of sustainable universities and green campus started to gain importance **(Figure 1).** Although there is no single general definition exist, "green university" concept sometimes perceive as one-dimensional since current applications give more importance to environmental topics and neglecting economic and social aspects. However, the multidimensional nature of the term green campus should be taken into consideration [3-5]. Hence, it would be more accurate to evaluate and associate the "green campus" concept with "sustainable university". A sustainable university is defined as a higher education institution that deals with minimizing the negative environmental, economic, social and health impacts at a regional or global level, caused by the use of its resources during fulfilling the functions of teaching, research, social assistance and partnership [6-7].

University campuses are complex systems in which education and research processes are carried out by consuming materials, energy and water [8]. In China, the education sector is responsible for 40% of the total electricity consumption in the public sector [3]. Therefore, studies have been gaining attention to reduce anthropogenic effects on campuses [9]. In addition to their academic achievements and reputations, universities are competing to reduce the human impact on environmental problems such as climate change.

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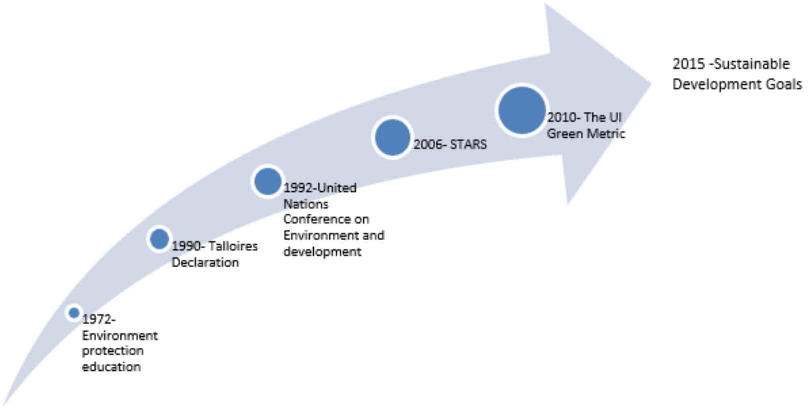



*Adapted from (Tan et al., 2014) study.

*Figure 1. Important developments regarding the “green campus”*

It is known that university rankings have become popular in recent years [10]. The ranking topics ranging from research, education and academic reputation to environmental performance [10]. In most university rankings, research and academic reputation rank first and followed by education while environmental issues have little or no attention [10-11]. The UI GreenMetric ranking is an important initiative that makes an international assessment of the sustainability of universities [10]. UI GreenMetric was created in 2010 by the University of Indonesia and it consists of six main categories which are Setting & Infrastructure (%15), Energy & Climate (%21), Waste (%18), Water (%10), Transportation (%18) and Education (%18) as shown in **Table 1** [12]**.** UI GreenMetric has been a ranking system that constantly renews itself over the years and has received positive [7] and negative [13] comments with this feature. The theme of 2020 is stated as “SDGs and universities responsibility for the challenges in the world” [5].

*Table 1. UI GreenMetric categories and scores*

| Categories | Total Score | Percentage (%) |
|---|---|---|
| Setting & Infrastructure (SI) | 1500 | 15 |
| Energy & Climate (EC) | 2100 | 21 |
| Waste (WS) | 1800 | 18 |
| Water (WR) | 1000 | 10 |
| Transportation (TR) | 1800 | 18 |
| Education (ED) | 1800 | 18 |

The increase in the number of applications to UI GreenMetric has led to an increase in academic publications. **(Ragazzi and Ghidini, 2017)** conducted analyzes and made suggestions on how the ranking system could be improved [13]. **(Marrone et al., 2018)** stated changes are necessary, especially in the setting and infrastructure (SI) category [14]. **(Muñoz-Suárez et al., 2020),** analyzed academic ranking success and sustainability relations by comparing UI GreenMetric with the results of other academic ranking systems [15]. **(Caeiro et al., 2020),** evaluated the results of different ranking systems including UI-GreenMetric, in order to understand the effects of universities on sustainable development [16]. **(Sonetti et al, 2016)** compared the UI GreenMetric performances of two universities in Italy and Japan [7]. **(Puertas and Marti, 2019)** evaluated the UI GreenMetric results with cluster analysis and divided them into different sustainability classes [17]. In addition, UI GreenMetric performance anaylsis of universities from different countries such as Africa [4], Brazil [18], India [19], the Philippines [20], and Russia [9] were done.

UI GreenMetric is also popular in Turkey as well as all over the world since it has accepted applications without any preconditions and free of charge. Bilkent University has been the only university from Turkey to participate since the 2010. Zonguldak Bulent Ecevit University (ZBEU) applied for the first time in 2014 and started to take an active role in GreenMetric and became the representative of Turkey for UI GreenMetric. ZBEU ranked first in Turkey in 2014, 2015 and 2016. Istanbul Technical University (ITU), which applied for the first time in 2017, ranked first in Turkey in 2017, 2018 and 2019. An international workshop was held at Istanbul University with the participation of the UI GreenMetric team in 2017 [21]. National workshop was organized by ZBEU in 2019 to discuss problems faced during and after application [22]. The increasing interest in UI GreenMetric by universities in Turkey has led to university-specific case studies [23-24] and the development of local sustainable university models [25]. Many publications have been made in Turkey from the perspective of ecological campuses [26] and green building certification systems [27-29]. General evaluation of UI GreenMetric for the year 2015 was made at national level [25]. The master thesis were done about green campus [30] and national green campus ranking system suggestion based on GreenMetric [31]. In addition, five state and five private universities from Turkey compared in terms of their sustainable-ecological parameters [32]. Besides, YOK (higher education board of Turkey) has new initiatives about the Green Metric.

While there were 29 universities in Turkey in 1987, this number increased to 207 in 2019 [33-34]. Today, 7.9 million students, including graduates, study in higher education institutions in Turkey. The increasing number of students in the last 35 years is an important opportunity for the establishment of environmental management and sustainability systems in universities. Considering the approximately 10% of the country's population is educated in higher education institutions and 21% of universities in Turkey applied to UI GreenMetric in 2019 are clarified the importance of the subject. Despite the increasing interest in the UI GreenMetric system in Turkey, no study on national performance analysis has been found during literature research. A new study is needed when factors such as the increasing number of UI GreenMetric applications, YOK's interest in this subject and universities’role on SDGs. The aim of this study is to examine the UI GreenMetric performances of universities in Turkey and to give suggestions to become green universities.

## 2. MATERIAL AND METHOD

### *2.1. Material*

The data required to review and compare UI GreenMetric performances were taken from the UI GreenMetric website. Detailed information about the green campus projects of the universities applying UI Green Metric from Turkey were obtained from the official websites of the universities. In addition, the number of academic publications containing the term “green campus” was obtained from the Web of Science (WoS) [35].

### *2.2. Method*

In the study, a literature search was conducted using Web of Science (WoS), Scopus, Google Scholar, Dergipark and YOK Thesis Center search engines. The national and international studies were examined by using the keywords "green campus", "GreenMetric", "sustainable development” and “university”. UI GreenMetric shares category and continent based results since 2014 and 2017 respectively. Therefore, the category reviews were made for the years 2014-2019 and analyzes of the continents were made for the years 2017-2019. The UI GreenMetric results between 2010 and 2019 were compared in order to understand how the performances of universities in Turkey have changed in the general ranking and in the country. Also, it has been tried to determine whether there is a relationship between the performance of the countries that are successful in UI GreenMetric and academic interest (number of publications) by examining the academic studies that include the word "green campus" in WoS. Suggestions were made to become a green campus by evaluating the interviews held at the ZBEU national workshop and using the literature resources.

## 3. RESULTS AND DISCUSSION

### *3.1. Academic publications and successful countries in the UI GreenMetric ranking*

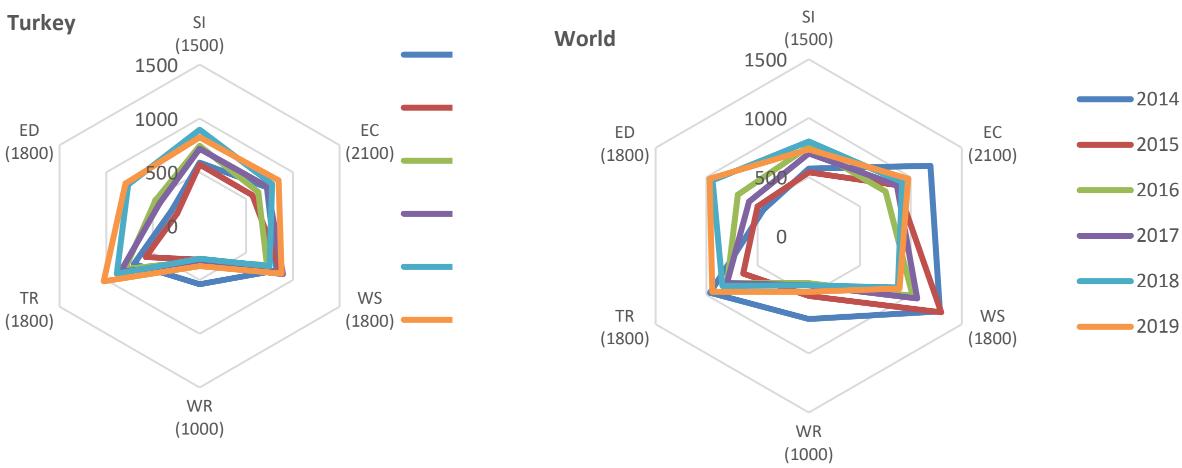
In order to understand whether the number of academic publications is an effective parameter on the country`s UI GreenMetric performance, apart from the development level of the countries, the publications including the word "green campus" in WoS were examined. There is no direct relationship between publications and ranking, have been found however some positive effects were observed. For example, one of the most publishing countries in Europe is the United Kingdom and it has the most universities in the top 20. Similarly, in the Asian continent, the universities in the top 20 are generally from China, Malaysia, Indonesia and Taiwan, which have more publications compared to other Asian countries. A total of 983 papers (article, conference paper, book chapter, etc.) containing the term green campus was published between 1996-2020. The number of publications has started to increase rapidly and reached the highest point with 140 publications in 2017. The most



publications were made in the USA and China with 249 and 163 publications respectively. Turkey is the 11th country with the highest number of publications with 29 publications containing the term "green campus" [35]. This is promising for future national success and performance. The effect of the UI GreenMetric ranking system, on the number of publications with the terms "green campus" and "sustainable university" is a significant topic to be addressed in the future.

### *3.2. Overall ranking performance by categories*

In order to examine the performances of universities in Turkey, the average of the scores between the years 2014-2019 were calculated. The same calculations were made with the overall results for comparison (**Figure 2).** According to the average results of Turkey in 2019, the "transportation (TR)" category was the most successful category with an average score of 1027 (57% of the total score of the category). The average of the “Setting & Infrastructure (SI)” category is 824 (55%), while “Waste (WS) category is 879 (48.8), “Education (ED)” category is 794 (44.1%), “Energy and Climate (EC)” category is 845 (40.3%) and “Water (WR)” category is 370 (37%).




*SI: Setting & Infrastructure, EC: Energy & Climate, WS: Waste, WR: Water, TR: Transportation, ED: Education

*Figure 2. Change of category average scores in Turkey and world general ranking in 2014-2019*

The highest increase is seen in the "Education (ED)" category (from 16.6% in 2014 to 44.1% in 2019), while a decrease in the "Water (WR)" category (from 2014 to 54.1% to % 37.0% in 2019). In the "Waste (WS)" category, there was an increase in performance across the country between 2018 and 2019. This is due to the Zero Waste Regulation published in the country. In addition, performance changes can be observed due to changes in UI GreenMetric indicators as well as the activities of universities. According to the 2019 UI GreenMetric guide, although there is no change in the questions in the "Structure and Infrastructure (SI)" category, the options for the questions "*1.9. Area covered with vegetation in the form of forest in the campus (%)*” and “*1.10. “Cultivated vegetation area (%) within the campus*” have been changed. This change, which required universities to have more green spaces in order to get the same score as the previous year, caused the performance of 842 points (56.1%) in 2018 to decrease to 824 points (55%) in 2019. This shows that universities should have a more comprehensive sustainability vision rather than just setting targets according to UI GreenMetric indicators. When the same results are examined for world universities, the most successful category was “Education (ED)” with 971 points (53.9%) and the most unsuccessful category was “Energy and Climate (EC)” with an average score of 974 (46.4%). After success in 2014 and 2015, the waste (WS) category has declined rapidly in the last four years.

*Table 2. UI GreenMetric average scores of universities in Turkey in 2019*

| Ranking | SI (1500) | EC (2100) | WS (1800) | WR (1000) | TR (1800) | ED (1800) | Total (10000) |
|---|---|---|---|---|---|---|---|
| 1-99 | 1050 | 1150 | 1575 | 800 | 1425 | 1600 | 7600 |
| 100-199 | 983 | 1183 | 1075 | 625 | 1225 | 1275 | 6367 |
| 200-299 | 969 | 1031 | 1050 | 384 | 1281 | 984 | 5700 |
| 300-399 | 908 | 883 | 988 | 421 | 1096 | 913 | 5208 |
| 400-499 | 771 | 896 | 911 | 421 | 889 | 632 | 4521 |
| 500-599 | 759 | 741 | 834 | 225 | 931 | 650 | 4141 |
| 600-699 | 678 | 590 | 563 | 290 | 855 | 575 | 3550 |

* SI: Setting & Infrastructure, EC: Energy & Climate, WS: Waste, WR: Water, TR: Transportation, ED: Education

The average score of Turkey 2019 is shown in **Table 2**. The university performance in the top 300 in the world rankings, performed close to each other except for the Water (WR) and Education (ED) categories. Although the universities ranked among the top 300 and 500 are more successful than the upper ranking range in the Water (WR) category, they lagged behind, especially due to their performance in the Setting and Infrastructure (SI), Transportation (TR) and Education (ED) categories. Universities ranked among the top 600 and 700 should draw attention to their low performance in Waste (WS) and Energy and Climate (EC) categories.

### *3.3. Comparison of university scores in Turkey with the average scores of the continents*

A total of 780 universities applied to the UI GreenMetric ranking system in 2019. The number of universities applying from the Asian continent is 373 (48%), the European continent is 229 (29%), the South American continent is 95 (12%), the North American continent is 64 (8%), the African continent is 14 (2%), and the Oceania continent is 4 (1%). It is no coincidence that UI GreenMetric was founded by the Asian country (Indonesia) and received more applications from the Asian continent. It is also known that since the beginning of the 2000s, there has been an increasing interest in green campus studies, especially in China, Malaysia, Taiwan and Indonesia [36-37].

The requirement for specifying universities which continents they belong to can cause confusion in a country that has connections to more than one continent like Turkey. Although only 8 of the 43 universities applying from Turkey are geographically located in the European continent, 25 universities chose Europe as the continent in 2019. The remaining 18 universities chose the Asian continent. UI GreenMetric has been sharing the results by continents since 2017 **(Figure 3).** According to this, although the average score of the universities in Turkey has increased over the years. It has lagged behind the world average and other continents except for Asia and Africa. **(Muñoz-Suárez et al., 2020)** stated that new universities (founded within the last 100 centuries) predominate among the top 500 universities in UI GreenMetric [15]. They explained as the Asian universities were dominant in the first 500 and these universities were generally established in the last century and the performance of Turkey is compatible with this theory.

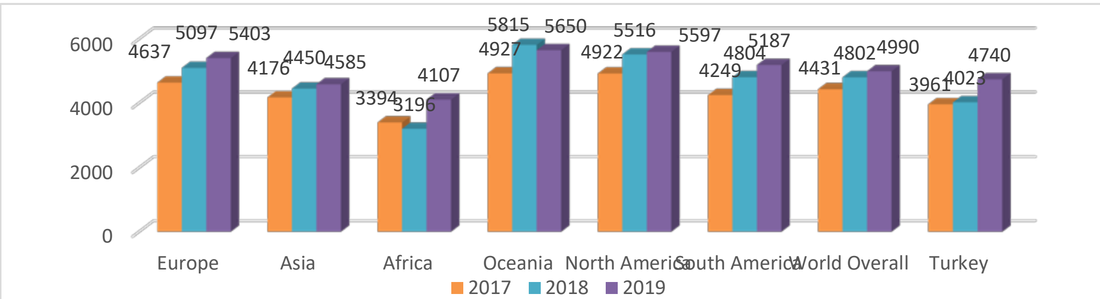



*Figure 3. Average scores of continents and Turkey in UI GreenMetric*

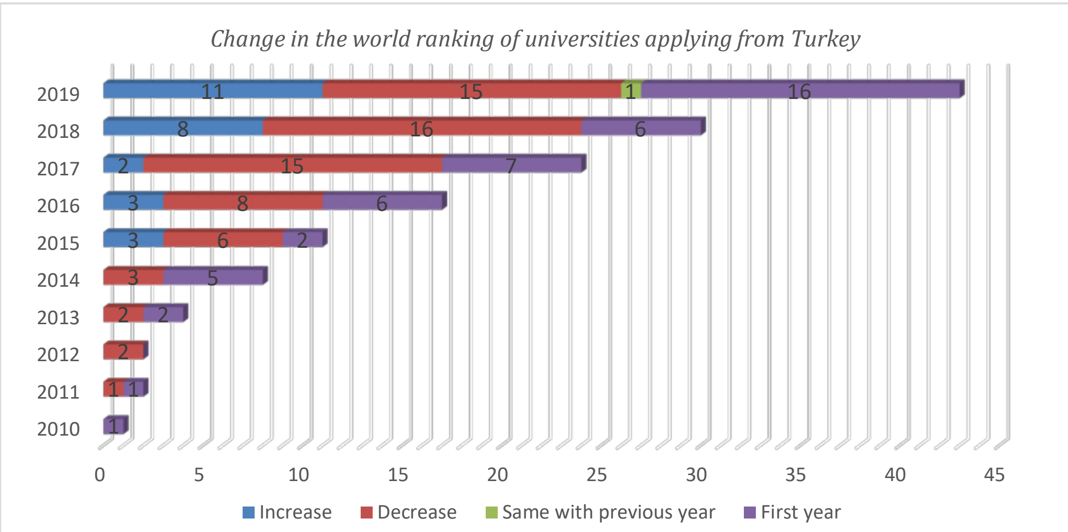
### *3.4 Change of UI GreenMetric performance of universities in Turkey over the years*

UI GreenMetric has received increasing attention from Turkey since its establishment. The number of applied universities has increased rapidly in the last three years and it was constant only in 2012.

*Table 3. UI GreenMetric rankings of universities in Turkey*

| Ranking | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-99 | 1 | - | - | - | - | - | - | 1 | 1 | 1 |
| 100-199 | - | 2 | 1 | - | - | - | 1 | 2 | 2 | 3 |
| 200-299 | - | - | 1 | 4 | 4 | 4 | 4 | 4 | 5 | 8 |
| 300-399 | - | - | - | - | 4 | 6 | 7 | 5 | 5 | 6 |
| 400-499 | - | - | - | - | - | 1 | 5 | 6 | 6 | 7 |
| 500-599 | - | - | - | - | - | - | - | 5 | 5 | 8 |
| 600-699 | - | - | - | - | - | - | - | 1 | 6 | 10 |
| **Number of universities (Turkey)** | **1** | **2** | **2** | **4** | **8** | **11** | **17** | **24** | **30** | **43** |
| **Number of universities (Total)** | **95** | **178** | **215** | **301** | **361** | **407** | **516** | **619** | **719** | **780** |

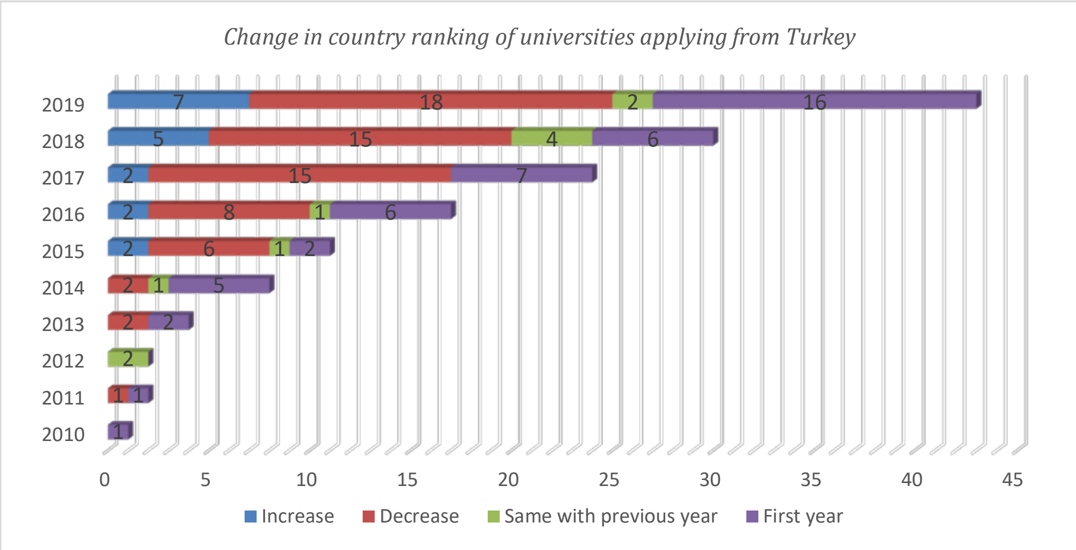
Universities that ranked in the top 100 in Turkey are Bilkent University, which applied in the year UI GreenMetric was first published, and ITU. As seen in **Table 3**, there are four universities in the top 200 and twelve universities in the top 300 in 2019. The remaining 31 universities (72%) are in the 300-700 range. Results also shows university performances in Turkey vary widely. Results shown in **Figure 4** and **Figure 5** over the years in order to understand the overall performance change in the country according to these most of the universities have a decreasing trend in the general ranking. The number of universities with lower ranking ternd in the UI GreenMetric ranking in 2017, 2018 and 2019 was respectively 15, 16 and 15 while increasing rankings were respectively 2, 8 and 11. Although the average scores have increased over the years, their place in the ranking is decreasing **(Figure 4).** This is due to the increase in average scores at other universities applying for the UI GreenMetric ranking. As **(Ragazzi and Ghidini, 2017)** and **(Macin et. al., 2020)** mentioned, the absence of any sustainability classification in UI GreenMetric may cause the ranking change depending on the performance of other universities, although the university performance in terms of sustainability does not change [13]-[38].




*Inonu University did not apply in 2014. Therefore, the years 2013 and 2015 were compared.

*Figure 4. Change in the world ranking of universities applying from Turkey between 2010-2019*

Although the total scores of 14 universities in the national ranking and 13 universities in the general ranking increased, their rankings decreased in 2018. These numbers were changed to 9 (in national ranking of Turkey) and 7 (in the world) in 2019.




* Inonu University did not apply in 2014. Therefore, the years 2013 and 2015 were compared.

*Figure 5. Change in country ranking of universities applying from Turkey between 2010-2019*

## 4. PROBLEMS AND SUGGESTIONS TOWARDS TO BECOMING GREEN CAMPUSES

At the national workshop held by ZBEU, the problems faced by universities in Turkey during and after the UI GreenMetric application process were discussed. In this section, suggestions are made to be more successful in UI GreenMetric and how to serve the SDGs in order to become sustainable universities in the long term.

- Obtaining "institutional data" is one of the challenges faced by universities in Turkey. Considering the concept of a sustainable university in a broader perspective, **"sustainability offices**" are recommended [39]. Sustainability offices are necessary for universities to realize their sustainability visions, to acquire the habit of keeping data and to carry out multi-disciplinary studies. The office should regularly publish sustainability reports. One of the duties of the sustainability office is to keep this data on a regular basis. If it is not possible to establish an office in the short and medium term, a relevant unit of the university restaurant should be appointed. It will be useful for this unit to keep basic information regularly, such as electricity, water and natural gas consumption, the number and areas of buildings on the campus, the number of vehicles on the campus, the list of projects carried out and partnered with the university. Many universities in America and Europe are developing their projects under the management of "sustainability offices", including universities in top 20 ranking of Green Metric. In addition, Asian universities have been interested in this subject and have achieved successful results [40].
- Organizing activities related to green areas in the campus with the participation of internal stakeholders were suggested for the **Setting and Infrastructure (SI)** category. **(Caeiro et al., 2020)** stated that stakeholder participation is important in adopting SDGs and becoming a green campus [16]. Increasing green areas with the help of non-profit organizations (NGOs) will also be beneficial in terms of creating social awareness.
- Performance of universities in Turkey follow closely the top 20 universities in the world ranking, especially in **Education (ED), Setting and Infrastructure (SI)** categories. However, they are clearly behind in the **Energy and Climate (EC)** category. Renewable energy and smart building topics come to the fore and future projects and investments should focus on these projects. New projects should meet the energy needs of the campus from renewable energy sources by considering that the main

purpose is to reduce energy consumption and carbon footprint. However, the effects of these projects will be understood in the medium and long term and they will be relatively costly.

- **In the Waste (WS) and Water (WR**) categories, cooperation between the local government and the university is necessary. As mentioned in **(Amaral et. al., 2020)**, sustainability studies that use "top-down" and "bottom-up" approaches at the same time are more successful [41]. Studies are generally carried out with a “top down” approach in Turkey. One of the important example is Zero Waste project [42]. Waste category results were increased in 2019 because many universities have started composting applications [43-44] after the Zero Waste Regulation. It is possible to implement projects similar to zero waste, on issues such as water recycling and use of renewable energy but the support of the state and local governments is required. Furthermore, YOK added UI GreenMetric as an indicator to the “General Report of University Monitoring and Evaluation” [45]. This development is very important in terms of discussing how state and local governments can contribute to green campus practices. **Waste and water consumption** can be reduced by training and campaigns to be carried out within the university. For example, research conducted at Rhodes University has shown that knowing how much waste is produced in dining halls can reduce the amount of food waste [46]. It is possible to reduce the use of plastic bottles by placing water dispensers in different parts of the campus [47]. Grey water use may increase for universities in Turkey and rainwater harvesting is also feasible [31].
- In particular, it would be beneficial for universities ranked low in Table 3 to produce projects in categories such as **Transportation (TR)** and **Education (ED)** that do not require any cost on campus, but will enable them to take action more easily on the way to becoming a green campus. The publication of guidelines that will reduce the number of vehicles entering the campus and highlight the comfort of pedestrians will ensure more success in the **Transportation (TR)** category without any cost.
- **In the Education (ED**) category, projects should be developed on topics such as sustainability, green economy, and biotechnology, which gain attention today. Academic publications and university stakeholders should take a more active role. Thanks to internal surveys, trainings and the active role of student clubs, it will be possible for universities to engage in sustainability activities with all internal stakeholders. While discussing, during the Covid-19 proces, the question of whether distance education (and/or blending education) will dominate the future without a campus education [48], embracing **sustainable university** concept is essential. Therefore, universities should include courses containing “SDGs” in their curriculum within the scope of being sustainable institutions. In addition, education should cover to other stakeholders of the campus other than students [2].

## 5. CONCLUSION

UI GreenMetric has been developed to better understanding of sustainability in education, to bring green projects in agenda of higher education institutions, to be more effective in reaching the SDG, to compare the initiatives of institutions on campus sustainability and to keep universities informed from each other. The number of newly applied universities to UI GreenMetric increases every year, but the rankings decreases. 72% of the universities applying from Turkey did not ranked in the top 300 and the most unsuccessful categories across the country were Water (WR) and Energy and Climate (EC) in 2019. The major problems are coming from lack of sustainability offices and inability to provide data for the application. However, GreenMetric indicators do not capture specific factors such as the level of development in the country or stakeholder participation. Universities in developing countries sometimes do not receive adequate support from local governments for basic needs such as waste management, water treatment and transportation. This causes a part of the budget for sustainability to be allocated to basic needs and prevents equal conditions between universities. This shows that it is necessary to focus on global and long-term goals, rather than just UI GreenMetric indicators. Furthermore, solutions climate change mitigation depend on the success of small-scale projects such as university campuses. Although it is not possible to reach the SDGs in the short term, it is understood from the number of universities applying to UI GreenMetric that universities in Turkey volunteer to support sustainable development. The universities in Turkey should make short, medium and long-term plans within the framework of the sustainable vision with the support of state and local governments.

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# Advanced quality and sustainability when printing irreversible thermochromic inks

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**Abstract**

*Worldwide, there is a growing need for use of recyclable and biodegradable materials, made from natural resources, for a variety of applications. This trend is followed by the printing industry as well, which is trying to use environmentally friendly materials and reduce the consumption of environmentally unfriendly materials. In addition, the used materials should give the satisfying quality of the end-product. Thermochromic inks can be reversible (color change is multiple) or irreversible (color change is one-time and permanent). Irreversible printing inks are initially either colorless or colored and when exposed to high temperatures they get colored or change to another color. Therefore, the aim of this paper is to examine the possibilities of two printing substrates (uncoated and coated) for the application of irreversible thermochromic inks in order to find a more environmentally friendly option that gives a satisfactory print quality. The dynamics of color change was monitored through one heating cycle every few degrees. Their colorimetric characteristics were described using spectral reflection curves and the CIELAB color system. Based on the obtained results, it can be concluded that with the change of temperature, the color tone changes slowly and continuously. The differences are evident for the selected printing substrates due to their different properties. However, these variations are imperceptible to the eye of the observer and according to the obtained results, it can be concluded that the tested inks behave similarly on the used substrates. In addition, more environmentally sustainable materials can be a good option in the use of printing with irreversible water-based thermochromic inks.*

**Keywords:** thermochromic inks, sustainable materials, colorimetric characteristics

## 1. INTRODUCTION

During distribution, storage and before the sale in stores, food products are exposed to various external influences that adversely affect their quality. Their premature deterioration causes large amounts of waste and thus financial losses. The validity date of the product in these cases cannot serve as a guarantee of product freshness, and due to the non-transparency of some packaging materials without opening the packaging itself, it is not possible to visually determine whether the product is still safe for consumption.

Intelligent packaging can be defined as packaging that contains an external or internal indicator that provides information about changes to which the product has been exposed over time. This type of smart packaging can detect and record internal and external changes in the production environment [1]–[3]. Chromogenic materials respond to an external stimulus by changing color. [4]. Nowadays, the use of chromogenic printing inks in the field of intelligent packaging is growing. In this area, they apply to indicator labels that make intelligent packaging "intelligent".

Thermochromic inks can be divided according to the type of color change into reversible and irreversible inks. Reversible inks return to their original state after a period of exposure to an external stimulus, while irreversible inks retain their color change without returning to the original color [5]–[7].

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Some researchers are of opinion that only the reversible changes should be included in terms of thermochromism because irreversible color changes caused by heating are, for the most part, only the results of true chemical reactions, and for that reason do not require special terminology. Closer studies reveal that the situations are in many cases not so simple and clear. The mechanism responsible for the thermochromism of organic compounds varies with the molecular structure of the compound. The color change is the result of equilibrium changes, either between two molecular species or between different crystal structures or between stereoisomers [8].

Thermochromic inks are mostly used for the production of time-temperature indicators. In this way, it is possible to visually determine whether the product has been exposed to an inadequate temperature. They are widely used in industrial applications for observing heat patterns and for detecting high and low-temperature points on surfaces of heat engines, pipelines and refrigerations fins. Thermochromic pigments have reached widespread use through different industries, including the textile industry, printing technology, military applications, plastic industry, industrial and interior design, etc. [8]–[11].

Printing inks for printing such indicators should adhere well to the label material or to the packaging material (if they are printed directly on the packaging itself). In addition, it is important that they are stable when printed and that they do not react prematurely to changes in temperature, light, etc [12], [13]. Also, it is very important that when a product is exposed to adverse conditions, the color change remains irreversible in order to obtain accurate information about the condition of the product.

The eco-friendly paper has a smaller environmental impact and carbon footprint. Mostly, when taking about environmentally friendly paper, recycled paper and FSC certificated paper are considered. Paper for printing may be coated or uncoated. The main purpose of paper coating is to improve the surface quality, optical properties (brightness, gloss or opacity), smoothness, and the most important - printability and print image quality [14]. When printing coated papers, printing ink sits on top of the paper, rather than being absorbed. On the contrary, when printing uncoated porous paper, the printing ink is absorbed deeper into the paper structure resulting in duller print. In the case of coated paper, the color of the prints is brighter and more vibrant to the eye [14]. Uncoated papers are considered as environmental friendlier than coated papers because they yield a higher percentage of fiber for recycling. In addition, the clay coating also creates a greater amount of sludge that must be disposed of.

This paper aims to examine the possibilities of two printing substrates (uncoated and coated) for the application of irreversible thermochromic inks to find a more environmentally friendly option that gives a satisfactory print quality. To analyze the quality of the printed ink, a colorimetric color analysis will be performed to monitor the color path through the heating process and to compare the color characteristics on both tested substrates.

## 2. EXPERIMENTAL PART

Two different types of papers, coated and uncoated, were used as a substrate in printing trials to find a more environmentally friendly option that gives a satisfactory print quality. Uncoated paper (UN) is matt wood-free printing paper grammage $100 g/m^2$ and the other is $70 g/m^2$ cellulose coated paper (CO).

Also, two commercially available screen-printing thermochromic (TC) inks were used for printing. Both inks were water-based irreversible TC inks with different activation temperatures.

MG60 was TC ink with an activation temperature of 60°C. At this temperature, the color begins an irreversible change from light pink to magenta. The second color used, IR75, has an activation temperature of 75°C and at that temperature it begins its change from colorless to pink. The third color used, MIX60/75, was a mixture of these two TC colors.

The printing trials were carried out using a semi-automatic screen-printing device (Holzschuher K.G., Wuppertal), employing 62/64 mesh for MG60 and 120 mesh for IR75. The samples were printed in full tone.

Spectral reflectance was measured by using Ocean Optics USB2000+ spectrometer using a 30 mm wide integrating sphere under (8:di) measuring geometry (diffuse geometry, a specular component included). The printed samples were heated on the full-cover water block (EK Water Blocks, EKWB d.o.o. Slovenia).

A different initial temperature was set for each sample, depending on its activation temperature. After reaching a certain temperature, a sample was placed on the circulator plate and an integration sphere was placed on it.

Reflectance spectra were measured in one heating cycle. The measurements were performed in the steps of 1 nm for the spectral region from 400 to 700 nm. Ocean Optics SpectraSuite software was used for the calculation of the CIELAB values from measured reflectance. The D50 illuminant and 2° standard observer were applied in these calculations.

## 3. RESULTS AND DISCUSSION

In order to show thermochromic color changes through temperature change, measurements were performed in temperature cycles depending on the activation temperatures of irreversible TC inks. Using the spectral reflection curves and the CIELAB color system, the color changes on both paper substrates were displayed. The results are presented in graphs showing the spectral reflection curves at different measured temperatures. On the MG60 sample, color change was monitored from 40°C to 80°C. Sample measurements were mostly performed every 2°C, and around the activation temperature every 1°C in order to more accurately monitor the color change on the sample. On the IR75 sample, color change was recorded from 65°C to 82°C every 1°C.

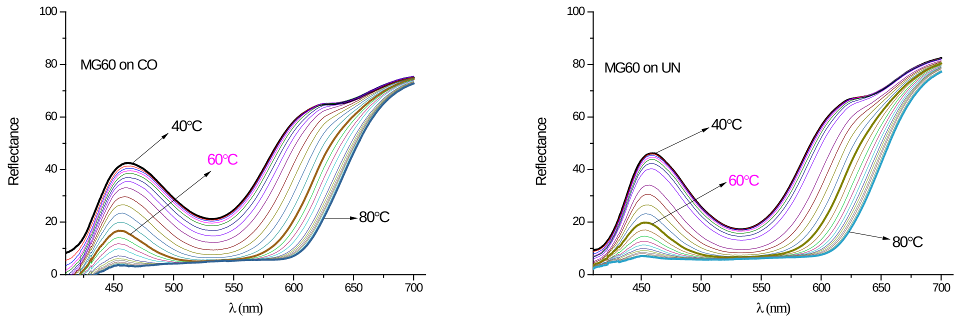


*Figure 9. Spectral reflectance curves of irreversible MG60 on coated (CO) and uncoated (UN) paper substrates*

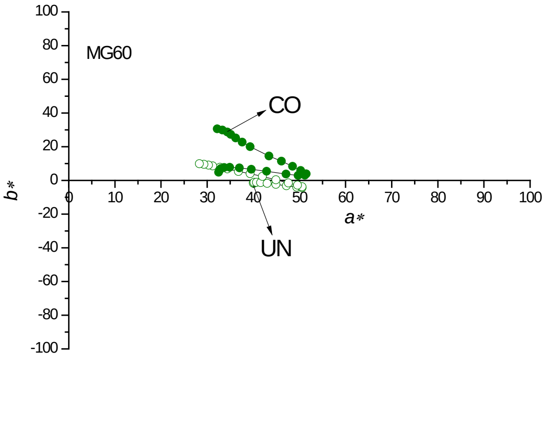


*Figure 2. Changing of CIELAB values of MG60 sample in the (a*,b*) plane during heating on both paper substrates*

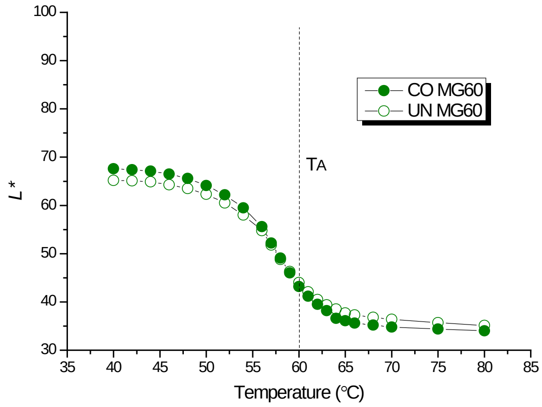


*Figure 3. CIELAB lightness L* of MG60 in dependence on temperature during heating on both papers*

Figure 1 shows the spectral reflection curves of the printed irreversible color MG60 on both papers. There is a similar trend of change on both paper samples. At the initial measurement temperature, 40°C, on both substrates, the curves are almost identical. The reflection decreases with increasing temperature and the curves narrow, i.e. at higher temperatures the differences are less noticeable and the color retains the same color characteristics. Although the activation temperature is at 60°C, the color at higher temperatures becomes more intense and the color saturation increases, which can be seen at the *a*/b** graph. The MG60 on both substrates has a similar color change path during heating (Figure 2). Figure 3 shows a decrease in the brightness *L** even before the activation temperature.

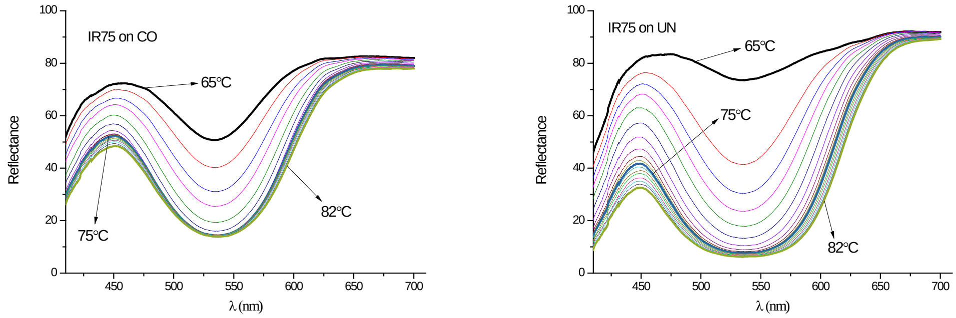


*Figure 4. Spectral reflectance curves of irreversible IR75 on coated (CO) and uncoated (UN) paper substrates*

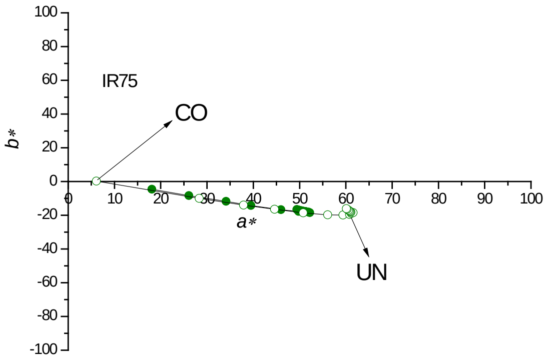


*Figure 5. Changing of CIELAB values of IR75 in the (a*,b*) plane during heating on both paper substrates*

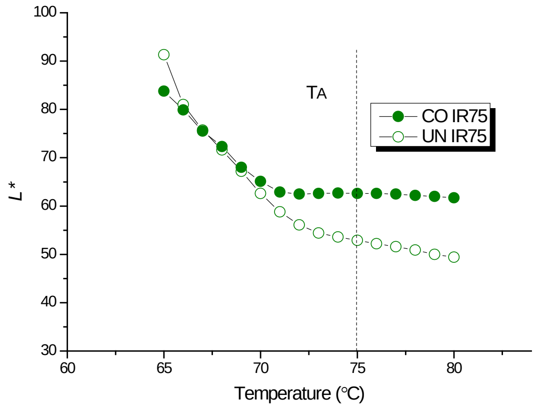


*Figure 6. CIELAB lightness L* of IR75 in dependence on temperature during heating on both papers*



The IR75 inks has a slightly different trend of change on the examined papers. At the initial measurement temperature, 65°C, the difference between the spectral reflection curves on these two substrates is most noticeable (Figure 4). The reason for this is probably that uncoated paper has higher whiteness. Since the IR75 ink is colorless before an irreversible change occurs, the initial spectral reflection curve is higher on that paper. Based on the *a*/b** graph (Figure 5), the IR75 on both papers has an almost identical color change path during heating. On the *L**/T graph (Figure 6), the difference between the two prints is more noticeable and the color is more saturated on the uncoated paper. Also, as with the MG60, it can be observed that the irreversible change started even before the activation temperature and this is the same on both paper substrates.

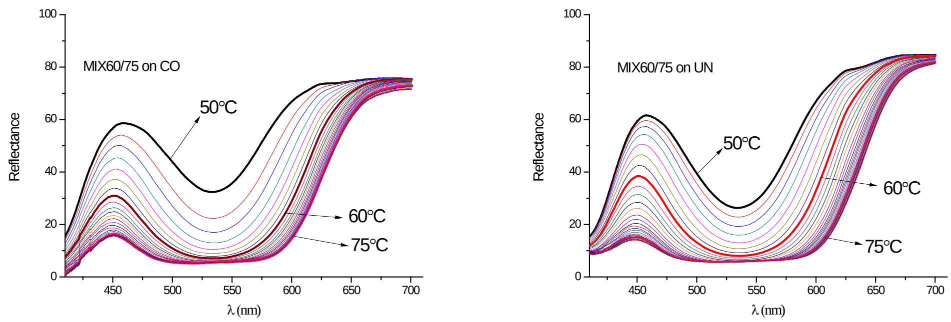


*Figure 7. Spectral reflectance curves of MIX60/75 on coated (CO) and uncoated (UN) paper substrates*

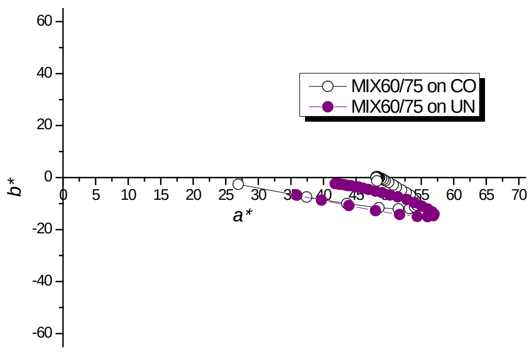


*Figure 8. Changing of CIELAB values of MIX60/75 in the (a*,b*) plane during heating on both paper substrates*

The MIX60/75 sample is a combination of two tested colors in a 50:50 ratio. Because of their different characteristics, the goal was to determine the differences in prints with respect to the different characteristics of the paper. It can be concluded that the color path is not completely identical, however, the changes are relatively small and quite imperceptible to the eye of the observer as shown in Figures 7 and 8.

## 4. CONCLUSION

In this paper, the print quality of two irreversible thermochromic inks on two different types of paper was examined in order to establish the assumption that environmentally sustainable materials can be a good option for their printing, in this case, uncoated paper due to higher fiber yield. Coated papers, compared to uncoated, have lower ink demand, i.e. the ink penetration into the paper sheet is smaller. Therefore, the ink does not spread as much, and the print image is clear and sharp resulting in enhanced print density and the print gloss.



Comparing the obtained measurement results for selected thermochromic inks, it can be concluded that by changing the temperature the hue of both TC inks changes slowly and continuously on both paper substrates.

Although the values are not completely identical, these variations are imperceptible to the eye of the observer. Larger differences were observed on the IR75, which is also affected by the color of the paper substrate due to the initial colorless condition. These differences disappear after the TC color changes irreversibly.

From the *L* */T graph it can be noticed that the thermochromic reaction (color change) occurred even before the activation temperature itself and that at higher temperatures both TC inks become more saturated. The mix of the two tested TC inks on the same substrates also shows very small differences and the changes are similar to each of these two colors.

Even though paper coating increases printability and print image quality, based on this work, it can be concluded that the tested TC inks behave similarly on coated and uncoated paper. In addition, more environmentally sustainable materials (uncoated papers) can be a good option for printing with irreversible thermochromic inks.

In the following research, it is planned to include a larger number of environmentally friendly materials in order to monitor their stability to some external conditions and to determine the impact of the substrate on the stability of TC inks.

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***Biography***: Assistant Professor Rahela Kulčar has been employed at the Faculty of Graphic Arts, University of Zagreb since 2004. At the same faculty she defended her doctoral dissertation entitled "Colorimetric analysis and stability parameters of UV-thermochromic printing inks" in 2010. She has been working as an assistant professor since 2017 and at the moment she is the holder of two courses at the undergraduate study, "Photographic Processes" and "Qualitative methods of testing color reproduction". Her areas of interest are inks, photography, colorimetry, and factors that influence different color perception. In the field of photography, her focus is primarily on analogue photography and alternative photographic techniques. In the field of inks, these are thermochromic inks, their stability to various external influences, and the interaction of inks and paper. Current research is focused on the influence of physico-chemical properties of printing media on the colorimetric properties of thermochromic prints and their impact on UV stability.

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# Use of Structural Equation Modeling to Develop a Sustainable Hunting Scale

***Yasar Selman Gultekin*[1]*, Ugurcan Oztokat*[2]**

**_Abstract_**

*Ensuring the sustainability of hunting and wildlife, by identifying hunter profiles with different characteristics in Turkey; it can be possible by analyzing the perceptions and attitudes of hunters regarding hunting and the continuity of wildlife. The aim of this study is to develop a sustainable hunting scale with structural equation modeling in order to determine the perceptions and attitudes of hunters about the sustainability of hunting and wildlife. In order to achieve this aim, it is aimed to determine the basic components of sustainable hunting by using Confirmatory Factor Analysis and Structural Equation Modeling in the method of the study by obtaining data with structured and closed-ended questionnaires to be developed with hunters with hunting certificates. Within the scope of the study, the studies on sustainable hunting in the literature were examined and statements that could constitute the main factors were formed. As a result of the study, it is planned to bring policy suggestions to decision makers and practitioners with the scale that can be developed.*

**Keywords:** Sustainable hunting, Hunter's associations, Scale development, Confirmatory factor analysis

## 1. INTRODUCTION

Hunting is an activity that has emerged with the effort of meeting the basic needs of human beings and has its own rules over time. Hunting is defined as activities carried out with the aim of capturing an animal alive or dead for different purposes [1]. When hunting activities is planned well, it provides benefits for providing the sustainability of natural resources and bringing environmental, economic and social concerns together. The place of local people in hunting planning and management is quite important in terms of the contribution of income that is obtained from protection works and activities on regional economy [2].

Hunting emerges as a way of life beyond being a culture and tradition in Turkey. In order to ensure the sustainability of hunting and wildlife, determining the behavior of hunters, especially their training, has a crucial place [3].

Interest in structural model analysis for relational studies is increasing in the social sciences discipline. Structural Equation Modeling (SEM) methodology is a robust statistical analysis technique consisting of a combination of manifest and latent variables that are used in many areas such as psychology, sociology, education, economics and marketing. SEM is an effective model testing and development technique that can explain the cause-and-effect relationship of variables in mixed hypotheses related to statistical models and allows the theoretical models to be tested as whole.

The aim of this study is to conduct sustainable hunting scale to identify stakeholders' perceptions and attitudes of against to their hunting activities, and to discuss the availability of SEM as a new approach to the provide recommendations to existing hunting problems. The SEM methodology is an untested method in sustainable

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hunting planning and management in Turkey. It will be applied in sustainable hunting planning and will have an important place to cover some gap in the literature and studies on hunting for the future research.

### *1.1. Hunting and Sustainability*

The hunting concept has evolved with the development of the hunting weapons of people as a result of their needs and expectations during centuries [4]. According to reference [5], the hunting concept comes to the agenda with the sustainability concept. Sustainable hunting, which is the basis of conservation of ecological balance, has emerged as a result of sustainable development. European Commission (EC) launched a European Union (EU) “Sustainable Hunting Initiative” in order to improve the understanding of the legal and technical aspects on hunting and to develop a program of scientific, conservation and awareness raising measures to promote sustainable hunting [6].

The sustainable use of natural resources ensure that biodiversity remains in balance. Sustainable hunting and wildlife management is related to planning the use of hunting and wildlife resources in a way that does not affect the use of future generations. Ensuring the sustainability of hunting can be possible with the sustainable management of the relationship between the hunter and the prey, as well as the natural resource management. [5]. The studies carried out in this context appears to have taken pay attention to the issues of preventing unconscious and excessive hunting, supporting rural development, ensuring the organization of hunters and their participation in resource management, determining the number of hunters according to hunting grounds and game animal species, providing self-control, providing financial support for protection and development in order to ensure sustainable hunting and wildlife [7].

Because sustainable hunting has a wide variety of elements, it is necessary to understand its structure. In order to ensure long-term sustainability of hunting, it is necessary to take into consideration the basic elements of the structure of this activity. The work and thought cooperation of local people, decision-makers, private sector, NGO's and scientists, crucial stakeholders of wildlife planning and sustainable hunting, is a process that can be applied and facilitated.

### *1.2. Structural Equation Modelling*

Structural Equation Modeling (SEM) is an analyzing method in use of many fields such as psychology, sociology, education, economics and marketing. SEM is composed of multivariate statistical methods [8]. It is seen that the use of SEM is limited in the field of hunting planning and wildlife management, against to many studies made in different branches of science by using SEM in Turkey [9] [10] [11]. It can be possible to use of SEM as a new method in the field of hunting management in literature. SEM is basically based on the researcher's thoughts related to a research topic by testing a model of inter-variable relationships that existed before studies are done through data obtained in the research result. The most significant difference between methods such as variance analysis (ANOVA), multivariate analysis of variance (MANOVA), factor analysis (FA), regression analysis, which are the most used statistical methods in SEM [12]. The main objective of the SEM is to explain the interdependency relationship pattern between the one or more observed variables and the implicit non-observable sets of structures. Three main components of the SEM [13]. These components are path analysis, conceptual synthesis of structural models and measurement models, and finally general estimation processes. Development of SEM should be addressed through some statistical concepts on a historical level. These analyzes are regression analysis, path analysis, confirmatory factor analysis (CFA) and SEM [14].

The concept of CFA emerged in the 1950s. Karl Joreskog developed the CFA in 1960 with his theoretical studies of whether or not the data set of a defined structure could be tested. FA is used to construct measurement instruments whereas CFA is used to test the existence of theoretical structures [14].

SEM is mainly a general statistical methodology. SEM uses path diagrams to show basic models in causal relationships. SEM was first recognized as "JKW" models because it was developed by Karl Joreskog, Keesling and Wiley. It was later used as "Linear Structural Equation Models" with the development of the LISREL (Linear Structural Relations) program [15]. [16] states that it would be better to call it "Factor Analytical Structural Equation Models" (FASEM) because SEM is based on FA. However, only the SEM concept has been used in recent years due to the use of nonlinear structural equation models [16].

There are two parts the measurement and the structural model in most general form of SEM. The measurement model specifies how the latent variables or theoretical structures are related to the observed variables and how they are represented. The structural model identifies the causal relationships between latent variables and describes causal effects [8] (Figure 1).

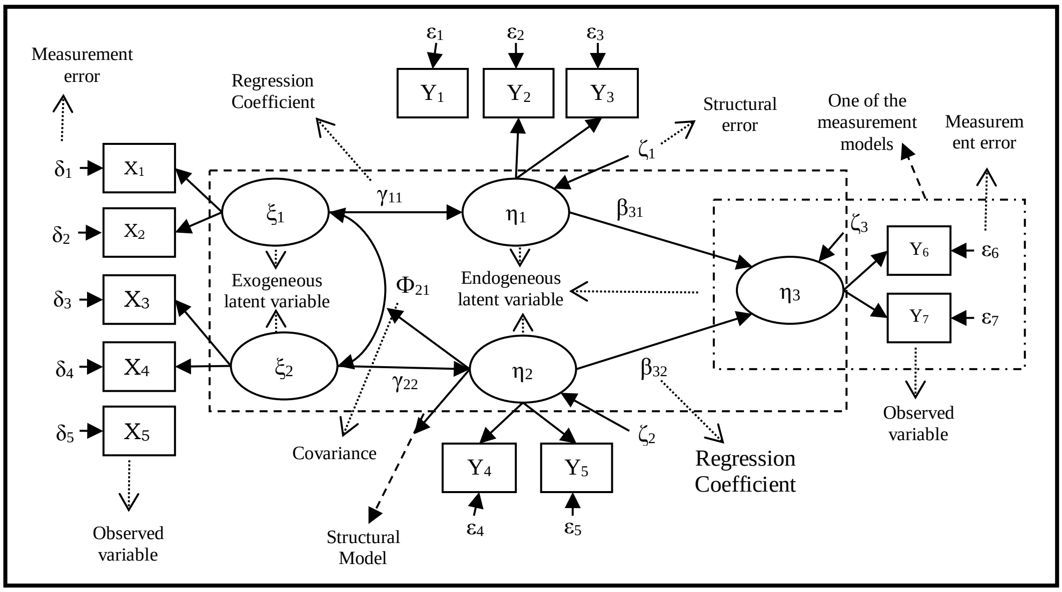


*Figure 1. A Typical Structural Equation Model Demonstration [17]*

When SEM model is tested many different criteria are used in evaluating the significance of the developed model. These measures are defined as goodness of fit values. There are many statistical functions related to this goodness of fit indexes. Commonly used indexes in SEM are Similarity ratios between chi-square statistics ($\chi 2$), Root-Mean-Square Error Approximation (RMSEA), Goodness-of-Fit Index (GFI) and Adjusted Goodness-of-Fit Index (AGFI) [14].

Other fit measurement values of SEM include Parsimony Normed Fit Index (PFI), Goodness of Fit Index (GFI), Comparative Fit Index (CFI), Incremental Fit Index (IFI), Relative Fit Index (RFI) [13]. Researchers using SEM often use GFI, AGFI, RMSEA, CFI, and NNFI criteria as well as chi-square values in their studies [11]. In the AMOS analysis, the AIK (Akaike Information Criterion), CAIC (Consistent Akaike Information Criterion) and ECVI (Expected Cross Validation Index) model comparison indexes are used in addition to these criteria [10]. Table 1 summarizes the most commonly used metrics for evaluating the suitability of the SEM and the data for these metrics.

*Table 1. Goodness of fit values in SEM [8] [10] [15].*

| Fit Indexes | Good fit | Acceptable fit |
|---|---|---|
| **General Model Fit** | | |
| $\chi^2$ | $0\leq \chi^2 \leq 2sd$ | $2sd \leq \chi^2 \leq 3\ sd$ |
| ($\chi^2/sd$) | $0\leq \chi^2/sd \leq 3$ | $3\leq \chi^2/sd \leq 4\text{-}5$ |
| **Comparative Fit Indexes** | | |
| NFI | ≥0,95 | 0,94-0,90 |
| NNFI | ≥0,95 | 0,94-0,90 |
| IFI | ≥0,95 | 0,94-0,90 |
| CFI | ≥0,97 | ≥0,95 |
| RMSEA | ≤0,05 | 0,06-0,08 |
| **Absolute Fit Indexes** | | |
| GFI | ≥0,90 | 0,89-0,85 |
| AGFI | ≥0,90 | 0,89-0,85 |
| **Conservative Fit Indexes** | | |

| | | |
|---|---|---|
| PNFI | ≥0,95 | - |
| PGFI | ≥0,95 | - |
| **Root Mean Based Fit Indexes** | | |
| RMR | ≤0,05 | 0,06-0,08 |
| **Model Comparison Fit Indexes** | | |
| AIC | | Smaller values than the compared model |
| CAIC | | Smaller values than the compared model |
| ECVI | | Smaller values than the compared model |

## 2. MATERIALS AND METHODS

The data obtained by scanning the studies on hunting and SEM studies are the theoretical models that can be used in hunting planning and hunting management studies. SEM methodology is used in analyzing the views, thoughts, perceptions, attitudes and perspectives of the stakeholder groups. SEM can be used as an analysis methodology in this respect. The views and perception on sustainable hunting of hunting stakeholders need to be holistically analyzed in sustainable hunting planning. SEM is used in some studies both on social and natural studies [1] [2] [3] [4] [5]. It is possible to transform the described factors obtained from studies related to hunting through SEM into a theoretical model.

## 3. RESULTS AND DISCUSSUION

When examined in related to hunting studies in Turkey, it is seen that stakeholder groups' perception about perception attitudes takes place [3] [18] [19]. Factors are effective in the sustainable hunting perception are the latent variables regarding the structural model, the essence of hunting, hunting culture, sustainable hunting, the hunting ethics, requirements of sustainable hunting, and sustainable hunting strategies.

In order to analyze the stakeholders of sustainable hunting by using SEM, the sustainable hunting perception (SHP) model which is theoretically developed according to related studies. There is related six factors can be described on SHP model: The essence of hunting (EH), The hunting culture (HC), Sustainable hunting (SH), The hunting ethics (HE), Requirements of sustainable hunting (RSH), Sustainable hunting strategies (SHS). According to main factors, studies related to the subject can be examined and the Sustainable Hunting Perception Measurement Model (Research Model) represented in Figure 2.

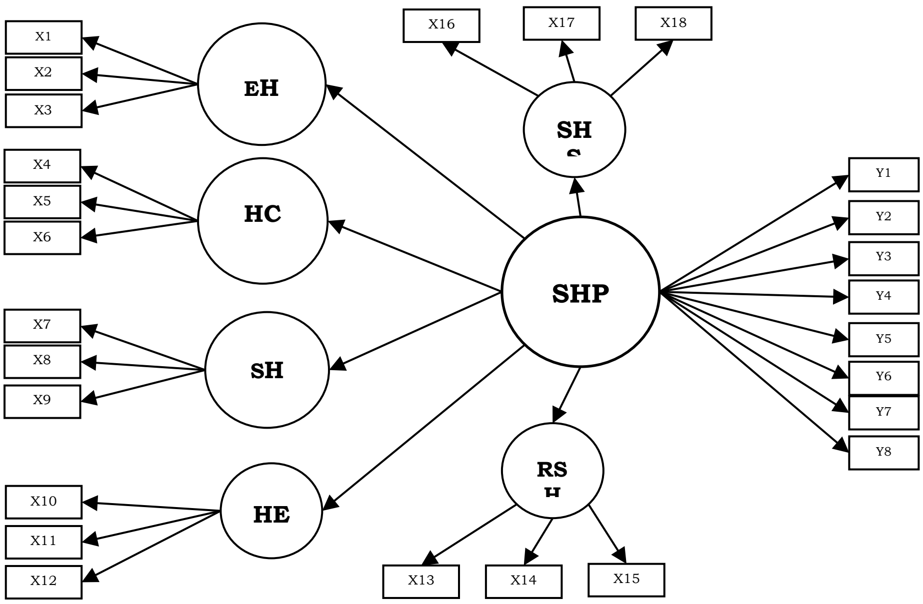



*Figure 2. Theoretical research model of sustainable hunting perception (SHP)*

## 4. CONCLUSION

SEM methodology has limited attention when it is used in the literature from studies done in the field of social sciences (10-20%). This rate is quite lower when compared the natural science studies in Turkey. In recent years, SEM has been used in very different scientific fields. Since the use of SEM in sustainable hunting is very limited in Turkey, the use of SEM in solving socio-economic problems and the continuing increase in such studies can provide significant contributions to the use of SEM in sustainable hunting and especially in solving socio-economic problems on this topic.

It can be possible to apply scientific studies to develop the stakeholders in place and to sustainable development by evaluating local potential with participatory hunting planning using SEM methodology. It will also be possible to obtain guidance on how the ecotourism sector should develop with different stakeholders in different land use policies and how it is likely to develop in future years.

It is possible to use SEM as a methodology for solving problems related to sustainable hunting management. However, the establishment of measurement and structural models requires a theoretical and statistical infrastructure to be done using SEM. If provide the appropriate conditions can meet, robust results will be obtained from the studies to be done in future research.

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# Digitalization of Farming and Sustainable Agricultural Development

***Andriy Popovych[1]***

**Abstract**

*Digitization is one of the most recent processes of transformation of world agriculture by overcoming existing environmental, economic and social problems and can be called the "third green revolution", since digital farming technologies allow to analyze and process large amounts of information, control and reduce production risks, meet the information needs of a wide range of stakeholders, from the state to the end consumer, as well as to ensure overall security. To answer the question of link between digitalization of the agricultural sector and sustainable development the article analyzes the potential of ICT technologies in agriculture, studies models of digital farming, considers the prospects for using digital economy tools in solving the problems of sustainable development of the agricultural sector. In particular, the article examines the advantages of ICT in terms of the rationality and sustainability of agriculture, provides an overview of the main technologies of intelligent farming in interaction with the infrastructure of the agricultural market. It also analyzes potential shortcomings, identifies barriers that impede the timely and large-scale implementation of information technologies in agricultural enterprises, limit the availability of the "digital revolution" in agriculture for small farmers and women, especially in developing countries. A practical analysis of this problem consists in conducting an economic and statistical analysis of the use of modern high-precision agricultural technologies in the vegetable growing industry. As a result of an econometric assessment of the data of small and medium-sized agricultural enterprises, the main factors of the existing development trends are identified and the main problems of sustainable development of sub-sectors are highlighted. The final model presupposes the development of an integrated approach to organizing sustainable development aimed at preserving natural landscapes, as well as improving scientific methods for environmental monitoring of agricultural lands and other areas that have not been effectively used.*

**Keywords:** agriculture, digitalization, information and communication technologies, sustainable development

## 1. INTRODUCTION

The digital economy is the future stage in the development of the global economic system due to the transformation of all spheres of human activity under the influence of information and telecommunication technologies. The spread of the Internet and other innovative technologies indicates the impossibility of ignoring their impact on the global economy in general and on its individual industries such as agriculture in particular.

Over the past decade, the priorities of the agricultural sector towards increasing its efficiency have changed to those based on up to date innovative solutions. Information and communication (ICT) technologies, which are usually understood as automation, informatization, digitalization, are being actively implemented today in all sectors of the economy, including agroindustry [1]. The purpose of introducing ICT in the agricultural sector

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is to increase the productivity of agricultural and processing enterprises by improving business processes with the help of innovative services [2].

"Digital agriculture" as it is often called implies the full-scale implementation of the digital economy, which consists of digital production technologies and robotic systems, as well as the commercialization and export of new scientific developments. The digital transformation of agriculture sector makes it possible to provide a technological breakthrough to farming to increase in capital and labor productivity at "digitalized" agricultural enterprises [1].

On the other hand, the modern paradigm of agricultural development presupposes both productive longevity and environmental sustainability with the preservation of habitat and focus on the optimal use of natural resources. It requires the deepening of the integration of ecology, crop production, livestock production and the business [2]. Achieving this level is possible with the gradual development of economic methods that ensure the relationship between natural and anthropogenic ecological systems and aimed at harmonizing the laws of ecology and economics [3].

The experience of the development of the agrarian sector testifies that as a result of the "technological revolution" classical extensive agriculture is being replaced by intensive and scientifically grounded. Information and satellite systems, multi-operational energy-saving agricultural units are widely used, considerable attention is paid to the selection of high-yielding varieties of agricultural crops, the creation of biologically active components for soil enrichment, new environmentally friendly means of combating weeds, pests and quarantine diseases of agricultural plants [4].

That is, there is a need for environmental management, which can develop on the basis of environmental entrepreneurship, one of the effective development directions of which can be the organization of environmental production of domestic high-quality products that solve food security problems. The main task of green management should be the creation of a management system that, on the one hand, reduces the impact of production technologies on the environment, and on the other, increases production efficiency [5]. The development of rural areas without the effective use of information capital is impossible as it contains valuable data relating to all areas of the economic entity and areas related to the sale, exchange, production of goods and services [4].

According to the generally accepted strategy, sustainable agriculture and the organization of agricultural landscapes should include regional specialization of agriculture, including the integrated use of land, the combined use of irrigated and non-irrigated lands, the development of land reclamation through the creation of various forms of plants, measures for the protection of biological diversity, and others [5]. Thus, the above theoretical substantiation of the greening process allows us to identify the factors that determine the technological and socio-economic basis of the organization of ecological agricultural production, ensuring its sustainable and effective development. It allows to solve the problems of increasing the environmental and economic efficiency of production by restoring, preserving and stimulating the natural cycle of substances destroyed by the processes of intensification of production, as well as maintaining the diminishing potential soil fertility and expanding reproduction due to the rational organization of agricultural land, the use of adaptive farming systems and improving the quality of products and increasing its competitiveness.

Ensuring the sustainability and manageability of agricultural land use is currently impossible to achieve without the use of the latest technologies and, first of all, digital. The most important direction of increasing the competitiveness and sustainable development of regional agri-food systems in the context of scientific and technological progress, the introduction of innovations is the widespread use of biological factors of economic growth: the achievements of genetics, breeding and seed production, new varieties and hybrids of plants that differ from their predecessors in higher indicators of potential yield, content in grain production of valuable nutrients, responsive to fertilizers, irrigation, drought resistance, immunity to diseases and pests. Digitization of agriculture is a prerequisite for achieving the effectiveness of the above-mentioned innovations [6].

## 2. OVERVIEW OF DIGITAL TECHNOLOGIES USED IN AGRICULTURE

"Digital economy" of the agricultural sector is a fully digitalized and automated production that is controlled by intelligent systems in real time, without human intervention, going beyond the boundaries of one enterprise, with the prospect of uniting into a global industrial network of things and services [7]. The information aspect in the activities of an agricultural enterprise becomes an integral part of any business process, an indispensable condition for the operation of modern technology, a prerequisite for the successful organization of the production process itself and means of improving the quality of the workforce.

The list of the digital methods and techniques used in agriculture today includes but not limited to precision farming, smart farms, smart greenhouses, monitoring the use of agricultural machinery using satellite navigation systems (for example, GPS) and sensors, smart storage for vegetables and fruits, irrigation automation, electronic trading platforms for farmers, technical devices such as drones, which include both ground-based drones and unmanned aerial vehicles and copters, as well as winged drones, etc. The other technical devices of information technologies in agriculture are weather stations, soil moisture sensors and other special applications used to collect data from the environment and soil and transfer them to the cloud system at a given time interval.

The main function they perform include monitoring the state of agricultural crops, calculating index indicators of plant mass, estimating the future harvest, detecting disease-causing manifestations, weed plants, insect pests [7]. The software allows you to register and notify farmers via SMS messages about the spread of diseases and pests in certain areas, store historical data on key soil and crop parameters for each season, as well as general information about diseases, pests and plants. As a result of the use of such technologies by farms, operating costs are optimized and yields increase by an average of 15-20% due to a reduction in the volume of seeds, agrochemicals, fertilizers and water used, which are used strictly "on demand." [8]

Digitization in agriculture also provides an opportunity to create complex automated production and supply chains, covering retail chains, wholesale trading companies, logistics, agricultural producers and their suppliers in a single process with adaptive management [9]. The digital transformation scenario assumes a systemic, accelerated digitalization of agricultural production and integration with the areas of digital economy programs which dictates the need for the inclusive use of logistics cargo transportation, stimulating domestic consumption, developing product exports and building platforms that provide end-to-end digital solutions to create added value and ensure the competitiveness of agrarian business. In turn, the digitalization of commodity flows and production makes it possible to systematically accumulate trade lots for the export of agricultural products. This creates conditions for attracting private financing for the platforms and applications of agricultural producers, the active involvement of agricultural consulting services [8].

The creation of information and consulting services in helps rural producers to make better decisions for the development of production taking into account external factors. Advance information on the occurrence of adverse factors (weather conditions, the spread of pests and disease outbreaks, changes in the market situation) and possible risks must be carried out through developed information and communication technologies and automated information systems. Supporting business projects by assessing the effectiveness of new digital technologies, making recommendations for improving production, introducing innovative technologies and disseminating information about new developments allows farmers to keep abreast of modern advances and spend money not on traditional technologies, but to implement an innovative structure in the economy [10].

The movement towards the development of precision farming is the initial stage in the global reform of agricultural technologies. The introduction of satellite navigation in agriculture contributes to an effective assessment of the reliability of equipment, to collecting data on its condition, location and problems that may arise in the course of work. The satellite technologies is a large-scale production and resource-saving complex that provides for full control of transport facilities, fuel reserves and the adaptation of the system to a specific enterprise [11].

The implementation of digitalization contributes to the development of a new agricultural technology policy and growth in related industries: information and communication technologies, production of innovative agricultural equipment, as well as equipment for precision farming, biological products (plant protection products, stimulants and fertilizers), optimization of the use of mineral fertilizers and chemical plant protection products, reducing the impact on the environment, developing breeding and seed-growing centers, introducing new educational standards in training programs in agricultural universities and colleges, as well as in advanced training courses, professional service of agricultural consultants, optimizing the life cycle processes of the agricultural industry due to digitalization of processes [11]. For sustainable development of agriculture, concepts of organizational and economic potential and the global introduction of informatization, accumulating information resources and knowledge for effective economic management, are constantly being developed making it possible to implement economic regulations for operating in specific conditions and to establish the processes of expanded reproduction of goods in all sectors of agriculture [12].

Furthermore, unified electronic systems are being formed that allow for full monitoring and analysis of the efficiency of agriculture in the country. This information system combines the subsystems used in the registration of farmers-producers of agricultural products, identification of land allotted for agricultural work, registration and identification of animals, their health and productivity. It also includes managing the application for financing for agricultural projects, the farmer lending system, as well as leasing operations and the registration of agricultural machinery. All these data will be sent online to a single processing center, which allows you to quickly identify problem areas in the agricultural sector and promptly make optimal decisions to improve the efficiency of the country's agriculture [13].

Distributed information processing technologies and cloud storage technologies also have high potential and obvious advantage in agriculture because of the ability to combine computing power to solve the most complex problems and implement modern highly efficient information systems, depending on current needs. The efficiency of collection, storage and processing of empirical data significantly increases when conducting research and analyzing the effectiveness of the use of certain agricultural technologies [14].

Agriculture is characterized to a greater extent by the automation of routine work, rather than the strengthening of the intellectual capabilities of managers. The most well-known technologies are implemented in the framework of applied computer programs to optimize the placement of crops in zonal systems of crop rotation and animal feeding rations, for calculating the doses of fertilizers, for carrying out a complex of land surveying and land management, for maintenance of the state cadaster of the history of fields and the development of technological maps for the cultivation of agricultural crops, for regulation of plant nutrition and microclimate in greenhouses, for control over the storage process of fruits and vegetables, the quality of cultivated products, soil pollution, for assessment of the economic efficiency of production, for management of technological processes in facilities of production and storage of raw products and foods and much more [13].

The use of geographic information systems (GIS) in crop production makes it possible to obtain more accurate data on the soil, on the peculiarities of sowing certain seeds or on the required amount of fertilizers, which makes it possible to increase the yield. For example, in the process of growing some crops, it is extremely important to observe a certain amount of seeds that must be planted on the site. This process can be monitored using special equipment that has information about the yield levels in different parts of the field over the past years. At the end of the harvest period, the device records the performance of each area. This data is then automatically sent to the geographic information system for further analysis and planning of the next sowing work. GIS allows you to regulate almost any calculations in crop production: they update and build maps of land, control the movement of agricultural machinery, process data and calculate technological operations [15].

Thus, the use of modern information and communication technologies is one of the main conditions for the effective development of agriculture. It is necessary to introduce and develop "e-agriculture", to train highly qualified IT specialists in the field of agriculture, to improve the knowledge and skills of small and medium-sized agricultural producers. In other words, information and telecommunication technologies should provide automated data exchange at the federal, district, regional and district levels [3]. At the same time, in many countries, primarily developing countries, agriculture lags far behind in the use of digital technologies in comparison with other sectors of the economy. If we compare the share of information and communication services in GDP, at present in the United States the indicator is 25%, in the EU countries - 15%, in developing countries - no more than 5% [16].

The progress of the process is slowed down by the existing problems of the countries based on social, economic, psychological and other prerequisites. The introduction of large-scale machine production faced a number of contradictions caused by the need to use a colossal amount of information and the impossibility of processing it using traditional technologies. The low threshold for informatization of society is explained by the psychological unpreparedness of the population for informatization, a low level of computer literacy, conservatism of the population and a lack of desire to accept innovations.

The slow introduction of ICT in agriculture of developing countries is due to the presence of such constraining factors as problems with the Internet (especially in remote regions), which makes it difficult to use software online, lack of financial resources for the implementation of information and communication technologies in most agricultural producers, lack of digital literacy and digital skills among agricultural producers, low level of infrastructure provision for the implementation of digital technologies and platform solutions. Therefore, the main reasons for the lag in the development of digital agriculture are, firstly, the low share of coverage of the territory of the regions with the Internet and communications, secondly, the lack of funding, thirdly, there are problems in the legal framework: the lack of the necessary legal mechanisms to regulate the use of digital technologies and, finally, the lack of the necessary specialists.

The problem of insufficient development of agriculture can be solved by attracting investments, targeted state support and large-scale informatization of industries [17]. Increasing the economic efficiency of the agricultural sector to the level of competitiveness in the world market is impossible without improving all areas of the economy, as well as introducing innovative technologies and production automation into its structures. Nevertheless, it is possible for agriculture to receive targeted expansion and development, subject to the creation of new links of the digital economy, with an increase in the productivity of agricultural enterprises to provide food to residents in the required amount, which will lead to the stability of the country's food security and an inevitable recovery of the economy as a whole.

At the same time, each country has its own digital agriculture system that meets the needs of that country and acts in the interests of national policies. As practice shows, the effectiveness of any national digital agriculture system is determined by the presence of a modern infrastructure that ensures information security, cybersecurity and personal data protection, electronic platforms for the provision of electronic services, digitized information under the jurisdiction of government bodies, full coverage of the territory with 4G and 5G broadband communications, information platforms, on the basis of which the interaction of services with persons employed in the agricultural sector is ensured, informational and financial support for people employed in agriculture.

## 3. THE STATE OF AFFAIRS AND DIGITALIZATION TRENDS IN FARMING

Stability of production is an indispensable requirement for the effective development of any branch of the national economy, but this factor is especially important in agriculture. The existing instability of agricultural production is manifested, first of all, in the annual fluctuations in the volume of crop production. Moreover, an increase in production does not necessarily lead to a decrease in the level of its variability. This is a consequence of the fact that the main focus is on increasing production volumes, and the task of increasing its sustainability remains unresolved. Therefore, it is necessary to develop such a structure for the use of agricultural land, which would optimally combine both an increase in production volumes and an increase in its sustainability in each agricultural enterprise.

Fluctuations in the production of agricultural products in the developing countries are often caused by a significant deterioration in the quality characteristics of agricultural land and land degradation. The main reasons for the decrease and annual variation in harvest volumes are associated with the lack of substantiated scientific and methodological approaches for the reorganization of agricultural enterprises, strategies for land use, the formation of a land use system, reliable, high-quality information on soil, geobotanical, hydrological, geological, soil-erosion and other types of survey, assessing the ecological state of lands, applying the landscape-ecological approach in solving issues of land use, organizing land tenure, land use, state financing of programs and measures for land restoration, increasing their productivity, lack of proper control over the state and use of land by agricultural producers.

An increase in the intensity of the degradation processes of the land and property complex, which has a negative impact on the development of harvest growing, is also associated with a sharp deterioration in the financial and economic situation of agricultural producers, with a decrease in the general level of farming culture and a violation of the requirements of the farming system, with the use of depleting types of land use and technologies.

International agreements and support from the Food and Agriculture Organization of the United Nations play a significant role in the development of national digital agriculture systems of developing nations which have significant agricultural sectors constituting important part of domestic economy. It supports the implementation of a unified statistical data system on agricultural production, which is of strategic importance for agricultural policy planning. An integrated web system TRIACS is supported in the developing countries, which includes modules for administration and control over payments of subsidies to farmers. Farmers are supported in the development of digital technologies in agricultural and horticultural crops. The US Agency for International Development has developed software that allows the small-scale farmers to keep records of plants and send SMS alerts in case of plant diseases.

The Ukrainian Horticultural Business Development Project (UHBDP), sponsored by the Canadian Government through MEDA, provides tangible assistance to farmers. The program operates in the Nikolaev, Kherson, Zaporizhya and Odesa regions. The uniqueness of the program lies in the fact that it is a non-profit project of one or several companies, and it is aimed at a wide range of people working with the land. Assistance was also provided in the introduction of innovative technologies, in terms of digitalization, the creation of a database and a map of farms. This assistance is personal and is aimed at small farmers and land users, they are the focus of the project.

Within the framework of the program, continuous and local soil monitoring of agricultural lands using GIS technologies was deployed, information databases on soil fertility were formed, ecological frameworks were developed taking into account the relief conditions, genetic characteristics of the soil and its agricultural use, providing a deficit-free level of energy balance of the agricultural landscape. In addition, an landscape structuring of agricultural lands was carried out and the most effective measures to maintain and reproduce soil fertility were determined, taking into account its state in each agricultural landscape, recommendations were developed for the effective use of agricultural lands, the prevention and elimination of the consequences of negative processes (de-humification, erosion , over-consolidation, desertification, etc.), work has been launched on chemical reclamation and phytomelioration of acidic and saline soils, restoration of the fertility of degraded and low-value lands.

The creation of a system of information support for decision-making processes based on GIS technologies made it possible to increase the overall efficiency of agricultural production by presenting relevant analytical information on the entire range of necessary parameters for making optimal and timely management decisions. GIS technologies are especially important in the management of agricultural production in regions with risky farming. These territories require constant monitoring of the conditions for the development of crops and the conduct of agrotechnical and agrochemical measures. Surveillance can be carried out both in individual fields and within a district, region, or over a wider area [18].

In the process of introducing and using GIS technologies in crop production, the project at least partly connected number of agricultural units to satellite navigation systems, which allow, using a GPS receiver and special software, to obtain the exact coordinates of the contours of the fields. An important element of the process of collecting, analyzing and processing the necessary data for the subsequent adoption of informed management decisions and their expert support is software and hardware (dispensers, measuring sensors) and their relationship [19].

## 4. EMPIRICAL ANALYSIS OF ICT USAGE IN SMALL FARM VEGETABLE GROWING

For the purpose of this research the vegetable farming in the East and South Europe is chosen where over the past 35 years, the amplitude of fluctuations in vegetable production reached 242% of the average annual harvest for this period. The volumes of other agricultural products harvesting also experienced significant fluctuations, which negatively affected the efficiency of the related processing industries.

The main goal of this study is a theoretical and methodological substantiation of the need for the introduction and effectiveness of the use of information technologies on the platform of geographic information systems (GIS) in the implementation of agrotechnical measures in vegetable growing. For this analysis, the database of the UHBDP in terms of growing vegetables, collectively referred to as tomatoes, cucumbers and peppers, by small farms in Bulgaria, Romania and Ukraine is used.

Analysis of the time series of vegetable production in the region makes it possible to distinguish three stages in the development of vegetable growing, formed under the influence of general structural changes in the agrarian economy over the past thirty plus years, that is, during the transition of the studied countries from a planned socialist economy to a market economy and the improvement of the latter. In the pre-reform period, vegetable farms for sowing annually bought seeds of the elite and the first reproduction, which ensured a sufficiently high yield and varietal purity. Mineral fertilizers were widely used and the intensive development of technology has also contributed to the annual increase in the yield of vegetables.

The process of reduction of acreage of vegetable crops in the 90s was accompanied by a decrease in yields and gross harvest of vegetables. This situation is associated with the prevailing price disparity in the sub-industry, which led to a shortage of working capital from producers for the purchase of mineral fertilizers, chemical protection products, high-quality seeds, and equipment renewal. The technology of growing vegetables was simplified everywhere, the quality of the product obtained decreased. The fall in effective demand led to a decrease in their production by more than 3 times while sales dropped by almost 40 times. Vegetable lands were often sown with other crops with lower agrotechnical qualities and a high degree of weed infestation. During the period from 1990 to 2001, the technical equipment of vegetable growing has sharply decreased. Depreciation of energy resources, primarily tractors, amounted to 90%, other equipment - 65%, the doses of fertilizers, the volume of capital investments in the reconstruction and construction of reservoirs, pumping stations, rice irrigation systems were reduced significantly, which led to a decrease in productivity, the gross harvest of vegetables in the region decreased annually by an average of 12%.

The alignment of price relations in agriculture and related sub-sectors in the period after 2002, the intensification of the financing of vegetable growing from the state and regional budgets led to the fact that the domestic vegetable market became profitable, and it became profitable for producers to invest in its production. The increase in the doses of mineral fertilizers ensured an increase in the yield of vegetables. Since 2005, the area under vegetables has expanded by an average of 7% per year. However, natural and climatic conditions do not allow excluding the import of vegetables from the balance of products.

In the first post-reform decade, the main factors of fluctuations in the indicator were the economic crisis, the unstable price situation in the rice and adjacent markets and the lack of funds from producers to carry out reproduction processes in the sub-industry, as well as natural and climatic features. The low value of the sustainability of the trend in the area under vegetables in the last decade is a consequence of the reactions of producers to the changing conditions in the markets of agricultural raw materials by shifting the area under crops for more profitable crops like corn and sunflower.

The analysis of the structural variability of the trend was carried out by using the econometric modelling. Its advantage is the use of one general regression equation, rather than several piecewise linear dependencies in the period under consideration.

The linear regression equation with dummy variables is:

$$y = \alpha + \beta\bar{x} + \gamma\bar{d} + \varepsilon \qquad (1)$$

where y is the dependent variable, x is a vector of independent variables, d is a vector of dummy variables (if it corresponds to the truth, it is equal to one, otherwise it is equal to zero), α is a free coefficient, β, γ are estimated regression parameters, ε is the regression error.

The difference in the size of the harvest of the current year to the previous one in absolute terms was chosen as a dependent variable, and the absolute value of the difference in the amount of fertilizers applied to the vegetable crops and dummy with unit value in case of application of GIS technologies as independent variables. Analyzing the relationship between the volatility of vegetable yields in the region and the difference in the doses of fertilization and use of GIS technologies, a linear equation of the following form was compiled:

$$YLD_{ij} = \alpha + \beta FRT_{ij} + \gamma GIS_i + \varepsilon \qquad (2)$$

where $YLD_i$ is the difference in yield of a type of vegetables in agricultural organizations of the region, $FTL_i$ is difference in the amount of mineral fertilizers applied per hectare of planting a type of vegetable crops in agricultural organizations of the region during the period under review, c/ha, GIS is a dummy variable, the value of which is equal to one if the farmer used GIS technologies and zero if not, i is individual farm, j is correspondingly means tomatoes, cucumbers and paprika.

Application of linear regression for the above equation for each type of studied vegetable crops produced the following results:

*Table 2.Results of econometric estimation for tomatoes (TMT), cucumbers (CCB), paprika (PPR)*

| Dep. Variable: | TMT | | CCB | | PPR | |
|---|---|---|---|---|---|---|
| No. Observations: | 361 | | 332 | | 192 | |
| R-squared: | 0.712 | | 0.656 | | 0.840 | |
| Adj. R-squared: | 0.784 | | 0.664 | | 0.929 | |
| F-statistic: | 345.0 | | 205.8 | | 178.7 | |
| Prob (F-statistic): | 0.000 | | 0.000 | | 0.000 | |
| Log-Likelihood: | 1463.8 | | 953.06 | | 726.31 | |
| vars | FRT | GIS | FRT | GIS | FRT | GIS |
| coef | 2.1486 | -10.3178 | 1.5037 | -3.2090 | 2.1889 | -7.9265 |
| std err | 0.076 | 1.378 | 0.035 | 0.437 | 0.090 | 1.434 |
| t | 28.234 | 7.486 | 42.736 | 7.350 | 24.240 | 5.526 |
| P>\|t\| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Omnibus: | 91.969 | | 45.838 | | 26.359 | |
| Prob(Omnibus): | 0.000 | | 0.000 | | 0.000 | |
| Skew: | -0.113 | | 0.030 | | 0.026 | |
| Kurtosis: | 1.944 | | 2.066 | | 2.045 | |
| Durbin-Watson: | 1.681 | | 1.662 | | 1.701 | |
| Jarque-Bera (JB): | 17.547 | | 12.121 | | 7.314 | |
| Prob(JB): | 0.000155 | | 0.00233 | | 0.0258 | |

All coefficients of three equations (2) turned out to be statistically significant at a one-percent level of significance, therefore, a change in the independent factors was accompanied by a change in the resulting amount of dependent variable. Analysis of the set of vegetable yields in the region showed a statistically significant dependence on the parameters of the linear trend in the studied data which are the change in amount of fertilizer used and application of GIS technology. Moreover, all the coefficients have the expected sighs. So, the positive coefficient of a variable standing for difference in mineral fertilizer use negatively affects the stability of the levels of the yields, which characterizes the deviations of the actual levels of the set relative to the previous year, while the negative sign of the coefficient responsible for the application of GIS supports the stability of the trend in the analyzed periods.

Note that the data is best approximated by a linear relationship, which indicates a significant reserve for the improving the stability of the vegetable sub-sector of the agriculture of the region. The coefficient of stability of the yield in this period was 32%, which is 11.5 percentage points higher than the coefficient of the growth trend of harvested areas. Thus, the growth of the gross harvest of vegetables in the region has recently been provided, to a greater extent by the growth of yields, rather than by extensive factors. An increase in the dose of mineral fertilizers per 1 kg of active ingredient per hectare of sowing led to an increase in yield by an average of 2.1 kg for tomatoes, by 1.5 kg for cucumbers and 2.2 kg for paprika. The influence of factors of development and modernization of vegetable growing in the equation identifies the dummy variable. The fact of application of GIS technology by a farmer on average leads to decrease in variability of yields by 10 centners for tomatoes, by 3 centners for cucumbers, by 8 centners for paprika. Thus, it can be concluded that the GIS technology lead to more sustainable development in vegetable growing in small farms.

## 5. CONCLUSION

Digitalization of agriculture is a developing area aimed at increasing agricultural production through the improvement of information and communication processes. The digital technologies should also provide path to the sustainable development of farming. There are plenty of new tools to by introduced to the agricultural sectors but the degree of implementation of information technologies in agriculture is inextricably linked with the social-economic situation in the country and to expand the scale of informatization, along with economic conditions, political, technical and social conditions are required, especially in the developing countries. However, even small scale application of digital technologies like GIS in particular sub-sector of agriculture can provide necessary proof of positive influence of digitalization on sustainability of agriculture.

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# Recycling of aged inkjet prints with nano technology based inks

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***Abstract***

*Paper recycling has become an imperative at the end of the life cycle of all paper products. The development of technological processes in printing technology is usually associated with innovations in printing presses, but significant contributions also occur in the use of new graphic materials. In this research special attention was given to new formulation of printing ink which is based on nanotechnology. The samples were printed on a digital inkjet printing press Kodak Prosper 6000C. The mentioned printing press is using Adaphos NIR® technology for drying inkjet prints. The significance of this method is important because it provides the possibility of printing newspapers, but due to the reduction of energy use, which contributes to the reduction of the carbon footprint and the greenhouse effect. Another notable reason to use the selected printing press is in the use of new inks formulation which is based on nanotechnology. Nano-sized inks particles provide important properties to the prints obtained, for example enabling higher optical densities, as well as volume of gamut. Due to the stated property, as well as due to a good comparison with the real conditions of recycling the printed samples were subjected to a process of accelerated aging. The process of accelerated aging was conducted at several different intervals in order to study the effect of accelerated aging on the properties of recycled laboratory paper sheets. The process of accelerated aging was simulated in a climate chamber under conditions of elevated temperature and humidity and without the influence of solar radiation. By changing the printing technique, using nanotechnology-based inks, the changes in the qualitative properties of recycled sheets of laboratory paper occur. Changes in qualitative properties are manifested in the changes in the optical properties of laboratory sheets of paper, which are studied in this scientific paper.*

**Keywords:** Inkjet prints, nanotechnology inks, accelerate ageing, recycling, optical properties

## 1. INTRODUCTION

Environmentally more sustainable production includes: innovative materials, clean technologies, closed loop systems, energy and material flows [1]. Generally, sustainability is significant for the development and except the concept of environment includes economic and social factors, implementation of society values and quality. Fortunati and O'Sullivan investigated the social sustainability of print newspaper versus digital media, and how the media system is an important factor of social participation and sustainable social change, as well as compared their economic model [2].

Cleaner production in graphic process of printing is a term for conserving raw material and energy, pollution prevention and emission reducing. For graphic products it means reducing their environmental impact during

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life cycle. Life cycle assessment of the product has to be considered and included in planning and starting from graphic design in early stage of product creation [3, 4].

The ecological footprint largely depends on the printing techniques, the chemical composition of the ink, the type of printing substrate, and the characteristic of the prints, such as size and shape.

In the past, digital machines, due to their capacity and technology, were tied only to small editions, but with the development of computer speed and RIP software, new graphic materials, especially dyes, are also associated with large editions. With the advancement of technology high-performance digital machines can make a print that follows the quality of conventional printing techniques. Contributes to the increasing use of the mentioned technologies are reduced of relative costs of digital printing techniques [5]. The digital printing contributes to sustainable development. These printing techniques, in regard to some printing techniques has advantage in fewer influence on environment mainly due to faster make ready and the absence of plate making and its related chemicals, materials, emissions and wastes [6].

Easiest ways to reduce the environmental impact of printing is to use eco-friendly inks: water based, plant based and nanoparticles based inks. New formulated inks emit very few organic compounds while they dry and as a result, are better air quality in working area. In the water based ink higher alcohols or glycols act as moisteners and are probably the oldest eco-friendly ink available. Algae based inks are relative innovation [7]. These inks make use of renewable algae cells as the basis of their black pigment. Plant based ink from algae and other plant based materials for inkjet printing will still be developed [8].Steward and co- authors investigated of nanoparticle innovation with application to print on paper. They using network mapping method and three types of nano-innovation, which includes in research: nano inks, nano fiber and nano coating [9].Authors concluded that the emergent contributes tendency is to the performance goals of printability rather than drinkability.

Sustainable production of the raw materials for papers can be obtained from any virgin fibers which is FSC certified, but the mentioned raw materials are not often used in the production of newsprint printing substrate because newspaper printing substrate doesn't require such optical and mechanical properties It is usually to use raw materials with large amount of recycled fibers [10]. Recycled fibers are even more environmentally friendly than FSC certified fiber, because recycled fibers require less bleaching than virgin fibers obtained from trees. Primarily, recycling facilitates in reducing the production of methane from landfills. Due to climate change concerns about the environment, climate change and the optimal utilization of natural resources, much attention has increasingly been paid to shifting waste management up the waste hierarchy. The researcher from University College London found that greenhouse gas emissions would increase by 2050 if will be recycled more paper as current methods and use fossil fuels and electricity from grid [11].

In this paper presents the influence of printing techniques, ink and substrate formulation as well as prints exposed to moist heat accelerated ageing on ink detachment in recycling process. Deinking ability is explained in terms of brightness and effective residual ink concentration. The color coordinates L*, a*, b* were used to determine the effects of residual ink, respectively a soluble color due dye. The results are important for obtained quality secondary raw material as well as in production new formulation of graphic materials.

## 2. EXPERIMENTAL PART

### *2.1. Materials*

The Kodak water- based pigmented process color inkjet inks are used in the experimental work. The earlier color pigment inkjet inks were causing nozzle clogging and have poor color gamut. The advantage of Kodak for Stream inkjet technology lies in a propriety micro –milling process that de-aggregates and fractures primary particles, resulting in smaller ones. By connecting nanoparticle pigment and knowledge of pigment dispersant chemistry, that is ideal across a wide range of processes and applications. Kodak's inkjet inks with nanoparticle pigments enabling higher optical densities, higher volume gamut, has superior print durability including lightfastness and water fastness.

A wide range of commercially available inkjet compatible printing substrate can be run on Kodak Prosper 6000 C presses at full press speeds. These include industry standard uncoated, coated and glossy paper from 42-270 gsm. In this article a commercial printing substrate was used for printing a magazine. Coated paper has a special coating applied to the surface to one side. This coating allows the ink to be evenly absorbed into to paper.

The Kodak Prosper 6000 C press was used to print the samples. The press incorporates a number of smart components that optimize print quality [12]. This press use technical innovation in press design, drying, print speed and Kodak's Intelligent Prints innovation System (IPS). It is an advanced press management process that constantly monitors system operation to ensure color quality and imaging performance. The imaging system combine to delivering, there are significant ink saving compared to thermal inkjet presses. Prosper press is able to deliver print quality that's comparable to offset printing

### *2.2. Methods*

### 2.2.1. Ageing of samples

Accelerated ageing is to expose the object to a higher level of energy, mostly heat but also to light or other radiation and aggressive pollutants. Deinkability behavior depends on different factors, and one of them is ageing of the prints. Colored inkjet prints with nanotechnology inks were exposed to moist-heat accelerated ageing at $80^{o}C$ and 65% relative humidity without the light [13]. Samples treated 1,2,3,6 and 12 days in Kottermann 2306 conditional chamber.

### 2.2.2. Paper recycling process

Printed paper samples were recycled by means of chemical deinking flotation under laboratory conditions defined by standard procedures described in ISO 21993:2020 [14]. The ISO method is based on INGEDE Method 11[15]. Non-aged and accelerate aged samples were recycled. Samples with all chemicals were disintegrated using Enrico Toniolo disintegrator. A certain amount of pulp suspension was separated after disintegration process before flotation (marked UP). Remained pulp suspension was transferred to laboratory flotation cell. During flotation process, froth was collected and removed from pulp suspension. Residual pulp suspension was used for production deinked handsheets (marked DP). Laboratory paper handsheets of $45g/m^2$ UP and DP were made using automatic sheet-forming device Rapid-Köthen Sheet, PTI [16]

### 2.2.3. Deinkability evaluation

The efficiency of recycling process was evaluated by measuring optical properties of laboratory handsheets made from un-deinked pulp (UP) and deinked pulp (DP) obtained from untreated inkjet prints and accelerate aged ones. Evaluation of optical parameters was conducted according to spectrophotometric standard methods. The spectrophotometer Technidyne ColorTouch was used to measure the L*a*b* values (under following condition: D50 illumination and $2^0$), measure of diffuse blue reflectance factor, that is ISO brightness and determination effective residual ink concentration (ERIC number) by infrared reflectance

## 3. RESULTS AND DISSCUSSION

Flotation is the most used technology for ink removal in the paper recycling process. The deinkability is assessed by quality factor of the deinked pulp: color shade, dirt specks, and the efficiency of the process itself can be monitored by ink elimination, ERIC number and filtrate darkening.

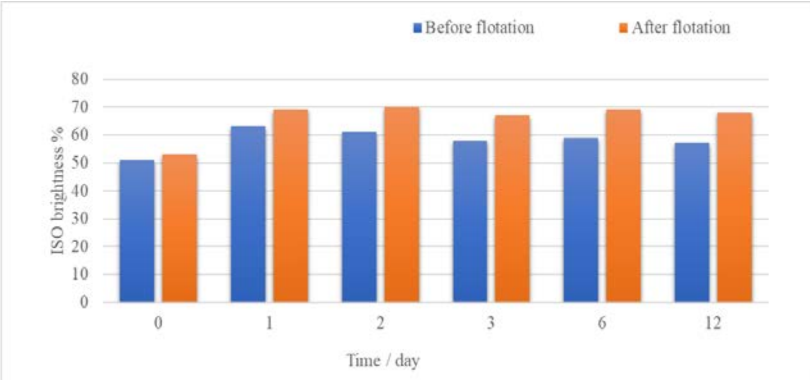


Figure 1. The value of ISO brightness handshets made from undeinked UP and deiked pulp DP and non aged and aged inkjet prints

Deinkability behavior depends on ageing of prints. The efficiency of deinking process (Fig.1) is further clarified by brightness gain (ΔB= brightness of handsheets made from DP pulp - brightness of handsheets made from UP pulp. The results show that the highest brightness gain is 11.3 points for 12 days aged inkjet prints, 10.11 points for 6 day aged prints, 9.00 points for 3 days aged prints, 9,00 points for 2 days aged prints, 6,02 points for 1day aged prints and 2,10 points for non- aged prints (Fig.1). These results show the efficiency of the recycling process in relation to the ageing days of the prints.

In addition brightness gain should be observed as ΔB= brightness of handsheet UP in relation of the prints ageing days – brightness of handsheets UP from non aged prints. The results show: $UP_{1\ day}$-$UP0_{day}$ =12.10 points, $UP_{2\ days}$-$UP0_{day}$ =10.05 points, $UP_{3\ days}$-$UP0_{day}$ =7.30 points, $UP_{6\ days}$-$UP0_{day}$ =8.02 points and $UP_{12\ days}$-$UP0_{day}$ =6.03 points.

Brightness after pulping illustrates variation in ink fragmentation, and depends on the type of ink. Typical water based inkjet inks disintegrate into very small particles during pulping. These particles are very difficult to remove by flotation deinking and remain in the suspension and can reattach to the fibers. In general, the ink removal process by deinking flotation process is based on the difference between hydrophobic inks and hydrophilic paper fibers, which is not the case here.

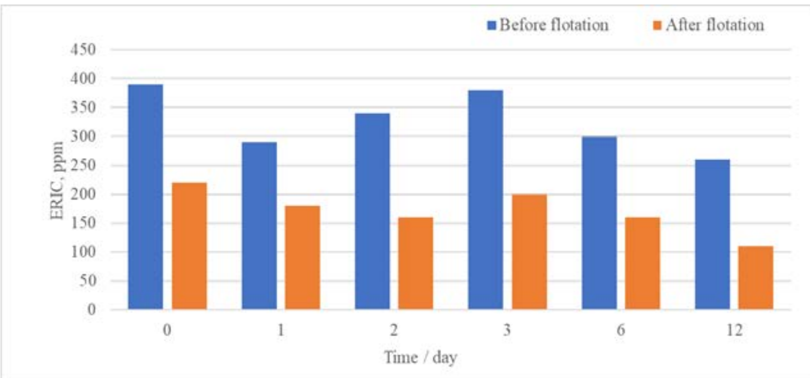


Figure 2 The value of the ERIC for handshets made from non deinked UP and deiked pulp DP and non aged and aged inkjet prints

ISO brightness is affacted by the presence not only of ink also of other light absorbing material in the blue part of the spectrum as lignin, cromophores and dyestuffs. The ink Effective Residual Ink Concertation (ERIC) method mesaurents in the infrared part of the spectrum and the light absorption coeficient of the ink is greater than the asorption coeficient of the fibre and other components and provide sensitiv estimating the concentration of ink, and is most effective for submicron particles.

T printshe obtained results show an inversely proportional relelationship betwen the resolts of brightness and ERIC, ie increasing the brightness, decreaes the value of ERIC. The results for handsheets UP show: $UP_{1\ day}$-$UP_{0\ day}$ =- 100 points, $UP_{2\ days}$-$UP_{0\ day}$ =-50 points, $UP_{3\ days}$-$UP_{0\ day}$ =-10 points, $UP_{6\ days}$-$UP_{0\ day}$ =-91 points and $UP_{12\ days}$-$UP_{0\ day}$ =-130 points, and for handsheets DP show: $UP_{1\ day}$-$UP_{0\ day}$ = -40 points, $UP_{2\ days}$-$UP_{0\ day}$ =-60 points, $UP_{3\ days}$-$UP_{0\ day}$ =-20 points, $UP_{6\ days}$-$UP_{0\ day}$ =-40 points and $UP_{12\ days}$-$UP_{0\ day}$ =-110 points (Fig.2). Bases on the results, it could be concluded that in some cases when ink particles have detached from the fibers and dispersed into the aqueous phase that they are redeposited on the fiber surfaces.

Figure 3 shows the L* chromatic coefficient which presents the lightness of the color on handshets made from un-deinked pulp (marked UP) and deinked pulp (marked DP) obtained from untreated inkjet prints and accelerate aged. The results obtained are as follows: $L^*_{UP\ non\ aged\ prints}$-$L^*_{DP\ non\ aged}$=-2.21 points, $L^*_{UP\ 1\ day\ aged\ prints}$-$L^*_{DP\ 1\ day\ aged}$=-2.69 points, $L^*_{UP\ 2\ days\ aged\ prints}$-$L^*_{DP\ 2\ days\ aged\ prints}$=-5.31 points, $L^*_{UP\ 3\ days\ aged\ prints}$-$L^*_{DP\ 3\ days\ aged\ prints}$=-6,30 points, $L^*_{UP\ 6\ days\ aged\ prints}$-$L^*_{DP\ 6\ days\ aged\ prints}$=-5,39 points, $L^*_{UP\ 12\ days\ aged\ prints}$-$L^*_{DP\ 4,00\ days\ aged\ prints}$=-4.00 points.

The influence of accelerated ageing of inkjet prints on the chromatic coefficient L* of the handsheet UP made from non-deinked pulp was determined as follows: $L^*_{UP1\ day\ aged\ prints}$-$L^*_{UP\ non\ aged\ prints}$ =5.51, $L^*_{UP\ 2\ days\ aged\ prints}$-$L^*_{UP\ non\ aged\ prints}$ = 4.20, $L^*_{UP\ 3\ days\ aged\ prints}$-$L^*_{UP\ non\ aged\ prints}$ = 3.80, $L^*_{UP\ 6\ days\ aged\ prints}$ $L^*_{UP\ non\ aged\ prints}$ = 4.11, $L^*_{UP12\ days\ aged\ prints}$-$L^*_{UP\ non\ aged\ prints}$ =3.40.

In addition, the results of the accellerted ageing influence on the chromatic coeficient L* of handsheet DP are presented: $L^*_{DP1\ day\ aged\ prints}$-$L^*_{DP\ non\ aged\ prints}$ =6.09, $L^*_{DP2\ days\ aged\ prints}$$L^*_{DP\ non\ aged\ prints}$ = 7.40, $L^*_{DP3\ days\ aged\ prints}$-$L^*_{DP\ non\ aged\ prints}$ = 5.99, $L^*_{DP6\ days\ aged\ prints}$ $L^*_{DP\ non\ aged\ prints}$ = 7,56, $L^*_{DP12\ days\ aged\ prints}$-$L^*_{DP\ non\ aged\ prints}$ = 6,09.

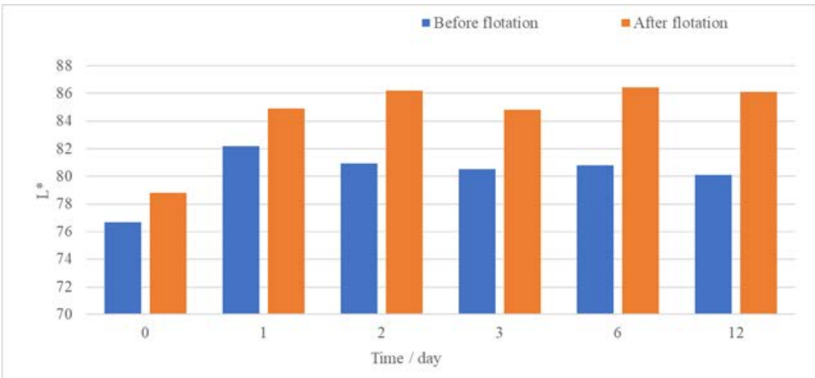


Figure 3. The value of the chromatic coefficient L* for handshets made from undeiked UP and deinked pulp DP and non aged and aged inkjet prints

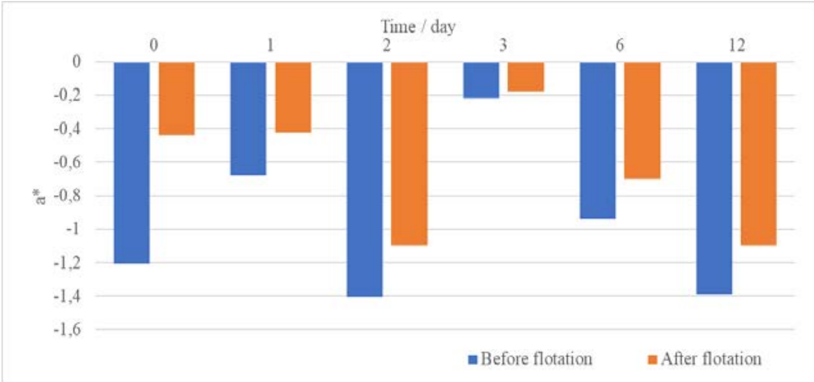


Figure 4. The value of the chromatic coefficient a* for handshets UP made from undeinked and handshets DP made from deinked pulp and non aged and aged inkjet prints

Chromatic coefficient a* represents colour position on red-green axis. All the results of measuring the chromatic coeficient a* are in the negative part of the red –green axis, so they are in the green area. The biggest negative value have handsheets as folows: handsheet $_{UD,\ non\ aged}$ = a*-1.21, handsheet $_{UD,\ aged\ 2days}$ = a*- 1.41, handsheet $_{UD,\ 12\ days}$ = a*-1.39. After deinking flotation, ecrease in the negative value of the chromatic coeficient a* was found in all cases, and the largest is for handsheet DP made from non aged inkjet prints, handsheet $_{UD,\ non\ aged}$ - handsheet $_{PP,\ non\ aged}$ = a*-0.77.

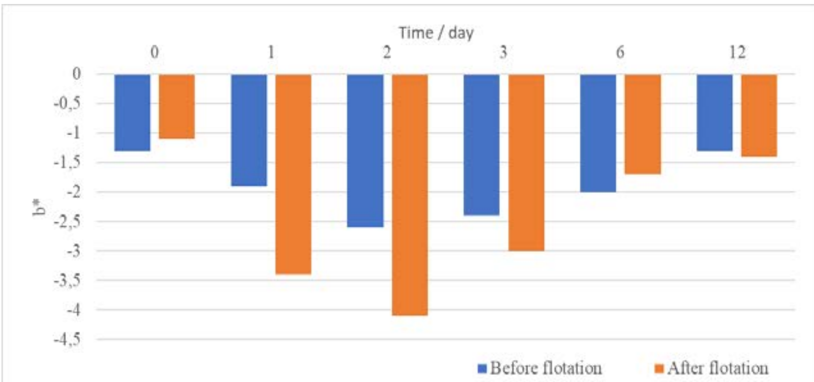


Figure 5. The value of the chromatic coefficient b* for handshets UP made from undeinked and handshets DP made from deinked pulp and non aged and aged inkjet prints

Chromatic coefficient b* represents color position on yellow-blue axis. All the results of measuring the chromatic coefficient b* are in the negative part of the yellow-blue axis, so they are in the blue areas. The best results are achieved by deinking flotation of the non aged sample: handsheet $_{UD,\ non\ aged}$ = b*-1.31 and handsheet $_{PD,\ non\ aged}$ = a*-1.10. With exposed to ink jet prints to moist heat ageing without the light does not notice the depedance to the value of the chromatic coefficient b.

## 4. CONCLUSIONS

Despite the fact that the consumption of these kinds of printing inks based on nanotechnology is still limited, due to a precautionary principle it is necessar to examine thir possible impact on paper recycling process. The results of the optical properties of the recycled laboratory paper show that used inks are difficult to recycle,



although some changes were obtained by flotation, but the differences obtained are insignificant, i.e., very small. The deinking flotation method is not entirely the best method for recycling of prints with nano technology based inks because slight differences in the optical properties of the recycled laboratory paper (obtained before and after flotation) are achieved. Also, the colorimetric parameters indicate a slight coloration of the sheets of paper which may point to the release of colorants into the pulp suspension. Future research should be focused on new processes and/or chemicals research, such as adsorption or enzymatic deinking, which in other studies have proven to be successful methods for removal of poorly deinkable inks like water-based inks.

## ACKNOWLEDGMENT

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