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Research Article

Study on Application of Native Millet Starch for Cotton Warp Yarn Sizing

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Abstract

Weaving efficiency is greatly affected by the warp yarns strength and other properties. To improve these warp yarn properties, sizing is done with various agents either natural or synthetic sizing materials. Most of the natural sizing agents used in the industry is made of starch. Starch is obtained from different sources with different properties. Like potato, maize, corn, millet. In this study millet sizing chemical has been studied on its performance on sized warp yarns. Ring spun cotton yarn of 34 Nm was sized using the millet sizing chemicals and its properties studied. And also the properties of the sized warp yarn like tensile strength, elongation and size removal percentage after desizing were also studied. End breakage rate on the loom was observed to check the weaving efficiency. From the results it was seen that the tensile strength, strength gain and elongation of yarns sized with millet sizing chemicals. Here the tensile strength and strength gain are in the range and the elongation is above the range but while comparing this result from the modified starch relatively good and it is cost effective while comparing from modified starch. After the data is analyzed the output result of the research is described as follows. The tensile strength, elongation and warp end breakage is 65.04%, 18.25% and 8per two hour respectively and for modified starch the tensile strength and elongation is 59.5% and 21.2% respectively and cost wise the company can save 4 million ETB per annum if it uses millet grain starch for warp sizing.

Keywords: Sizing; Fabric; Yarn; End breakage; Tensile strength; Elongation.

Introduction

In the sequence of textile processes, sizing has continued to retain its importance in the value chain and has proved necessary even with today's demanding requirements. Using innovative techniques, the sizing machine and chemical manufacturers have tried to keep pace with the increased speed of looms [1]. Prediction of the efficiency of sizing-type of size, amount of size, penetration of size in different yarn structures, and the mode of different deformations of the sized yarns, in terms of weaving efficiency has confounded textile scientists and technologists for a long time [2]. Sizing is the process of applying the size material on warp yarn. Sizing of the warp yarn is essential to reduce breakage of the yarn and thus production stops on the weaving machine. On the weaving machine, the warp yarns are subjected to several types of actions i.e. cyclic strain, flexing, abrasion at various loom parts and inter yarn friction [1]. With sizing, the strength, abrasion resistance of the yarn will improve and the hairiness of yarn will decrease [2].

The degree of improvement of strength depends on adhesion force between fiber and size, size penetration as well as encapsulation of yarn. Different types of water soluble polymers called textile sizing agents/chemicals such as starch, polyvinyl alcohol (PVA), carboxy methyl cellulose (CMC), acrylates are used to protect the yarn. Also wax is added to reduce the abrasiveness of the warp yarns. The type of yarn material (e.g. cotton, polyester, linen), the thickness of the yarn, and type of weaving machinery will determine the sizing recipe. The sizing liquor is applied on warp yarn with a warp sizing machine .after the weaving process the fabric is desized (washed) [1,3,4].

Millet is the most important cereal crop grown in the world. African introduced millet into the U.S. in the early 17th century. Millet is the 3rd most important cereal crop in the Ethiopia, next to teff & maize. Millet grain has high amount of starch concentration which make

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it ideal for warp yarn sizing in textile industry. Millet, like other cereals, rich in starch the average chemical composition of the millet being: 0.68% ash, 3.67% fat, 12.21% protein, 83.45% total carbohydrates, 79.77% starch (amylose 26.6%), and 34.9 mg of tannic acid per 100 g of flour. A high degree of variability among evaluated properties was found, particularly in the pasting properties peak viscosity (2809–5184 mPa/s), breakdown (1169–3170 mPa/s), and final viscosity (3030–4401 mPa/s) with onset temperature (T^o) and gelatinization enthalpy (ΔH) varying between 66.8 and 72.6°C, and 5.38 and 8.48 J/g, respectively, which makes up about 60–80% of normal kernels and has an excellent potential for industrial applications[5,6].

Developing alternative sizing agents that can reduce the sizing cost and environmental problems associated with textile sizing is of vital importance for the long-term sustainability for the textile industry. Studies to make less sizing cost and more environmentally friendly are mainly based on two approaches. First, to develop new textile sizing agents, which provide superior sizing properties with less cost and are at the same time they have biodegradable properties. Second approach is to increase the biodegradability of PVA in textile effluent treatment plants and mix the starch size paste with PVA to minimize the cost of sizing paste [7].

Starch, the most common sizing agent has been widely used for textile warp yarns sizing and it has also been chemically modified to make starch suitable for sizing synthetic fibers and their blends [8,9]. Starch is composed almost entirely of the polysaccharides amylose and amylopectin. The physical arrangement of amylose (Figure 1) and amylopectin (Figure 2) and the interaction between starch molecules and other components determine the physicochemical and functional properties of starch [9,12]. The current research work is aimed in utilization of native millet starch is used for warp yarn sizing and study on performance of the yarns sized with this starch.

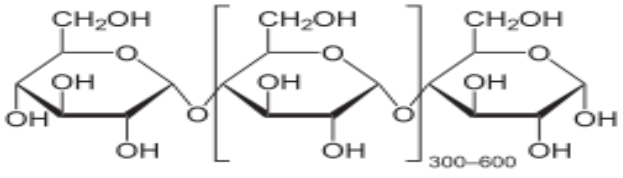

Figure 1. Structure of amylose molecule

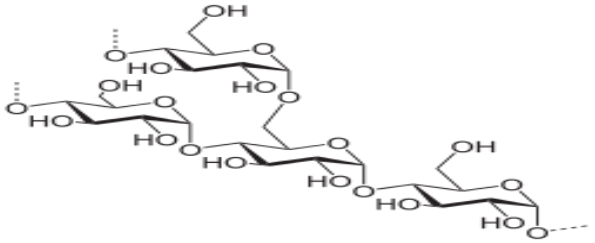

Figure 2. Structure of amylopectin molecule

Materials and experimental methods

Materials used

In this study 34Nm count yarn was sized using starch extracted from millet grain starch .Karl mayer sizing machine available in Kombolcha® textile share company was used for warp sizing and fabric is constructed on rapier loom. Single and double end yarn strength tester machine was used for yarn property testing and enzyme was used for desizing fabric to test for size removal. Martindale Abrasion resistance tester was used to test abrasion resistance of fabric constructed using yarn sized with millet grain starch.

Sizing process

The warp yarns were sized in a conventional cylinder sizing machine with 9 drying cylinders. During sizing, all the parameters including the machine used, its speed (30-40m/min), yarn tension, squeezing roller pressure ($2kg/cm^2$), yarn stretch percentage (1-1.2%), total number of ends (3986) were kept constant.

Solution was prepared and cooked as given in Table 1. Viscosity (flows per second) of the prepared solution was measured using the zahn cup and converted to ASTM standard unit of centistokes. The viscosity result indicated that millet starch solution achieved a viscosity of 13.5 flows/sec.

Table 1. Size solution preparation and cooking parameters

Parameter	Value
MLR	1:13
Cooking time	30 min
Cooking temperature	85 oc
Size box temperature	83 oc
Machine speed	40 m/s

Size take up percentage was calculated using equation (1).

$$Size\ take\ up\ \% = \frac{[weight\ of\ sized\ yarn - weight\ of\ unsized\ yarn]}{weight\ of\ unsizedyarn} \times 100 \quad (1)$$

Percentage increase in strength is given by equation (2).

$$Percentage\ Increase\ in\ Strength = \frac{(Ss - Su)}{Su} X\ 100 \quad (2)$$

Results and discussion

Unsized and sized yarn tests

The tensile strength and elongation test of both the unsized and sized yarn was tested. This was to compare the strength imparted by the starch. The tensile strength of unsized yarns was tested on Autodyne 300 single yarn strength tester. It was done according to ASTM D2256 standards with a clamp speed of 1000 mm/min and pretension force of 450 N.

Sized yarn test result

Tensile strength and elongation test result

The integral yarn strength is a major contributing factor to both tensile strength and tear strength of fabrics [7]. According to Ping and Greenwood, tensile strength of a fabric in either the warp or weft direction is the function of yarn strength. The breaking load and elongation test for sized yarn has been done using single and double end thread strength tester.

Size removal percentage test for sized yarn by desizing

Size removal percentage was calculated after desizing the samples. Enzymatic desizing was done at mass liquor ratio of 1:20, using 6 % w/w biolase enzyme and 5% w/w NaCl at a temperature of 60°C for 1 hr with 1.5 g/l wetting agent. Desizing is the process of removing the size material from the warp yarns in woven fabrics. Easy desizing ability is one of the greatest requirements of sizing agent. The higher the water solubility of sizing agents, the lesser will be the energy consumption. This leads to more economic process [11]. Desizing ability of sizing agents depends on factors like viscosity of size paste, moisture regain of size film, and solubility of size film in water. All these factors are directly or indirectly dependent on the chemical structure of the size material [2, 11].

End break test

Plain fabric was constructed on rapier loom using 34 Nm count of cotton weft yarn. The fabric width was 150cm with warp and weft crimp of 5% and 4%, respectively. All machine parameters were kept constant and end break rate was recorded for duration of 2 hours. The breaks/10^5 ends/10^4 picks were calculated and compared against Bombay Textile Research Association (BITRA) standard.

Yarn test results

Tensile strength

The tensile strength of yarn sized with millet grain starch and unsized yarns were measured and the result is shown in figure 3.

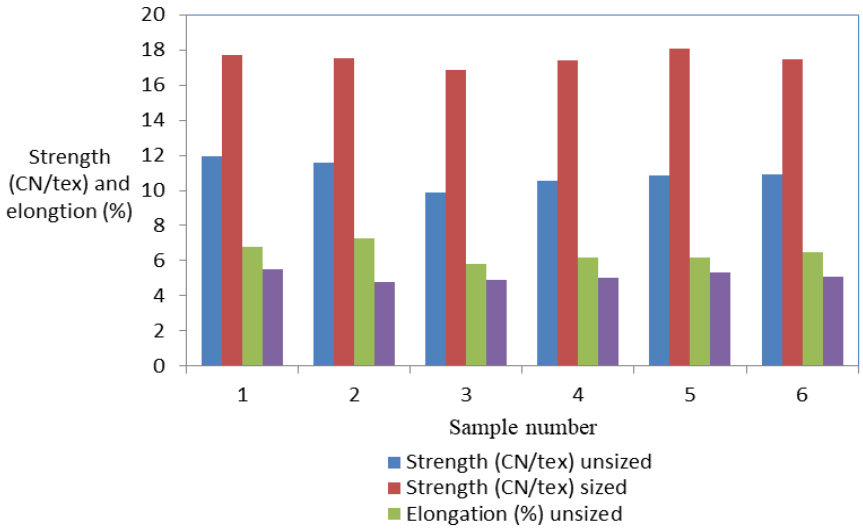

Figure 3. Graph showing tensile strength and elongation result of sized and unsized yarns

$$Percentage\ Increase\ in\ Strength = \frac{(Ss - Su)}{Su} X\ 100 \quad (3)$$

$$= \frac{17.47 - 10.95}{10.95}\ x\ 100 = 59.6\%$$

$$\text{Loss in elongation} = \frac{\text{Average elongation unsized} - \textit{Average elongation sized}}{\text{Average elongation unsized}} \text{x100} \quad (4)$$

$$= \frac{6.48 - 5.12}{6.48} \text{ x } 100 = 21.3\ \%$$

$$\text{Size take up} = \frac{\text{Sized yarn weight} - \textit{Unsized yarn weight}}{\textit{Unsized yarn weight}} \times 100 \quad (5)$$

$$= 8.1\%$$

From the result we can see that the strength gain is found to be 59.6% which acceptable as per BITRA standard (25-40) % which ensures that Millet grain starch can give sufficient strength to the sized yarn and can be utilized for warp sizing. The loss in elongation is found to be about 21.3% which is higher as compared to company standard which is 20% and this may show improvement in the strength gain.

Desizing process

The sizing agent on the fabrics after weaving has to be removed before the next textile production process. Ability of the size to be removed (de sized) is an important index to evaluate sizing performance. The loss in fabric weight before and after de sizing was calculated to determine the weight % de sizing. The loss in the fabric weight after washing is called size removal, and it is determined as following equation (6).

$$\text{Size removal \%} = \frac{W1-W2}{W1} * 100 \quad (6)$$

Where, W1 and W2 are the fabric weight before de sizing and fabric weight after de sizing respectively

Table 2. Desizing recipe for sized yarn

Chemicals used	Concentration
Biolase/ Amylase	5 ml
Sodium chloride (NaCl)	2 g
Non-ionic wetting agent	0.7 ml
Sequestering agent	0.5 ml
Acidic acid	0.1 ml

MLR: 1:10; pH=6.7; Temperature=70°C; Time=60 min

Weight the de sized fabric sample, compare with the original gray fabric sample weight and calculate weight loss in percentage. The equation (7) is used to calculate the weight loss (%, w/w):

$$\text{Wt\%} = \frac{W1-W2}{W1} * 100 \quad (7)$$

$$= \frac{10-9.28*100}{10} = 7.2\%$$

From this result we can seed that there is sufficient amount of weight loss on the fabric after desizing which insure easy desizability of the millet starch used.

End breakage test result and loom efficiency

Using sizing starch used in this research work warp yarn is sized and plain fabric was constructed on loom to see performance of the yarns and end breakage rate was recorded for two hours. Here comparison of end breakage rate for millet grain starch and other native starches was done according to research reported by Temesgen *et al* [2]. The following table shows end breakage rate recorded on loom used during construction of fabric using yarn sized with millet grain starch in comparison with others. From the end breakage test result we can see that millet grain starch has better performance in terms of end breakage rate than corn starch.

Table 3. End breakage test result of native millet starch in comparison with other common starches [2]

Starch used	End breakage result Breaks/loom/hr
Corn starch	2.2
Potato starch	1.68
Cassava starch	1.68
Millet starch	2.0

Cost Analysis

Cost analysis was done for sizing chemical developed in this research to see its feasibility in terms of cost .Here daily need of company for sizing chemical in terms of cost for equal amount of production was used as means of comparison for sizing chemical developed in this research and chemical that the company is using currently from different manufacturers. The daily and yearly expenditure of company for sizing chemical that it is using currently and estimated expenditure of company for the newly developed sizing chemical is given in comparison in the following table, table 4

Table 4. Cost comparison of millet starch sizing and current company sizing chemical

Chemical used	Total Daily cost (Birr)	Total Yearly cost (Birr)
Current company chemical	17,351.56	6,246,561.6
New chemical (Millet)	5,700	2,052,000

As we can see from the above table the company is spending around six million birr yearly for warp sizing with the current chemical and recipe it is using but if the company uses

millet starch for warp sizing, it can spend only around 2 million Ethiopian birr. From this we can see that the company can save around 4 million birr per annum if uses millet starch for warp sizing and this shows millet starch is cost effective comparatively.

Conclusions

From this research work we can see that there is good size take up percentage up to 8.1% and more than 50% increase in strength .From the desizability test we can see that there is weight loss of up to 7.2% which shows easy desizability of millet starch sized yarns and easy removal of the starch which is one of the requirements from any sizing chemical. From the end breakage test result we can see that millet starch sized yarns has better end breakage rate than maize starch sized yarns. Cost analysis result has shown that by using millet starch for warp yarns sizing, the company can save up to 4 million birr per annum as compared to the sizing chemical that the company is using currently. Generally from this research work we can conclude that millet grain starch can be used for warp yarn sizing in textile industry and it is having good performance on the yarns and also it is cost effective sizing material.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgement

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