International Journal of Materials and Chemistry 2024, 14(6): 103-108
DOI: 10.5923/j.ijmc.20241406.02

Study of the Composition of Sizing and Its Impact on the Properties of Sizing Yarn

Rano Akhadovna Ismatova[1], Avaz Sanokulovich Kazakov[2], Matluba Mukhtarovna Amonova[3]

[1]Doctor of Philosophy (PhD) in Technical Sciences, Associate Professor, Bukhara State Medical Institute, Bukhara, Uzbekistan
[2]Lecturer, Academic Lyceum of Bukhara State Medical Institute, Bukhara, Uzbekistan
[3]Doctor of Philosophy (PhD) in Chemical Sciences, Associate Professor, Bukhara Institute of Innovative Education and Medicine, Bukhara, Uzbekistan

Abstract The goal of the given scientific work is to discuss new development of sizing composition and its impact on basic mechanical properties of sizing yarn. Some disadvantages of traditional synthetic sizing agents, such as high cost and complicated processing, influence the yarn being treated. In this context, a new composition was developed which includes starch, polyvinyl alcohol, and hydrolyzed polyacrylonitrile. The main objective was to reduce edible starch consumption while simultaneously improving the mechanical properties of yarn. The research, via systematic experimentation and analysis, tried to obtain the ideal ratio of components in the sizing composition to produce superior physicochemical interactions. Among key findings is the enhancement in yarn tensile strength by 25% and reduction in breakage rates during weaving by 30%, along with a tremendous improvement in machine performance compared with traditional starch-based sizing methods. These result not just in improved yarn strength but also reduce machine idle time and cost of upkeep, enhancing the overall production efficiency of the system. Besides that, the work also involves greener alternatives in textile processing through the development of thickening agents suitable for sustainable methods in fabric printing. These showed very good colorfastness combined with low fabric stiffness, meeting industrial objectives for sustainability and quality in textile production. This work thus lays the foundation for the development of environmentally responsible practices with enhancements in performance and efficiency in textile manufacturing.

Keywords Composition, Flexibility, Sizing, Elasticity, Strength, Impact, Properties, Sizing yarn, Components, Fibers, Yarn production process, External influences, Technological process, Textile production, Physicochemical conditions, Polyvinyl alcohol (PVA), and hydrolyzed polyacrylonitrile (HIPAN), Macromolecules, Electronegativity, Cotton yarn, Textile sustainability, Colorfastness, Textile processing

1. Introduction

Sizing of yarns is very important in modern textile industries to improve the mechanical and processing properties of yarns so that they can be woven on high-performance looms. Conventional sizing agents include food-grade starch, which has been widely used due to their easy availability and effectiveness. However, consumption of these materials raises huge concerns regarding resource sustainability and economic feasibility considering the ever-growing global demand for food products.

Synthetic sizing agents, being homo- and copolymers, were introduced to surmount all these challenges. In such regards, synthetic agents have the advantage of sizing without the use of food-grade materials and show advantages regarding uniform film formation and high adhesion to fibers. They have a number of disadvantages. Synthetic polymers are expensive, often difficult to procure, and lack multifunctionality for fibers of varied chemical composition. Moreover, at the same time, they present some problems during the desizing process: high consumption of water, longer processing times, incomplete removal from fabric surfaces. The critical disadvantage refers to the tendency of yarns sized exclusively with synthetic polymers to stick together upon drying; this creates a lot of inefficiency during weaving and their use on high-speed machines.

Given these limitations, the search for novel yarn sizing methods becomes pressing to combine advantages of natural and synthetic agents. Among these, the development of water-soluble polymer-based sizing compositions, especially with the use of starch, polyvinyl alcohol, and hydrolyzed polyacrylonitrile, assumes importance in view of the potential for reduction of food starch consumption and improved yarn performance. In spite of such a possibility, scientific investigation into such hybrid compositions is scant, with only a few studies pointing toward preliminary understanding in their formulation and application [1].

Received: Dec. 16, 2024; Accepted: Dec. 29, 2024; Published: Dec. 31, 2024
Published online at http://journal.sapub.org/ijmc

This paper, therefore, seeks to fill this knowledge gap by formulating and providing a physicochemical justification for a new sizing composition in cotton yarn, incorporating PVA and HIPAN. The study aims to optimize formulation and processing parameters for minimal dependency on food-grade starch, maintaining improved elastic, structural, and mechanical properties of the sized yarn. The use of special-purpose textile auxiliary substances further improves the properties of the proposed composition through solving the problem of sticking and ensuring efficient yarn treatment on high-performance looms [2,43,44,45,46].

It is assumed that during the interaction at the molecular level between starch, PVA, and HIPAN polymer groups, some amide-CO-NH-, urea-NH-CO-NH-, carbamate-OCO-NH2, ester -OCO-, and other functional groups may form. These will enhance the elastic properties of the adhesive film, reducing its electronegativity, hence improving its mechanical properties.

Besides, the study pointed out that the drying process is of crucial importance for sizing cotton yarn. Among the key parameters - temperature, drying time, and warp movement speed - the optimal kinetics was established to dry the yarn treated with the proposed composition. Results are given in Table 1 and provide the comprehensive understanding of the drying process and its influence on weaving efficiency [4].

Thus, this work brings about the improvement of different sustainable and resource-efficient technologies in textile production because of both economic and ecological benefits by responding to challenges developed by both traditional and artificial sizing agents (Table 1).

Based on the study of the kinetic parameters of the sizing process, the developed compositions determined the concentrations of the components included in the sizing composition, which is presented in Table 2. As can be seen from the table, the amount of the sizing polymer composition is 50 g / kg, against the starch-based sizing–70 g/kg, i.e. starch consumption is reduced by 25–30% [3].

Table 1. Kinetic parameters of the drying process of yarn sized with a composition based on starch, PVA and HIPAN at a ratio of 1:0.05:0.01, respectively

	Developed sizing composition			Factory–made starch–based dressing
	Drying temperature, °C			
	85	90	95	90
Base moisture, %	58	54	59	43
True adhesive, %	7	6	6	7
Second drying period time, min.	12	10	9	14
Drying speed, m/sec	0,5	0,8	0,8	0,5
Total drying time	22	10	10	24

Table 2. Optimal technological parameters for the preparation of sizing based on the developed composition

Components of the dressing	Content of adhesive components, g/l				Starch dressing
	Type of yarn				
	Cotton yarn number				
	34	40/1	40/2	54	
Polyvinyl alcohol, g/kg	3,0	2,0	3,5	3,5	–
Hydrolyzed polyacrylonitrile, g/kg	2,0	2,0	2,5	2,5	–
Starch, g/kg	45	50	50	50	70
Gelatinization temperature, °C	85–90	85–90	85–90	85–90	90–100
Gelatinization time, min	20–25	20–25	15–20	15–20	30–35

Table 3. The physical and mechanical properties of yarn treated with sizing obtained under optimal preparation parameters

Indicators	Unit change	Developed size		Factory size, starch
		Cotton yarn number		
		34	40/1	34
Viscosity, solution flow time	sec	6	7	7
True adhesiveness	%	23–25	19–21	10–12
Relative increase in strength	%	18–20	17–19	13–15
Relative breaking elongation of yarn	%	7–8	6–7	9–11
Yarn moisture content	%	10–12	10–11	10–15
Coefficient of variation: breaking load	%	90–100	90–100	90–100
Adhesion to yarn	kg/cm	0,8–1,2	1,0–1,4	0,7–1,2
Abrasion resistance coefficient	%	0,6–1,2	0,5–0,9	0,8–1,4
Breakage	arr/m	0,31	0,37	0,61

It was found that the drying rate is predetermined by the chemical nature of the preparation, the fiber composition of the yarn, and the time and temperature conditions of drying. The ability of yarn treated with various sizing preparations to lose moisture mainly depends on the type of composition. The relatively low ability to retain water molecules is explained by the presence of hydrophobic cycles in the PVA and HIPAN macromolecules [5,26,27,28,29,30,31,32,33].

It should be noted from the data obtained that the specific breaking load is one of the main physical and mechanical indicators of cotton yarn. The breaking load of yarn sized with the proposed composition is 13–15% higher than in the traditional case, with the same coefficient of variation.

Below are comparative results of cotton yarn sizing with a composition based on the developed composition with data on yarn sizing with starch under the conditions of the enterprise LLC "NAQSH OYDIN" (Table 3). As can be seen from Table 3, the concentration of the sizing, which has a significant impact on the cost of the sizing, fluctuates within 45–50 g/kg of the composition, against 70 g/kg of starch sizing, although the true adhesive remained at the same level. According to the results of the experiment, it was found that in the case of sizing cotton yarn with the developed sizing compositions, a significant reduction in starch is achieved, i.e. by 25–30%, which is in economic and environmental terms about the feasibility of using the developed composition [6].

It has been established (Table 4) that yarn breakage depends on a number of factors: the method of its spinning, the chemical nature of the fiber composition of the yarn, the nature of PVA and HIPAN and their amount in the sizing agent. Processing yarn with this sizing agent during weaving allows reducing warp breakage by 35–40%, increasing productivity by 5–10% and reducing shedding by 20–25% compared to starch sizing agents [7].

Table 4. The average breakage and productivity rates in weaving

Fabric, art	Machine brand	Breakage, rev/m	Productivity, in/hour
47/44	AT	0,29	10,15
150	ATP	0,41	5,78
544	AT100	0,27	11,05
12209	AT100	0,24	8,66
15182	STB	0,36	7,74
Average		0,32	9,23

The results of the analysis of the technological indicators of the process of sizing yarn with the developed polymer compositions (Table 4) show that as a result of sizing a strong base is obtained with minimal consumption of sizing and TAS [12].

2. Conclusions

Thus, it is shown that the viscosity of aqueous solutions depending on the concentration, temperature and pH of the solution of the sizing composition is described by a first–order equation. It is approximately 2–3 times lower than sizing preparations from starch sizing. The use of preparations from the developed composition of the sizing composition allows increasing the speed and degree of impregnation of the yarn in the sizing process, which increases the mechanical fixation of the adhesive film on the fiber and has a positive effect on weaving [8].

It has been found that cotton yarn treated with polymer compositions can be processed on various types of weaving machines, while providing a 35–40% reduction in breakage and a 5–10% increase in machine productivity compared to yarn sized with starch sizing [9,34,35,36,37,38,39,40,41,42].

At the present stage of development of textile industry, pigments and active dyes are mainly used in the production of printed fabrics. The share of these dyes in comparison with other classes of dyes reaches up to 80%. Despite this, printing with the above–mentioned dyes, which have advantages and difficulties from the technological point of view, remains an urgent task. Justification of the choice of thickener largely depends on their rheological and printing properties, as well as the quality of the coloring of the printed fabric. It should be noted that in textile enterprises, starch and its derivatives are mainly used as cheap thickeners when printing with cold dyes. However, the use of starch as a thickener has a number of disadvantages, namely, it enters into chemical interaction with active dyes, and this in turn leads to a significant overconsumption of starch and dye, and is also poorly washed off the surface of the fabric [10].

The use of modified starch as a thickener for printing inks, which forms a strong film on the surface of the fabric, leads to an increase in its rigidity, which is not typical for printing with active dyes. In this regard, it is proposed to use a thickening polymer composition that forms films with increased elasticity [11,13,14,15].

In addition, the analysis of the data in Table 6 shows that cotton fabric printed with active dyes based on starch thickener does not sufficiently ensure the color fastness to dry friction (2 points) and imparts increased rigidity to the printed fabric (6.7 times). In order to solve this problem, a sericin solution was introduced into the composition of the recommended printing composition in addition to modified starch and CMC, while the rigidity index (2.7–6.7 times) practically decreases to the level of alginate thickener (1.8 times), (changes in the range of 0.2–1.1) [16,17,18,19,20].

The analysis of the obtained results (Table 6) shows the importance of maintaining the quantitative ratio in the starch system within 5.0–5.5%, Na–CMC–0.2–0.3% and sericin–0.15–0.2%. This reduces the stiffness of the fabric, produces bright and durable colors, and eliminates any pronounced spreading of paint beyond the outline of the pattern with full fabric printing. The degree of fixation of active dyes (after washing the printed samples) is at a high level (95–96%).

Table 5. Performance of fabrics printed with reactive dyes

Quality indicators	Thickener composition			
	Factory		Recommended composition	
	Alginate based	Based on modified starch	Based on modified starch and CMC	Based on modified starch, CMC and sericin
Colour fastness to dry friction, points	5	2	3	4
Colour fastness to wet friction, points	4	3	4	4
Colour fastness to washing, points	5/5	4/3	5/4	5/5
Colour intensity F(R)	18,6	13,8	17,4	18,5
Increase in hardness, times	1,6	6,7	2,7	1,8

Table 6. The coloristic characteristics of cotton fabric printed with active dyes thickened with compositions

Print quality indicators	Factory thickener based on alginate, 4.5%	Thickener based on modified starch, Na–CMC and sericin at a concentration of 5.0; 0.3 and 0.2%, respectively
Color fastness to dry friction, points	5	5
Color fastness to wet friction, points	5	4
Color fastness to washing, points	5/5	5/4
Color intensity, %	10,6	11,9
Fabric stiffness, $\mu N \cdot cm^2$	1300	1430
Degree of fixation, active dye, %	96,5	95,2
Color variation, %	–	95,2
Degree of penetration, %	94,3	92,5

REFERENCES

[1] Amonova, K. I., Ravshanov, K. A., & Amonov, M. R. (2008). Evaluation of the possibility of using sericin to improve the efficiency of sizing cotton yarn. Composite Materials, (4), 66–68.

[2] Amonova, K. I. (2008). Rheological properties of aqueous solutions of polymer compositions and their influence on the sizing effect. Composite Materials, (2), 32–36.

[3] Amonov, M. R., Ravshanov, K. A., Khairullayev, C. K., & Amonova, K. I. (2008). Study of the desizing process of cotton yarn sized with starch-based compositions. Reports of the Academy of Sciences of the Republic of Uzbekistan, (4), 68–69.

[4] Amonov, M. R., Razzokov, K. K., Ravshanov, K. A., Majidov, A. A., Nazarov, I. I., & Amonova, K. I. (2007). Investigation of the relaxation properties of cotton yarn sized with polymer compositions. Uzbek Chemical Journal, (2), 27–30.

[5] Yariev, O. M., Amonov, M. R., Amonova, K. I., & Majidov, A. A. (2007). Evaluation of the rheological properties of polymer compositions based on natural and synthetic polymers. Composite Materials, (1), 6–10.

[6] Majidov, A. A., Amonov, M. R., Razzokov, K. K., & Nazarov, I. I. (2007). Study of thermodynamic characteristics and surface-active properties of polymer compositions based on starch and polyacrylamide. Composite Materials, (2), 24–27.

[7] Ismatova, R. A., Ibragimova, F. B., Amonov, M. R., & Sharafutdinova, R. I. (2019). Development of a new composition for sizing cotton yarn. Universum: Technical Sciences, 11(68), Part 3, 82–85.

[8] Ishmatov, A. B., Yaminova, Z. A., & Rudovsky, P. N. (2015). Justification of modes for obtaining sericin in powder form for preparing sizing compositions. Izvestiya VUZ. Technology of the Textile Industry, (6)(360), 79–83.

[9] Ishmatov, A. B., Rudovsky, P. N., & Yaminova, Z. A. (2012). Application of sericin for sizing warp yarns. Izvestiya VUZ. Technology of the Textile Industry, (6), 76–79.

[10] Yaminova, Z. A. (2013). Development of a sizing recipe from silk waste for sizing cotton warps. Bulletin of the Tajik Technical University Named After Academician M. S. Osimi, 2(22), 64–69.

[11] Kochkina, N. E., Vashurina, I. Y., & Kalinnikov, Y. A. (2004). Humic acids as a means of modifying starch-based sizing compositions. Textile Chemistry, 1(24).

[12] Vashurina, I. Y., Kochkina, N. E., & Kalinnikov, Y. A. (2004). Influence of humic acids on the properties of starch-based sizing compositions. Izvestiya VUZ. Technology of the Textile Industry, (1), 41–43.

[13] Vashurina, I. Y., Kochkina, N. E., & Kalinnikov, Y. A. (2006). Features of the effect of peat humic acids on the structure of starch-based sizing gels. Journal of Applied Chemistry, 79(2), 322–325.

[14] Zakharchenko, A. S., Aleshina, A. A., & Kozlova, O. V. (2012). Study of the properties of film-forming polymers used in finishing textile materials. Izvestiya VUZ. Chemistry and Chemical Technology, 55(3), 87–91.

[15] Yaminova, Z. A. (2015). Physical and chemical aspects of obtaining sericin from silk waste to size cotton yarn. Austrian Journal of Technical and Natural Sciences, (1–2), 121–123.

[16] Shagina, N. A. (2008). New technologies in the textile industry. Bulletin of the Dagestan State Technical University. Technical Sciences, (10), 100–101.

[17] Kozlova, O. V., & Melenchuk, E. V. (2013). The use of domestic polymers in the creation of retroreflective textile materials. Izvestiya VUZ. Chemistry and Chemical Technology, 56(2), 121–123.

[18] Bondareva, T. P., & Nevskikh, V. V. (2011). Fabric production technology: A study guide. Minsk. (p. 335).

[19] ISO 5725.1–6. (n.d.). Accuracy (trueness and precision) of measurement methods and results. Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.

[20] Stepanova, T. Yu., & Sakharova, S. G. (2010). Modification of the frictional properties of multifilament threads through emulsification. Izvestiya VUZ. Technology of the Textile Industry, (8)(239), 12–14.

[21] Stepanova, T. Yu., Talanova, V. A., & Sakharova, S. G. (2010). A static model of the effect of surfactant solution properties on the wear resistance of polyester fibers. Izvestiya VUZ. Chemistry and Chemical Technology, 53(6), 76–78.

[22] Stepanova, T. Yu., Sakharova, S. G., & Romanychev, N. K. (2008). Influence of high molecular weight alcohols on the mechanical and tribological properties of polyester yarn. Factory Laboratory. Diagnostics of Materials, 74(4), 62–63.

[23] Nazarov, S. I., Yariev, O. M., Sharipov, M. S., Muzaffarov, D. Ch., & Nazarov, I. I. (2005). Starch modified with phosphate salts for applications in different branches of industry. 23rd Discussion Conference: Current and Future Trends in Polymeric Materials, Prague, 52–53.

[24] Nazarov, S. I., Yariev, O. M., Nazarov, I. I., & Ravshanov, K. A. (2009). Modification of starch for use in fabric printing with reactive dyes. Uzbek Chemical Journal, (2), 57–60.

[25] Niyozov, E. D., Yoriyev, O. M., Sharipov, M. S., & Razzokov, K. K. (2009). Structural formation in solutions of thickening compositions based on polysaccharide derivatives and synthetic polymers. Composite Materials, (4), 6–10.

[26] Amonov, M. R. (2002). Optimization of the composition of thickening agents for fabric printing. Journal of Plastics, (9), 44–45.

[27] Ibragimova, F. B., Amonov, M. R., & Ikhtiyarova, G. A. (2002). Assessment of the effect of the affinity of thickening compositions on the yield strength and fixation of printing dyes. Journal of Plastics, (10), 42.

[28] Sharipov, M. S., Yariev, O. M., Ravshanov, K. A., & Amonov, M. R. (2008). Microstructure of thickening compositions based on oxidized starch modification. Journal of Plastics, (7), 55–57.

[29] Sharipov, M. S., Yariev, O. M., Ravshanov, K. A., Amonov, M. R., & Ruziyeva, R. (2007). Fixation degree of reactive dyes during printing with a composite thickener based on oxidized starch. Composite Materials, (3), 93–95.

[30] Epishkina, V. A., Tselms, R. N., Vasiliev, V. K., & Kiselev, A. M. (2006). Rheological and printing properties of synthetic thickeners for pigment printing. Izvestiya VUZ. Technology of the Textile Industry, (6), 86–92.

[31] Epishkina, V. A. (2011). Integrated technology for finishing fabrics for special purposes. Vestnik SPbGUTD, (2), 17–20.

[32] Zakharchenko, A. S., Melenchuk, E. V., & Kozlova, O. V. (2010). Efficient technology for simultaneous dyeing and finishing of textile materials. Izvestiya VUZ. Technology of the Textile Industry, (6), 41–45.

[33] Melenchuk, E. V., Zakharchenko, A. S., & Kozlova, O. V. (2010). Technology of dyeing textile materials with pigments. Izvestiya VUZ. Technology of the Textile Industry, (7), 37–40.

[34] Shagina, N. A. (2008). New technologies in the textile industry. Bulletin of the Dagestan State Technical University. Technical Sciences, (10), 100–101.

[35] Kuznetsova, E. E., Tretyakova, A. E., & Safonov, V. V. (2014). Study of the rheological indicators of printing compositions based on thickeners of various origins optimal for screen printing. Izvestiya VUZ. Technology of the Textile Industry, (1), 77–82.

[36] Kuvaeva, E. Yu., Odintsova, O. I., Melnikov, B. N., & Andreev, K. L. (2005). Use of new surfactants for strengthening the dyeing of fabrics colored with direct dyes. Izvestiya VUZ. Technology of the Textile Industry, (1), 54–57.

[37] Krotova, M. N., Odintsova, O. I., & Melnikov, B. N. (2006). Study of the influence of cationic surfactants on the state of reactive dyes in solution. Izvestiya VUZ. Chemistry and Chemical Technology, 49(7), 63–66.

[38] Odintsova, O. I., Krotova, M. N., & Kuvaeva, E. Yu. (2009). Influence of nonionic surfactants on the solubilization of disperse dyes. Izvestiya VUZ. Chemistry and Chemical Technology, 52(7), 65–68.

[39] Pogorelova, A. S., Vashurina, I. Y., & Kalinnikov, Y. A. (2006). Application of humic acids in the Rongalite-potash printing technology for textile materials with vat dyes. Izvestiya VUZ. Technology of the Textile Industry, (1), 55–59.

[40] Aleyeva, S. V., Zabyvayeva, O. A., & Koksharov, S. A. (2007). Influence of textile auxiliaries on the destruction of cotton fiber during alkaline boiling. Izvestiya VUZ. Technology of the Textile Industry, (2), 64–67.

[41] Volkov, V. A., Shchukina, E. L., Amarloui, A., Ageev, A. A., Kukleva, K. K., & Eleev, A. F. (2008). Nanotechnology of molecular layering in anti-adhesive modification of fabric fibers. Chemical Fibers, (2), 34–40.

[42] Niyozov, E. D., Yoriyev, O. M., Sharipov, M. S., & Razzokov, K. K. (2009). Structural formation in solutions of thickening compositions based on polysaccharide derivatives and synthetic polymers. Composite Materials, (4), 6–10.

[43] Niyozov, E. D., Sharipov, M. S., & Yariev, O. M. (2010). Viscosity-cohesion properties of thickening compositions based on carboxymethyl starch. Uzbek Chemical Journal, (4), 56–57.

[44] Kozlova, O. V., & Melenchuk, E. V. (2013). The use of domestic polymers in the creation of retroreflective textile materials. Izvestiya VUZ. Chemistry and Chemical Technology, 56(2), 121–123.

[45] Kalugina, M. S., Mikhaylovskaya, A. P., & Kiselev, A. M. (2016). Dyeing of polyamide fabric. Vestnik of Saint Petersburg State University of Technology and Design. Series 1, (2), 78–81.

[46] ISO 5725.1–6. (n.d.). Accuracy (trueness and precision) of measurement methods and results. Part 2: Basic method for determining the repeatability and reproducibility of a standard measurement method.