

INVESTIGATION ON VARIOUS FLAX FIBER PROPERTIES TO IDENTIFY THEIR POTENTIAL AND SUSTAINABLE APPLICATIONS

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Abstract: This article represents the results of an analysis of different flax fiber properties which were expressed in different forms such as Spinning Consistency Index (SCI), Micronaire values, Maturity, Length, Uniformity, Short Fiber Index (SFI), Strength, Elongation, Moisture, Rd, y+b, Color Grade, and Trash Count. All these properties were found from the High-Volume Instrument (HVI) testing machine. In past, flax fiber was mainly used as a long staple form, however, now it can be used as a cottonized form that means short-staple form, which is mainly done by blending with another short-staple spinning. In this experiment, different cottonized flax fibers, which were taken from different conditions, were used. Properties of Spinning Consistency Index (SCI), Maturity, Length, Uniformity, Short Fiber Index (SFI), Strength and Moisture Regain % showed higher quality for Scoured flax fiber. Micronaire value, Elongation %, Color grade, and Trash count gave upper quality for Bleached China Flax. Rd value for Bleached SFL-70 flax fiber and +b for both Mira flax and Anger flax dark exhibited excellent results.

Keywords: Short staple Flax fiber, Fiber properties, analysis

I. INTRODUCTION

Flax is the ancient fibers that are very hygienic, style to the wearer, feel to originality, and outstanding brightness [1]. The plant fiber crops cotton and flax have a long history of being used in clothing by the textile apparel industry due to their comfort level. Cellulose is a major component of flax fiber. There is 71% cellulose in flax fiber [2]. Flax stalks contain approximately 30% fiber and 70% trash both of which have been contaminated by bacterial endotoxins, same as cotton [3]. Flax contains fibers and fiber bundles with various diameters due to non-uniformity in retting and processing. Flax is a straight non-crimped fiber. It has various fiber bundle diameters and also a high-level short fiber[3]. Cottonization of flax is when fiber bundles are broken down to their ultimate by mechanical or chemical means. These broken flaxes are called cottonization of flax. The length of broken ultimate

cells or individual fiber of about 25 to 40 mm in length and these are cottonized flax[1]. The Spinning Consistency Index is a calculation for predicting the spin ability of the fiber. A fiber sample of constant weight is measured by passing air through the fibers and measuring the drop in pressure (Micronaire) [4]. Maturity Index (Mat) indicates the degree of cell wall thickness [5][6]. The weight measurement of the Upper Half Mean Length is calculated from the fibrogram. A fiber beard of randomly clumped fibers is scanned optically across its length and the fibrogram is derived from it. The Uniformity Index expresses the ratio of the Mean Length to the Upper Half Mean Length. It is an indication of the distribution of fiber length within the fibrogram [7]. The Short Fiber Index is a value that is calculated using a sophisticated algorithm. The fibrogram is mathematically converted to a length distribution curve. The SFI is an indication of the number of fibers (%) that are less than 0.5 inches (12.7 mm) in length [8]. The bundle strength is the breaking strength of the flax fibers in grams per tex [9]. The fineness is calculated from the micronaire value [10]. The fiberboard is broken at a continuous deformation rate (CRE = Constant Rate of Extension) and with a 1/8-inch distance between the clamps. Elongation is a measurement of the elastic behavior of the fibers in the bundle [11]. Moisture is the amount (%) of water (H₂O) that is present in the sample being tested. Reflectance (Rd) value expresses the whiteness of the light that is reflected by fibers. Yellowness value expresses the yellowness of the light that is reflected by the cotton fibers. The color grade (C grade) of a sample is determined in a two-filter colorimeter. Trash is measured on the same glass window as the color measurement [12]. Flax is a natural fiber that is mainly grown in Europe. Flax shows very good mechanical properties and can be spun to form continuous natural fiber yarns [13]. Bleached Mira Flax: Behaving very similarly to cotton, bleached cottonized flax fiber retains the unique properties of flax – bactericidal action, ecological properties, etc. Its production technology relies on a smart combination of mechanical and chemical treatment of short flax fiber and is flexible in terms of fiber parameters (length, linear density, shive removal degree, etc.). With low quantity of operations, the mechanical treatment is fiber-sparing, leaving the structure intact and causing no excessive splitting of bust bundles in the ready product.

The chemical treatment imparts the product with a set of auxiliary qualities, rendering it elastic, soft, crimped, hygroscopic, antibacterial, fire- and bio-protected, etc.[14][15]. Harwood et al. studied that Flax fibers have some significant advantages such as high tenacity and natural brightness[16]. In addition to the use of textile, flax is a raw material for oil and composites. The demand for flax fiber is increasing owing to its ecological and comfort properties. Jackowski et al. have been initiated around the world to broaden the application of flax in clothing using woven fabrics and knitting[17]. Flax (*Linum usitatissimum* L.) is an agricultural crop grown on 12 million acres worldwide [18] that can provide food [19], fuel [20], and fiber [21]. Flax fibers are abundantly available in Canada, well known for their low cost and high strength characteristics [22]. Flax is the source of industrial fibers and, as currently processed, results in long-line and short (i.e., tow) fibers [23]. Flax fibers present a polygonal shape with 5 to 7 sides [24]. S.K. Batra investigated that the longitudinal view of a fiber reveals a non-constant transverse dimension. The fibers are thicker nearer the root and become thinner nearer the tip. On average, a fiber is 19 μm in width and 33 mm in length. It is, however, important to note the variation of the geometric dimensions, i.e., the transverse and longitudinal dimensions lie in the range of 5 to 76 μm and 4 to 77 mm, respectively [25]. Hearle found that the flax fiber consists of highly crystalline cellulose fibrils spirally wound in a matrix of amorphous hemicellulose and lignin [26]. Wang et al. found that the fibrils are oriented with a tilt angle of 10–11 $^\circ$ with respect to the axis of the fiber and hence display a unidirectional structure [27]. Gassan et al. studied those Flax fibers, which originate from renewable resources, are an interesting alternative to mineral fibers. Their low cost, together with their low density, high specific rigidity and recyclability, constitute the major incentives for their use in composites [28].

II. METHODOLOGY

(i) Fiber

In the described experiment, cottonized flax fiber was used to find out the required properties. Here eight types of flax fiber were used to complete the research work. The name of eight types of flax is Bleached Mira Flax, Bleached China Flax, Bleached SFL-36 Flax, Bleached SFL-70 Flax, Mira Flax, Anger Flax Dark, Anger Flax Scoured-SFL, and Scoured Flax. Bleached Mira flax behaves similarly to cotton fiber. Bleached china flax, bleached SFL-36 flax, and bleached SFL- 70 flax all are treated with bleaching chemicals. Bleaching of fiber was performed by immersion of alkaline treated fibers in a 0.25% sodium hypochlorite (NaOCl) for 1 h and then washed and dried in the oven at 60°C for 24 h. Mira flax is raw flax that is not treated with any chemicals. Anger flax dark is not treated with scouring chemicals. Anger flax scoured SFL is treated with chemicals. Scoured flax is also treated with scouring chemicals. For alkalization of flax fiber, it was first washed with a 2% detergent solution

(Ultra liquid Tide based on anionic, cationic, and non-ionic biodegradable detergents) and after it was washed with distilled water to eliminate extractives, especially some waxy materials. It was then dried at 60°C for 24 h. After drying, it was immersed in a 5% sodium hydroxide (NaOH) solution for 3 h and then washed with distilled water and dried in an oven (Despatch Oven Co., Minneapolis, MN) at 60°C for 24 h. There were eight different bales for eight types of flax fiber. The weight of each bale was 180kg. Ten samples were taken from each bale. A random sampling procedure was applied for the collection of ten samples from each bale. In random sampling, every individual fiber of a bale has an equal chance of being selected in the sample. The weight of each sample was 10.5 gm.

(ii) Methods

In the beginning, 10.5 grams of flax fiber were taken to test the specimen in a High-Volume Instrument (HVI) following the ASTM D5867 standard. A relative air humidity of $65 \pm 2\%$ and a temperature of 21 ± 1 $^\circ\text{C}$ were maintained during measurements. Ten measurements were taken for each sample at different places then we have taken their average value. From HVI we have measured Spinning Consistency Index (SCI), Micronaire, Maturity, Length, Uniformity, Short Fiber Index (SFI), Strength, Elongation, Moisture, Rd, +b, C Grade, and Trash Count. The Spinning Consistency Index (SCI) is a calculation for predicting the spinnability of the fiber. A multiple regression equation can provide valuable information to anticipate the yarn strength and spinning potential. The Maturity Index is a relative value that is calculated using a sophisticated algorithm that includes the HVI measurements of micronaire, strength, and elongation. The Uniformity Index expresses the ratio of the Mean Length to the Upper Half Mean Length. It is an indication of the distribution of fiber length within the fibrogram. The Short Fiber Index (SFI) is a value that is calculated using a sophisticated algorithm. The fibrogram is mathematically converted to a length distribution curve. The SFI is an indication of the number of fibers that are less than 0.5 inches (12.7 mm) in length. The strength of flax fiber is the breaking strength of fiber expressed in cN/tex. Elongation is a measurement of the elastic behavior of flax fibers in the sample. Moisture is the amount (%) of water (H_2O) that is present in the sample being tested. The degree of reflectance (Rd) expresses the whiteness of the light that is reflected by the flax fibers. The yellowness (+b) value expresses the yellowness of the light that is reflected by the flax fibers. C grade and trash count value is also measured by High Volume Instrument (HVI). Technical data regarding samples are presented.

III. RESULTS AND DISCUSSION

TABLE 1: SUMMARY OF DIFFERENT FLAX FIBER PROPERTIES

Parameters	Bleached Mira Flax	Bleached China Flax	Bleached SFL-36, Flax	Bleached SFL-70, Flax	Mira Flax	Anger Flax Dark	Anger Flax Scoured-SFL	Scoured Flax
SCI	132	72	41	79	91	69	29	140
Micronaire (µm)	7.36	7.10	7.91	7.75	7.26	7.35	8.14	7.70
Maturity	1.11	1.04	1.04	1.06	1.09	1.06	1.05	1.16
Length (mm)	33.44	30.76	34.12	35.50	32.95	38.35	35.94	39.75
Uniformity (%)	73.0	69.0	69.5	71.1	71.1	71.9	70.9	72.9
SFI	11.9	15.6	12.0	11.4	13.5	10.6	11.4	10.1
Strength (cN/tex)	51.4	37.8	26.9	34.2	48.2	38.7	27.4	58.3
Elongation (%)	1.9	2.2	1.5	1.9	2.1	1.2	1.2	1.9
Moisture (%)	6.6	6.0	5.5	5.5	6.0	6.5	4.8	6.6
Rd	81.1	83.9	82.1	90.0	43.1	30.2	45.7	46.4
y=b	8.3	5.5	6.5	5.8	14.0	14.0	12.7	12.3
C Grade	21-1	31-1	31-1	11-1	85-5	85-5	84-4	84-4
Trash Count	1	0	1	0	25	281	47	8

(i) SCI of flax fibers

From figure 1, it can be said that the value of scoured flax is showing higher result 140 as compared to other flax fiber and this result indicates high quality in the SCI system. Anger flax is showing the minimum value of SCI and that is 29. The mean value of SCI for different flax is 81.62. From the spinning system, we must know that, if the SCI value is less than 85 then it is not used for the spinning process. Because a lower SCI value means lower strength of the fiber. So, if we use scoured flax or bleached Mira flax in the spinning system then it may be possible to get finer yarn quality. The standard deviation is less than 1.50% for the entire sample.

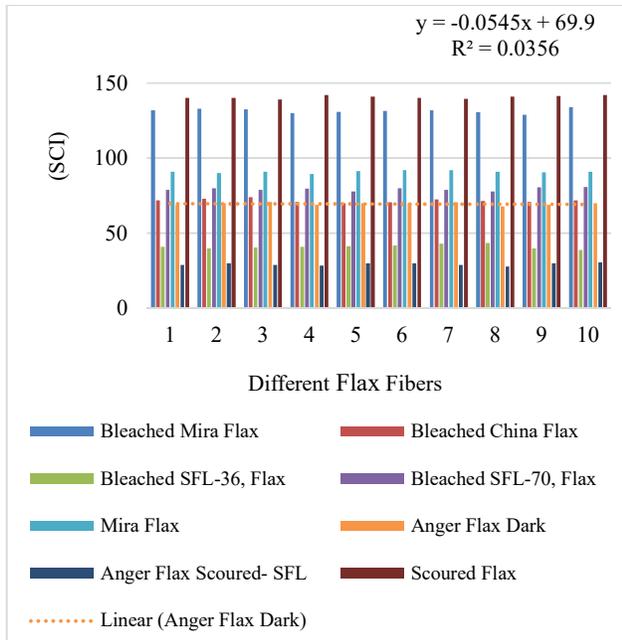


Figure 1: SCI value of different flax fibers

Figure 2, represents that, bleached china flax showed a lower value of 7.10 compared to other flax fibers. In fiber micronaire, a lower value indicates finer quality, and it

will better for yarn quality. As flax is a coarser fiber and all the values of this fiber indicate coarseness. From them, bleached china flax represents higher and anger flax scoured-SFL represents a lower value. The mean value of micronaire for different flax is 7.57. So, from the result, it can be said that bleached china flax, Mira flax, anger flax dark, and bleached Mira flax may provide higher yarn quality. The standard deviation is less than 1% for all the samples.

(ii) Micronaire value of flax fibers

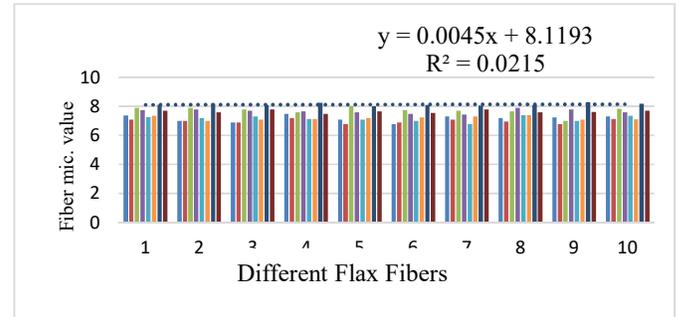


Figure 2: Micronaire value of different flax fibers

(iii) Maturity of flax fibers

From figure 3 it is said that scoured flax fiber showed their upper value of 1.16 as compared to other flax fibers. In fiber maturity, a higher value indicates more mature fibers, and its effect will better for yarn quality. The mean value of maturity for different flax is 1.07. Generally, the maturity range of flax fiber is 0.2 to 1.2, so the value of all the flax fibers was acceptable. From the result, it can be said that bleached Mira flax and scoured flax results may providing higher results among other flax fibers. The standard deviation is less than 1% for all the samples.

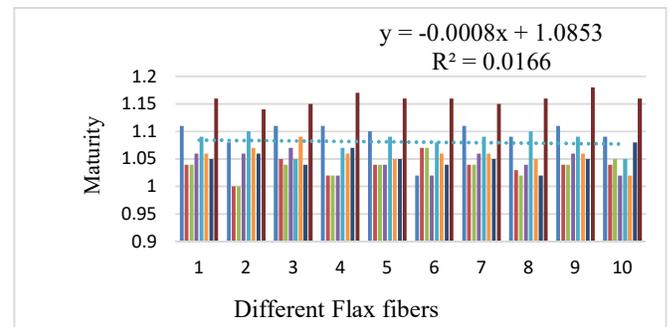


Figure 3: Maturity of different flax fibers

(iv) Length of flax fibers

From figure 4 it can be said that cottonized flax is used in this experiment, so the length of all flax fiber is almost the same. Cottonising of flax fiber involves reducing the length of the fibers to make them suitable for cotton machinery. This is normally done by the cutting process. The maximum length is found for scoured flax 39.75 mm and the minimum length is found for bleached china flax 30.76 mm. The mean value of length for different flax is 35.10 mm. In this experiment, the fiber length is more than 30mm, so it can be used for blending purposes with different fibers such as cotton, polyester, Tencel, etc. The standard deviation is less than 1% for all the samples.

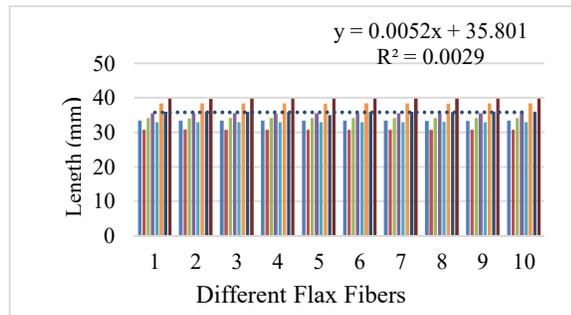


Figure 4: Length (mm) of different flax fibers

(v) Uniformity of flax fibers

Uniformity is one of the main fiber properties among other properties. Uniformity is calculated as the ratio of the average length of all fibers to the average length of the longest 50 percent of the fibers in the sample. A high uniformity value indicates uniform fiber length distribution and is associated with a high-quality product and with low manufacturing waste. So, from the above figure, we can say that bleached Mira flax has a maximum value of uniformity and that is 73%. Bleached chine flax has a minimum uniformity value and that is 69%. The mean value of uniformity percentage for different flax is 71.17%. The standard deviation is less than 1% for all the samples.

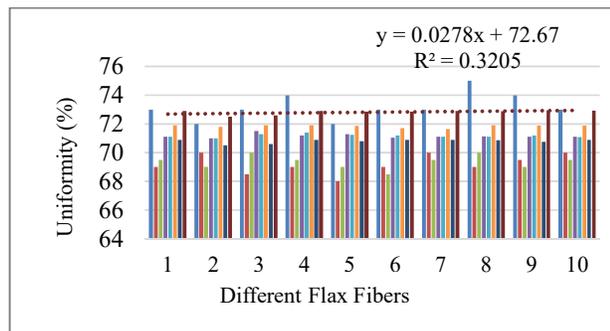


Figure 5: Uniformity of different flax fibers

(vi) SFI of flax fibers

From figure 6, it can be expressed that, bleached china flax showed a higher result of 15.6, and scoured flax exhibit a lower result of 10.1. The mean value of SFI for different flax is 12.06. It means scoured flax quality is higher and bleached china flax quality is lower. A short fiber index is a numerical value that indicates the processability of flax calculated from its length and tenacity values. An increase of 1% (absolute) in SFI can decrease ring-spun yarn strength by 1% or more. Overall, it can be said that scoured flax may be giving better quality among other flax fibers. The standard deviation is less than 1% for all the samples.

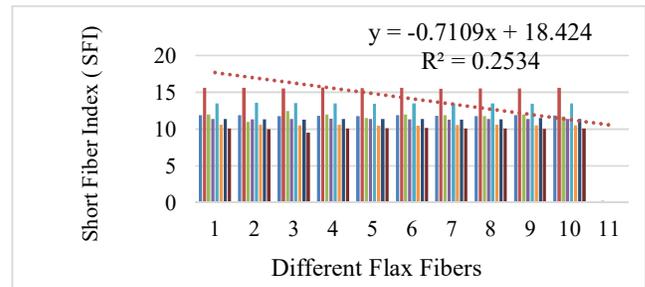


Figure 6: SFI value of different flax fibers

(vii) Strength of flax fibers

From figure 7, it can be said that scoured flax showed the peak value of 58.3 cN/tex among other flax fibers in this experiment. The lowest value of strength is 26.9 cN/tex for Bleached SFL-36, Flax. The mean value of strength for different flax is 40.36 cN/tex. In fiber strength, an upper value indicates more strength, and it will better for yarn quality. Normally after bleaching fiber strength is reduced. As flax is a bast fiber, so its strength is higher than any other natural fiber. So, from the figure, it can be said that bleached Mira flax, Mira flax, and scoured flax may afford better quality among other fibers. The standard deviation is less than 1% for all the samples. The standard deviation is less than 1% for the entire sample.

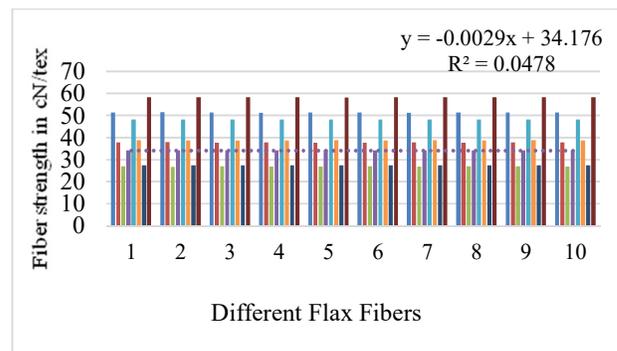


Figure 7: Fiber strength of different flax fibers

(viii) Elongation% of flax fibers

In figure 8, it can be expressed that, flax fiber bears low elongation% as compared to standard fiber elongation%. The mean value of elongation % for different flax is 1.73. It may cause the presence of lignin in flax fiber. Also, flax fiber is brittle, and stiffness and the ultimate length of flax fiber is very low. So, in this experiment, bleached china flax and Mira flax may be giving better results as compared to other flax fibers. The standard deviation is less than 1% for all the samples.

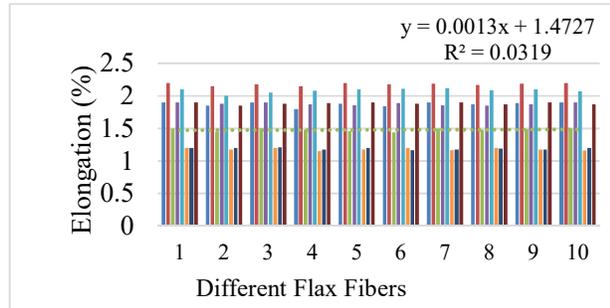


Figure 8: Elongation % of different flax fibers

(ix) Moisture Regain% of flax fibers

From figure 9, it can be illustrated that bleached Mira flax, anger flax dark, and scoured flax possess the peak value of 6.6% and anger flax scoured-SFL bears the lowest value of 4.8%. The mean value of moisture regain% for different flax is 5.93. Other fibers show medium value. This value varies due to their processing condition. The peak value indicates a better result for moisture regain %. Overall, it can be said that bleached Mira flax, anger flax dark, and scoured flax may endow with better results among other flax fibers. The standard deviation is less than 1% for the entire sample.

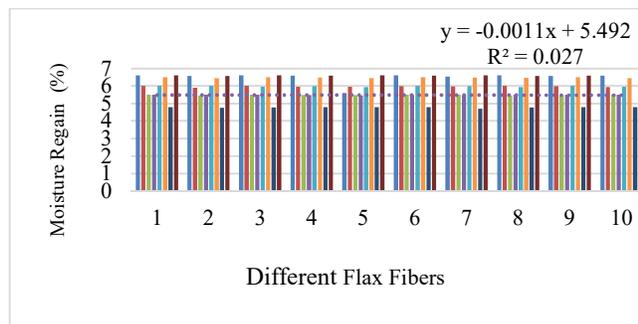


Figure 9: Moisture Regain% of different flax fibers

(x) Rd value of flax fibers

The degree of reflectance (Rd) indicates how bright or dull a sample is. If the rate of Rd value is higher than it can be said that its quality is higher. Figure 10 expresses fiber fineness against different flax fibers. In the above figure, bleached SFL-70 flax shows the maximum value of reflectance and that is 90%. The minimum value of reflectance shows Anger Flax Dark and that is 30.2%. The mean value of reflectance for different flax is 62.81%. The color of flax fiber is dull and, in this experiment some flax fiber was bleached so their rating is higher. Finally, it can be said that bleached flax fiber may be giving a better result. The standard deviation is less than 1% for all the samples.

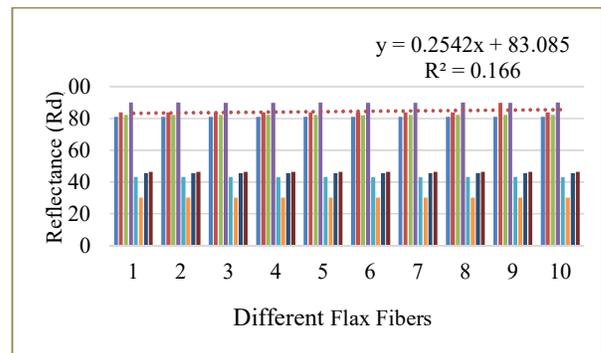


Figure 10: Rd value of different flax fibers

(xi) Yellowness (+b) of flax fibers

Yellowness (+b) indicates the degree of color pigmentation. From figure 11, it can be said that the relation between +b and Rd shows inversely proportional. If the value of Rd is increased, +b decreased. The mean value of yellowness for different flax is 9.88. Overall, it can be said that Mira flax, anger flax dark, anger flax scoured-SFL, and scoured flax on condition that a better result. The standard deviation is less than 1% for all the samples.

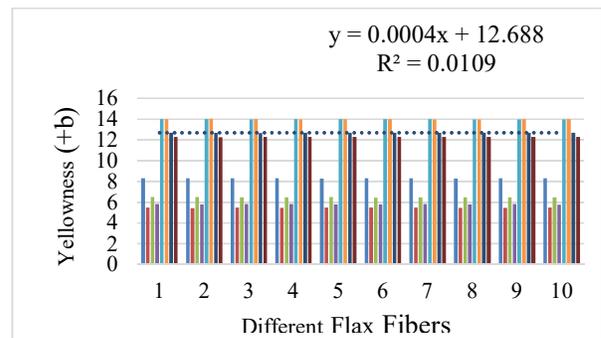


Figure 11: +b value of different flax fibers

(xii) Color grade and trash count

From the experimental table, it can be discussed that the color grade of Mira flax, anger flax dark, anger flax scoured-SFL, and scoured showed higher values that means its quality indicates a lower value. The same incident occurs for trash count. It may cause natural baste fiber and after bleaching its quality become higher. So finally, it can be express that, for Color grade and trash count, bleached flax may show a better result.

Cottonized flax makes a new era in our textile field, especially in the Spinning sector. Now a day knitted, woven also fancy products are produced from these fibers and their market value is high. This research work will motivate every researcher in this field who wants to work successively.

IV. CONCLUSION

During the research work, eight types of flax fiber were taken, and thirteen fiber properties were analyzed by the HVI method. It has been observed that the properties of SCI, Maturity, Length, Uniformity, SFI, Strength and Moisture Regain% for Scoured flax fiber show better results compared to others. That means yarn produced from Scoured flax fiber is more durable as well as comfortable to the wearer. Micronaire value, Elongation%, Color grade and Trash count for Bleached China Flax exhibits their upper result among other flax fibers. So finer yarn can be produced with bleached china cotton. Besides pretreatment should be done with special care due to the high color grade. Rd value for Bleached SFL-70 flax fiber expresses good quality and +b for both Mira flax and Anger flax dark shows excellent results. On the other hand, bleached China flax displays a lower value for fiber Length, Uniformity, SFI, +b fiber properties. Anger flax dark shows the inferior value for fiber Color grade, Trash Count, Elongation%, and Rd properties. Also, Anger Flax Scoured-SFL exhibits lower value for SCI, Micronaire value, Elongation%, and Moisture Regain%. Anger Flax Scoured- SFL is responsible to produce coarser yarn with low absorption properties. So overall it can be said that Scoured flax fiber and Bleached China Flax may be providing the better result for ring-spun yarn processing. Since flax is a natural cellulosic fiber, the product produced from flax is biodegradable and contributes to sustainable application.

At present we are fully dependent on cotton fiber, but Flax fiber has excellent properties with its strength, coolness, biodegradable, and comfort. Firstly, we have used this by blending with other natural and synthetic fibers but if we can develop a new machine design then it is possible to produce 100% flax yarn from cottonized flax fiber. In this work, an investigation on various flax fiber properties to identify their potential and sustainable applications were analyzed. This research can be extend through the following future works.

- Need flax fiber production in our country also as cotton and jute fiber.
- Special machine development can overcome productivity.
- Need more industry to produce flax yarn and its derivatives.

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