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Structure Formation of Compositions Consisting of Polysaccharides and Polyacrylates in Aqueous Solutions and Creation of Moisturizing Ingredients Based on Them

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Abstract This scientific article studies the interaction of polysaccharides and polyacrylates in aqueous solutions and the processes of structure formation of emollient ingredients based on them. Polysaccharides and polyacrylates, with their natural and synthetic properties, play an important role in bioorganic systems, making their composition and changes in aqueous solutions particularly significant. The study analyzes macromolecular structures formed as a result of these interactions and their physicochemical properties, with a focus on viscosity, elasticity, and stability. Experimental results revealed that viscosity increased by 35%–50% at pH levels of 6–7, optimal temperature (25℃–30℃), and a mixing time of 45–60 minutes. Elasticity improvements of 25% were observed under similar conditions, indicating enhanced structural stability. The interactions between polymers and polysaccharides significantly influenced structural changes in aqueous solutions, demonstrating their potential in creating emollient ingredients. The study also highlights the ability of these compositions to increase moisture retention by 20%–30%, providing practical applications in the agro-industrial, pharmaceutical, and cosmetic sectors. These findings underscore the potential of using polysaccharides and polyacrylates to create innovative and effective emollient compositions, paving the way for new technological opportunities.

Keywords Polysaccharides, Polyacrylates, Aqueous solutions, Yarn sizing, Sustainable processing

1. Introduction

The sharp increase in the world's population gives rise to an increase in demand for fabrics based on natural fibers. At the same time, the rapid development of the textile industry means that the demand for manufactured products is being increased year by year. In particular, the creation of water–soluble polymer–based dyeing compositions and their application in the dyeing process of spun yarns enables the enhancement of the physical and mechanical properties of dyed yarns. Improvement of the quality and competitiveness of semiproducts and products based on cotton fiber is one of the most topical tasks for the enterprises of light industry. One of the solutions that they offer is to develop resource –saving technologies which would help to reduce the consumption of starch and chemical reagents–the imported food products of our republic–in the production of food [1,2,3,4,5,6,7].

Up to now, in research and development of new technologies for the production of water–soluble polymer compositions, attention is paid to research and development work that allows the receipt of effective and high–quality finishing polymer compositions in order to fully replace starch, which is considered a food product, or to sharply reduce its consumption. In this regard, great attention is paid to working out very effective finishing compositions for yarn finishing in the enterprises of the textile branch of industry, to obtaining a thin, durable elastic film on the fiber surface with the assistance of finishing agents, establishing their adhesion to the fiber and stability to the effect of mechanical forces; for decreasing the consumption of starch during the finishing process; the development of technology that has been able to gain wide acceptance and make it possible to obtain energy– and resource–saving finishing agents instead of foreign ones [8,9,10,11,12,13,14,15,16,17].

In our country, certain results are being achieved in the direction of the production of new types of products of the chemical industry, including large–scale measures are being implemented in the field of providing the local market with import–substituting abrasive compositions. In our republic, great attention is paid to the implementation of measures to protect the environment and the development of a scientifically based system of industrial facilities management through the

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introduction of innovative technologies. The "Development Strategy of New Uzbekistan for 2022–2026" sets out priority areas for economic development and specifically identifies issues of increasing the number of types of finished products with high added value based on deep processing of local raw materials, and mastering qualitatively new types of products and technologies. In this regard, the creation of economically efficient and environmentally friendly technologies for the production of natural and water–soluble polymer abrasive materials based on local raw materials is of great importance.

The process of coating cotton–based yarns is one of the important technological processes in industrial production to obtain finished fabrics. The main task of this process is to select polymer components with adhesion properties on the surface of soft yarns and to form a highly elastic film on cotton–based yarns with high wetting ability, sufficient adhesion, and the main ingredients are called coating agents. The formation of a thin film on the surface of the yarn should be stable during storage and use, as well as easy washing from the coated yarn and good biodegradability [18].

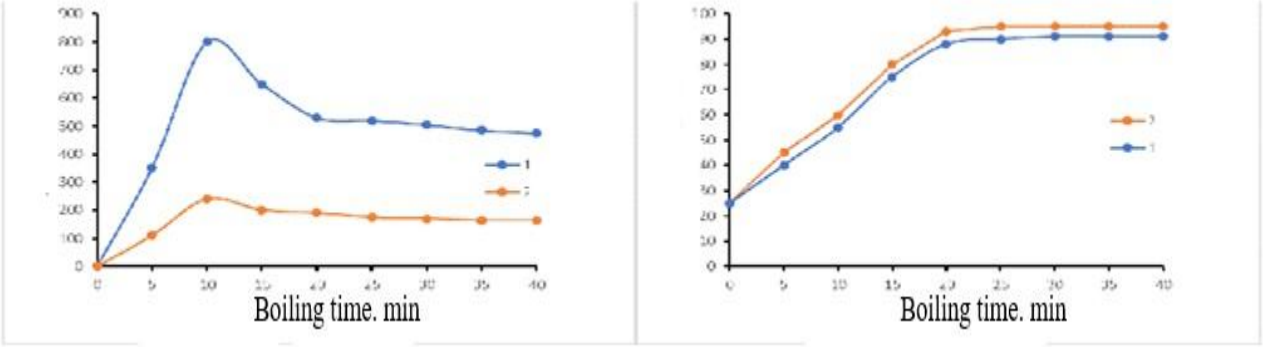
The development and use of new starch–based materials will not only reduce the consumption of starch as a food raw material, but also partially or completely eliminate the use of imported starch–based materials, while maintaining high requirements for the technological properties of starch production [19,20,21,22,23,24].

The annual global demand for binders is estimated at 3 million tons, of which 75% is starch (60%–potato and corn, 15%–modified), 12%–polyacrylics, 11%–PVA, CMC and other types of binders–2%. The presented data show that the main fining agent is starch. However, the use of starch as a fining agent has a number of disadvantages: the main ones are the fragility of the film formed on the fiber, the lack of high adhesive properties. Therefore, the main direction of the research is to obtain fining agents based on water–soluble synthetic polymers and improve their adhesion to the surface of the yarn and increase its adhesive properties.

It is known that cotton–based yarn is subjected to a number of mechanical effects during processing, which leads to a decrease in its properties. Numerous studies have shown that the use of water–soluble synthetic polymer materials significantly improves the physical and mechanical properties of yarn, as well as reduces the number of yarn breaks during the weaving process.

It is impossible to obtain finished fabric from soft cotton–based yarn, that is, during the process of obtaining fabric, the yarn is subjected to great friction and mechanical force on weaving looms. This, in turn, leads to softening of the yarn and an increase in the number of yarn breaks.

Therefore, in the textile industry, in order to reduce the breakage of the yarn, increase its resistance to friction, and increase the volume and ability to obtain fabric from the yarn, the yarn must be dyed. In order for the dyed yarn to have the required operational and technological properties, the dye must also have certain rheological and physico–mechanical indicators. In particular, the dye must penetrate the yarn surface as well as the yarn, increasing the strength of the soft yarn. Secondly, it must be homogeneous, sticky, have a certain viscosity, and form a strong thin, elastic film on the surface of the yarn when drying. In the preparation of dye, the main component is the dye, that is, the sizing agent, which is mainly starch, which is considered a food product. In textile enterprises of our republic, corn starch is mainly used as a dye. This starch is not produced at chemical enterprises, therefore it is imported from abroad for foreign exchange. This, firstly, leads to an increase in the cost of the manufactured product, and secondly, it prevents enterprises from operating at the same rate. Therefore, the development of new types of thickeners based on local raw materials and water–soluble polymers is of great importance. The main direction of research in this regard is aimed at modifying rice starch obtained from local raw materials instead of starch obtained from various leguminous plants in the thickener composition with water–soluble high–molecular–weight synthetic polymers such as potassium salt of pyrophosphoric acid, acrylic emulsion and sodium salt of carboxymethylcellulose (Na–CMC). Taking into account the above, in this section, the possibilities of using modified starch as a thickener in the process of thickening cotton fiber yarns were studied.



1–Starch–4.0%
2–Composition with Starch–4.0%, Na–CMC–0.2%, AE–0.5%, K2H2P2O7–0.04%.

Figure 1. The boiling time of the starch (1) and the proposed softening composition (2) is dependent on their flow time (a) and temperature (b)

Regardless of the composition of the slurry, alkali is added when preparing it, that is, the preparation of starch slurry is carried out in an alkaline environment (pH–7.5–8.0), the main reason for this is that starch macromolecules decompose well in an alkaline environment and act as a simulator for the swelling of starch granules. Therefore, swelling leads to an increase in the viscosity of this starch gel, while starch depolymerization leads to a decrease in it. Taking this into account, in our next study, we studied the dependence of the viscosity of the proposed slurry composition on the preparation time and temperature [25,26,27,28,29,30].

The dynamics of viscosity change is shown in Figure 1. The results show that when the starch concentration in the slurry is 4.0%, the introduction of small amounts of Na–CMC, AE and $K_2H_2P_2O_7$ components primarily reduces the flow time of the slurry composition by 4.5–5.0 times, which means that the degree of polysaccharide saturation increases sharply. At the same time, it can be seen that the temperature of the proposed slurry preparation is reduced by 15–20℃ compared to starch slurry [41,42,43,44,45,46].

It should be noted that under the physicochemical parameters of the process of preparing the sizing, interaction between polymer groups and reactive groups of PVA and HIPAN is possible. The products formed as a result of this interaction contain, in particular, amide–CONH, urea–NHCONH, carbamate–$OCONH_2$, ester–OCO and other groups. Their presence in the macromolecules of the polymer composition makes it possible to improve the elastic, structural and mechanical properties, and reduce the electronegativity of the adhesive film formed on the yarn during sizing.

An important factor for sizing cotton yarn is drying the yarn after sizing. Therefore, to establish the temperature and time parameters for drying sized yarn, as well as to determine the speed of movement of the warp during sizing, the kinetics of drying yarn treated with compositions was studied (Table 1) [47,48,49,50].

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% [31,32,33,34,35].

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 [36,37,38,39,40].

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 the comparative results of measuring cotton yarn with a composition based on the composition formed with data from measuring yarn with starch in the conditions of the “NAQSH OYDIN” LLC enterprise (Table 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, ℃			
	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, ℃	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. Physico–mechanical properties of the yarn, machined glue, obtained with optimal preparation parameters

Indicators	Unit of measurement	Developed dressing		Factory size, starch
		Cotton yarn number		
		34	40/1	34
Viscosity, solution flow time	sec	6	7	7
True glue	%	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	%	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	%	06, –1,2	0,5–0,9	0,8–1,4
Breakage	rpm	0,31	0,37	0,61

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 economically and ecologically about the feasibility of using the developed composition.

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