

Study of colorimetric properties of kraft papers

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Abstract. This article discusses the production of kraft paper incorporating waste materials from the silk industry and secondary recycled paper (MS-3A), along with fillers and adhesives, as a means of conserving valuable cotton cellulose. The production process utilized waste from the Margilan "IPAKCHI" joint-stock company's silk reeling operations. The preparation of the paper samples followed an approved technological regulation and was carried out in the testing laboratory of the "Global Komsco Daewoo" joint venture. The resulting new composite kraft papers were investigated for their colorimetric properties. The standardized indicators for these kraft papers allow for a comprehensive assessment of their behavior during the printing process, and therefore, it is recommended to use them for printing multi-color packaging products.

1 Introduction

Globally, paper production capacity is expected to reach 510 million tons by 2025, driven by increased demand for packaging, printing, and writing papers, which is projected to rise to 16 kg per capita. This growth in demand for paper and cardboard is associated with population growth and the development of the global economy. However, the increase in demand also negatively impacts the environment. In this context, rational issues such as the efficient use of energy sources, reduction of carbon dioxide emissions, and the necessity of using alternative non-wood secondary raw materials for paper production have become pressing concerns. Addressing these ecological issues, resource utilization, waste recycling, and safety approaches are being increasingly emphasized [1-2].

In all civilized countries, there is a noticeable trend towards the development and application of technologies referred to as the "Zero Waste Production Principle." Currently, significant attention is being paid in our country to converting alternative and secondary raw materials into finished products. Research is being conducted in the Republic to produce paper and cardboard products using various alternative and local secondary raw materials, including waste from the textile industry [3-4].

In Uzbekistan the primary national raw materials are cotton and silk, which play a significant role in paper production. These materials are used to produce high-quality paper. However, considering that it is not economically efficient to produce packaging kraft paper from pure cotton cellulose, incorporating silk reeling waste fibers and recycled paper into cotton cellulose can help conserve valuable cotton cellulose. This approach not only utilizes

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industrial waste but also addresses issues in the pulp, paper, and packaging industries, alleviates the shortage of printing materials, and reduces the cost of kraft paper production.

2 Experimental part

It is well known that our country occupies a leading position in the world in the cultivation of natural fiber. Every year, about twenty to twenty-two thousand tons of cocoons are produced in our republic [5]. In terms of the volume of preparation of this valuable raw material, it ranks fourth in the world after China, India, and Brazil, but the share of unusable cocoons in them is 25-30%. Due to the lack of rational technology in the processing of such waste, silk processing enterprises discard them. These wastes are not used for the production of textile products due to their short fiber content, excessive entanglement, and coloring of the fibers.

The objective of this research is to develop waste-free technologies and improve production methods by incorporating fibrous waste generated during cocoon storage and reeling, which are negatively affected by various factors, into the composition of paper pulp. Additionally, this study aims to produce kraft paper for packaging products from fibrous waste generated during the cocoon reeling process.

For the production of kraft paper at "Global Komsco Daewoo" LLC, several batches of cotton cellulose (PS) were used according to Uzbek State Standard 645. In order to conserve valuable cotton cellulose, waste from cocoon reeling processes, such as cocoon strippings, fibers, and secondary waste paper (MS-3A) generated at the Margilan "IPAKCHI" Joint Stock Company silk reeling factory, were added to the paper pulp composition as supplementary materials.

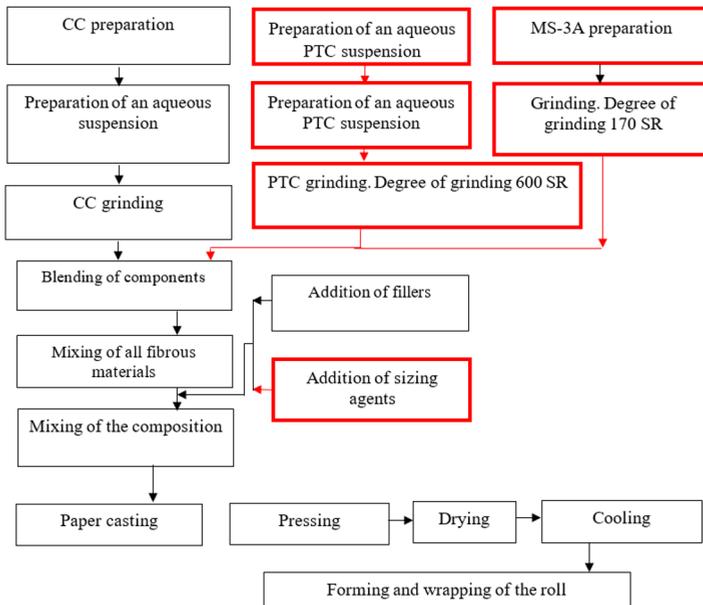


Fig. 1. Technology of kraft paper production based on local raw materials.

During the experimental work, kraft papers were prepared using primary and secondary fibrous materials, fillers, and sizing agents. The preparation of paper samples and the evaluation of their physical and mechanical properties were carried out in the testing laboratory of "Global Komsco Daewoo" JSC according to the approved technological

regulations. In the laboratory, kraft paper was obtained based on the sequence shown below, and sample papers were taken from the prepared kraft paper mass.

In conducting the research, in order to achieve the desired degree of grinding of the cellulose fibers, they were ground in a PFI mill at a speed of 3000 rpm to a Schopper-Riegler ($^{\circ}$ SR) of 45-55 (ISO 5267-) and for lower-grade secondary fibers to a grinding degree of 17° SR. Cationic starch was used as a fiber retention aid on the screen. This solution was added to the fiber suspension until the pH reached 6.8, then stirred for 1 minute. Modified cationic starch was added to the mass as a sizing agent in an amount of 1.5% relative to the normal paper mass. To achieve a good sizing effect, it is required that the pH of the paper mass be in the range of 4.5-5.0, for which $Al_2(SO_4)_3$ was used as a precipitating reagent [6].

Table 1. Kraft Paper Composition Variants.

Sample No	Compositional content		
	CC, %	PTC, %	MS-3A, %
1	100	-	-
2	90	5	5
3	80	10	10
4	70	15	15
5	50	-	50
6	-	-	100

The process selected for laboratory kraft paper production, as shown in Figure 1. For the sample, it was determined that the mass of 1 m² of kraft paper should be in the range of 100-120 g. Sample preparation was carried out in a laboratory setting using the "Rapid" (Germany) sheet forming apparatus to obtain sample kraft paper (Table 1).

Research to determine the optimal composition of the paper was carried out based on existing regulatory documents TU 17.12.14.199-013-00279054-2020. In all variants, the percentage composition of the main components of the paper composition was changed.

The study of the printing properties of paper and the evaluation of colorimetric color quality in printed copies are of particular interest, as they depend on the structure and properties of the initial material, as well as the parameters of the printing process. Predicting the printing properties of paper allows not only to improve its quality, but also to obtain a controlled result of the printed product, which in turn allows to save paper during printing and improve product quality. For this purpose, it is necessary to analyze the printing properties of paper using a complex test scale based on the technology of printing multi-color images [7].

In this work, the main goal was to evaluate the color gamut, colorimetric quality, and graphic accuracy of printed copies on the surface of new kraft papers obtained experimentally.

3 Results and discussion

3.1 Color spectrum

In printing multicolor products using separate printing plates, the desired color is created from a mixture of CMYK inks. Color has three important properties: hue, saturation, and lightness. To characterize the colors resulting from CMYK combinations, we use the method of colorimetry. The amount of color is indicated by a three-digit value denoted by L^* , a^* , and b^* . By representing a small set of CMYK combinations, we obtain a color gamut graph with coordinates a^* , b^* , and L^* , C. In this system, the L^* coordinate determines the lightness,

while a^* and b^* represent the chromaticity. When constructing the color space, the mutually perpendicular a^* and b^* axes are placed on a horizontal plane, these coordinates are measured from -100 to +100. The L^* coordinate passes perpendicular to the a^* and b^* plane at the intersection of the a^* and b^* axes. The color gamut graph reflects all the indicators of modern printing technologies, materials, and processes [8].

To evaluate the multicolor image printed on the surface of the kraft paper taken for the experiment, control test scales were used, and the relative areas of the raster elements of individual inks were selected and measured according to the scale fields. The evaluation of the test prints was carried out based on the separate determination of the optical density of each ink. The color gamut was evaluated using classical CIE colorimetry methods. Based on the results obtained, the Lab* CIE color gamut graph was plotted in the coordinate system of the color space, as depicted in Figure 2.

Figure 2 depicts a color gamut graph constructed from the results of measuring the Lab values of colors in prints produced using the offset printing method. This graph aids in determining the color reproduction characteristics of the prints and their relationship with the technological parameters of the printing process.

The technological control of color indicators for assessing the quality of printed products (optical density, relative area of raster elements, etc.) was carried out by analyzing the relationship between color management systems and the optical density of CMYK inks depending on the area of raster elements. The color gamut created in the color gamut graph was compared with the indicators specified in the standard of the created color gamut. They clearly show that this method made it possible to achieve a wider color gamut on the same material than provided for in the standard.

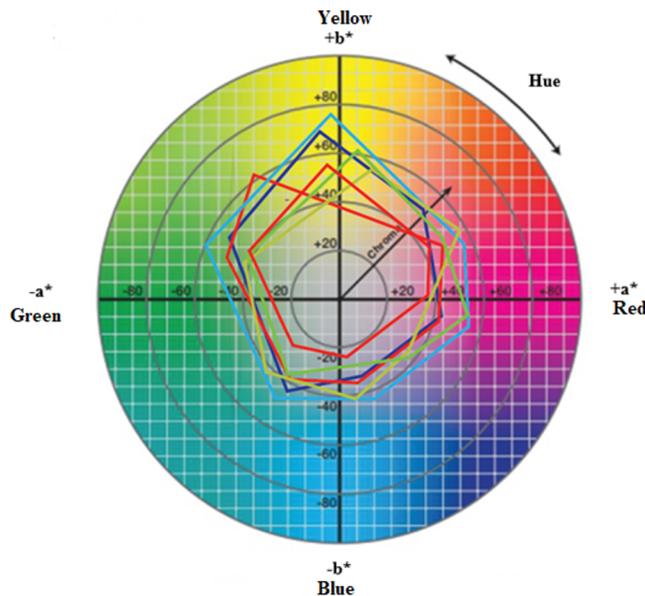


Fig. 2. Color Gamut.

The quality characteristic of the radiation – the color of the Lab color gamut of the printed copies on the experimental papers, the deviation of ΔE from the standard in color was calculated according to the following formula:

$$\Delta E = \sqrt{(a_1 - a_2)^2 + (b_1 - b_2)^2 + (L_1 - L_2)^2} \quad (1)$$

where L , a , b are the color coordinates of the original.

Analysis of the obtained results indicates that there are no significant differences in the comprehensive colorimetric Lab evaluation of printed color images on the investigated kraft papers. The dyes applied to the surfaces of these papers meet all regulatory requirements. Furthermore, the research findings suggest that the 3rd and 4th types of kraft paper are particularly well-suited for printing high-quality products.

Table 2. Calculation of color contrast in experimental kraft papers.

Kraft Paper Type	Plate Number	Selected Color	L	a	B	ΔE
1	1	Light Blue	59.11	-25.40	-31.76	5.97
	1	Light Blue	62.06	-27.05	-26.83	
		Δ	2.95	1.65	4.93	
		$(\Delta)^2$	8.7	2.7	24.3	
2	1	Light Blue	57.49	-26.25	-39.99	3.1
	1	Light Blue	60.06	-27.26	-41.39	
		Δ	2.57	1.01	1.4	
		$(\Delta)^2$	6.6	1.02	1.96	
3	1	Light Blue	50.26	49.33	-0.84	4.3
	1	Light Blue	52.75	45.96	-1.80	
		Δ	2.49	3.37	0.96	
		$(\Delta)^2$	6.2	11.36	0.92	
4	1	Light Blue	58.96	23.46	23.16	4.5
	1	Light Blue	64.15	22.44	17.82	
		Δ	5.19	1.02	5.34	
		$(\Delta)^2$	26.94	1.04	28.5	
5	1	Light Blue	42.73	8.71	-18.02	6.9
	1	Light Blue	44.30	7.68	-17.60	
		Δ	1.57	1.03	0.42	
		$(\Delta)^2$	2.46	1.06	0.18	
6	1	Light Blue	73.80	-6.84	39.38	7.6
	1	Light Blue	76.97	-3.66	45.48	
		Δ	3.17	3.18	6.1	
		$(\Delta)^2$	10.05	10.1	37.2	

Trapping refers to a parameter (expressed as a percentage) that describes the transfer of a second ink to a first ink in a consecutive printing process. It is measured using a spectrophotometer and is controlled through elements that monitor the overall ink transfer. In practice, this involves printing two overlapping ink layers on a sample. For triad inks, the following binary overprints are calculated: green area = cyan + yellow; red = magenta + yellow; blue area = cyan + magenta [9].

Table 3. Optical density (E Status) indicators (cyan, magenta, yellow, black) of images printed on the surface of experimental kraft papers.

Y 100+C 100%					
Kraft paper samples	V	C	M	Y	Trapping %
					Y+C
1	0.71	0.99	0.59	0.97	89.0
2	0.72	1.14	0.54	1.01	90.5
3	0.74	1.12	0.56	0.99	92.5
4	0.76	1.11	0.57	0.98	93.4
5	0.71	1.00	0.50	0.90	86.4
6	0.66	1.02	0.49	0.84	85.9
Y 100 M 100%					
Kraft paper samples	V	C	M	Y	Trapping %
					Y+M
1	0.48	0.19	0.81	1.06	80.3
2	0.51	0.19	0.95	1.06	85.0
3	0.50	0.18	0.93	1.08	87.0
4	0.57	0.17	0.83	1.09	89.8
5	0.49	0.18	0.88	0.91	80.6
6	0.41	0.13	1.09	0.89	80.4
M 100+C 100%					
Kraft paper samples	V	C	M	Y	Trapping %
					M+C
1	1.15	1.09	1.00	0.61	83.6
2	1.14	1.10	1.05	0.60	82.9
3	1.16	1.07	1.02	0.60	82.7
4	1.17	1.11	1.03	0.62	83.7
5	1.10	1.00	1.05	0.52	80.6
6	1.04	0.88	1.18	0.51	71.7

Trapping is evaluated based on the ink transfer (ink receptivity) coefficient.

$$T_p = \frac{D_{12} - D_1}{D_2} \cdot 100\%; \quad (2)$$

where: D_{12} is the optical density of the two-color area; D_1 is the optical density of the first (bottom) ink area; D_2 is the optical density of the second (top) ink area. Based on the conducted research, it can be concluded that the printing properties of the experimental kraft papers meet the specified regulatory requirements. The standardized indicators for these kraft papers allow for a comprehensive assessment of their behavior during the printing process, and therefore, it is recommended to use them for printing multi-color packaging products.

3.2 "Gray balance"

To achieve high-quality printing, the cyan, magenta, and yellow inks must be balanced relative to each other. This balance, known as "gray balance," is assessed using specific areas of a control scale. These areas have the same shape as the elements that control the overall ink transfer and are formed when all three primary colors are printed on top of each other [10]. The most accurate method for controlling gray balance is visual, as the eye quickly perceives when the neutrality of gray is altered, i.e., when a color cast appears. To quantify this difference, measurements were taken using a spectrophotometer.

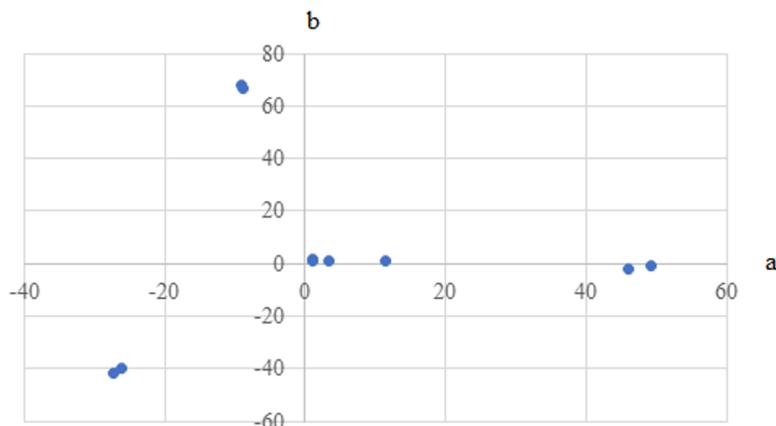


Fig. 3. Gray balance.

Figure 3 shows the resulting neutral gray when cyan, magenta, and yellow (CMY) inks are printed sequentially on a sheet-fed offset printing press. This is intended to determine which combination of dot areas of the primary colors (CMY) provides the gray balance. To evaluate the quality of prints made using the offset printing method, a color graph was constructed corresponding to the values for the CIE $L^*a^*b^*$ model. Kraft papers No. 2 and No. 6 in the CIELab coordinate system have a faint red tint. The highest intensity of purple in the experimental kraft papers indicates that the cyan ink neutralizes the magenta, and its purity improves with a slight change in intensity. On the other hand, the yellow and cyan inks in kraft papers No. 5 and No. 6 reduce the absorption of green to such an extent that they appear neutral in print. The results of color image transformation when forming a color management algorithm differ with changes in the level of sensitivity coefficients of light signals, aimed at optimizing efficiency.

4 Conclusion

In offset printing, color images are observed to be evenly distributed across the surface of the printed material. The color gamut graph did not show any incorrect lighting or rough change tendencies. The described control colorimetric parameters printed using the equal contrast offset printing method were found to be consistent with the quality indicators of printed products available in the international standard ISO 12647-2.

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