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RESEARCH ON THE PRINTING AND TECHNICAL PROPERTIES OF KRAFT PAPER INCORPORATING "COTTON CELLULOSE-INDUSTRIAL WASTE-PACULATE"

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Abstract: In this study, to conserve valuable cotton cellulose, the paper pulp was composed of light industrial cocooning waste from our Republic (specifically, the mat and fiber produced during cocooning at the Margulon "IPAKCHI" joint-stock company) and secondary paper waste (MS-3A). Binders and adhesives were used in the preparation process. The kraft paper samples were prepared in the test laboratory of the "Global Komsco Daewoo" joint venture.

Keywords: kraft paper, cotton pulp, optical density, uniformity of printing, printing inks, printing mold.

Introduction. Currently, the global increase in demand for packaging products necessitates the continuous enhancement of packaging material types and technologies. Significant attention is given to converting alternative and secondary raw materials into finished products. Research within the republic is focused on producing paper and cardboard products utilizing various alternative and local secondary raw materials, including textile industry waste [1].

In Uzbekistan, the primary national raw materials are cotton and silk, which play a significant role in paper production. Although high-quality paper is made from these materials, producing kraft paper for packaging from pure cotton cellulose is not economically viable. To address this, the industry can conserve valuable cotton pulp by incorporating waste paper and fiber waste generated during the cocooning of cotton pulp. This approach helps address challenges in the pulp, paper, and packaging industry, mitigates the shortage of printed materials, and reduces the cost of kraft paper [2].

Uzbekistan is known for being one of the world's leading producers of natural fiber, with annual production of cocoons in the Republic reaching approximately twenty to twenty-two thousand tons [3]. Ranked fourth globally in valuable raw material production, Uzbekistan follows China, India, and Brazil. However, a significant challenge lies in the fact that 25-30 percent of cocoons are deemed unusable due to the absence of efficient processing technology. Consequently, cocoon enterprises discard this waste. These remnants are unsuitable for textile production due to their short fiber content, excessive fiber entanglement, and coloration issues. The objective of this study is to integrate fibrous waste, resulting from various factors that detrimentally impact the process of cocoon storage and spinning, into paper pulp composition. This aims to establish waste-free technologies, enhance production methods, and create kraft paper suitable for packaging products utilizing fibrous waste generated during cocoon spinning.

2. Materials and Methods

2.1 Experimental Details

At JV "Global Komsco Daewoo" (Uzbekistan) several batches of cotton pulp (PS) were employed for kraft paper production in accordance with DSt 645 standards. To preserve valuable cotton cellulose, mat and fiber waste, along with secondary paper waste (MS-3A) generated during cocooning at the Margulon "IPAKCHI" joint-stock company in the Republic, were included as additives to the paper pulp. The scientific endeavor utilized MS-1A, MS-2A, and MS-3A waste paper.

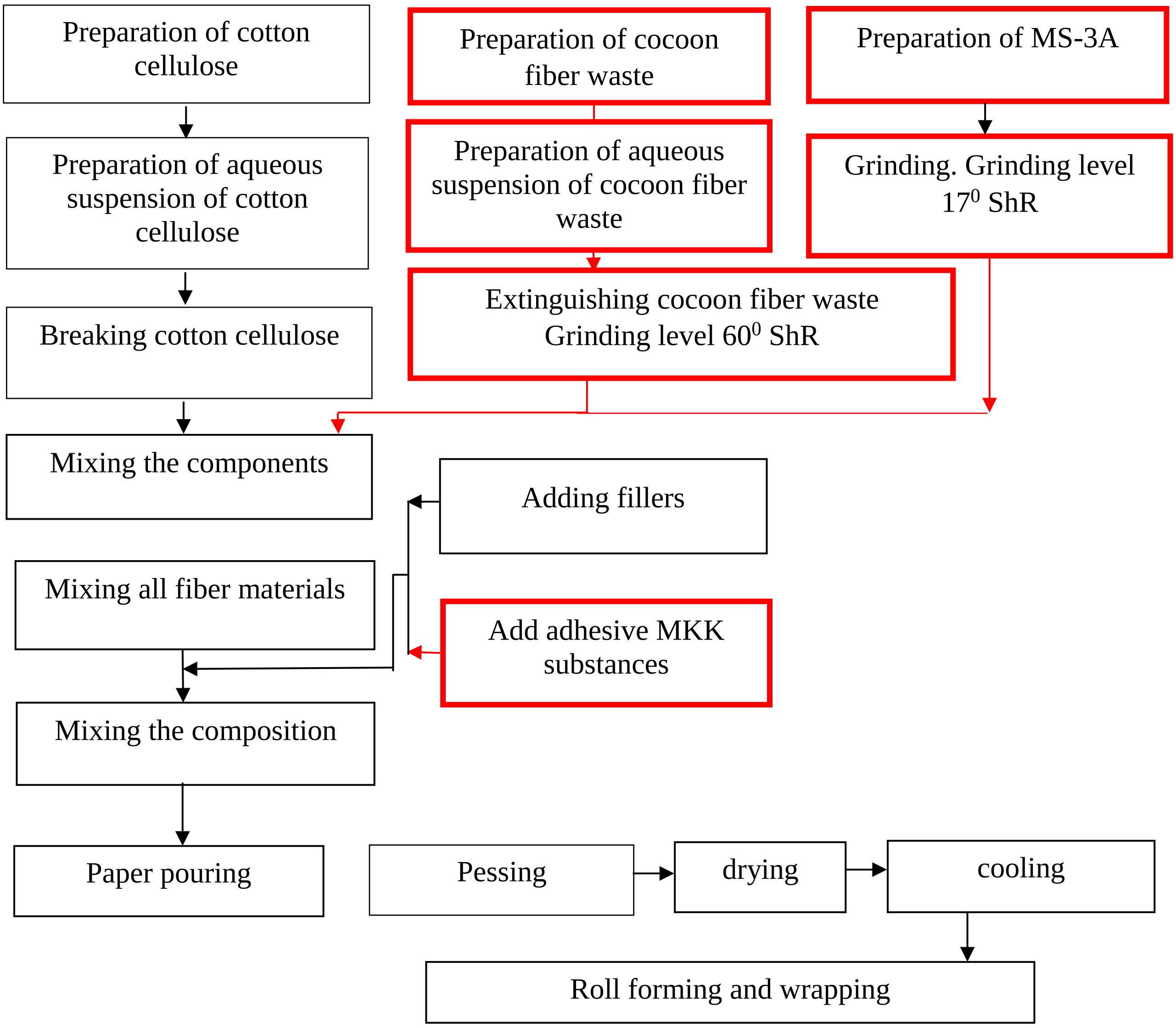

Fig. 1. Production technology of kraft paper based on local raw materials

The production of kraft paper under laboratory conditions followed a predetermined sequence, and sample papers were extracted from the bulk of the finished kraft paper mass [4]. Figure 1 illustrates the selected process for laboratory kraft paper production.

2.2 Materials. The studies aimed at determining the optimal composition of the paper composition were conducted in accordance with the existing normative documents

TU 17.12.14.199-013-00279054-2020. Across all variations, adjustments were made to the percentage composition of the primary components of the paper composition.

Table 1. Options for the composition of kraft paper

Samples №	Composition content		
	Cotton cellulose, %	Cocoon fiber waste, %	MS-3A, %
1	100	-	-
2	90	5	5
3	80	10	10
4	70	15	15
5	50	-	50
6	-	-	100

2.3 Methods. The mass of 1 m^2 of kraft paper for the sample was determined to fall within the range of 100-120 g. Sample preparation involved the utilization of the "Rapid" (Germany) machine, specifically designed for sheet molding under laboratory conditions, to create the kraft paper sample.

During the printing process, achieving high-quality prints and ensuring quality control of printed products heavily relies on key factors such as the clarity and saturation of colors. Additionally, the quality of the printed output is influenced by various indicators, including the surface microgeometry of the printed material, its roughness, porosity, elasticity properties, as well as attributes such as whiteness and transparency.

Further research is necessary to explore the implications of utilizing paper with varying properties in the printing process. The objective of this scientific endeavor was to investigate the impact of Kraft paper with a novel composition on the quality parameters of the printed output.

The quality of the printed image encompasses a series of controlled test scale items, enabling the evaluation of the printed product's quality and usability levels [5]. This control mechanism utilized in printing facilitates a detailed description of the color gamut reproduction system (cyan, magenta, yellow, black) on the test scale. In the rapid control test scale developed within this thesis:

100 percent of the area used to control the supply of paints;

Trepping fields (blue (C+M), green (C+Y), red (M+Y)) to eliminate defects in the process of printing multi-color products;

The control of ink distribution in the printing mold to achieve a uniform gray area in 80 percent ink coverage entails color ratios of 75 °C, 62 M, 60 Y lin/cm^2.

To monitor ink slippage on the paper, control elements such as plus lines or concentric circles positioned perpendicular to the printing plate edges are employed.

Brightness control for each color is conducted within areas of 80 and 100 lin/cm.

A comprehensive set of primary colors ranging from 2 to 100 percent on a gradation scale (2, 4, 6, 8, 10, 20, 30, … 100%) is utilized for color assessment.

Analytical image scales incorporating 40- and 80-percent raster line areas, integrating frequency linear elements of the raster points, were chosen. These scales were utilized for printing copies on a RYOBI 542HXX sheetfed offset printing machine. During the mock-up preparation, essential information regarding the color of the printed copy was meticulously considered. The layout of the developed test file is depicted in Fig. 2.

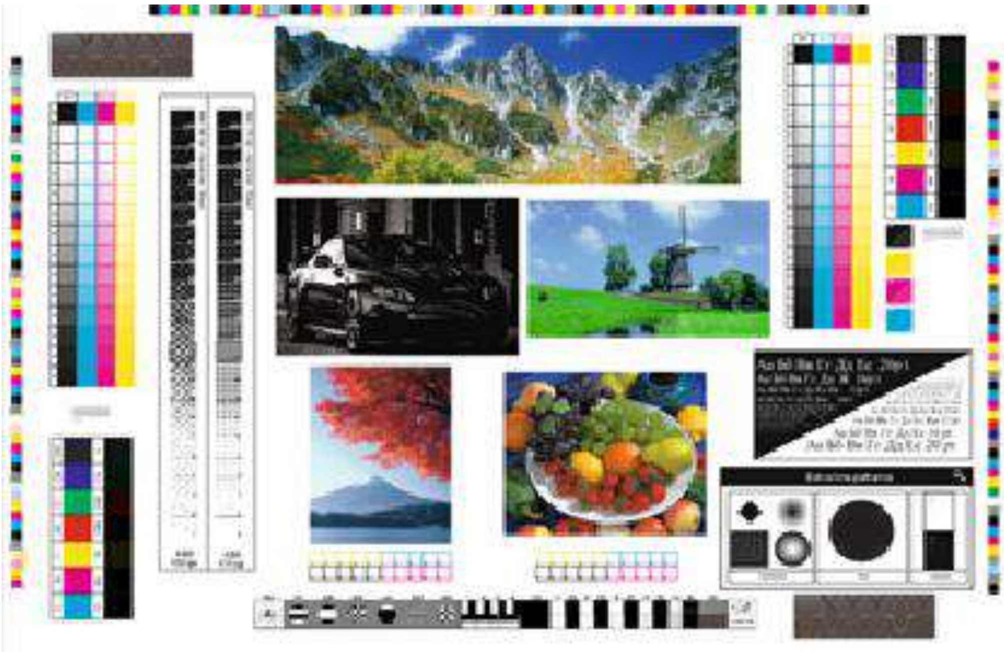

Fig. 2. Control test scale

2.4 Preparation of Printing Molds.

The preparation of printing molds utilized "Computer - printing mold" technology. These molds were produced on thermosensitive Agfa aluminum plates, which ensure raster dot accuracy ranging from 1% to 99%. The curing process was conducted with a curing time of 22 seconds at a specific curing temperature, 24 °C (21-28 °C).

Experimental kraft papers were printed using Sun Chemical Express series sheet offset printing inks at a production rate of 12,000 copies per hour. The ink sequence applied was black (K), cyan (C), magenta (M), and yellow (Y). The printing equipment operated at a constant speed of 1.2 meters per second. A pressure of 20 N/cm^2 (0.80 MPa) was maintained, aligning with the optimal technological pressure range between the mold and offset cylinders (0.5-0.8 MPa). The maximum paint layer thickness achieved in the mold was between 1.2 and 1.8 micrometers.

The quality of printed copies is evaluated by various indicators, the most critical of which is the uniform distribution of the paint layer on the paper surface. Uneven dye distribution significantly impacts the optical density, colorimetric properties, and gradation quality of the printed product [6].

The distribution of the paint layer across the microporosity of the printed material's surface is analyzed to characterize the transfer of paint from the mold to the paper. This analytical method enables the assessment of the compatibility of the "printing material - paint" system for specific types of printed products. The image quality in printing is significantly influenced by the conditions under which the paint transfer coefficient is determined. This coefficient is, in turn, influenced by the physicochemical and surface properties of the printed material [7].

This is explained by the amount of paint required to fill all external surface irregularities during its distribution on the printed material. The experiment aimed to further investigate the printing and technical characteristics of kraft papers and to determine their interaction with printing inks. The paint distribution on the printed material's surface, quantified by the paint layer coefficient, is used to describe the printing process. This coefficient is determined by the ratio of the amount of paint transferred to the print to the amount of paint on the mold's surface [8].

This research was conducted using a laboratory test copy press. Test samples were printed with Sun Chemical Express offset inks according to the methodology outlined in reference [9]. The experiments aimed to determine the ink acceptance index of the paper under specified conditions. During printing, the pressure force was set at 705 N, the speed at 1.5 m/s, and the thickness of the paint layer in the copies varied from 0.5 to 2.5 μm. The amount of ink in the mold and on the copies was measured using the densitometer method, while the thickness of the ink layer was determined through calculations.

Special consideration was given to maintaining consistent air parameters in the environment, which were as follows: relative air humidity ranging from 50% to 55%, and a temperature range of 20 to 21°C. Sun Chemical Express Series sheetfed offset printing inks exhibit rapid setting on the copy and demonstrate excellent ink transfer. These inks transfer uniformly from the mold to the surface of the printed material, resulting in an ink layer thickness ranging from 2 μm to 1.6 μm. Optical density readings of the printed images are examined to assess their conformity to the extended color gamut, utilizing an air color dye. Determining the reliability of the research was carried out by the method of variational statistics [10]. The method for assessing the accuracy of experimental results is outlined below. The accuracy of the measured values for the thickness of the paint layer on the copy, determined using a spectrodensitometer device, was evaluated according to the example provided in Table 2.

Table 2. The thickness of the paint layer in the copy, μm

Indicator	1	2	3	4	5
The thickness of the paint layer, μm	1,00	1,00	1,04	1,05	1,06

2.5 Assessment of the reliability of measurement results

Arithmetic average of all measurements: $\bar{X}_{cp}$=1,03

The sum of the squares of the deviations from the arithmetic mean:

$$R = \sum_{1}^{n} (x - \bar{x}_{cp})^2 = 0{,}0034 \quad (1)$$

Average permissible error, E:

$$E = \frac{2\sigma}{\sqrt{n}}, \quad (2)$$

Were σ is mean square deviation:

$$\sigma = \frac{R}{\sqrt{n-1}} \quad (3)$$

$$\sigma = \frac{0{,}0034}{\sqrt{5-1}} = 0{,}00273; \quad (4)$$

$$E = 2 \cdot \frac{0{,}00273}{\sqrt{5}} = \frac{0{,}00545}{2{,}25} = 0{,}0024 \quad (5)$$

Coefficient of change, V,%;

$$V = \frac{\sigma}{x_{cp}} \cdot 100 = \frac{0{,}00273}{1{,}03} \cdot 100 = 0{,}26\% \quad (6)$$

Reliability of research, ξ, %;

$$\xi = \frac{E}{\bar{x}} \cdot 100 = \frac{0{,}0024}{1{,}03} \cdot 100 = 0{,}22\%. \quad (7)$$

ξ< 5%, which shows the reliability of the experiment.

3. Results and Discussions

After the measurements, a corresponding graph is created (Fig. 3).

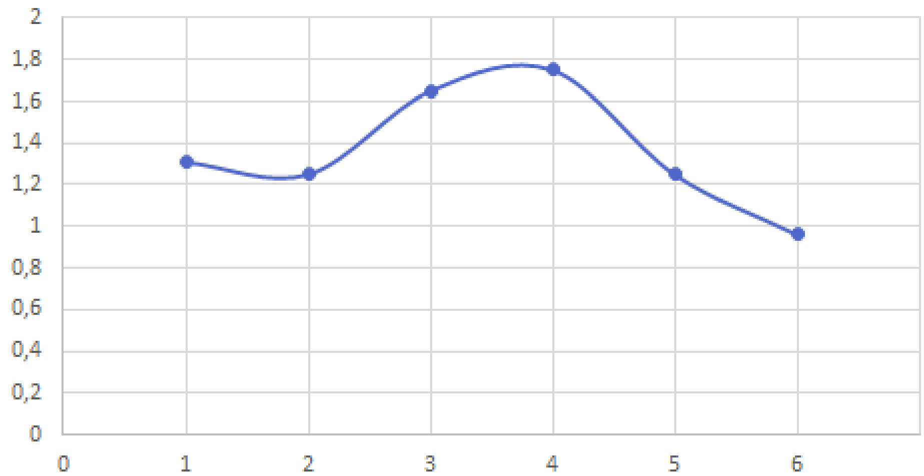

Fig. 3. Analysis of determining the thickness of the paint layer

In 1, 2, 5, 6 types of kraft paper, the layer thickness of air color paint is 1.10-1.28 microns. The thickness of the paint layer on type 3 and type 4 kraft paper is 1.6-1.8 microns. This means that the inks used for printing on the surface of the experimental kraft papers show that they have the ability to create the optimal required ink layer and provide high-quality coloring.

To evaluate the optimal optical density of the ink layer, a crucial parameter in the printing process, an image was printed on kraft paper typically recommended for packaging products using Sun Chemical Express series inks. The thickness of the paint layer transferred from the printing mold to the printed surface was assessed by measuring the field optical density of areas with 100% color saturation on a control scale. This measurement was conducted using a specialized device called a spectrodensitometer, which offers enhanced accuracy and enables standardized value analysis. The experiment adhered to established standards**.** One day after the paint layer has completely dried on the surface of the printed copy, the optical density of the printed images was measured using a spectrodensitometer. At the same stage, it was determined that the quality of the printed product conforms to ISO 12647-2 densitometric standards. The measurement procedure was carried out on experimental kraft papers for black, blue, red, and yellow paints. After all the measurements were made, the average result was calculated for each kraft paper and the obtained optical density indicators were included in the table (Table 3).

Table 3. Optical density indicators in copies printed by sheet offset printing ($D_{o.z}$)

Colour	ISO 12647-2	Kraft paper samples 1	2	3	4	5	6
Cyan	1,00	1,15	1,18	1,25	1,34	1,22	1,10
Magenta	0,95	1,45	1,53	1,48	1,45	1,47	1,59
Yellow	0,95	1,02	1,17	0,95	1,03	1,03	0,99
Black	1,25	1,34	1,19	1,25	1,34	1,30	1,42

Based on the data obtained (Table 3), the following conclusion can be drawn: the optical density values of the primary colors in copies printed with Sun Chemical Express offset inks conform to European standards ISO 12647-2. This indicates that the experimentally produced kraft paper is suitable for printing multi-colored products that meet standardized technological process requirements. Additionally, a significant advantage of these high-quality, low-cost products is the potential to incorporate kraft paper made from new local raw materials into the production of packaging products.

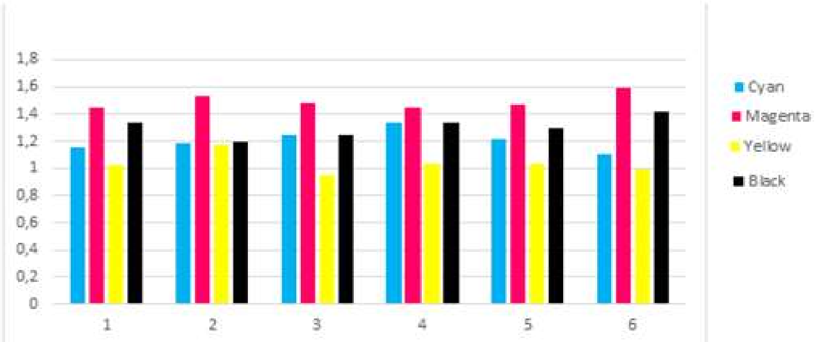

Figure 4. Optical density values (1-6 kraft paper samples)

The optical density values of the printed images were found to be Do.z=1.45÷1.65. The obtained data correspond to the UzDSt 1114:2006 standard. It should be noted that the optical density values of the printed images do not differ significantly from each other, which is due to the closeness of the properties of kraft papers.

Table 4. Evaluation of the uniformity of printed copies

Colour	Samples of kraft paper						
	O'zDSt 1114:2006	1	2	3	4	5	6
Uniformity of printing	0,001÷0,025	0,020	0,010	0,009	0,010	0,018	0,019

As shown in Table 4, the highest optical density in the printed copies, despite having almost the same thickness of the paint layer, is achieved by the paint layer on the surface of kraft paper samples No. 3 and No. 4. This observation supports our hypothesis regarding the role of fiber structure. The smooth surface of these kraft paper samples ensures the desired thickness of the paint layer during the printing process.

Conclusions. The experimental results indicate that kraft paper types No. 3 and No. 4 exhibit high optical density. This can be attributed to the uniform penetration of printing inks into the pores of the kraft paper, resulting in a consistent paint layer on the surface. Consequently, these kraft paper samples have a smoother surface texture. Conversely, kraft paper samples No. 5 and No. 6 demonstrate lower optical density, suggesting that their surface smoothness is inferior to that of samples No. 3 and No. 4.

The transfer of ink from the printing mold to the surface of kraft paper primarily depends on the level of contact between the ink and the printed material's surface. Greater smoothness leads to more even ink distribution, resulting in higher quality printed products. Analysis of the obtained data reveals that the best results were achieved with kraft paper samples No. 3 and No. 4, which incorporate fiber waste from cocooning. Additionally, the use of modified cationic starch glue enhances the overall smoothness of the printed material's surface by reducing macro and micro irregularities. This improvement facilitates a more uniform distribution of printing ink and yields superior printing of individual image elements.

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CONTENTS

TECHNICAL SCIENCES: COTTON, TEXTILE AND LIGHT INDUSTRY

Dustkobilov U. Circular economy practices in the textile industry: Current status, indicators, and development opportunities	3
Kuldashov G., Oripov J. Forecasting the temperature gradient of cotton revolt	10
Kuldashov G., Oripov J. Optoelectronic three-wave moisture meter of raw cotton	16
Umarov A. Research on the optimization of the saw gin's roll box	26
Tursunov A., Sharibaev N. Techniques and devices for mitigating environmental pollution in cotton processing industries	36
Ganikhanov Kh., Mavlyanov A., Abdusamatov A., Mirzaumidov A. Effect of the forces on the separation of fiber flow from the saw in an improved lower fiber removal device	43
Nurulloyeva Kh., Abdusamatov A., Mirzaumidov A. Experimental determination of the load on the multifaceted columns on the elastic supports of the cotton ginner	49
Muradov A. Study of the dynamics of the drive mechanism of moving needles	54
Ismatullayev N., Shamsiyeva M. Development of technology for producing leather from african catfish skins	59
Rahmatova S. Theoretical study of the quality indicators of newly structured knitted fabrics based on a mathematical model	65
Parpieva N., Kayumov J., Parpiyev D., Lastochkin P. Theory of torsional vibrations of grooved cylinders	71
Komilov Sh., Mamadaliyev N., Jurayeva G. Quality indicators of cotton fiber analyzed	83

TECHNICAL SCIENCES: AGRICULTURE AND FOOD TECHNOLOGIES

Sobirova M., Mohamed R., Farmonov J., Samadiy M. Impact of calcium chloride on the cheese yield during swiss cheese manufacturing process	91

Kurayazov Z., Ravshanov S., Kanoatov X. Analysis of the influence of the whitening process during preparation for flouring on the quality of bakery flour made from a mixture of wheat and rye grains	**96**
Xusanxodjayeva F., Meliboyev M., Ergashev O. Development of technology for complex processing of garlic onions	**105**
Meliboyev M. Development of complex processing technology for the secondary mass of watermelons and zucchini	**112**
Nishonov U., Mominov U. Evaluation of organoleptic properties of soft drinks prepared from plant materials	**118**
Khurmamatov A., Yusupova N., Sarsenbayev N., Mallabayev O. Results of determination of bitumen movement modes at different temperatures	**124**
Yusupova N., Sarsenbayev N., Mallabayev O. Results of improving the construction of the plate heat exchange	**130**

CHEMICAL SCIENCES

Jumayeva D., Zaripbaev K., Oxunjonov Z., Nomonova Z. Compositional analysis of raw materials in sorbent production	**135**
Abdumalikov A., Ummatov O., Mamajonov B., Esonkulova N., Ochilov G. Thermal treatment of various samples of low-molecular-weight polyethylene – a by-product of polyethylene production	**145**
Mamajonova M., Salixanova D., Abduraxmonov E., Ismailova M. Energetics of water molecule adsorption on modified bentonite surfaces	**153**
Abdurahimov A., Abdullayeva F., Usmonova Z. Infrared spectroscopic analysis of the purification of sunflower oil from waxy substances using perlite and vermiculite	**160**
Eshbaeva U., Gökhan Z., Bahri B. Theoretical foundations for ensuring the mechanical strength of papers containing collagen hydrolysates	**167**
Eshbaeva U. Research on the printing and technical properties of kraft paper incorporating "cotton cellulose-industrial waste-paculate"	**172**
Makhkamova D. Research on the separation of zinc from metallurgy waste with a mixture of ammonia and ammonium salts	**181**
Yuldasheva M., Makhkamova D., Turayev Z	**188**

Study of interaction of components in the H_3BO_3–KNO_3–H_2O system	
Juraev M., Siddikov D., Askarova O.	194
Aboveground components of salvia sarawschanica	
Davlatova O.	202
Zeolite-based bimetallic composite catalysts for pyrolysis and gasification: chemical technologies for deep biofuel upgrading and conversion intensification	
Davlatova O.	208
Use of BaNaY faujasite zeolite–based bimetallic composite catalysts for deep biofuel purification and selective xylene separation	
Shamuratova M., Giyasidinov A., Eshmetov I., Nurjanova G.	214
On the study of physicochemical properties of soils in the regions of the republic	
Hoshimov F., Lutpillayeva M.	220
Optimized chemical synthesis of stable silver nanoparticles using various reducing and stabilizing agents	
Sarimsakova N.	227
Investigation of the adsorption properties of the sorbent obtained in the process of modification of clinoptilothite in the purification of natural gas from sulfur compounds	
Kokharov M., Bakhronov Kh., Sultonov A., Jumaeva D., Jumaboeva Z., Gaybullayeva D., Abdumutalova G.	234
Adsorption isotherm of hydrogen sulfide on an activated adsorbent derived from hybrid paulownia tomentosa wood	
Ikramov M., Zakirov B.	243
Optimization of the aqueous solubility of monoammonium phosphate, potassium nitrate, and magnesium nitrate via thermodynamic analysis and selective crystallization	
Nazhimova N., Seitnazarova O.	249
Study of the chemical and mineralogical composition of thermal power plant wastes	

TECHNICAL SCIENCES: MECHANICS AND MECHANICAL ENGINEERING

Berdiev U., Hasanov F., Avazov B., Ostanayev., Viktor M.	256
Study of the nature and prospects of practical application of the magnetocaloric effect in energy-efficient cooling systems	

Sodikov T. Research of mechanical part of solar photovoltaic power station	**263**
Otamirzayev D. Calculation of absorption coefficient of organic dye N719 for dye-sensitive solar cell (DSSC)	**270**
Abduvakhidov M. Study on determining the bending and torsional stiffness of packaged working bodies	**276**
Abduvakhidov M. The study torsion fluctuations packet worker organ with provision for influences of the correlation longitudal acerbity their element	**280**
Shodmonov J. Energy-integrated smart textiles: international trends and prospects for uzbekistan's research ecosystem	**285**
Djurayev Sh. Integrated genetic-differential evolution approach for simultaneous pressure-drop reduction and efficiency enhancement in multi-cyclone dust collectors	**292**
Mamaxanova Z. Technological principles for creating a suit that ensures high reliability and safety in aquatic environments	**297**
Pirnazarov U. Theoretic observation of the cotton movement in the operating camera of the new separator	**306**
Pirnazarov U. Investigation of the interaction between the moving separator screen surface and the cotton mass	**315**
Yusupov D., Abduraximov D., Muxammadjonov M. Determination of energy loss in the magnetic core of oil power transformers under long-term operation conditions	**319**

ADVANCED PEDAGOGICAL TECHNOLOGIES IN EDUCATION

Abdullayev X. Transition function of second-order element	**326**

ECONOMICAL SCIENCES

Isroilov R. Criteria, indicators and laws of small business development	**331**

Isroilov R.	
Concept of assessment of the economic development potential of small business and its evaluation	**340**
Bustonov M.	
Econometric analysis of the activities of multi-sectoral farms	**348**
Bustonov M.	
Global digitalization: paths and problems	**356**
Kadirova Kh.	
Prospects for development and improvement of the mechanism of functioning of the stock market	**366**