A research of Comparing of the Effects on the Color Properties of Offset, Laser and Inkjet Print Systems on Uncoated Recycled Papers

Ufuk Yılmaz[*1], **Ahmet Tutuş**[2], **Sinan Sönmez**[3]

[*1,2]Kahramanmaraş Sütçü İmam Üniversitesi Orman Fakültesi, Orman Endüstri Mühendisliği Bölümü, KAHRAMANMARAŞ
[3]Marmara Üniversitesi Uygulamalı Bilimler Yüksekokulu, Basım Teknolojileri Bölümü, İSTANBUL

(Alınış / Received: 30.03.2021, Kabul / Accepted: 25.04.2021, Online Yayınlanma/ Published Online: 28.04.2021)

Keywords
Offset,
Laserjet,
Inkjet,
Recycling,
CMYK

Abstract: In the scope of the study, base papers prepared according to INGEDE 11p standard are used to be recycled. These recycled papers are subjected to pulping, storage, flotation, bleaching and paper production processes, respectively, using some methods. The optical and physical properties of the produced papers are determined, respectively. Later, offset, laserjet and inkjet prints are made on these papers. After this stage, color measurements of these printed papers are made with spectrophotometer and their printability is examined with some parameters. According to the study data, it has been observed that offset printing with many parameters exhibits a superior performance against laserjet and inkjet printing, and lower performance in some parameters. It has been determined that inkjet printing has a lower performance than laserjet printing. It is determined that offset printing reached a wider area in the color universe obtained with L* a* b* values of printing types, and inkjet printing had the lowest color space.

Kaplamasız Geri Dönüştürülmüş Kağıtlarda Ofset, Lazer ve Mürekkep Püskürtmeli Baskı Sistemlerinin Renk Özellikleri Üzerindeki Etkilerinin Karşılaştırılması Üzerine Bir Araştırma

Anahtar Kelimeler
Ofset,
Lazerjet,
İnkjet,
Geri dönüşüm,
CMYK

Öz: Çalışma kapsamında INGEDE 11p standardına göre hazırlanan baz kağıtlar geri dönüştürülmek üzere kullanılmıştır. Geri dönüştürülen bu kağıtlar, bazı yöntemler kullanılarak sırasıyla hamurlaştırma, depolama, flotasyon, ağartma ve kağıt üretim işlemlerine tabi tutulmuştur. Üretilen kağıtların sırasıyla optik ve fiziksel özellikleri belirlenmiştir. Daha sonra bu kağıtlara ofset, laserjet ve inkjet baskılar yapılmıştır. Bu aşamadan sonra basılı kağıtların renk ölçümleri spektrofotometre ile yapılarak bazı parametrelerle basılabilirlikleri incelenmiştir. Çalışma verilerine göre birçok parametre ile ofset baskının laserjet ve inkjet baskıya göre üstün performans, bazı parametrelerde ise daha düşük performans sergilediği görülmüştür. Mürekkep püskürtmeli baskının lazer püskürtmeli baskıya göre daha düşük performansa sahip olduğu tespit edilmiştir. Baskı türlerinin L* a* b* değerleri ile elde edilen renk evreninde ofset baskının daha geniş bir alana ulaştığı, en düşük renk aralığına inkjet baskının sahip olduğu tespit edilmiştir.

***İlgili Yazar:** kufu27@hotmail.com

1. Introduction

It is well known the paper production (likewise the other brands of industry) has enormous effects on the environment. The using and processing of raw materials has a variety of negative effects on the environment. At the other hand there are technologies which can moderate the negative impacts on the environment and they also have a positive economic effect. One of these processes is the recycling, which is not only the next use of the wastes [1]. Materials recovered after the creating process of basic paper are considered reused paper [2]. The most common method used to remove ink particles in the paper or on the paper surface in recycling is the flotation method. After this process, a number of processes are performed to make the paper usable (such as beating, bleaching, etc.). Paper, which is the most important part of the printing industry, is used with many printing types. However, the most common printing types today are offset and digital printing. Many studies have been conducted on the printability properties of recycled papers [3, 4, 5]. However, developments in the recycling and printing sector encourage continuous new study in this field.
It is known that each type of printing has advantages over each other in different matters. While offset printing is suitable for high circulation jobs, digital printing is in an advantageous position in terms of saving time. While inkjet printing works on a different system, toner laserjet prints are in a different position in terms of longevity. In this study, the color properties of offset, inkjet and laserjet prints on recycled papers are investigated.

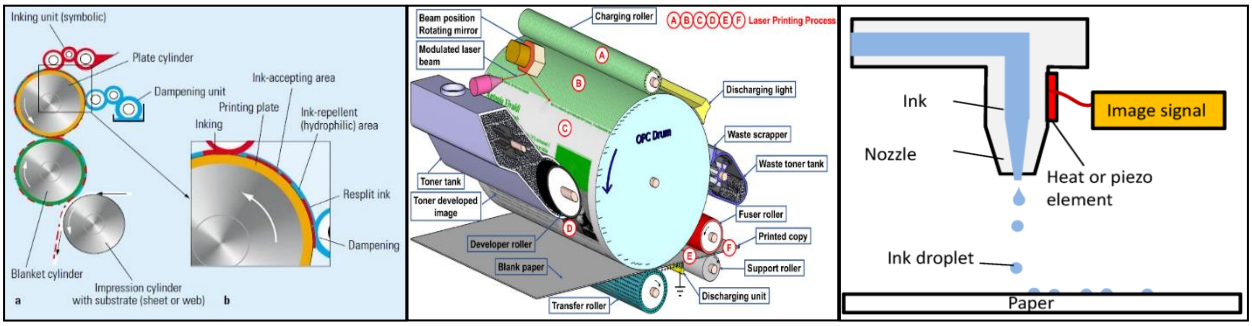

Figure 1. Working principles of printing types (left; offset, Middle; laserjet, right; inkjet) [6,7]

2. Material and Method

2.1. Material

The papers used as base paper in this study are bobbin papers produced from waste office papers and printed using water-based ink at Kombassan Paper Company. Base papers prepared with INGEDE 11-p are used for recycling within the scope of the study. INGEDE 11p is a method that can be used to remove the coloring matter contained in printed paper products under these conditions standard. Used chemicals (sodium hydroxide, sodium silicate, hydrogen peroxide, oleic acid, FAS, magnesium sulfate, EDTA) are obtained from Tekken (Istanbul-Turkey), and Sigma Aldrich (Turkey).

2.2. Method

2.2.1. Recycling process

Reference papers are torn into 2x2 pieces according to the INGEDE standard. The shredded papers are allowed to soak for 10 minutes in metered water at 50 ^{o}C to swell the fibers. It is pulped for 20 minutes using a pulp maker (Hobart type) using sodium silicate (1.8%), hydrogen peroxide (0.7%) and oleic acid (0.8%). Then the pulp is taken to the flotation pool. The flotation process can take 30 minutes at 1% of conversation. The obtained pulp after this process is pounded in Holander according to ISO-5267-1 standard, and the Schopper Riegler tool is adjusted to 35 ± 5 SR^{o}. Then, the bleaching process is applied as the first step (FAS 0.4%) and as the second step (H_2O_2). Finally, 80 g/m^2 paper is produced using the Rapid Kothen RK-21 papermaking machine.

2.2.2. Microscopic images

SEM (Scanning Electron Microscope (ZEISS/EVO LS10) images are obtained from USKIM laboratories of Kahramanmaraş Sütçü İmam University.

2.2.3. Test methods

The standards for optical and physical properties applied to papers Table 1 below.

Table 1. Standards for optical and physical properties applied to papers

Optical and physical tests	**Standards**
Grammage (g/m^2)	TAPPI T 410 om-88
Breaking length (m)	TAPPI T 494 om-01
Burst index (kPa m^2/g)	TAPPI T 403 om-91
Tear index (mN.m^2.g)	TAPPI T 414 om-88
Brightness (%ISO)	ISO/DIS 2470
Whiteness (% ISO)	ISO 11475
Yellowness (E313)	ASTM E313
ERIC	ISO 22754
CIE-Whiteness (D65/10°)	ISO 11475
L*, a* and b* (D65/10°)	ISO 5631-2

Triplicate tests are applied to base papers and test papers in accordance with the standards given in Table 1.

2.2.4. Printing process

The color measurement scales given in Figure 2 below are printed with each printing method on the recycled paper that physical properties are determined by the methods mentioned above. The prints are made at 22 ° C and 55% relative humidity. Offset printing for recycled papers is carried out on the Heidelberg Speed master CD 102 printing machine. Inkjet prints; In the Epson EcoTank L3060 printing machine, laserjet prints; in Canon LBP613Cdw printing machine are performe. After printing, density, CIE L* a* b*, printing chroma values are measure according to ISO 12647-6: 2020 standard using X-Rite eXact™ Spectrophotometer (D50 illuminant, 2° observer, 0°/45° geometry) [9].

Figure 2. Color measurement scale

2.2.5. Print density

Print density is a measure of how dark the reflected light or print looks. Density is affected by the proportions and properties of each major component such as solvents, dyes, pigments and auxiliary materials. Print density is calculated according to the formula below;

$$D = 10log\left(\frac{R_{\infty paper}}{R_{print}}\right) \qquad \text{eq1.}$$

$R_{\infty paper}$: Paper reflectivity, R_{print}: print reflectance factor [10].

2.2.6. Print chroma and Hue angle

Chroma means "color saturation" and can be measured by the color intensity channel. Chroma values that are decisive for print quality are desired to be high [11]. Chroma values of print samples are performed as follows:

$$C^* = \sqrt{a^{*2} + b^{*2}} \qquad \text{eq2.}$$

The hue value, that is, the angle of the color, varies according to where the color is in red, green and blue. If the hue value is 0°, the color is red, if 90° is yellow, if 180° is green, if it is 270°, it is blue. Hue angle is calculated according to the formula below;

$$h_{ab} = arctan\left(\frac{b^*}{a^*}\right) \qquad \text{eq3.}$$

2.2.7. Trapping

Ink trapping in half tone areas is another print quality attributes requiring individual detection of half tone dots. Trap-ping can be described as the ability of one printed colour to be perceived when printed on top of another colour and can e calculated by the following formula; [12],

$$Trapping = \frac{D_{1+2} - D_1}{D_2} \times 100 \qquad \text{eq3.}$$

Where
D1 = Density first printed color
D2 = Density of second printed color
D1+2= density of the colour overprint

3. Results

Physical and optical values of the papers produced for test prints after recycling and base paper are given below.

Table 2. Physical and optical values of recycled an base papers

	Grammage (g/m²)	Brightness ISO (%)	Porosity (m³/min)	Surface smoothnes (ml/min)	Whiteness ISO (%)	Yellowness ASTM	ERIC	Contact Angle (°)	Surface Energy (mj/m²)
Recycled p.	81	84.44	132	339	71.38	-19.52	263.92	31,6	53,6
Base p.	80	98.47	688	366	80.12	-27,66	86	-	-

After printing color measurement scales with offset, Laserjet and inkjet printing machines on the papers whose optical and physical properties are given in Table 1 above, the L* a* b* values of the CMYK colors shown in Table 3 below are measured with a spectrophotometer.

Table 3. L* a* b* values according to printing types

		Cyan	Magenta	Yellow	Black
Offset	L*	50.04	52.75	86.89	23.00
	a*	-31.01	65.03	-0.24	-0.89
	b*	-39.23	6.00	85.87	5.17
Laserjet	L*	55.16	51.14	83.53	26.32
	a*	-21.16	55.90	-4.68	1.76
	b*	-43.13	4.31	72.12	0.36
Inkjet	L*	57.51	53.1	81.63	31.90
	a*	-17.74	53.27	3.41	2.82
	b*	-40.25	3.49	67.37	0.64

In Table 4 below, density and print chroma values are given according to printing types.

Table 4. Density, chroma and printing contrast values according to printing types

		Cyan	Magenta	Yellow	Black
Offset	Density	1.23	1.00	1.06	1.34
	Chroma	58.87	83.73	86.89	23.03
Laserjet	Density	1.20	1.18	1.18	1.44
	Chroma	51.52	59.32	71.82	1.80
Inkjet	Density	0.84	0.94	1.10	1.33
	Chroma	39.34	47.79	65.78	2.82

When Table 4 is examined, the printing type that showed the best performance in the density values of cyan color is offset printing with 1.23. The printing type with the highest value in magenta, yellow and black with 1.18, 1.18, and 1.44 values, respectively, is laserjet printing. In these colors, inkjet printing and offset printing exhibited values close to each other. In magenta, a value of 1.00 from offset printing, 0.94 from inkjet printing, 1.06 from yellow offset printing, 1.10 from inkjet printing, 1.33 units from offset printing in black and 1.33 units from inkjet printing are obtained.

When we examine the printing chroma values, it is seen that offset printing performs much better than laserjet and inkjet printing. While a value of 58.87 is obtained in offset printing in cyan color, a value of 51.52 is obtained in laserjet and 39.34 in inkjet. In the chroma values of the magenta color, a value of 83.73 for offset printing, 59.32 for laserjet and 47.79 for inkjet is obtained. Yellow color is the highest chroma value in all printing types. In the chroma of the yellow color, a value of 86.89 units in offset printing, 71.82 units in laserjet and 65.78 units in inkjet is obtained. Black color is the lowest printing chroma in all printing types. Trapping values of offset, laserjet and inkjet prints are given in Table 5 below.

Table 5. Trapping values according to printing types

Trapping	Offset	Laserjet	Inkjet
M+Y	98.10	92.2	28.23
C+Y	99.20	98.17	76.90
C+M	76.90	94.07	55.37

When Table 5 is examined, offset printing with a value of 91.10 in trapping values of M + Y colors has shown a superior performance compared to other printing types. While Laserjet exhibited a performance of 92.2 units, inkjet printing is measured as the lowest value with a value of 28.23. In C+Y colors, offset printing is measured as 99.20, while laserjet is measured as 98.17 and inkjet as 76.90. Laserjet showed the best performance in C+M colors with a value of 94.07. Next comes offset with 76.90 and finally inkjet printing with a value of 55.37.Hueanglevalues of offset, laserjet and inkjet prints are given in Table 5 below.

Table 6. Hue angle values according to printing types

	Cyan	Magenta	Yellow	Black
Offset	51,67	5,27	89,84	80,23
Laserjet	63,87	4,41	86,29	11,56
Inkjet	66,21	3,75	87,10	12,79

When Table 6 is examined, it is seen that the printing type with the highest hue angle in cyan color is inkjet with 66.21. The printing type with the highest hue angle of the magenta color is offset printing with 5.27. It has been observed that the printing type with the highest hue angle in yellow color is offset printing with 89.84. The same is true for the black color. Offset printing is demonstrated a very superior performance with 80.23 compared to other printing types. In general, it has been seen that the most successful printing type in terms of hue angle is offset printing. After offset printing, it can be said that inkjet printing shows a better appearance than laserjet printing.

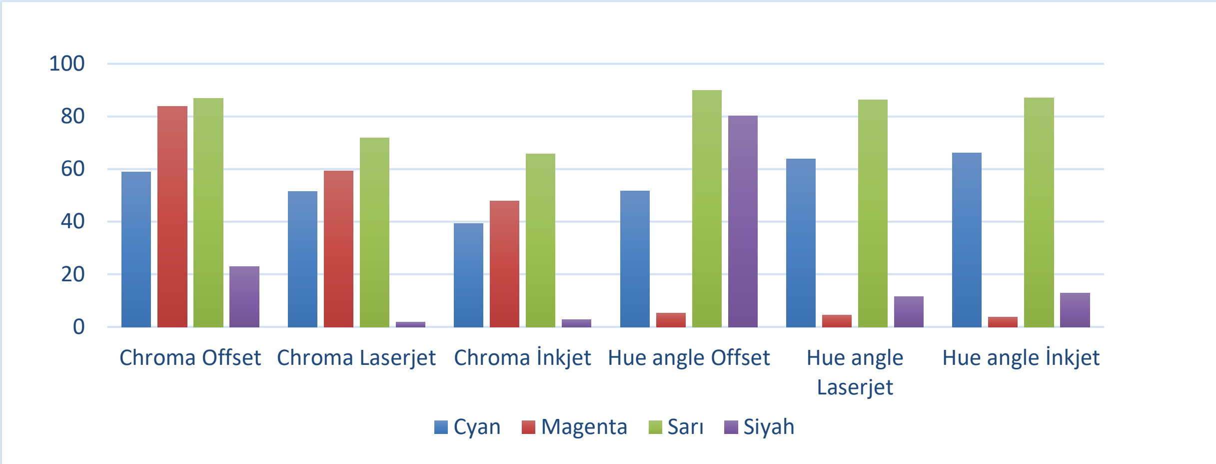

Figure 3. Graphical representation of the chroma and hue angles of the printing types

SEM (Scannin Electron Microscop) images of base paper and recycled paper are given in Figure 4 below. When the images are examined, it is seen that not all of the fillers in the base paper can be disposed of after recycling.

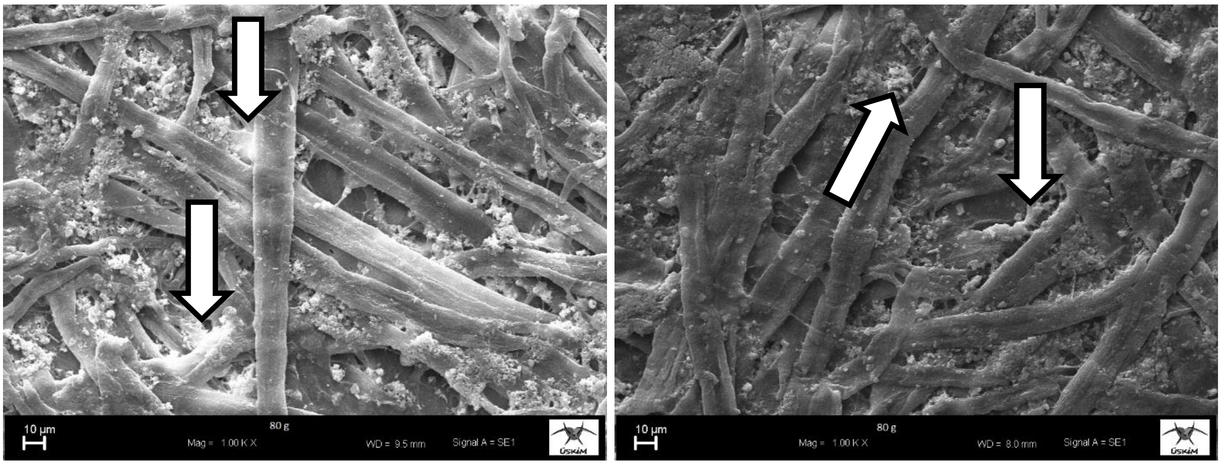

Figure 4. SEM images of recycled paper and base paper, Left: Base paper, Right: recycled paper

The color universe of offset, laserjet and inkjet prints is given in Figure 5 below. When the figure is examined, it is seen that offset printing has a much wider color universe compared too the printing types.

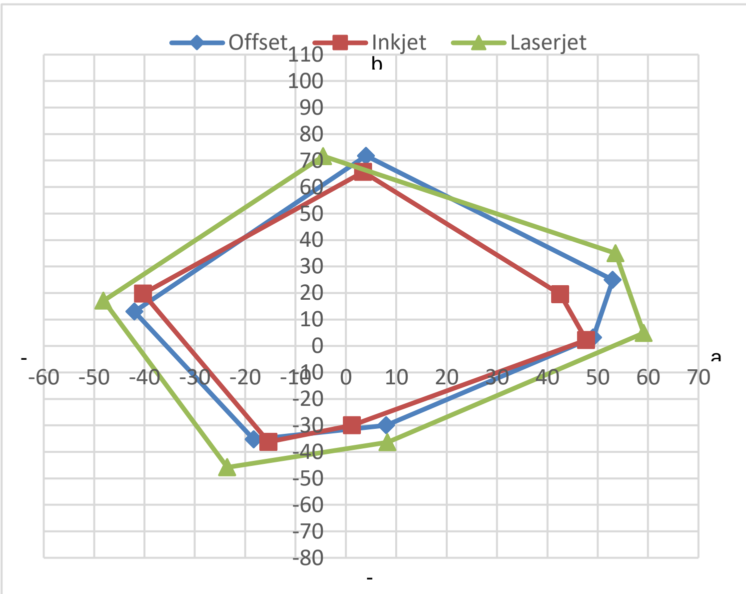

Figure 5. Color universe of printing types

4. Discussion and Conclusion

As understand from the data obtained at the end of the study, it is seen that offset printing performed better than the other two printing types in printability parameters. For example, when we examine the trapping values, we can see that offset provides 8% better adhesion in M + Y colors compared to laserjet. Again, in M + Y colors, there is a 98% ratio in offset, while this ratio remained at 28% in inkjet. In the Hue angle values, we can see that the cyan inkjet has 23% superiority over the offset and a 5% superiority over the laser jet. However, in magenta yellow and black colors, we can see that offset printing performs superior to both prints. For example, offset has established an 83% advantage over black inkjet. This ratio is 85% against laser jet. When chroma values are examined, it is seen that cyan color offset is 12% superior to laserjet and 34% superior to inkjet. It is understood that offset printing values give more suitable results in terms of printing chroma, density, trapping and hue angle. It has been determine that Laserjet printing gives better results than inkjet printing in general. It can be considered that the fillers in the base paper and that could not be completely removed from the pulp with the single recycling process have a positive effect on the printability properties. However, as it is known, the fillers in the paper have a negative effect on the strength properties of the paper. More studies on similar issues are needed to better understand this issue.

References

[1] Iveta Čabalová, František Kačík, Anton Geffert and Danica Kačíková. (2011). "The Effects of Paper Recycling and its Environmental Impact", Environmental Management in Practice, DOI: 10.5772/23110.

[2] Vijay Kumar, J. S. Kalra, Devvret Verma, Shipra Gupta. (2019). "Process and Environmental Benefit of Recycling of Waste Papers", International Journal of Recent Technology and Engineering, Volume-8 Issue-2S12. DOI: 10.35940/ijrte.B1020.0982S1219.

[3] Karademir A, Karahan S, Imamoglu S, et al. (2013). "Use of enzyme and ultrasonic energy in paper recycling", J His Cul Art Res.; 1(4):280-297, Turkey.

[4] Imamoglu S., Karademir A., Pesman E., Aydemir C., Atik C. (2013). "Effects of Flotation Deinking on the Removal of Main Colors of Oil-Based Inks from Uncoated and Coated Office Papers", BioResources 8(1), 45-58.

[5] Le, Y., and He, B. (2011). "Characterizations of ink pigment penetration and distribution related to surface topography of paper using confocal laser scanning microscopy," BioResources 6(3), 2690-2702.

[6] Navarroa L. C., Navarrob A.K.W., Rochaa A., Ricardo Dahab. (2018). "Connecting the Dots: Toward Accountable Machine-Learning Printer Attribution Methods", Journal of Visual Communication and Image Representation, DOI: 10.1016/j.jvcir.2018.04.002.

[7] Lau G.K, Shrestha M. (2017) "Ink-Jet Printing of Micro-Electro-Mechanical Systems (MEMS)" MDPI Journal, https://doi.org/10.3390/mi8060194.

[8] Çiçekler M, Tutuş A. (2019) "Atık Gazete Kağıtlarının Geri Dönüşümü Üzerine Bir Araştırma" Congress on AGRIFOR, pp. 125-135, Muğla.

[9] Sonmez, S. (2017). "Comparison of into the effects of ultraviolet flexo ink on printability of the paper boards coated with carboxymethyl cellulose and polyvinyl alcohol", Journal of Polytechnic, Vol. 20 No. 4, pp. 985-991, doi: 10.2339/politeknik.369134

[10] Pauler, N., Wågberg, J. and Eidenvall, L. (2001). Simulation of optical properties of inkjet prints with Kubelka-Munktheory, FSCN/DPC – Digital Printing Center, pp. 1-18.

[11] Sönmez S. (2011) "Interactive Effects Of Copolymers and Nano-Sized Pigments On Coated Recycled Paperboards İn Flexographic Print Applications", Asian Journal Of Chemistry, No. 6, Vol. 23, pp. 2609-2613.

[12] Lundstr¨om J., Verikas A. (2010) "Detecting half tone dots for offset print quality assessment using soft computing" IEEE International Conference on Fuzzy Systems, DOI: 10.1109/FUZZY.2010.5584433