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Process Variant Strength of Cotton-Flax Blended Plain Woven Fabric Manufactured in an Industrial Process: An Assessment from Grey to Finished Fabric

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Abstract Sustainability is a major concern globally for all manufacturing industries. Textile and Readymade garment industry is developing yarns, fabrics, and garments from natural textile fibres to replace synthetic textile fibres to protect against environmental threats. This study aimed to develop a cotton and flax blended plain-woven fabric using an industrial manufacturing process for commercial cotton-linen garment production. 21 Ne ring spun yarn was used in both warp and weft to produce cotton-linen plain woven finished fabric with a ratio of 70:30 cotton and flax fibre respectively. Tensile strength, tearing strength, yarn crimp, shrinkage, and grams per square meter (GSM) were measured for the quality evaluation of the fabric. Process-wise tensile and tearing strength reveals that tensile strength of the finished fabric decreased by 16 percent for warp direction and increased by 29 percent for weft direction. On the contrary, the tearing strength of the finished fabric increased by 33 percent and 22 percent for the warp and weft directions, respectively. GSM of the finished fabric increased by 11 percent. The variation in tensile, tearing strength, and GSM suggests that yarn crimp and shrinkage are vital factors that are affected by the chemical treatment in the bleaching and mercerization process.

Keywords Flax fibre, Linen fabric, Blended yarn, Sustainable textiles, Tensile strength, Tearing strength

1. Introduction

Textile industry disposes of the largest amount of synthetic chemicals and fibres into the environment among all other manufacturing sector [1]. Synthetic textile fibre like polyester, nylon and acrylic has several adverse effects on the environment [2]. Among all synthetic textile fibres, polyester fibre takes the highest share in the global textile and fashion industry [3-4]. This extensive use of polyester fibre is now a great concern for the sustainability of the planet because it releases toxic chemicals and has very low degradation in soil [5]. Fossil fuels are also being used for the production of synthetic fibres [6]. Considering all the adverse effects of synthetic fibres to the environment, textile manufacturers are seeking alternative natural fibres to synthetic fibres. Apart from the environmental aspects, health awareness of the garment users is also increasing day by day and also building pressure on the use of sustainable raw materials from natural sources [7-8].

Cotton fibre is the only natural fibre that has the second largest consumption after synthetic fibres but it is not possible for cotton fibre alone to replace a reasonable share of synthetic fibres [9]. Other natural fibres are potential in this connection. Flax is a bast-type natural textile fibre, which is grown as the skin of the flax stem. Flax fibre is collected after the retting process of the flax stem [10-11]. Flax fibre is a lignocellulosic fibre. The amounts of cellulose and lignin are around 70 percent and 2 percent, respectively [12]. Flax fibre is historically used for the production of clothing because of its unique textile properties. The Flax fibre has less shrinkage and is stronger than cotton [13]. Flax fibre produced linen garments provide better comfort to wearers in the summer season [14]. Flax fibre does not require any chemical treatment like other bast fibres; for example, jute for the processing in textile machinery. This fibre is normally used in long form as it grows for the production of flax yarns and fabrics using its own spinning system, which is popularly known as the wet spinning system [15]. To mix with cotton, flax fibre requires cottonization [16]. The main disadvantages of flax fibre are stiffness and coarseness that lead to mixing with other soft and fine fibre like cotton using the blending process in yarn manufacturing. Blending is a process where two or more different fibres are mixed together in order to achieve combined properties when a single fibre cannot meet the required properties of textile fabrics or garment [17]. For blending with cotton or other soft fibre, flax fibre is made to a similar length as cotton fibre [18]. Flax is widely used in blending with cotton and other fibers for the production of ring-spun yarns in the cotton spinning system. However,

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cottonized flax-cotton blended yarns are mostly used to manufacture knitted fabrics [19]. Very few studies have been conducted to develop woven fabric produced from Flax-cotton yarns and investigate the physical properties of grey and finished fabric, in particular the mechanical properties [20]. Again, most of the studies have been conducted on a laboratory scale, but here in this study, an end-to-end industrial manufacturing process is used to develop and investigate physical properties.

2. Materials and Methods

2.1. Raw Materials

Cotton-Flax blended yarns were used and spun in the ring spinning section of NZ Textile Mills Ltd., Bangladesh. The blend ratio of the yarns was 70% cotton and 30% flax. Yarn count was 21 Ne for both warp and weft yarn. Figure 1 shows the microscopic image of the flax-cotton blended yarn. The Image shows the main body and the protruding fibres on the yarn surface.

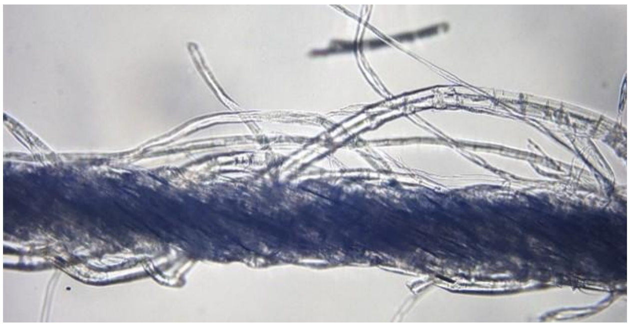

Figure 1. Microscopic image of the 21 Ne flax-cotton blended yarn

2.2. Production Grey State Cotton-Flax Blended Plain Woven Fabrics

Table 1. Recipe used in Sizing Machine

Sizing Recipe	Values
PVA	2 kg/500L
Wax	2 kg/500L
Drop size (CC30)	18kg/500L
Drop size (CC300)	10 kg/500L
Viscosity	19 sec
Steam condensate	10-12%
Cooking time and temperature	40 min, 90℃
Drying cylinder temperature	120/115/110/120℃
Refractive Index (Solid)	4.1%

Table 2. Process and Machine parameters in weaving

Parameters	**Warping**	**Sizing**	**Weaving**
Machine type	Sectional warping Brand, Four Star, China	Benninger Switzerland	Air Jet Toyoda 600, Japan
Speed	250 m/min	45 m/min	350 m/min

Industrial process from sectional warping to weaving was used to produce raw (grey) blended fabrics. The number of warp yarns per inch was 60 ends per inch (EPI), and the number of weft yarns per inch was 54 picks per inch (PPI) in the construction of the fabric.

The fabric width was set to 57 inches. The warp and weft yarn interlacement structure (weave) was 1 up and 1 down (1/1 plain). The sizing recipe was fixed as per Table 1. The process details are mentioned in Table 2. The relative humidity (RH) and temperature were kept at 75% and 27+/- 2℃, respectively in the weaving section.

2.3. Fabric Dyeing and Finishing

The pretreatment, such as singeing, desizing, scouring, and bleaching of the grey fabrics, was conducted by the respective industrial process. The pretreated fabrics were then dyed and finally finished in the Stenter process. The detailed process parameters of pretreatment, dyeing, and finishing are given in Table 3.

Table 3. Process parameters for chemical treatment of the cotton-flax blended Fabric

Process	Parameters
Singeing	Gas Pressure 18 Flame Intensity 4 Speed 80m/min.
Desizing	Enzyme 2 g/l Dwell time 6 hr Sequestering agent 6 g/l Wetting Agent 4 g/l.
Scouring	Caustic Soda 25 g/l Wetting agent 3 g/l Sequestering agent 4g/l Time 20 min, Temp 90℃.
Bleaching	Caustic Soda 8 g/L, Hydrogen Peroxide 9 g/l Stabilizer 5 g/l Wetting Agent 4 g/l Sequestering agent 4 g/l Time 12 hr, Speed 60 m/min.
Mercerizing	Caustic soda 22 g/L Temp 95℃, Speed 60 m/min pH 6-7.
Dyeing	Ready for Dyeing (RFD) Fabric

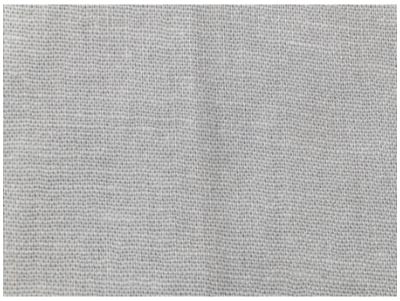

Figure 2. Plain woven (1/1 plain weave structure) cotton-flax blended RFD fabric

A microscopic image of the cotton-flax blended fabric in its finished state (Ready for dyeing fabric) is shown in Figure 2. Many long thick places are seen in the fabric, which is the main characteristic of cotton-flax blended fabric for a fashionable appearance in the final garment.

2.4. Methods

Fabric weight measurement was followed by ISO 3801: 1977 according to the determination process of mass per unit length and mass per unit area of woven fabrics. Tearing strength was measured in ISO 13937-1: 2000 standard to determine tear force using the ballistic pendulum method (Elmendorf). ISO 13934-2: 2014 method was used to measure the maximum tensile force using the grab technique. Yarn crimp in fabric measurement was followed by ISO 7211-3: 1984 standard. All measurements were carried out under standard laboratory conditions required for the physical properties of fabrics, and samples were conditioned accordingly before testing.

3. Results and Discussion

3.1. Tensile Strength of the Cotton-Flax Blended Fabrics

Tensile strength of a fabric indicates durability during using the fabric as a garment. It is the ability of a fabric to resist the force applied on its warp or weft direction for the elongation [21]. The tensile strength of Cotton-Flax fabric was measured both for the warp and weft way direction, and the results are shown in Figure 3.

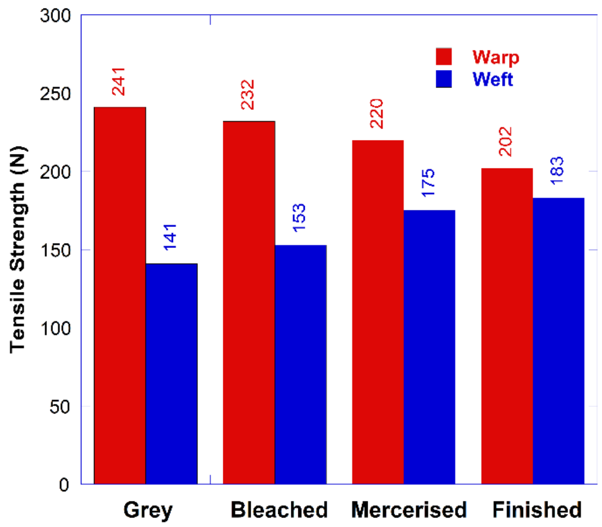

Figure 3. Tensile strength of cotton-flax blended plain-woven fabric at each stage of chemical treatment from grey to finished fabric for both warp and weft direction

The tensile strength in the warp direction was higher than that of the weft direction at every process from grey to finished fabric. As the number of yarns in the warp direction was higher in the fabric than the number of yarns in the weft direction, higher tensile strength in the warp direction of the fabric is developed. About 40 percent tensile strength difference is observed in warp and weft for grey state fabric, but the difference becomes gradually minimized after chemical treatments in bleaching, mercerizing, and dyeing, and finally reaches about 10 percent. The tensile strength gradually reduces by 16 percent in the warp direction from grey to finished fabric. In contrast to warp tensile, the tensile strength in the weft direction of the fabric gradually increases by 29 percent from grey to finished fabric. This result can be explained by the different chemical treatment of warp and weft yarns, and it is essential to check the tearing strength of fabrics for both the warp and weft direction for better clarification of the variation in tensile strength.

3.2. Tearing Strength of Cotton-Flax Blended Fabrics

Figure 4 states the tearing strength of Cotton-Flax blended fabric for both warp and weft way direction.

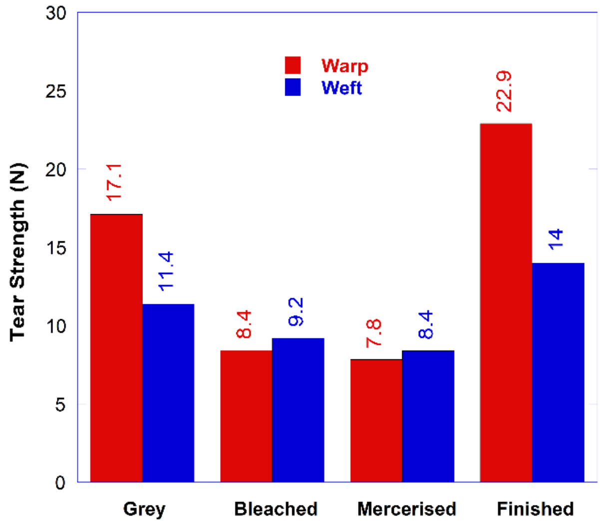

Figure 4. Tearing strength of cotton-flax blended plain-woven fabric at each stage of chemical treatment from grey to finished fabric for both warp and weft direction

Tear strength refers to a fabric's resistance to tearing or propagating a tear when subjected to external forces. It specifically measures the force required to initiate and continue a tear in the fabric, often in a weft and warp direction [22]. Tear strength is influenced by factors such as fabric construction, yarn properties, and subsequent chemical treatment of the fabric [23]. Fabrics with high tear strength exhibit better resistance to tearing, making them suitable for applications that involve frequent stress, such as sportswear, tents, and industrial textiles. The tearing strength of cotton-flax blended fabric in the warp direction was higher than in the weft direction, except in bleaching and mercerization. The higher tearing strength warp direction is also due to the higher number of warp yarns per inch in fabrics. The tearing strength of bleached and mercerized fabric for both warp and weft directions was almost similar. The tearing strength of finished fabric in the warp and weft direction increased by 33 percent and 22 percent, respectively, after the chemical process involved in bleaching, mercerization, dyeing, and finishing. This increased tearing strength can be developed in yarns by the shrinkage behavior of cotton-flax blended fabric after wet processing.

3.3. Shrinkage of Cotton-Flax Blended Woven Fabric

The shrinkage of the grey and finished fabric is graphically presented in Figure 5.

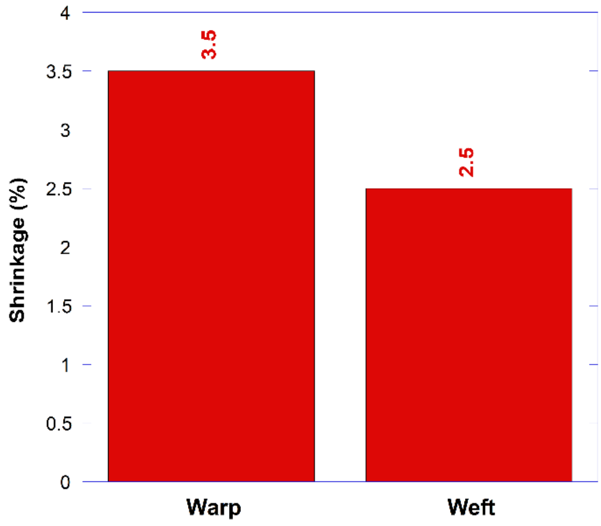

Figure 5. Shrinkage of cotton-flax blended plain-woven fabric for the warp and weft direction after the mercerization

Shrinkage is a common phenomenon in textile fabric, and it needs to be controlled before the production of garments in order to maintain the dimension of garments after washing or laundering for a comfortable fit and appearance. The shrinkage of fabric in the warp direction was higher by 1 percent than the weft direction. Warp yarns in fabric usually show a higher shrinkage value than weft yarns as a result of the tension generated by the processes during warping and weaving. The tension becomes released when fabric comes in a relaxed state, and the fabric gets shrinkage and yarn crimp develops. Yarn crimp of the fabric is presented in Figure 6.

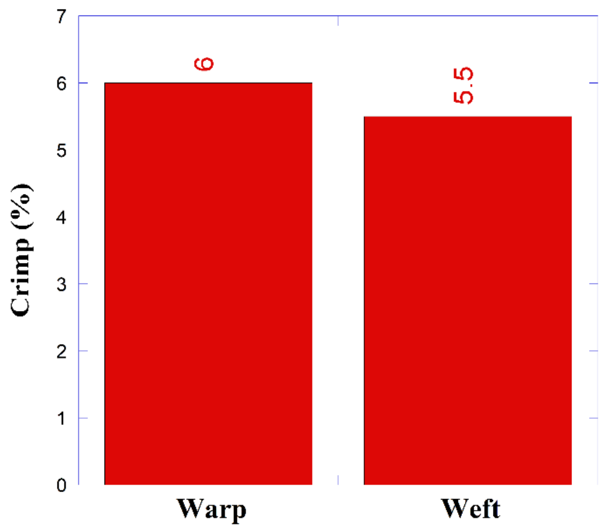

Figure 6. Yarn crimp of cotton-flax blended plain-woven fabric for the warp and weft direction at the finished state

Similar to the shrinkage, warp yarn crimp was higher by 0.5 percent than weft yarn of the finished fabric. The crimp in yarn is followed by the results of shrinkage in fabric. The higher yarn crimp and shrinkage in fabric increase the weight per unit area of the fabric, grams per square meter (GSM). GSM of grey and finished fabric is displayed in Figure 7.

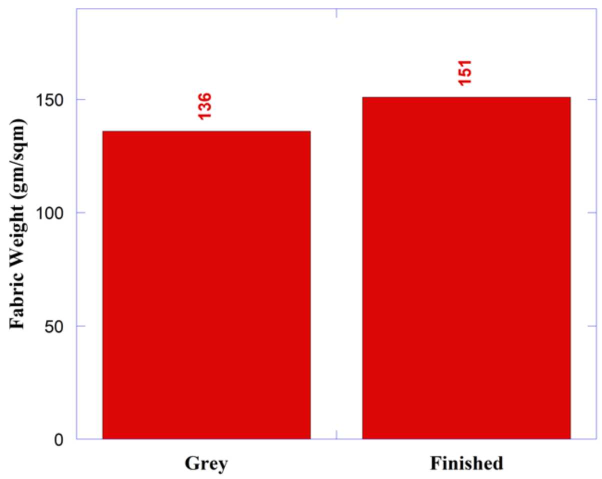

Figure 7. GSM of cotton-flax blended plain-woven fabric for grey and finished state

It is clearly noticed from Figure 7 that the finished fabric exhibited 11 percent higher GSM than the grey state. This higher GSM of finished fabric is due to the generation of shrinkage of the fabric during chemical treatment in bleaching, mercerization, dyeing, and finishing. The influence of shrinkage contributes to the variation of tensile and tearing strength for both the warp and weft way direction of cotton-flax blended plain-woven fabric. In the process of chemical treatment, hemicellulose, pectin, wax, and lignin content of both flax and cotton fibre are removed by the caustic soda [24]. When these constituents are released from fibre, they influence the weight and strength of the fabric. On the other side, when fabric shrinks after chemical treatment, the fabric regains its weight and strength loss.

4. Conclusions

This study was conducted to develop a cotton-flax blended plain-woven fabric using industrial manufacturing machinery and evaluate the physical properties of the fabric. Process-wise tensile and tear strength of the produced fabric for both warp and weft way direction were investigated in detail. The important finding of this study is the decrease in tensile strength in the warp way direction while increasing in the weft way direction of the fabric during the chemical treatment from scouring to finishing. In addition, tearing strength and GSM of the fabric increased in the finished state for both the warp and weft directions. These results are explained by the shrinkage and yarn crimp of the fabric due to the removal of compositional components of both cotton and flax fibre. Another finding is that the weft yarn of cotton-flax blended fabric is less affected by the chemical treatment. It can be recommended that control of the number of threads plays an important role in the physical properties of cotton-flax blended plain-woven fabric.

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