Determination Of The Most Suitable Option For Production With Uncoated Papers In Offset Printing By Multi-Criteria Decision Making Method

Zafer ÖZOMAY[1]🖉, Cem AYDEMİR[1], Şükrü Cem ÖZAKHUN[1]
[1] Department of Printing Technologies, School of Applied Sciences, Marmara University, Istanbul, Turkey
✉: ozomay@marmara.edu.tr 0000-0002-7650-733X,
Cem AYDEMİR 0000-0002-0202-6576, Şükrü Cem ÖZAKHUN 0000-0002-7491-3289

Received (Geliş): 16.10.2019 Revision (Düzeltme):05.12.2019 Accepted (Kabul): 10.12.2019

ABSTRACT

The visual quality of the print result is largely dependent on the optimum level of coalescence process of the underprint material and the ink. The structural characteristics of the paper are extremely important in that the print can be obtained without loss and with the desired colour value. Since paper and cardboard are heterogeneous and interchangeable materials, it is necessary to measure the structural properties and determine their effect on the printability parameters of these properties. In this study, 90 g/m^2 alternative papers, which are widely used in a certain product group and have different characteristics, are selected. 5 alternative papers were selected, elongation, strength, contact angle and surface energies were determined with the calibrated test devices. With offset printing, the ink is transferred to the paper by keeping the ink quantities constant with the cyan, magenta, yellow and black lines. Inks were measured for density and colour measurements followed by light fastness test and colour measurements were repeated. Differences in colour and paper properties are compared with multi-criteria decision making methods and given graphically. The optimal paper was selected using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solutions) method, which is a multi-criteria decision-making method for choosing the most appropriate paper for production.

Keywords: Multiple Criteria Decision Analysis, Offset Printing, Paper, TOPSIS

Ofset Baskıda Kaplanmamış Kağıtlarla Üretim İçin En Uygun Seçeneğin Çok Kriterli Karar Verme Metodu İle Belirlenmesi

ÖZ

Baskı sonucunun görsel kalitesi büyük ölçüde baskı altı malzemesi ve mürekkebin optimum birleşme sürecine bağlıdır. Kağıdın yapısal özellikleri, baskının kayıpsız ve istenen renk değeri ile elde edilebilmesi bakımından son derece önemlidir. Kağıt ve karton heterojen ve değiştirilebilir malzemeler olduğundan, yapısal özellikleri ölçmek ve bu özelliklerin basılabilirlik parametreleri üzerindeki etkilerini belirlemek gereklidir. Bu çalışmada, belli bir ürün grubunda yaygın olarak kullanılan ve farklı özelliklere sahip 90 g/m^2 alternatif kağıtlar seçilmiştir. 5 alternatif kağıt, uzama, kuvvet, temas açısı ve yüzey enerjileri test cihazlarıyla ölçümlenmiştir. Ofset baskı ile, mürekkep miktarları sabit tutmak suretiyle cyan, magenta, sarı ve siyah mürekkep kağıda aktarılmıştır. Yoğunluk ve renk değerleri için mürekkepler ölçümlenip, ardından ışık haslığı testi gerçekleştirilerek renk ölçümleri tekrarlanmıştır. Renk ve kâğıt özelliklerinde farklılıklar çok kriterli karar verme yöntemleri ile karşılaştırılarak grafik olarak verilmiştir. Baskıda en uygun kağıdı belirlemek için çok kriterli bir karar verme yöntemi olan TOPSİS (Alternatifler Arasından İdeal Seçimin Belirlenmesi) yöntemi kullanılarak baskıya en uygun kağıt belirlenmiştir.

Anahtar Kelimeler: Çok Kriterli Karar Verme, Kağıt, Ofset Baskı, TOPSİS

INTRODUCTION

Paper is a smooth material produced by making various tree species into pulp and cellulose, and then sifting and drying via various mechanical and chemical effects [1] and by gaining strength. Paper known as high-grade paper pulp are used for printing books, leaflets, brochures, etc. [1,2] When the paper surface is rougher and has a more porous structure, printed ink spreads and diffuses more. Paper is one of the materials that humanity needs thanks to its place in culture and industry. [3-5] Development of paper industry is accepted as one of the determinants of industrial and cultural development level of a country. [6-8] In order to produce a high quality paper to satisfy customer expectations, it is necessary to make the best choice among various paper types, to apply print standards combining the most appropriate print technique, to understand customer needs and implement everything meticulously until the designing stage. [9,10].

Multi-criteria decision making is a method used widely to classify alternatives with more than one criterion.

Cite as: *Özomay, Z., Aydemir, C., Özakhun, Ş.C. (2019). Determination Of The Most Suitable Option For Production With Uncoated Papers In Offset Printing By Multi-Criteria Decision Making Method. Mus Alparslan University Journal of Science, 7 (2), 667-672.*

Hwang and Yoon presented a study in 1981 on multi-criteria decision making. TOPSIS (Technique for Order Preference by Similarity to Ideal Solutions), one method, is used widely and developed by Hwang and Yoon (1981). [11,12] In this study test print measurements of high-grade paper pulp papers were carried out and the most ideal was identified via TOPSIS results.

MATERIAL and METHODS

In this study 5 samples from high-grade paper pulp papers used in printing industry were chosen. These samples were assessed on amount of percent decrease in CMYK density values, ΔE differences, stiffness length, stiffness width, ash content, tensile strength width, tensile strength length, contact angle, and surface energy for each CMYK colours after light-fastness were and results were shown in Table 1.
Testing prints were done putting papers with the same thickness but different properties one after the other while the offset printing system was working at a speed of 7000. Print pressure value was stabilised during the printing for papers with the same thickness. Printing setting conditions were met at an ambient temperature of 20 ^{0}C and at a relative humidity of 55% on condition that ink water balance was stabilised. [13,14] Changes in accordance with the physical properties of paper were compared under the condition that ink amounts transferred on each sample was equal. Light-fastness test was done using the light - fastness device with ISO 105-B02 [15] standard. Test scales for colour measurement were prepared in line with the ISO 12642-2 and ISO 12642-1 [16] standards.
Test prints were done in the press in which ISO 12647-2 [17-21] standard applied. Colour gamuts were prepared creating ICC profiles from the ECI 2002 colour measurement zone on the scale for test prints (Figure 1). Surface tone density values of print samples prepared in the study were obtained at 20 observer angle and under D50 light source. Measurements were carried out in line with ISO 12647-2 standard.

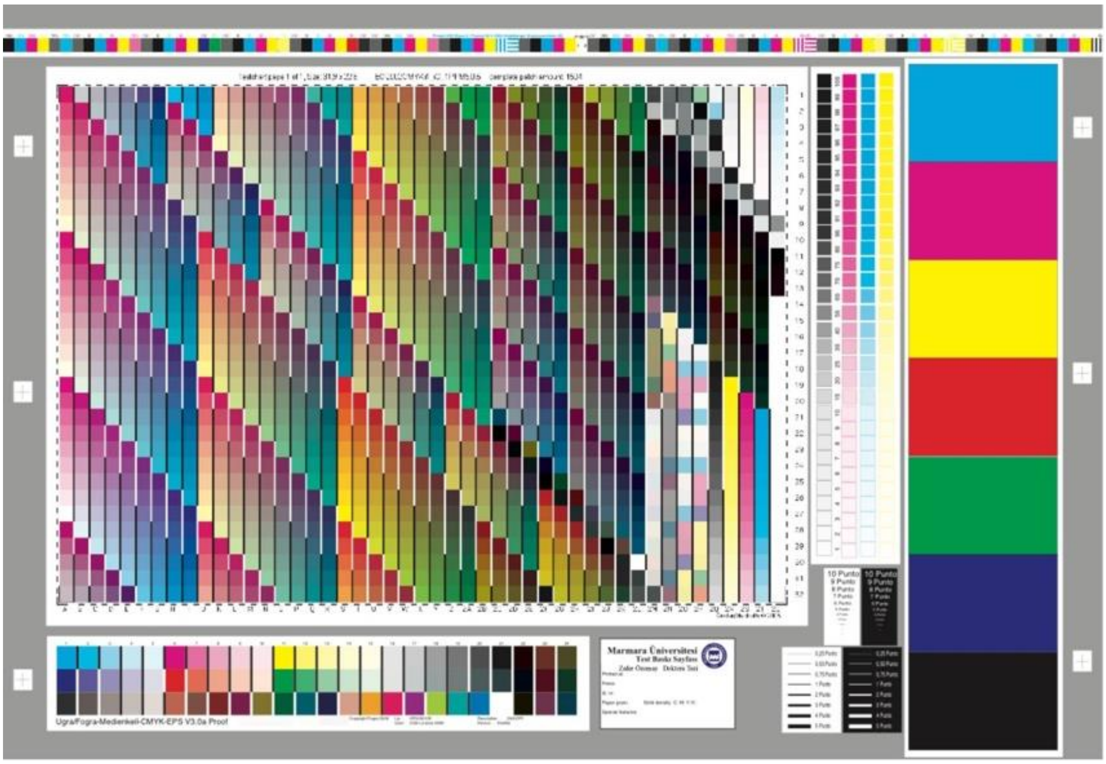

Figure 1. Print Testing Scale

FINDINGS

In the study, alternatives of TOPSIS method were found and assessment criteria were identified according to its advantages. Accordingly, there are 5 samples of high-grade paper pulp paper used in print industry. Selection criteria for high-grade paper pulp paper were amount of percent decrease in CMYK density values, ΔE differences, stiffness length, stiffness width, ash content, tensile strength width, tensile strength length, contact angle, and surface energy for each CMYK colours after light-fastness and these were calculated with the formula below and results were shown in Table 1.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \cdot & & & \cdot \\ a_{m1} & & \dots & a_{mn} \end{bmatrix}$$

Table 1. Properties of papers used

	Density				ΔE differences				Stiffness			Strength			
	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MAX	MAX	MIN	MAX	MAX	MAX	MIN
	C	M	Y	K	C	M	Y	K	St. Length	St. Width	Ash Amount	Break Strength Length	Break Strength. Width	C.A.	S.E.
IH1	8,18	15,69	58,59	3,33	1,15	2,74	11,08	1,51	0,6	0,2	24,43	94,13	64,91	82,90	35,10
IH2	1,03	13,83	65,26	1,75	2,30	2,46	12,17	1,59	0,4	0,2	23,64	84,61	58,35	81,60	35,50
IH3	1,83	9,43	49,48	1,67	3,24	2,44	12,76	1,57	0,6	0,2	21,63	83,67	57,70	86,50	33,80
IH4	0,99	9,09	57,14	1,74	2,12	2,07	10,46	2,58	0,6	0,4	20,25	84,61	58,35	96,40	30,20
IH5	9,17	9,90	58,95	5,79	2,78	2,37	10,92	2,74	0,4	0,2	24,27	95,32	65,73	91,30	32,00

Table 2. Decision Matrix of Criteria for Samples (A)

	Density				ΔE differences				Stiffness			Strength			
	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MAX	MAX	MIN	MAX	MAX	MAX	MIN
	C	M	Y	K	C	M	Y	K	St. Length	St. Width	Ash Amount	Break Strength Length	Break Strength. Width	C.A.	S.E.
IH1	8,18	15,69	58,59	3,33	1,15	2,74	11,08	1,51	0,6	0,2	24,43	94,13	64,91	82,90	35,10
IH2	1,03	13,83	65,26	1,75	2,30	2,46	12,17	1,59	0,4	0,2	23,64	84,61	58,35	81,60	35,50
IH3	1,83	9,43	49,48	1,67	3,24	2,44	12,76	1,57	0,6	0,2	21,63	83,67	57,70	86,50	33,80
IH4	0,99	9,09	57,14	1,74	2,12	2,07	10,46	2,58	0,6	0,4	20,25	84,61	58,35	96,40	30,20
IH5	9,17	9,90	58,95	5,79	2,78	2,37	10,92	2,74	0,4	0,2	24,27	95,32	65,73	91,30	32,00
MAX	9,17	15,69	65,26	5,79	3,24	2,74	12,76	2,74	0,60	0,40	24,43	95,32	65,73	96,40	35,50
MIN	0,99	9,09	49,48	1,67	1,15	2,07	10,46	1,51	0,40	0,20	20,25	83,67	57,70	81,60	30,20

The matrix was normalized by taking the square root of sum of root of scores and properties of criteria in the decision matrix in Table 2.

The formula shown below is used for normalising and matrix R is obtained.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \qquad R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ . & & & . \\ r_{m1} & & \dots & r_{mn} \end{bmatrix}$$

$$r_{11} = 8{,}18 \Big/ \sqrt{8{,}18^2 + 1{,}03^2 + 1{,}83^2 + 0{,}99^2 + 9{,}17^2} = 0{,}654$$

Relative weight values of the elements of the normalised decision matrix are found in line with the importance given to criteria. In study, weight values were accepted to be equal and shown in Table 3.
Then when units in each column of matrix R are multiplied by wj the related value, matrix Vij is created. Since the calculation was made accepting importance weight values to be equal, the formula is:

$$\sum_{i=1}^{n} W_i = 1 \qquad V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ . & & & . \\ w_1 r_{m1} & & \dots & w_n r_{mn} \end{bmatrix}$$

$$v_{11} = 0{,}654 \; x \; 0{,}0666 = 0{,}0435$$

Since the weight does not change when applied to matrix R, the data in Table 3 were accepted as matrix Vij and also formed the weighted normalised decision matrix.
Weight values of the criteria are given in Table 4. According to Table 4 whole criteria have same value.
While ideal solution was composed of the best performance values of weighted normalised decision matrix, negative ideal solution was composed of the worst values. Ideal solutions were calculated using the formulation shown below. In both formulas, I shows benefit or profit (maximization), and J shows cost (minimization) value. The values obtained from the benefit or profit (maximization), and J shows cost (minimization) value. The values obtained from the formula in Table 5 are as follows

Table 3. Matrix

	Density				ΔE differences				Stiffness		Strength				
	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MAX	MAX	MIN	MAX	MAX	MAX	MIN
	C	M	Y	K	C	M	Y	K	St. Length	St. Width	Ash Amount	Break Strength Length	Break Strengh Width	C.A.	S.E.
IH1	0,654	0,590	0,451	0,456	0,212	0,505	0,431	0,326	0,507	0,354	0,477	0,475	0,475	0,422	0,470
IH2	0,082	0,520	0,502	0,240	0,425	0,454	0,473	0,343	0,338	0,354	0,462	0,427	0,427	0,415	0,476
IH3	0,147	0,355	0,381	0,228	0,598	0,450	0,496	0,339	0,507	0,354	0,422	0,422	0,422	0,440	0,453
IH4	0,079	0,342	0,440	0,238	0,391	0,382	0,406	0,557	0,507	0,707	0,395	0,427	0,427	0,490	0,405
IH5	0,733	0,372	0,454	0,791	0,513	0,437	0,424	0,592	0,338	0,354	0,474	0,481	0,481	0,464	0,429

Table 4. Weight Values of the Criteria (wj*)*

Criteria	Weight Vector (wj)
C	0,06
M	0,06
Y	0,06
K	0,06
C	0,06
M	0,06
Y	0,06
K	0,06
Stiffness length 5° L&W mNm	0,06
Stiffness width 5° L&W mNm	0,06
Ash % 525 °C	0,06
Break strength Length Nm/gr	0,06
Break strength Width Nm/gr	0,06
Contact Angel .WGS	0,06
Surface Energy ASTM D5946	0,06
TOTAL	1,00

Table 5. Maximum and Minimum Values (A* and A-)

	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MAX	MAX	MIN	MAX	MAX	MAX	MIN
	C	M	Y	K	C	M	Y	K	St. Length	St.Width	Ash A.	B.S. Length	B. S. Width	C.A.	S.E.
IH1	0,654	0,590	0,451	0,456	0,212	0,505	0,431	0,326	0,507	0,354	0,477	0,475	0,475	0,422	0,470
IH2	0,082	0,520	0,502	0,240	0,425	0,454	0,473	0,343	0,338	0,354	0,462	0,427	0,427	0,415	0,476
IH3	0,147	0,355	0,381	0,228	0,598	0,450	0,496	0,339	0,507	0,354	0,422	0,422	0,422	0,440	0,453
IH4	0,079	0,342	0,440	0,238	0,391	0,382	0,406	0,557	0,507	0,707	0,395	0,427	0,427	0,490	0,405
IH5	0,733	0,372	0,454	0,791	0,513	0,437	0,424	0,592	0,338	0,354	0,474	0,481	0,481	0,464	0,429
A -	0,733	0,590	0,502	0,791	0,598	0,505	0,496	0,592	0,338	0,354	0,477	0,422	0,422	0,415	0,476
A *	0,079	0,342	0,381	0,228	0,212	0,382	0,406	0,326	0,507	0,707	0,395	0,481	0,481	0,490	0,405

$$A^* = \left\{ \left(\max_i v_{ij} \middle| j \in J \right), \left(\min_i v_{ij} \middle| j \in J' \right) \right\}$$

$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\}$$

For negative ideal solution the following formula is applied.

$$A^- = \left\{ \left(\min_i v_{ij} \middle| j \in J \right), \left(\max_i v_{ij} \middle| j \in J' \right) \right\}$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\}$$

$$A^{*} = \begin{Bmatrix} 0{,}079, 0{,}342, 0{,}381, 0{,}228, 0{,}212, 0{,}382, 0{,}406, 0{,}326, 0{,}507, 0{,}707, \\ 0{,}395, 0{,}481, 0{,}481, 0{,}490, 0{,}405 \end{Bmatrix}$$

$$A^{-} = \begin{Bmatrix} 0{,}733, 0{,}590, 0{,}502, 0{,}791, 0{,}598, 0{,}505, 0{,}496, 0{,}592, 0{,}338, 0{,}354, \\ 0{,}477, 0{,}422, 0{,}422, 0{,}415, 0{,}476 \end{Bmatrix}$$

Difference (distance) among the alternatives is measured. Distance of each alternative from the ideal solution is calculated using the below equation.

$$S_i^{*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{*})^2} \qquad S_i^{-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{-})^2}$$

$$S_1^{*} = \sqrt{(0{,}654-0{,}079)^2 + (0{,}590-0{,}342)^2 + (0{,}451-0{,}381)^2 + (0{,}456-0{,}228)^2} + (0{,}212-0{,}212)^2 + (0{,}505-0{,}382)^2 + (0{,}431-0{,}406)^2 + (0{,}326-0{,}326)^2 + (0{,}507-0{,}507)^2 + (0{,}354-0{,}707)^2 + (0{,}477-0{,}395)^2 + (0{,}475-0{,}481)^2 + (0{,}475-0{,}481)^2 + (0{,}422-0{,}490)^2 + (0{,}470-0{,}405)^2 = 0{,}778099465$$

$$S_1^{-} = \sqrt{(0{,}654-0{,}733)^2 + (0{,}590-0{,}590)^2 + (0{,}451-0{,}502)^2 + (0{,}456-0{,}791)^2} + (0{,}212-0{,}598)^2 + (0{,}505-0{,}505)^2 + (0{,}431-0{,}496)^2 + (0{,}326-0{,}592)^2 + (0{,}507-0{,}338)^2 + (0{,}354-0{,}354)^2 + (0{,}477-0{,}477)^2 + (0{,}475-0{,}422)^2 + (0{,}475-0{,}422)^2 + (0{,}422-0{,}415)^2 + (0{,}470-0{,}476)^2 = 0{,}615910233$$

$$C_i^{*} = \frac{S_i^{-}}{S_i^{-} + S_i^{*}}$$

$$C_1^{*} = \frac{0{,}615910233}{0{,}778099465 + 0{,}615910233} = 0{,}441826362$$

In the result C1 value is in the 0≤C≤1 interval, and C1 value approximating to 1 means it approximates to ideal solution, and it approximating to 0 means the distance to ideal solution. When the formula is implemented on all variables, following results are obtained and shown in Table 6.

Table 6. Maximum and Minimum Values (A* and A-)

	Si*	Si-	Ci	Order
IH1	0,778099465	0,615910233	0,441826362	4
IH2	0,525489938	0,909812401	0,633882058	2
IH3	0,551314865	0,911646773	0,623151523	3
IH4	0,308050014	1,01871823	0,767819274	1
IH5	1,037774928	0,27970774	0,212304683	5

RESULT and DISCUSSION

Paper whiteness value of high-grade paper pulp affects directly the delta E values arising in colours after light-fastness test. The difference occurred in papers with high whiteness following the light-fastness test is more compared to the ones with low whiteness. Although there was a difference between numerical values of surface contact angle, surface energy and density values, increase and decrease directions and density values are in the same direction.
As a result of the TOPSIS analysis conducted on high-grade paper pulp, it was found that the sample named IH4 was the ideal one. It is seen that the ideal paper had the minimum amount of ash. Also, the sample farthest from the ideal was found to be IH5 and that the amount of ash in this sample was maximum, which show that the implementation is consistent.

ACKNOWLEDGEMENT

This study is supported by BAPKO (Marmara University Centre for Coordination of Scientific Research) as part of the project numbered FEN-C-DRP-120514-0168.

REFERENCES

[1] Özomay Z. Kağıt ve kartonun yapısal özelliklerinin basılabilirlik parametrelerine etkisinin incelenmesi, Marmara Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi, 2016.

[2] Blayo A., Pineaux B. Printing processes and their potential for RFID printing, Proceeding of Joint sOc-UESAI Conference, 27-30, 2005.

[3] Zelzele O.B., Özdemir L. Dijital termal flekso baskı kalıbı hazırlama parametrelerinin kalıp üzerindeki nokta yapısına etkisinin incelenmesi, Marmara Fen Bilimleri Dergisi, 2 63-75, 2015.

[4] Kipphan H. Handbook of print media: technologies and production methods, Springer Science Business Media, 2001.

[5] Leach R. The printing ink manual, S.Science Business Media, 2012.

[6] Akgul A., Effect of water hardness on the offset printing quality, Asian Journal Chemistry, 24 4771-4773, 2012.

[7] Shiokawa D., Izumi K., Sugano R., Sekine T., Minami T., Kumaki D., Tokito S. Development of a silver nanoparticle ink for fine line patterning using gravure

offset printing. Japanese Journal of Applied Physics 56.5S2, 2017.

[8] Cahill V. Introduction to digital printing technology, Prepress; Graphic Artists, Pre-Press Personnel, Bobbin Magazine, 2-3, 1998.

[9] Kumar A.V., Dutta A., Fay J.E. Electrophotographic printing of part and binder powders, Rapid Prototyping Journal, 10(1) 7-13, 2004.

[10] Sirviö P. Experiences with paper and board substrates for digital printing, Proceedings of the IS&T International Conference on Digital Production Printing and Industrial Applications, 342-345, 2012.

[11] Aydemir C., Özomay Z., Karademir A., Kandırmaz Arman E. Effects of matte coating on the paper surface and print density, Science and Engineering of Composite Materials, 5 123-134, 2012.

[12] Özomay M., Türkiye'de yöresel dokunan bez örneklerinin doğal boyarmaddeler ile gri ilişkisel analiz yöntemi kullanılarak boyama özelliklerinin belirlenmesi, Marmara Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi, 2016.

[13] Özdemir A.İ., Seçme N.Y. İki aşamalı stratejik tedarikçi seçiminin bulanık TOPSIS yöntemi Iile analizi, Afyon Kocatepe Üniversitesi İ.İ.B.F. Dergisi, 11(2) 79-112, 2009.

[14] Ural E., Kandirmaz E., Potential of fish scales as a filling material in surface coating of cellulosicpaper, Journal of Applied Biomaterials Functional Materials, 2017.

[15] Schein L.B. Electrophotography and development physics, p. 203, 1992.

[16] TS EN ISO 105-B02, Kağıt- Renk haslığı deneyleri- Bölüm b02: Yapay ışığa karşı renk haslığının tayini, 2013.

[17] ISO 12642-2, Graphic technology Input data for characterization of 4-colour process printing, Part 2: Expanded data set, 2006.

[18] ISO 12647-2, Graphic technology, Process control for the production of half-tone colour separations, proof and production prints Part 2: Offset litho-graphic processes, 2004.

[19] Ünal H., Oğuz M. Ofset baskıda ISO 12467-2 standardının uygulanmasında dikkat edilmesi gereken kurallar ve önemi, I. Uluslararası Matbaa Teknolojileri Sempozyumu, 154-162, 2003.

[20] Dereli A., Mert H. Genel matbaa, Milli Eğitim Yayınları, 173-177, 1995.

[21] Hırd K.F. Offset lithographic technology, Offset Press Fundamentals 9-10.

[22] Dejidas P.L., Destree T. Sheetfed offset press operating, PIA/GATF Press, p. 159-160, 2005.