Formulations and Performance of Eco-Friendly Raw Starch Sizing Process

Qiuxia Yu, Shufang Hu, Ziming Jin,* Qiaoxian Chen, Xiaokang Wang, and Yining Zhang

In response to the green development concept of the textile industry, this article describes the development of a biodegradable and eco-friendly raw starch sizing agent formulation. The sizing agent performance, sizing quality, biodegradation, weave efficiency, and production cost of the raw starch formulation in raw starch sizing process were compared with three other formulations. The results showed that the formulation prepared with raw starch achieved a lower viscosity and higher stability compared with the other three formulations. The raw starch sizing exhibited excellent moisture regain, moisture absorption performance and breaking strength, high enhancement rate and low elongation, high penetration, low coating, and abrasion resistance. The raw starch formulation was shown to be energy-saving and environmentally friendly, with higher weave efficiency and lower production costs. The BOD_5/COD was 0.65, which means that the desizing wastewater is easy to degrade. Sizing agent cost was 17 to 61% lower and loom efficiency was 5% to 12% higher. This research provides a theoretical basis for promoting the usage of raw starch sizing in practical production, which contributes to green and eco-friendly processing.

DOI: 10.15376/biores.20.2.4174-4186

Keywords: Raw starch sizing process; Sizing agent performance; Sizing quality; Biodegradability

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INTRODUCTION

In the modern weaving process, warp yarns are repeatedly stretched and rubbed on the loom. In order to increase strength and abrasion resistance, reduce yarn hairiness and breakage, improve weave efficiency (Zhao *et al.* 2015), and reduce raw material loss during weaving, sizing the warp yarns has become an essential process before yarn weaving (Li *et al.* 2022). However, the large amount of wastewater generated during the desizing of commonly used polymer sizing agent is one of the main pollution sources in the textile industry, which is a great burden on the ecological environment. In recent years, the textile industry has strengthened environmental protections and sustainable development. Many new eco-friendly sizing agents have been gradually developed, such as natural sizing agent (Fahmida and Syduzzaman 2024), animal feather sizing agent (Yang and Reddy 2013), protein sizing agent (Reddy *et al.* 2014. Yang *et al.* 2017), *etc*. However, up to the present they have not been able to meet large-scale production requirements. The common textile sizing materials on the market are still starch, polyvinyl alcohol (PVOH), and polyacrylic acid (PAA) (Kapourani *et al.* 2023).

PVOH is an option for textile sizing that offers excellent abrasion resistance and strength, strong yarn adhesion, and film-forming stability. However, its desizing wastewater has high COD (chemical oxygen demand) and low BOD (biodegradability) (Savin and Butnaru 2008). PAA has good yarn adhesion and low environmental impact (Sun *et al.* 2012), but its cost is high and it is usually used as an auxiliary component. Starch sizing agent offers good adhesion and certain moldability to natural cellulose fibers (Zhao *et al.* 2013; Zhu and Zhu 2014). Compared to these two types of sizing agents, starch sizing agent has abundant resources, relatively low prices (Wang *et al.* 2021), and easy biodegradability. Therefore, it has a wider range of applications. Starch sizing agent has excellent advantages in environmental protection. However, due to the difference in starch structure, the starch sizing agent has the downsides of large-size film brittleness, poor viscosity stability or difficult gelatinization, and poor anti-ageing performance (Liu *et al.* 2006; Zhou *et al.* 2009; Li *et al.* 2016). The weaving speed of looms continues to increase. In order to meet the weaving needs, enterprises generally use a mixed formula of starch, PVOH, PAA, acrylic acid (AA), and other sizing agent in actual production. The sizing agent formula is complex, and the desizing wastewater contains many organic pollutants, resulting in high environmental degradation pressure.

To address the problems existing in typical sizing agents, this article developed an eco-friendly raw starch sizing agent formulation. The raw starch sizing agent does not contain PVOH or PAA. It solves the problem of PVOH not being eco-friendly and greatly simplifies the complexity of the mixed sizing agent formulation, reducing the sizing agent mixing time and saving energy consumption. The sizing quality is greatly improved, with effectively enhancing weave efficiency. At the same time, the wastewater from the eco-friendly raw starch formulation is quickly degraded, resulting in a significant reduction in the cost of sizing agent and air conditioning during the production process. The eco-friendly raw starch formulation has the advantages of a simple sizing agent formula, excellent sizing quality, improved weave efficiency, and eco-friendly energy saving and emission reduction.

This article compares the sizing agent performance, sizing quality, biodegradation, weave efficiency, and production cost of the eco-friendly raw starch formulation with three other factory formulations. A comprehensive evaluation of the production efficiency of eco-friendly raw starch technology is conducted to provide theoretical reference and a basis for the technological innovation of the sizing process. The goal is to actively promote the application of raw starch sizing agent in practical production, helping enterprises to reduce production costs and improve economic efficiency. At the same time, it can be more conducive to reducing environmental pollution and promoting the development of technology in the textile industry towards green intelligence.

EXPERIMENTAL

Raw Material and Sizing Agent Formula

The goal of this work was to select the raw starch formulation and compare the results with the formulations obtained from three other factories. There are different sizing agent formulations and mixing times. The other operations or process parameters in sizing process were kept the same, such that differing effects of the sizing operation could be mainly attributed to differences in formulation. The sizing agent formula contents are shown in Table 1.

The "1#" process is the raw starch sizing process, which used the 1# formulation listed in the table. The main sizing agent was corn starch, which was used in combination with a self-developed special additive, and viscosity reducing agents. The special additive was composed of glycerol, palm oil, sodium alginate, carboxymethyl β-cyclodextrin, AEO, and silicone compound. The viscosity reducing agent was ammonium persulfate. Special additives were used to improve the sizing agent performance, viscosity reducing agent can prevent starch from becoming too sticky and improve fluidity.

The 2# process used the corresponding formulation listed in the table. The main sizing agent was corn starch in combination with PAA. Its special additive was composed of glycerol and wax flakes, and the viscosity reducing agent was amylase. The main sizing agent of the 3# process was also corn starch and PAA. Its special additive was composed of wax flakes, AEO and glycerol, as well as viscosity reducing agent was amylase. The 4# formulation included PAA, PVOH, high-performance starch, and oxidized starch, and the special additive wax flakes.

The sizing process is shown in Fig. 1. All four processes used high-pressure sizing agent adjustment. The main sizing agent, auxiliary sizing agent, and the appropriate amount of clean water were poured into the high-pressure mixing barrels for mixing and grouting. The temperature was set at 118 ° C, and the pressure was 0.2 MPa.

Table 1. Sizing Agent Formulations for Four Processes

Name	1# formulation	2# formulation	3# formulation	4# formulation
Corn starch /kg	112.5	87.5	115	/
Special additive /L	7	27	13	3
Viscosity reducing agent /g	68	150	100	/
High-performance starch /kg	/	/	/	37.5
Oxidized starch /kg	/	/	/	50
PVOH/kg	/	/	/	25
PAA /kg	/	2	2	3
Total volume /L	900	900	900	900

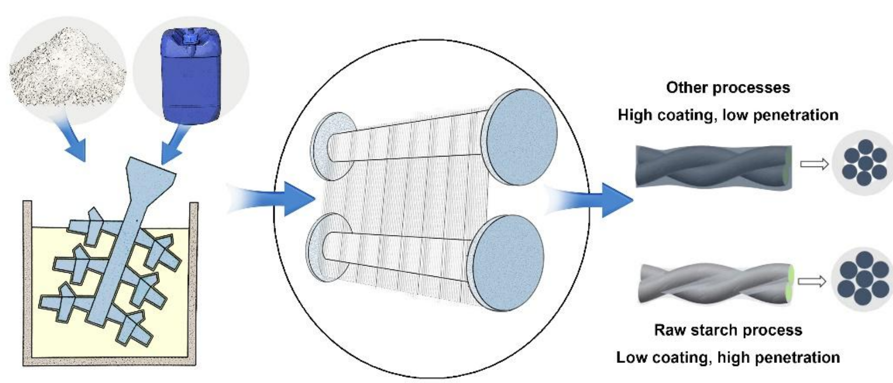


Fig. 1. Schematic diagram of the sizing process

The difference in the mixing process is that formulation of 1# process did not contain PAA or PVOH, so there was no need to deliver the sizing agent in batches. The mixing time was 5 min and the grouting time was 30 min. The sizing agents of the other three processes were added in two separate times, with a total mixing time of 10 min and a grouting time of 30 min.

After mixing, the performances of the sizing agents were evaluated. Then, the four types of finished sizing agents were inputted into the same sizing machine to size the warp yarn, resulting in finished sizing.

Instruments and Equipment

The following equipment was used: NDJ-79B rotary viscometer (Haichangji Geological Instrument Co., Ltd. China), 10×150×10(mm) customized polypropylene tank plate (self-made), XMTD-9000 constant temperature electric heating plate (Shanghai Lichen Instrument Technology Co., Ltd. China), YG026MB functional electronic fabric strength machine, YG747B semi-automatic fast speed eight basket oven (Nantong Hongda Experimental Instrument Co., Ltd. China), CH1006N constant temperature tank (Shanghai Shuangxu Electronics Co., Ltd. China), FA2004N electronic analytical balance (Shanghai Jingruo Scientific Instrument Co., Ltd. China), HD021N+electronic strength instrument (Nantong Hongda Experimental Instrument Co., Ltd. China), YG172A yarn hairiness analyzer (Beijing Jinyang Wanda Technology Co., Ltd. China) Y731 YG172A (Nantong Sansi Electromechanical Technology Co., Ltd. China), Nikon C2 confocal microscope laser scanning confocal microscope (Nikon Corporation), and cotton yarn (14.58tex, Rainbow International Group Ltd. China).

Methods

This experiment tested the performance of the prepared sizing agent. Cotton yarn was used as the raw yarn, and the raw starch sizing agent and three other sizing agents were used as experimental factors under four different formulations.

Comparative analysis of yarn quality of the four sizing systems was evaluated according to several indicators to assess the sizing quality of the raw starch formulation. The production cost, weave efficiency, degradability of desizing wastewater during the weaving process, and parameters in actual textile production were recorded in the course of experimentation. The goal was to comprehensively analyze the advantages of the raw starch formulation.

Methods for Sizing Agent Performance

Sizing agent viscosity and viscosity stability

Sizing agent viscosity and viscosity stability were measured according to the GB/T 22427.7-2008 standard. The viscosity of the sizing agent was measured using a NDJ-79B rotary viscometer, with a 1# rotor with a speed of 750 RPM and a unit of millipascals per second (mPa·s). The temperature of the tested sizing agent was 95 °C. A total of 1000 mL of the tested sizing agent was kept at 95 °C in a constant temperature bath. The viscosity value of the tested sizing agent was measured every 30 min with a NDJ-79B rotary viscometer. A total of 6 viscosity values were recorded and calculated based on the viscosity stability. The stability was calculated using Eq. 1,

$$C = 1 - \frac{max|\eta - \eta'|}{\eta_1} \times 100\% \quad (1)$$

where η_1 (mPa·s) is the viscosity measured at 95 °C for 1 h, $max|\eta\text{-}\eta'|$(mPa·s) is the range of the last five viscosity values, and C (%) is the viscosity stability.

Sizing agent adhesion strength

The improved roving method proposed by Xiangyue Jiang was used to measure and calculate the sizing agent adhesion strength. A sizing solution was poured evenly on cotton yarn. After applying pressure, it was dried, adjusted, and measured.

Solid content

The solid content of sizing agent refers to the amount of solid components in the sizing agent, usually expressed as a percentage. The solid content of the sizing agent in this experiment was measured according to HG/T 4266-2011 standard using a constant temperature drying oven and a balance.

Methods for Sizing Quality

Sizing rate and moisture regain rate

The desizing method was used to measure the sizing rate, and the sizing rate was measured and calculated according to the HG/T 5080-2016 standard. Due to using the raw starch formulation in this experiment, amylase must be used to remove the sizing first. The average value of 20 groups dates of dry weight and wet weight was measured, and the sizing rate was calculated according to Eqs. 2 and 3,

$$S = \frac{B_0 - B_1}{B_0} \times 100\% \tag{2}$$

$$A = \frac{W_2 - \frac{W_3}{1-S}}{\frac{W_3}{1-S}} \times 100\% \tag{3}$$

where S (%) is the hairiness loss, B_0 (g) is the dry weight of the sizing, B_1 (g) is the dry weight of the sizing after desizing, A(%) is the sizing level, W_3(g) is the dry weight of the yarn after desizing.

According to the GB/T 9995-1997 standard, the moisture regain of sizing is measured by the drying and weighing method. The average value of 20 groups of data for weight before and after sizing was obtained. Finally, the moisture regain was calculated according to Eq. 4,

$$W = \frac{W_1 - W_2}{W_2} \times 100\% \tag{4}$$

where W (%) is the moisture regain of the sizing, W_1 (g) is the wet weight of the sizing, and W_2 (g) is the dry weight of the sizing.

Breaking and elongation performance

The breaking performance of sizing includes breaking strength and breaking elongation. This experiment used the GB/T 3916-2013 standard to test the breaking strength and elongation at the break of sizing. The uniform sample length was 500 mm, and the tensile speed was 500 mm/min. The average value of 20 groups of data of breaking strength was measured.

The elongation performance includes enhancement percentage and elongation reduction percentage. The enhancement refers to the increase in breaking strength after sizing, as shown in Eq. 5. The elongation reduction refers to the situation where the breaking elongation decreases after sizing, as shown in Eq. 6,

$$Z = \frac{P_2 - P_1}{P_1} \times 100\% \tag{5}$$

$$D = \frac{D_1 - D_2}{D_1} \times 100\% \quad (6)$$

where Z(%) is the enhancement, P_1(cN) is the breaking strength of the raw yarn, P_2 (cN) is the breaking strength of the sizing yarn, D(%) is the elongation reduction of sizing, D_1(%) is the breaking elongation of the raw yarn, and D_2 (%) is the breaking elongation of the sizing. The average of 20 data groups of breaking elongation was calculated to obtain the final enhancement and elongation reduction percentages.

Hairiness index and hairiness reduction percentage

The yarn hairiness index refers to the sum of the number of hairiness on one side of the sizing surface per unit length. Generally, the cumulative numbers of hairiness on one side of a 10 cm length sizing surface with a length of 3 mm or more is called the hairiness index. This experiment was conducted in accordance with the FZ/T 01086-2020 standard to test the hairiness index of sizing, and 20 groups of data for the hairiness index before and after sizing were compared.

The hairiness reduction percentage refers to the ratio of hairiness reduced before sizing to the amount before sizing, as shown in Eq. 7,

$$Y = \frac{Y_1 - Y_2}{Y_1} \times 100\% \quad (7)$$

where Y(%) is the hairiness reduction, Y_1 is the average index of 3 mm or more hairiness on a 10 cm long raw yarn, and Y_2 is the average index value of 3 mm or more hairiness on a 10 cm long sizing. A total of 20 groups of data were calculated to obtain the reduction rate of sizing hairiness.

Abrasion resistance

The abrasion resistance can be characterized by an abrasion resistance number and an abrasion increase (%). The abrasion resistance number refers to the number of times the sizing is rubbed until it breaks. This experiment was conducted according to the GB/T 1798-2008 standard. Twenty groups of data before and after sizing were compared. The abrasion increase percentage refers to the ratio of the difference in abrasion resistance between the raw yarn and sizing to the abrasion resistance of the raw yarn, as shown in Eq 8. This is obtained by calculating 20 groups of data of abrasion resistance to obtain the abrasion increase,

$$M = \frac{N_2 - N_1}{N_1} \times 100\% \quad (8)$$

where M(%) is the abrasion increase, N_1(times) is the average number of times the raw yarn breaks, and N_2 (times) is the average number of times the sizing breaks.

Coating percentage and penetration percentage

The coating percentage of sizing refers to the ratio of the area covered by the sizing agent on the surface of the sizing to the cross-section of the yarn. The penetration percentage of sizing refers to the ratio of the area where the sizing agent permeates inside the sizing to the cross-section of the sizing.

The experimental data was obtained using the MATLAB based measurement method for penetration rate and coating rate proposed by Yu and Wu (2009). The results were calculated based on images from laser confocal microscopy (CLSM), using MATLAB software.

Biodegradation

The desizing process generates a large amount of wastewater. Wastewater being easy to biodegrade and having a small impact on the environment is the environmental evaluation requirement pursued by the sizing process. The value of BOD_5/COD is the ratio of five-day biological oxygen demand to chemical oxygen demand. Generally, it is used to evaluate the environmental friendliness of textile wastewater, which reflects the biodegradability of the wastewater.

This experiment used the same type of yarn for sizing quality experiment as the warp yarn to weave the fabric. The wastewater was obtained from desizing, and the biological oxygen demand (BOD) and chemical oxygen demand (COD) were measured according to HJ505-2009 and HJ/T399-2007 standards.

Weave Efficiency and Cost

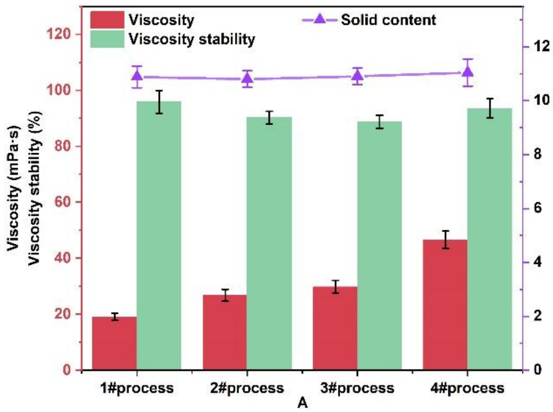
The sizing and weaving process is a system, with each link complementing each other, ultimately reflected in the goals pursued by the enterprise: high efficiency, high quality, high biodegradation, and low cost. By comparing parameters such as weave efficiency, air conditioning cost, and sizing agent cost, production efficiency can be reflected, and the advantages and disadvantages of the formulation in the actual production can be compared. These three parameters can intuitively reflect the production efficiency and profitability of the enterprise. A good formulation in sizing process can improve weave efficiency, air conditioning costs, and sizing costs, thereby reducing costs and increasing efficiency.

Statistical research was conducted on the weaving data of four enterprises using four different formulations for weaving in December 2022. The loom speed was fixed at 660 rpm/min. The loom speed, 100000-meter weft stop times, 100000-meter warp stop times, and loom efficiency data were recorded. The sizing and air conditioning costs were calculated based on the main sizing agent and additives costs, air conditioning energy consumption, and fabric output during the four formulations adopted by four enterprises.

RESULTS AND DISCUSSION

Sizing Agent Performance

The measurement was prepared according to the sizing agent process, and the process indicators of various sizing agents were measured using the methods described above. The results are shown in Figs. 2 and 3. The raw starch sizing agent without PVOH and PAA had the lowest viscosity and the best flowability because its special additive added to the raw starch formulation effectively reduced the viscosity of the starch sizing agent. The viscosity stability of the raw starch sizing agent was the best, and the adhesion strength exceeded 10% compared to other conventional processes. This is because adding the special additive improved the poor viscosity stability of traditional starch sizing agent, which improved the overall sizing quality. The surfactant of the additives had a strong wetting effect, which can increase the adhesion performance between the sizing agent and the yarn, and improve the strength, curling, and abrasion resistance of the yarn. The raw starch sizing agent had a moderate solids content, which met the requirement that the solid content of the sizing agent should be between 10% and 15%, effectively avoiding the problems of the thick sizing agent film caused by high solid content and unfavourable sizing caused by low solids content.



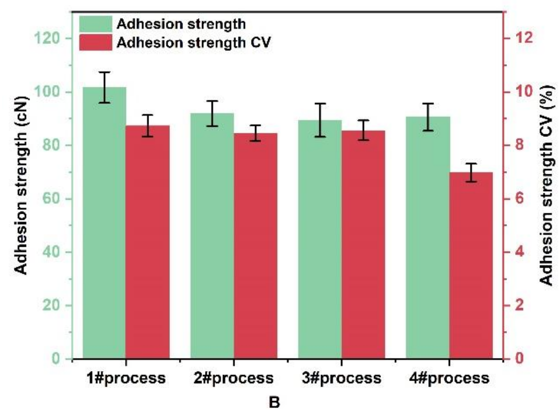
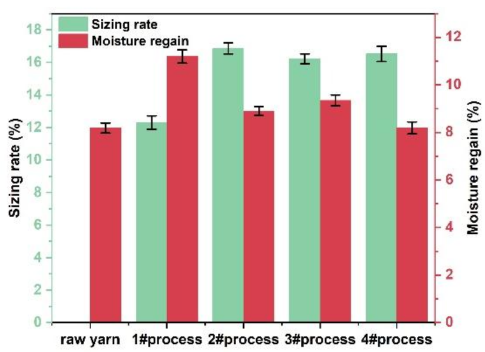


Fig. 2. Viscosity and solid content

Fig. 3. Abrasion resistance and resistance CV

Sizing Quality

The performance change indicators before and after sizing were measured using the above method. The sizing rate and moisture absorption results are shown in Fig. 4. The sizing rate using 1#formulation of 1#process was the lowest, decreasing by 30 to 33% compared to the other three processes. The raw starch formulation had higher moisture regain and stronger moisture absorption performance ability, far exceeding the other three formulations. Low sizing rate means that the sizing film was thinner and had stronger moisture absorption, which is beneficial for maintaining the stability of the sizing.



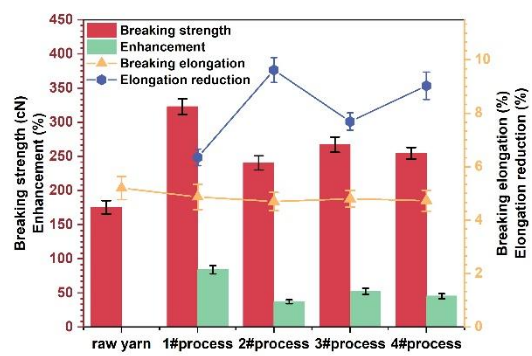
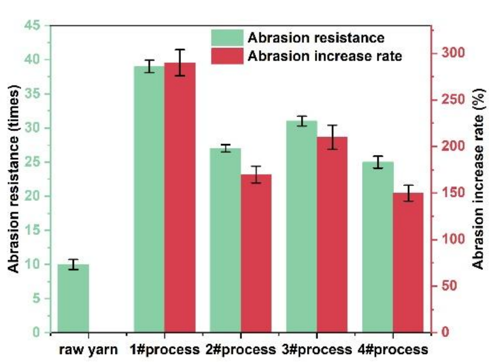


Fig. 4. Sizing rate and moisture absorption

Fig. 5. Breaking strength, enhancement, breaking elongation and reduction



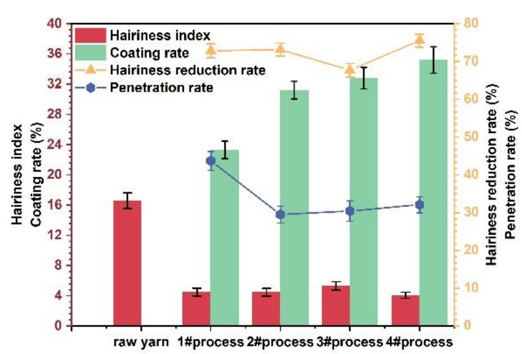
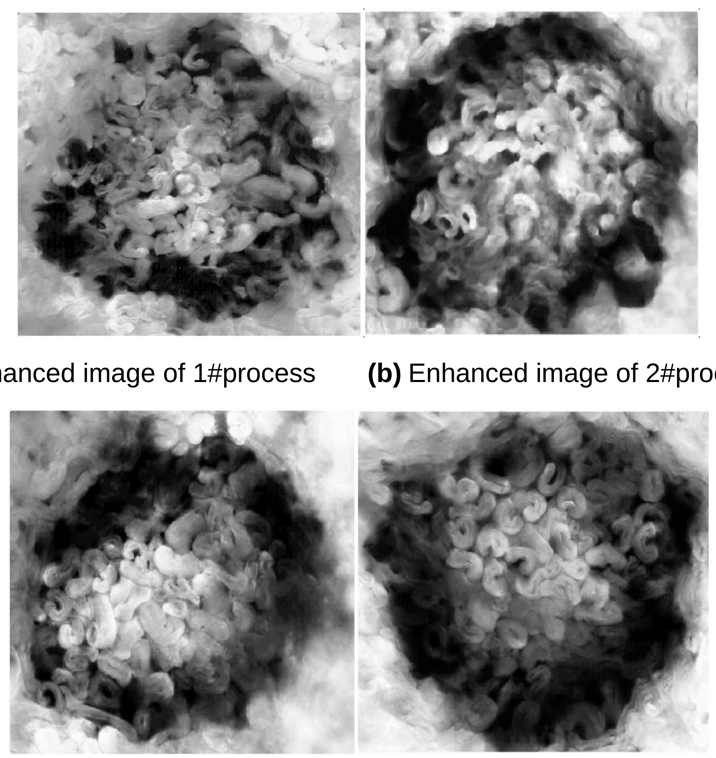


Fig. 6. Abrasion resistance and increase

Fig. 7. Hairiness index and reduction rate, coating and penetration

In Fig. 5, among the four processes, the breaking strength and breaking elongation of the raw starch sizing are the highest, with a 21 to 34% increase in breaking strength compared to other processes. Compared with the 2# process sizing, the enhancement of the raw starch sizing was about 2.26 times, while the elongation reduction was only 68.6%. The sizing using the raw starch formulation had the characteristics of a high enhancement rate and low elongation reduction, and the yarn strength was greatly improved. This is because sizing can improve the strength of sizing, but the sizing agent will form a hard film on the surface of the yarn, making the sizing more brittle and with greater friction, resulting in a decrease in breaking elongation. In contrast, the raw starch formulation had a low sizing percentage, with a thinner sizing agent film on the surface of sizing, making the yarn soft and elastic, reducing friction and compression during weaving, and making the warp and weft yarns less prone to breakage.

In Fig. 6, the abrasion resistance of the raw starch formulation was greatly increased by 290% compared to the raw yarn, far exceeding the other three formulations. The adhesive strength of the raw starch sizing agent was high, and the viscosity was low, making it easy to penetrate the inside of the yarn. After the sizing agent was bonded to the internal fibers, the bonding strength between the fibers was greatly improved, thereby increasing the abrasion resistance of the sizing and increasing the abrasion resistance numbers.



(a) Enhanced image of 1#process **(b)** Enhanced image of 2#process

(c) Enhanced image of 3#process **(d)** Enhanced image of 4#process

Fig. 8. Enhanced images of four sizing cross-sections

In Fig. 7, in terms of hairiness index and hairiness reduction rate, the hairiness index of raw starch sizing was 4.50, which was 72.8% lower than the raw yarn. Generally, the thicker the size film, the better the control of sizing hairiness. The raw starch sizing had a low sizing level, but the hairiness control effect was excellent because the sizing agent had strong adhesion and high penetration. The coating level of the raw starch sizing was 23.3%, which was 25% to 34% lower than other processes. The penetration was 43.7%, which was 36% to 48% higher than other processes. Low coating means that the sizing film was thinner, increasing the softness of the yarn. High penetration means that the raw starch sizing agent was more fully and tightly combined with the fibers inside the yarns. The comprehensive results show that the quality of yarn with raw starch formulation had been greatly improved.

Figure 8 shows enhanced cross-sectional images of the four types of sized yarns. Image grayscale, image denoising, and image enhancement processing were carried out on the sizing cross-sectional image. The results show that the internal fiber gap of 1# process sizing was less, while the fiber gap of the other three processes was more, indicating that the internal sizing agent and fiber of 1#process sizing were well combined. The dark black part of the outer ring of the image represents the external sizing agent of the sizing. Processes 2#, 3#, and 4# had more black parts, indicating that the sizing surface was coated with more sizing agent.

Biodegradation

The test results are shown in Table 2. According to relevant data, when the BOD_5/COD was less than 0.2, such results indicated very difficult biodegradability. Values of 0.2 to 0.3 mean difficult biodegradation, while 0.3 to 0.45 means biodegradable, and greater than 0.45 represents implies easy biodegradability. The industry standard FZ/T 15001-2017 specifies a BOD_5/COD limit value of 0.30. The raw starch formulation was easy to degrade, while the additives used in processes 2# and 3# were slightly less eco-friendly, and the 4# process containing PVOH was not eco-friendly. The addition of the special additive for the raw starch formulation did not hurt the biodegradability of the starch sizing agent. The process conforms to green and eco-friendly development, and the wastewater discharged from desizing was easily biodegradable. This also indicates that the production process of raw starch formulation is eco-friendly.

Table 2. Biodegradation of Four Processes for Desizing Wastewater

Name	1#process	2#process	3#process	4#process
BOD_5/ppm	3200	2588	2636	1146
COD/ppm	4949	7612	7532	14325
BOD_5/COD	0.65	0.34	0.35	0.08

Weave Efficiency and Cost

Weave efficiency

The results for weave efficiency are shown in Fig. 9. During the sizing and weaving process using the raw starch formulation, the number of weft stops decreased by 34 to 59%, and the number of warp stops decreased by 38 to 69% compared to the other three processes, with a significant reduction. The efficiency of the loom increased by 5 to 12%. This can be attributed to the fact that the raw starch sizing achieved good mechanical properties and was able to withstand high-strength weaving on the loom, effectively improving weave efficiency.

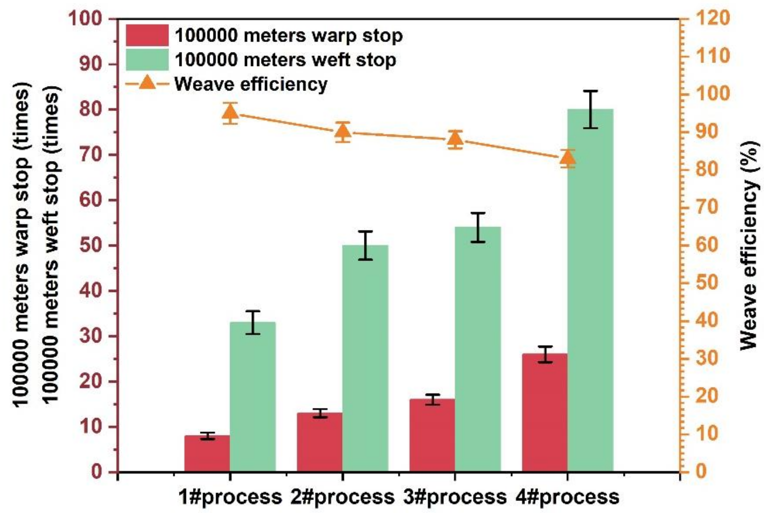


Fig. 9. Warp and weft stop10000 meters, and weave efficiency

Air conditioning cost and sizing agent cost

The test results related to costs are shown in Fig. 10. The results showed that the cost of sizing agent per barrel in the raw starch process was 17 to 61% lower, the cost of sizing agent per meter of cloth was 15 to 56% lower, and the cost of air conditioning per meter of cloth was 76 to 80% lower. This is because the raw starch formulation had a simple sizing agent formula, low sizing amount, and thereby was able to effectively reduce costs. The special additive used in the raw starch formulation reduced the moisture absorption and re-adhesion of the sizing agent, preventing the sizing agent film from adhering to large areas of shedding feathers and reducing the amount of shedding feathers that the air conditioning system needs to absorb. The air pressure and cleaning frequency of the air conditioning system were also reduced, which lowered the maintenance cost and greatly reduced the cost of air conditioning.

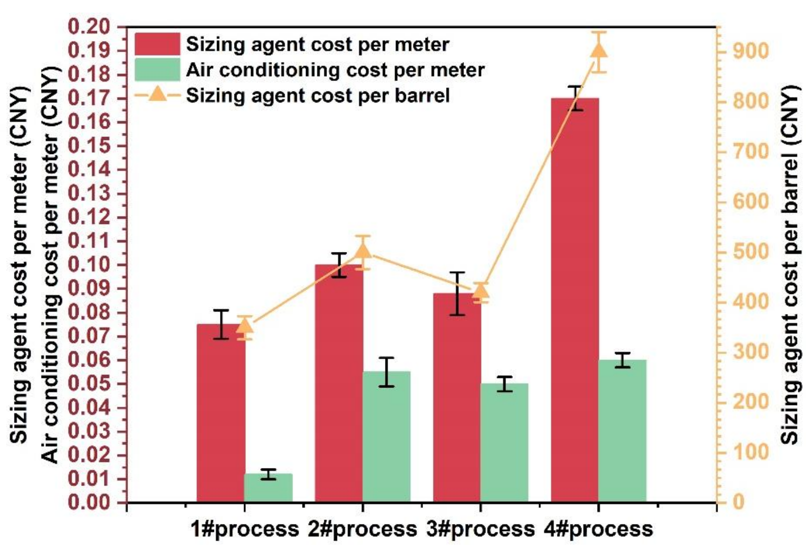


Fig. 10. Air conditioning cost and sizing agent cost

CONCLUSIONS

1. The raw starch sizing agent system exhibited good performance, low viscosity, good flowability, strong viscosity stability, high adhesion, and moderate solid content.
2. For cotton yarn, the raw starch sizing quality was dramatically improved due to the excellent performance of the raw starch sizing agent, compared with the other three sizing systems. The raw starch system had a lower sizing rate, a thinner and lighter sizing agent film on the surface, and more elastic sizing. The moisture absorption capacity far exceeded the other three types, and the stability of weaving was improved. Featuring excellent breaking strength, high enhancement, and low elongation reduction, the yarn's strength performance was greatly improved, making it easy to stretch and shrink sizing during weaving. Sizing achieved good abrasion resistance and rendered the yarn less prone to breakage during weaving, which reduced the hairiness index, making it easier to control the amount of hairiness during weaving. With lower coating and higher penetration rate, the sized yarn was softer and more elastic and had better abrasion resistance. The results show that the sizing quality with the raw starch process had been greatly improved.
3. Compared with the other three processes, the ratio of biological oxygen demand to chemical oxygen demand (BOD_5/COD) value of the raw starch process desizing wastewater was high, indicating that it was easy to biodegrade, highly eco-friendly. It also resulted in high weave efficiency with low required costs. The process was beneficial for reducing production losses in factories, it was able to improve production efficiency, it reduced wastewater discharge, and thereby it was able to protect the ecological environment.

ACKNOWLEDGMENTS

The authors are grateful for the support of the Zhejiang Sci-Tech University, China.

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Article submitted: November 26, 2024; Peer review completed: January 18, 2025; Revised version received: February 28, 2025; Further revised article received: March 6, 2025; Accepted: March 30, 2025; Published: April 17, 2025.
DOI: 10.15376/biores.20.2.4174-4186