Comparative Analysis Between Bangladesh's Locally Produced Potato Starch with Commercially Used One-Shot Sizing Material in Terms of Technical Feasibility

Fahmida Faiza Fahmi[1,2], Shilpi Akter[1], Dr. Md. Syduzzaman[1*]

[1]Bangladesh University of Textiles, Dhaka, Bangladesh.

[2]Primeasia University, Dhaka, Bangladesh.

Abstract

Sizing is an essential process of weaving that can minimize the rate of yarn breakage while weaving in the loom. Usually, diversified adhesives including natural starches, natural polymers and synthetic chemicals, are used to coat the yarn surface during sizing. Most of the sizing materials used in the textile industry of Bangladesh are imported. However, Bangladesh can efficiently produce starch domestically by utilizing the surplus amount of potatoes that become waste almost yearly. Insufficient cold storage facilities, surplus production, etc. are responsible for a notable amount of potato wastage in Bangladesh. The usage of these potatoes as sizing agent can be an effective solution to this issue, which can also save Bangladesh's sizing material import cost. This study assessed the technical feasibility of locally produced potato starch compared to the commercially used imported one-shot based sizing agents. Factors like yarn strength, extension%, abrasion resistance, size take-up%, reduction of yarn hairiness and yarn count were subjected for both of the sizing agents to carry out the assessment. Both of the sizing materials showed similar results with slight deviation while considering the strength, extension%, size take-up% and yarn count measurement. However, potato starch showed significantly improved performance in the parameters of abrasion resistance and reduction of yarn hairiness due to its excellent adhesive property. The study concluded that Bangladesh's locally produced potato starch can easily be a cost-effective, bio-degradable and sustainable substitute for commercial one-shot sizing agents in terms of technical feasibility.

Keywords— Sizing, potato starch, one-shot sizing, weaving, tensile strength, yarn hairiness.

1. Introduction

The textile industry is one of the notable sectors of Bangladesh for its contribution to the country's GDP [1]. Fabric manufacturing by weaving process is an impactful sector of textiles. Sizing is an essential procedure to ensure compelling weaving. Sizing is coating the warp yarns with a diversified range of adhesive chemicals, ensuring reduced hairiness and increased strength. As warp yarns undergo significant tension during weaving, yarns with less protruding fibers are required with optimum stress handling. Ineffective warp yarn sizing can increase the yarn breakage rate while weaving on looms. For its significant importance, sizing is known as "the heart of weaving" [2].

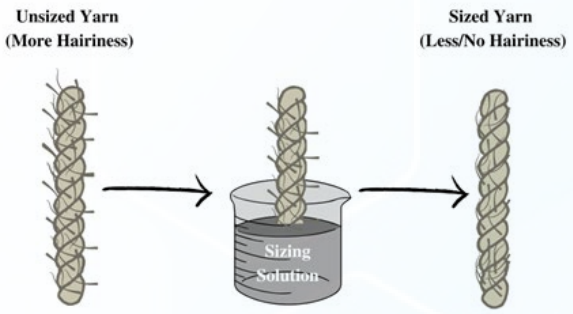

Figure 1: Mechanism of warp yarn sizing

Diversified natural, natural polymer and synthetic-based chemicals with an adequate adhesive property are usually used to ensure the effective sizing of the warp yarns. Various categories of starches, carboxymethyl cellulose (CMC) and polyvinyl alcohol (PVA) are typically employed as sizing agents [3]. Among them, starch is considered the most common sizing agent. In Bangladesh, significant amounts of sizing chemicals are imported, which costs a notable amount. However, Bangladesh can easily replace the market of imported starch with locally produced starch from potatoes. Bangladesh is globally recognized as one of the top potato-producing countries [4]. In the 2021-2022 fiscal year, over 11 million tons of potatoes are produced in Bangladesh, exceeding the country's total demand with a vast surplus [5]. The Food and Agriculture Organization of the United Nations (FAO) stated that in the 2021-22 fiscal year, around 8 lakh tons of potatoes will endure in the market as the residual amount [6]. Usually, surplus potatoes are kept in cold storage for selling in the market during the off season. Nevertheless, as the total amount of potatoes produced exceeds the total demand, potato farmers have experienced colossal losses and wastage of potatoes almost every year [7]. Insufficient cold storage is another barrier to effectively storing surplus potatoes [8]. Consequently, potatoes are sold at a minimal price at the cold storage gate during the end of the season while newly produced potatoes are ready to arrive in the market. The alternative use of this residual potato is compulsory in Bangladesh to reduce waste.

Starch is a primary ingredient in potatoes, consisting of around 60%-70% of the total dry matter in potatoes [9]. Therefore, extracting starch from the residual potatoes can open the door to alternative use in Bangladesh. As starch is an elementary sizing chemical, the extracted starch from local potatoes of Bangladesh can be easily used as a sizing agent in the weaving industry. Furthermore, locally-produced potato starch will cost less than imported starches [10]. Consequently, it will create a new market dimension for using the residual potatoes and Bangladesh can even import the potato starch after meeting the local demand. Potatoes for the starch industry can be bought directly from local farmers to ensure a deduction in raw material costs which also facilitates the farmers as well. Real heroes behind the potato industry can also eliminate additional costs like cold storage.

Along with easy availability and cost-effectiveness, potato starch has advantageous technical properties. The adhesive property of potato starch is excellent, making it a potential sizing element for the textile industry [11]. Due to this property, minimal potato starch is required to make the size solution compared to the other sizing elements. Another notable advantage of potato starch is its solubility in hot and cold water, so applying temperature is not mandatory while preparing the sizing solution with potato starch. The residual potato can be used in the food industry (majorly in the chips industry) after the removal of starch. So, the residual pulp also remains usable.

However, yarn sizing with adhesives like starch, PVA, etc. requires other materials like vegetable fat for lubrication, copper sulfate ($CuSO_4$), or zinc chloride ($ZnCl_2$) for antiseptic effect, etc., so maintenance of adequate material ratio is essential to ensure adequate sizing [12]. To avoid this issue, combined sizing chemicals known as one-shot or single-shot sizing agents are holding attention in the marketplace nowadays as all the necessary ingredients are combined within it in an adequate ratio. However, this type of one-shot/ single-shots is usually import-based and highly costly. For example, the price of 1 kg of one-shot sizing materials is almost 1.5 times costlier than the overall sizing cost while using the adhesives.

Bangladesh is facing an economic crisis due to growing inflation [13]. Due to this, importing materials became difficult and non-advantageous [14]. So, substituting locally produced potato starch as sizing material can be a beneficiary choice compared to using the one-shot/ single-shot based sizing agents in the weaving sector. However, only cost-effectiveness and affirmative social impact are insufficient to consider the material as an adequate substitute. Impactful and effective technical properties are required to ensure the predetermined outcome.

In this paper, the sizing performance of locally produced potato starch is demonstrated from the technical point of view compared to the one-shot/ single-shot sizing agent. Significant technical properties like yarn strength, yarn elongation, reduction of yarn hairiness, yarn abrasion resistance, size take-up%, etc., are considered for comparison. By this comparison, a decision can be made if Bangladesh's locally produced potato starch can replace the rising demand for one-shot sizing agents in the local and global weaving industry.

2. Materials & methods

2.1. Materials

100% cotton yarn of 20 Ne was selected for the assessment. The yarn was sourced from the Bangladesh University of Textiles spinning laboratory. The potato starch was produced using the potatoes bought from the local market. By synthesizing 1 kg of local potatoes, which were stored in cold storage in the earlier season, 233 gm of potato starch was obtained. Amatrolid 8923 was used as the commercial sizing chemical to execute the experiment.

2.2. Extraction of potato starch

Starch was extracted from the local potatoes by cutting them into minimal portions so that the starch contents could easily be removed from the potatoes' cells. Consequently, potatoes are washed out with adequate water to remove the starch particles from the potato. Thin mesh fabric was used to filter the potato's washed water. The water which was remained after potato washing was kept aside for 2/3 hours. After 2/3 hours, the starch particles were precipitated in the water. Then the starches were separated and dried in either oven or sunlight.

Finally, the potato starch powder was stored for further use and the residual potato pulp can be used in the food industry (predominantly in the chips industry).

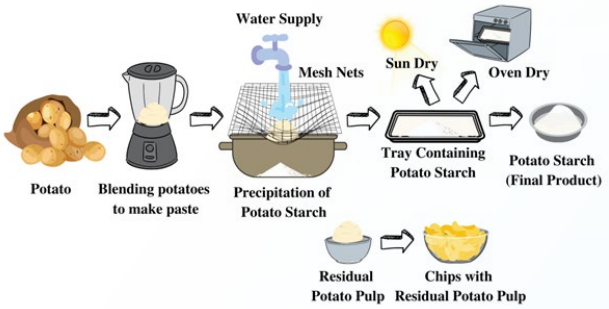

Figure 2: Potato starch extraction procedure

2.3. Sizing of warp yarns

The sizing of warp yarns was done using the sizing machine in the CCI laboratory of the Bangladesh University of Textiles. The CCI evergreen single yarn sizing machine, which originated in Taiwan, was used to accomplish the sizing process. The total amount of sizing liquor was one kg for the potato starch and the one-shot sizing agent. The drying of sized yarn was done by air blow system where the temperature of the drying chamber was 90°C.

In the case of potato starch-based sizing wetting agents like china clay, antiseptic agents like copper sulfate ($CuSO_4$) and softening agent like vegetable fat is required to make the size solution. The sizing recipe using potato starch is described in below-mentioned table-1.

Table 1: Sizing recipe using potato starch

No.	Ingredients	Quantity (gm)
1.	Potato starch (Adhesive)	100
2.	Vegetable fat (Softener)	10
3.	$CuSO_4$ (Antispetic)	3
4.	China Clay (Wetting agent)	15
	Water	1000 ml

However, in one-shot based sizing only the sizing chemical and water was used to execute the sizing process.

Table 2: Sizing recipe using one-shot sizing agent

No.	Ingredients	Quantity (gm)
1.	Amatrolid 8923 (one-shot sizing chemical)	200
	Water	1000 ml

2.4. Assessment of the quality of sized yarns

2.4.1. Measurement of tensile strength

The measurement of yarn strength can be expressed by assessing the breaking force of the yarn. The force required to break a yarn determines its degree of tensile strength. Yarns with more tensile strength can handle more amount of applied force. The yarn strength was measured using the Titan universal strength tester of James Heal company with a jaw separation of 500 mm. The testing was executed at the accredited laboratory of the Bangladesh University of Textiles. EN ISO 2062:2009 testing method was applied to execute the test. Five specimens were collected from the various potions of unsized yarn, potato starch-sized yarn and one-shot-sized yarn. The mean value of the specimens was measured as the value of single yarn-breaking force for all three variants of yarns.

2.4.2. Measurement of extension%

The elongation value of a single yarn was measured using the Titan universal tester of James Heal company with a jaw separation of 500 mm. The testing was executed at the accredited laboratory of Bangladesh University of Textiles by maintaining the testing method of EN ISO 2062:2009. Five specimens were collected from the different places of unsized yarn, potato starch-sized yarn and one-shot-

sized yarn. The mean value of the specimens was measured as elongation at break for all three varieties of yarns.

2.4.3. Measurement of the abrasion resistance

The abrasion resistance of yarn can be assessed by analyzing the number of weaving cycles a yarn can handle without breakage in a weaving loom. The abrasion resistance test was done in the CCI laboratory of the Bangladesh University of Textiles using the CCI evergreen loom. The Picks per inch (PPI) value of weft yarn was 50 and the loom RPM was 40. Five specimens of unsized yarns, potato starch-sized yarns and one-shot-sized yarns are taken in the warp beam to measure the value of abrasion resistance. The number of cycles a yarn can handle before breakage was calculated for five specimens taken from the diversified places of the yarns. The calculated mean value was considered the considerable value of abrasion resistance of single yarns.

2.4.4. Assessment of the size take-up%

Size take-up% is essential to analyze the sizing performance [15]. The size take-up% was calculated according to the below-mentioned equation (1).

$$\text{Size take-up\%} = \frac{\text{Weight of Warp Yarn (Sized)} - \text{Weight of warp yarn (Unsized)}}{\text{Weight of warp yarn (Unsized)}} \times 100\% \text{ [16] (1)}$$

Size take-up% was also calculated by considering the yarn samples collected from the five (05) different places of the yarn cone and the mean value was taken as the final result.

2.4.5. Assessment of yarn hairiness

The visual assessment of yarn hairiness was done according to the images of the yarn surface received from the Projectina microscope, situated in the accredited laboratory of the Bangladesh University of Textiles.

2.4.6. Assessment of yarn count

The count of the unsized and yarn sized with both potato starch and one-shot sizing agent was calculated by using the Wrap Reel situated in the testing laboratory of Primeasia University by following the below-mentioned equation (2).

$$\text{Yarn Count} = \frac{\text{Yarn Length (Yds)} \times \text{Weight Unit}}{840 \text{ Yds} \times \text{Yarn Weight (Pound)}} \text{ [17] (2)}$$

3. Results

Table 3 consists of the resulting data found after assessing the diversified factors of yarns before and after the sizing process. This finding indicates the diversity of technical properties, including the breaking force of single yarn, extension%, abrasion resistance, size take-up% and yarn count of yarns sized with potato and one-shot sizing.

Table 3: The values of breaking force, extension%, abrasion resistance, size take-up% and yarn count for the unsized yarn, potato-starch sized yarn and one-shot sized yarn

Technical Properties	Sample No.	Unsized Yarn	Sized Yarn (Potato Starch)	Sized Yarn (One-shot Sizing agent)
Tensile Strength (cN)	1.	278.97	349.25	365.26
	2.	288.76	337.69	326.71
	3.	307.84	398.13	411.19
	4.	277.36	349.11	349.9
	5.	281.22	308.21	325.41
	Mean	*286.83*	*348.478*	*355.694*
Extension (%)	1.	6.8	6.04	5.03
	2.	6.74	5.12	5.09
	3.	6.95	4.91	4.79
	4.	6.88	5.27	5.34
	5.	6.61	5.04	5.71
	Mean	*6.796*	*5.276*	*5.192*
Abrasion Resistance (Cycles)	1.	66	136	122
	2.	70	184	178
	3.	74	208	196
	4.	82	234	204
	5.	86	246	210
	Mean	*75.6*	*201.6*	*182*
Size take-up (%)	1.	-	10.27	12.31
	2.		12.46	10.05
	3.		14.05	11.77
	4.		10.23	14.74
	5.		9.79	9.53
	Mean	-	*11.36*	*11.68*
Yarn Count (Ne)	1.	19.83	18.37	19.14
	2.	19.72	17.43	17.79
	3.	20.08	19.96	18.86
	4.	21.11	17.72	18.89
	5.	19.38	18.39	18.03
	Mean	*20.024*	*18.374*	*18.542*

3.1. General properties

The general properties of both sizing materials including their visual appearance, color and odor, are outlined in table 4.

Table 4: General Properties of sizing materials. Potato starch, One-shot sizing agent (Amatrolid 8923)

Color: White, Odor:

No significant odor

Figure 3: Potato Starch, Figure 4: One-shot sizing agent (Amatrolid 8923)

3.2. Increase of tensile strength after sizing

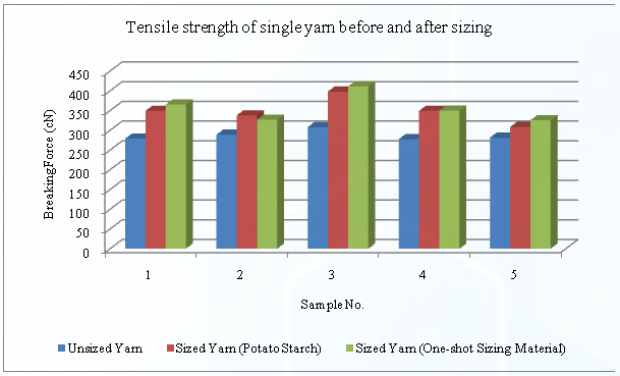

Figure 5: Tensile strength of a single yarn

Figure 5 represents the increment of tensile strength of a single yarn after the sizing procedure. According to the assessment, the mean value of the breaking force for the unsized yarn is 286.83 cN. The experimental analysis found that the mean value of yarns after sizing with potato starch and one-shot sizing was 348.478 cN and 355.694 cN.

3.3. Reduction of extension%

The extension% of the before and after sized yarn samples are denoted in figure 6. The extension% of yarn before the completion of the sizing process was 6.796%, while the extension% of yarn was reduced after sizing. The mean extension% of potato starch-sized yarns and commercial one-shot sized yarns were consecutively 5.276% and 5.192%. Though both of the sized yarns showed a reduction in extension%, potato starch-based sizing material experienced a more pleasing scenario in this property.

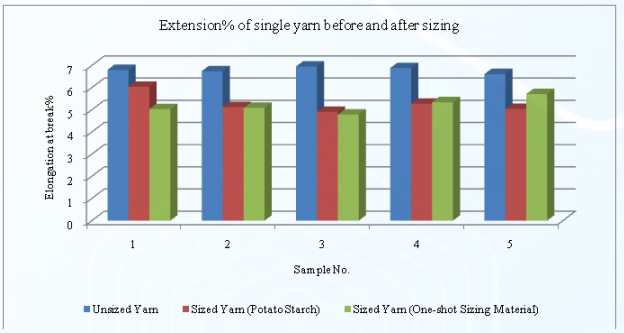

Figure 6: Extension% of a single yarn

3.4. Increment of abrasion resistance of single yarns

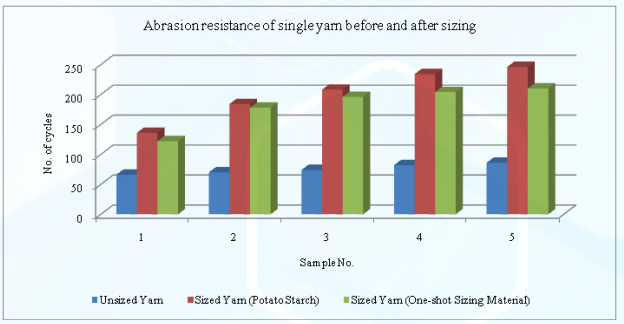

Figure 7: Abrasion resistance of a single yarn

3.5. Assessment of size take-up% of yarn

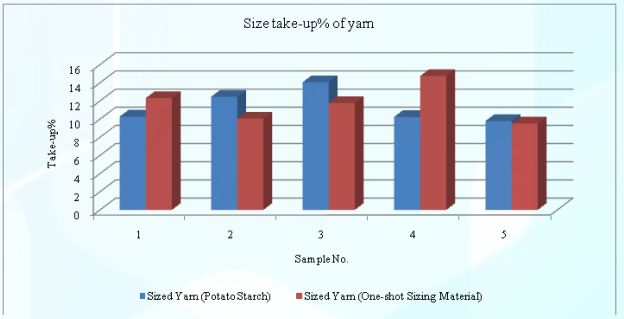

Figure 8: Size take up% of yarn

The potato starch and one-shot agent showed good size take-up in a single yarn. Though the unevenness in size take –up% was observed due to the irregularity of the yarn. Due to the thick and thin place of the yarn surface, the value of size take-up% is not uniform in every portion of the yarn. However, the mean value of size take-up% for both the potato and one-shot sized yarns were consecutively 11.36% and 11. 68%, according to the assessment plotted in figure 8.

3.6. Reduction of hairiness of the yarn

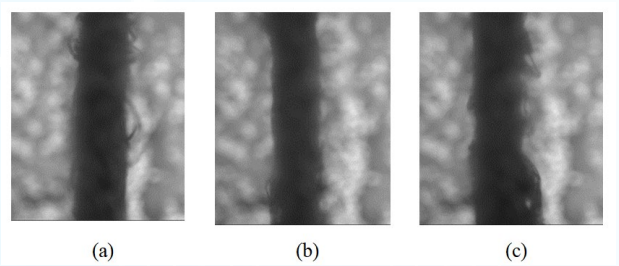

Figure 9: Yarn Hairiness of (a) unsized yarn, (b) sized yarn (potato starch) and (c) sized yarn (one-shot sizing agent)

Figure 9 represents the microscopic image of yarn before and after sizing. The unsized yarn showed more hairiness, potentially responsible for yarn breakage in the weaving loom. The hairiness of sized yarn for potato starch and one-shot sizing agent were visualized consecutively in figures 9(b) and 9(c). According to the microscopic image, the hairiness of potato starch sized yarn was minimal than the one-shot sized yarn

3.7. Reduction of yarn count after sizing

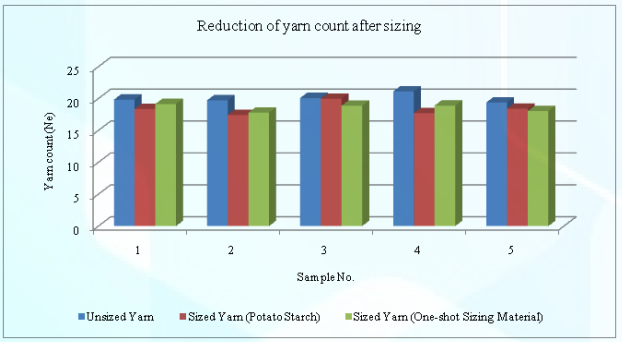

Figure 10: Reduction of yarn count after sizing

Figure 10 expressed the impact of sizing on the count of the yarn. The yarn count decreased after sizing as an adhesive coating was created on the yarn. Consequently, the yarn became thicker and the count of yarn was reduced. The significant reduction of yarn count decreases the quality of yarn in an impactful manner. The best possible outcome can be found while the reduction of yarn count was minimal with efficient sizing property. As per the assessment, the average yarn count without sizing was 20.024 Ne, while the value decreased to 18.374 Ne and 18.542 Ne for the yarns sized with potato starch and one-shot sizing agent consecutively.

4. Discussion

4.1. Assessment of technical properties

Sizing provides a uniform coating of size film on the surface of the warp yarn and reduces hairiness by creating bond with adhesive and fibers, as a result the strength of the yarn incremented. However, the amount of breaking strength was not constant in all portions over the yarn as it has thick and thin places. So, diversity was observed regarding the tensile strength assessment by considering the various portions taken as samples from the same sized yarn. The thin places of the yarn have tendency to early breakage while the thick or regular portions of the yarns minimize the impact. In case of potato starch based sizing and one-shot based sizing, the breaking strength performed in a relatively similar manner with slight deviation in the mean value where commercial one-shot based sizing agent showed minimally better performance than the locally produced potato starch.

Extension of yarn occurs due to the slippage of fibers present in the yarns when load is applied. After execution of sizing process, the gap among the fibers reduces due to the adhesive bond formation between sizing chemicals and fibers. The unfavorable factor of warp yarn

sizing is the reduction extension% of yarns. Both of the considered sizing material showed minimization of elongation at break%. However, potato-based sizing material provided slightly better output in terms of elongation reduction compared to the commercial one.

Hereafter, sizing procedure increment the force handling capacity of an yarn due to the coating of adhesive. This coating reduced the fiber damage tendency of yarns while weaving. The abrasion resistance of sized yarns was notably incremented after sizing. In terms of this property, potato starch-based sizing material showed more assertive outcome compared to the commercial one.

Inadequate take-up% increases the tendency of yarn breakage while surplus size take-up% makes the yarn stiffer with difficulty in desizing procedure. In this assessment, the size take-up% of both of the material based sized yarns was within the optimum level with minimal deviation in size take-up% value. Consequently, the hairiness of the fiber decreased in both of the cases where potato starch sized yarn showed more improved outcome due to its excellent adhesive property.

4.2. Future research scope

In this study, the assessment was done by considering only one type of yarn which is widely used in the textile industry. To analyze the performance scenario of using locally produced potato starch as sizing material, the assessment can be done by considering diversified type of yarns in terms of yarn count and composition. Further properties like weaving efficiency can also be assessed. To establish potato starch as a commercial substitute of imported sizing chemicals using in present days the feasibility of the product should be analyzed in terms of effective frameworks.

5. Conclusion

The comparative analysis regarding the technical feasibility of potato starch based sizing material as an alternative to commercially used one-shot based sizing material was described in this study. The outcomes of the assessment are mentioned as follows:

a. Potato starch based showed slightly minimal tensile strength with an average value of 348.478 cN, marginally lower than the commercial one (mean tensile strength 355.694 cN).

b. Yarn sized with potato starch provided a slightly better extension% of 5.276% compared to the one-shot sized yarn in which the extension% was 5.192%. Though the deviation among both materials is insignificant, the extension% was decreased significantly in both cases compared to the unsized yarn.

c. Regarding abrasion resistance, potato starch based yarn can handle 201.6 cycles on a weaving loom which is considerably higher than the one-shot based yarn's average value of 182 cycles.

d. The size take-up% and reduction in yarn count value are quite similar for both materials, where commercial one-shot showed a minimal increment in both properties compared to potato starch.

e. Due to the better adhesive property, potato starch based sizing material provides an acceptable coating on the yarn surface with a notable reduction of hairiness.

Locally produced potato starch can easily be an adequate substitute for commercially used imported one-shot sizing agents while assessing the technical performance. However, the one-shot is easy to use as it requires only water to make the size solution. In the case of potato starch, antiseptic and lubricating materials are needed. But due to suitable adhesive properties, the quantity of potato starch required to make

a particular size solution is usually 50% lower than the quantity of one-shot. So, the usage of potato starch is cost-effective as well. In addition, using potato starch in sizing can open up a new sector of potato consumption by which potato wastage can be reduced significantly. Consequently, this concept will help the rural potato farmers and bring significant impact in the area of social sustainability by creating a bridge between agriculture and textiles, the two dominant sectors of Bangladesh.

Acknowledgement

As this work is a portion of an ongoing thesis work of M.Sc. Program of Bangladesh University of Textiles, the authors are extremely grateful to the BPGS committee of BUTEX. The authors would like to extend their sincere thanks to the authorities and concerned persons of BUTEX CCI laboratory, BUTEX accredited laboratory and the testing laboratory of Primeasia University for their cordial support to carry out the research work.

Funding

The authors receive no funding to carry out the research process and publication of this article.

Conflict of interest

The authors had no conflict of interest with respect to interest and research work of this article.

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