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Analysis of the Properties of Plain Woven Fabrics Produced from Flax/Cotton Blend

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Abstract: ***Blend yarns spun from different blend ratio (70/30, 50/50, 30/70, 10/90) flax/cotton and 100% cotton were converted into fabrics through the integration of warp and weft yarns. The blend yarns were used as weft in the fabric construction using plain weave pattern. The properties of the produced blended fabrics were studied. The results show useful indications of the differences that exist in their physical and mechanical properties such as the fabric tensile strength, tearing strength, abrasion resistance, crease recovery, fabric drape, fabric thickness, fabric crimp and fabric sett. From the study it was discovered that as the flax content in the blend is increased, both tensile, tearing, abrasion resistance, fabric and crimp reduces.***

Key words: Cotton, flax, blend, warp yarn, weft yarn, fabric, properties

1. Introduction

Raw flax fibre consists of natural cellulosic polymers containing up to 30 % of various non-cellulosic impurities (Baley, 2002). The impurities in the flax fibres (Morrison and Danny, 2001) are hemicellulosic, lignin or woody matter, pectin and small amount of fats, waxes, protein and residual ash. These impurities have negative effect on the fibre hydrophilic and absorption properties (Zhang, et al., 2003; Fakin, et al.,2006). The major constituent of cotton fibre is cellulose with up to 89.3 – 90.5 % cellulose in raw cotton. Other constituents include waxes, pectins, protein and cuticular matters. Cellulose being the major constituent in cotton is a linear polymer consisting of D-anhydroglucose units joined together by β-1, 4-glycosidic linkage (Rollins, 1965). The strength of cotton fibre may be attributed mostly to the cellulose content in the fibre and is related to a number of structural factors e.g molecular chain length and the orientation of the cellulose (Danny, 2002). From the stand point of processing, wax is the second most important constituent of the cotton fibre. The presence of wax is important for the attainment of proper spinning.

The flax fibre is inferior to cotton interms of uniformity, so that flax yarns are characterized by pronounced irregularities when compared with cotton (Pringle, 1949; Kholar, 2005). However, in order to obtain the best fabric for a particular purpose at a suitable price, one often can achieve the desired result by blending the fibres. The blending of the fibres leads to the attainment of a mixture of characteristics of the individual fibres in the blended fabric. The properties of woven fabrics depend on the type and composition of fibres used. Thus, flax and cotton fibres are blended in order to achieve properties unachievable with single fibre type (Lawal, 2008). Therefore, textile manufacturers tend to blend in order to achieve improvement in quality and processing performance (Foulk and Danny, 2001). Other advantages include reduction/control of cost and to meet functional end-use requirements e.g. tensile and tear strength, abrasion resistance, drape, elongation, permeability, absorption etc (Punj, et al., 2004). The geometric structure of a fabric is extremely complicated especially when the cross-sectional and surface images of the fabric is viewed (Jinlin, 2004). On the general note however, every piece of woven fabric is an integration of warp and weft yarns through intersection. The extent of this interlacing is largely dependent on the friction between fibres and yarns entanglement (Grosberg, 1966). The distance between two parallel adjacent yarns determines the porosity of a fabric structure and it is such discrete porous structure that distinguishes fabric from a continuous engineering structure and /or materials (Jinlin, 2004). In view of the foregoing development, this research is intended to explore the use of the blended flax/ cotton of different ratios to produce fabric and investigate some of the physical and mechanical properties of the fabric.

2. Materials

The materials comprises of samples of blend yarns in the ratios of 70:30 flax/cotton (Sample A), 50:50 flax/cotton (Sample B), 30:70 flax/cotton (Sample C), 10:90 flax/cotton (Sample D), and 100% cotton yarns (Sample E) which serves as the control sample. These materials were used as weft yarns in the fabric construction. The materials were obtained from the Council for Industrial and Scientific Research (CSIR), Port Elizabeth, South Africa. It serves as the weft yarn. The other sized cotton yarns (20cc) were obtained from Zaria Industry Limited, Nigeria, which serves as the warp yarns on the weaver's beam.

Some of the machines used are: Pirn winding machine, tappet loom, Shirley crimp tester, Essdiel thickness gauge, Cusick drape tester, Martindale abrasion tester, Shirley crease recovery tester,Testometric testing machine, Elmendorf tearing tester, etc.

3. Methods

3.1 Pirn Winding Operation

The yarns from the cones were creeled unto the pirn winder frame. The diameter of the pirn used was determined depending on the type and size of the shuttle used. The yarn traverse length was set at less than 45^0 and the yarn from the cone was then passed through the tension device and set at the required tension . Because of the low strength of the yarns (flax), which makes it impossible to wind at various tensioning levels, the tension device was then set at zero. The yarn from the tension device was then passed through the protector device, guide and then unto the pirn. Four pirns from each of the yarn samples were produced at a machine speed of 450 rpm.

3.2 Weaving Operation

The first set of pirns from a particular blend of yarn was then introduced into the shuttle for the commencement of the weaving operation. The weave pattern used was the plain weave. From each of the five samples of yarns blends (A) 70:30, (B)50:50, (C)30:70, (D)10:90 and (E) 0:100 flax/cotton, four pirns were used from each. Upon exhausting the four pirns of a particular blend yarn. Two yards of fabrics were produced from each of the blend.

4. Testing

All the samples produced were conditioned under standard atmosphere for testing for at least 48 hours to attain a relative humidity of 65± 2% and a temperature of 20± 2°C.

4.1 Yarn Crimp Measurement

This test method covers the determination of the relationship between the length of a piece of fabric and length of yarn in the fabric and was carried out in both warp and weft directions for each of the fabric samples. The Shirley crimp tester was used in the measurement using the British Standards method (B.S 2862,1957).

The conditioned fabric was laid flat and kept free from tension and creases, after which a square strip (20 cm by 20 cm) was cut out of the sample fabrics. A dissecting needle was used gently to remove from the flap the outermost yarn while ensuring that the loss of twist is avoided. The last part of the end was then inserted into one grip of the apparatus. The grip was then closed to permit the withdrawal of yarn under slight tension until its end coincides with the datum line in the mirror on the apparatus. The straightened length of the thread was then measured. This was repeated for twenty threads in both warp and weft directions for all the sample fabrics. The mean, the coefficient of variation and the percentage yarn crimp were obtained. The formula used in calculating the % crimp is shown below;

$$\%\ \text{Crimp} = \frac{\text{straightened yarn length} - \text{length in fabric}}{\text{length of yarn in fabric}} \times 100$$

Where;

$\text{Length of yarn in fabric} = 20\ \text{cm}$

4.2 Determination of Fabric Sett

This test was carried out in accordance with the method described in BS Handbook, 1957; using the counting glass system. The fabric sample was laid flat on a horizontal surface and the counting glass placed on it so that one of the edges of its aperture becomes parallel to the warp threads. The number of warp yarns (ends) per centimetre (epcm) was then counted and recorded. With the other edge of the aperture parallel to the weft direction, the number of weft (ppcm) were counted and recorded. This was repeated on five different portions of the fabric sample for all the sample fabrics. The mean for ends and picks per centimetre were then calculated.

4.3 Determination of Fabric Thickness

This test was carried out in accordance with the procedure in BS Handbook 2544, 1974 using the "Essediel thickness guage. The test specimen's area for all the sampled fabrics was randomly selected.

The surface of the anvil was cleaned and the instrument was adjusted until the guage reads zero, the plates were then separated and uncreased, part of the specimen was placed in contact with the anvil without tension. The reading of the guage was observed and fabric thickness recorded. The pressure used was 1.96 $x10^{-3}$ N/mm^2. This was repeated ten times for all the sample fabrics. The mean and coefficient of the variation were then calculated.

4.4 Determination of Fabric Drape

The test was carried out in accordance with BS Handbook 1974 using the Cusick drape tester. From each of the sample fabrics, two specimens were cut with the aid of a template of 30 cm diameter. The specimen was placed on the lower horizontal disc of the apparatus to allow pin to pass through the centre of the specimen. The top disc was then positioned on the specimen with the pin fitted into the hole in the top disc. The lid of the apparatus was then lowered. An annular ring of paper of the same outside diameter (30 cm) as the test specimen was placed on the lid. The light of the instrument was then switched on and the periphery of the shadow on the paper ring was traced out. The paper was then removed, folded and its weight was obtained to the nearest 0.01 g. Then the paper ring which was drawn around the periphery of the shadow was cut and the area of the paper ring was then determined to the nearest 0.01 g. The results are expressed as a percentage drape coefficient.

$\text{Drape Coefficient} = \frac{M_2}{M_1} \times 100$ (Bhalerao, 2007).

Where;

M_1 = Weight of the annular paper.

M_2 = Weight of the outline of the shadow caste unto the annular paper by the fabric.

4.5 Determination of Fabric Crease Recovery

The Shirley crease recovery tester was used by applying both NIS 28,1983 and ISO 2313/BS EN 22313 standards. Rectangular shape 2 cm by 4 cm specimen was cut from both the warp and weft directions not less than 5 cm from the selvedge and conditioned to equilibrium in a standard atmosphere. The specimen was then folded end to end to form a square before insertion between the upper and lower surfaces of the loading device. A load of 1 kg was then applied to the folded specimen for 5 minutes after which the load was removed.

The specimen was then transferred to the measuring instrument by gently holding in the flat jaws of the forcep's one arm of the specimen. The other arm of the specimen was introduced between the two parts of the grips. Care was taken not to disturb the existing crease formulation.

The specimen was then released from the forceps and the grip closed. The grip was rotated so that the free arm of the specimen hang vertically. The free arm was allowed to hang vertically for 5 minutes by necessary rotation of the grip. At the end of 5 minutes, the crease recovery angle was read off and recorded. This was repeated for all the sampled fabrics.

4.6 Determination of Fabric Abrasion Resistance

The test was carried out in accordance with British Standard, 1974 using the Martindale wear and abrasion tester model 103. The top plate and sample holders were removed, the quick release nuts were then rotated to approximately 180^0 in an anti-clockwise direction and lifting them vertically. The retaining rings were then removed. A non woven felt of approximately 140 mm diameter was placed on top of each abrading table. Abrasive cloth of approximately 140 mm diameter was then cut and placed on each of the felts. The abrading table weight was put on top of the abrasive cloth, taking care to smooth out any wrinkles. The retaining ring was then dropped over the weight and secured in position with four nuts. Throughout this entire operation, it was ensured that both felt and abrasive material were free of creases and folds and held tightly in position over the top of the tables.

The hand-operated lever press was used to produce 38 mm diameter specimen of the cloth to be tested, equally, 38 mm diameter piece of polyurethane foam was cut. The sample holder was then unscrewed and the insert removed. The specimen was laid (face down), polyurethane foam and the head inserted and tightened firmly. The machine was set at appropriate rubs for each sample and the abrasion of each specimen was performed under a pressure of 12 kpa.

4.7 Fabric Tearing Strength

The test was carried out using the Elmendorf tearing tester SDL 008 model. 5 cm by 8 cm of the fabric sample was cut out with the sample cutter supplied with the tester. The cutting was for both warp and weft directions for all the sample fabrics to be tested (Booth, 1968).

With the pendulum in its initial operating position, the test sample was clamped centrally in the jaws with the specimen side facing the initial incision knife. The test sample was then slitted with the pivoted knife blade. The knife was allowed to return to its rest position. The pendulum upon initial incision would tear the remaining portion of the sample. The pendulum release lever was then depressed smartly, keeping the lever depressed, the pendulum was caught gently as it swung back to its initial position. The reading was then noted and recorded. The pendulum and pointer were then returned to the initial position and the torn sample was removed. Five test specimens from the sample fabrics were used. From the means, tear strengths were then calculated.

4.8 Fabric Tensile Strength

This test was carried out using the Testometric testing machine. The speed of the instrument used was 60.0 mm/min with a load cell of 500 kgf. 200 mm by 100 mm of the sample fabric in both warp and weft directions were cut. Using the standard test mode which allows standard test to be performed, the tester when initially powered up after delivery will normally be set- up for standard tests and in tension mode.

Tare button was pressed which zero the load figure. With the positioned crosshead knock- off blocks and desired crosshead speed, the sample was loaded in the grips and up button of the machine was pressed to start the test. At the end of the test, the peak load and extension figures were displayed automatically and the readings were noted and recorded. The down button was then pressed which returns the crosshead to the lower crosshead knock- off block. The peak load and extension figures were then cancelled by pressing the Endtest button. The tester then becomes ready for another sample to be loaded. Five different tests for each of the sampled fabrics were carried out.

5. Results And Discussion

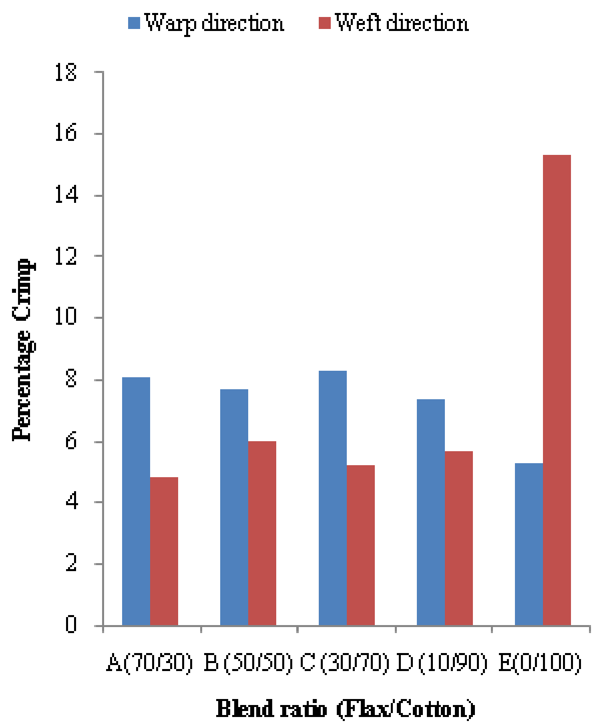

Figure 1: Percentage Crimp versus Blend ratios for warp and weft directions

From the result shown in Figure 1 , it was discovered that percentage crimp reduces as the flax content in the blend is increased i.e. weft directions (where the blend yarns were used as picks in the fabric construction). It was clear from the result that in almost all the samples except for sample E, percentage crimp in the weft direction is lower than the corresponding warp direction. This may partly be attributed to the yarn linear density of the weft yarns spun at 39 tex. Yarn crimp on the weft direction shows that sample A

(70:30 flax/cotton) has the least percentage crimp (4.8%), followed by sample C with percentage crimp of 5.2% . On the other hand sample E recorded the highest percentage yarn crimp when the fabric sample was tested in the weft direction (15.3%). Interms of higher percentage crimp in the same weft direction sample B is second, with precentage crimp of 6.0% . sample E recorded least crimp percent in the warp direction while sample C recorded the highest crimp percent in the same warp direction.

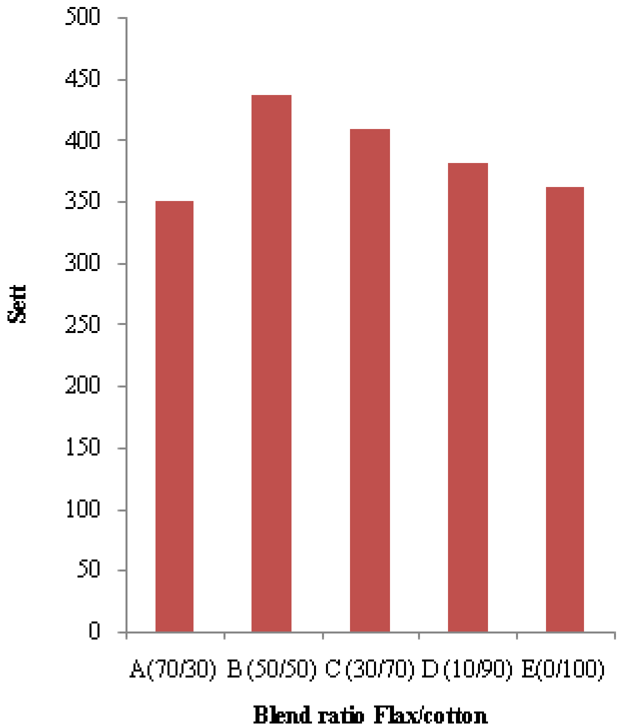

Figure 2: Fabric Sett versus Blend ratio

It can be observed that sample A (blend of 70:30 flax/cotton) fabrics has the least number of ends and picks per centimeter (351.2) as shown in Figure 2. This is closely followed by sample E (controlled sample 100% cotton yarn) fabric with 363.4 ends x picks per centimeter. On the other hand, sample B recorded the highest fabric sett with 437.4 ends and picks per centimeter. Sample C however recorded 410.8 ends and picks per centimeter and is second in terms of the fabric density (sett).

Figure 2 shows that as the flax content in the blend is increased, the ends and picks per centimeter increases for sample B, C and D. Sample A with the highest percentage of flax recorded the least fabric density. One of the major reasons is the effect of twist on the yarn during the spinning process, thus, sample A has the highest twist.

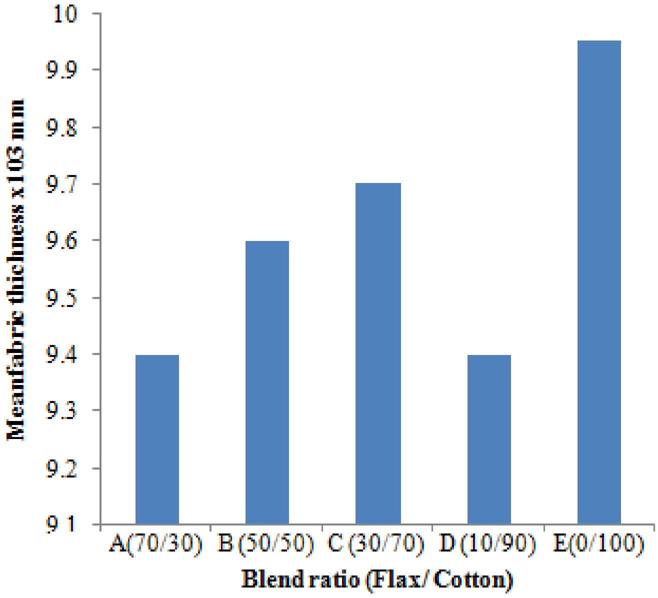

Figure 3: Fabric Thickness versus Blend ratios

Results obtained from the thickness test carried out is shown in Figure 3 above. It would be realized that sample A (70:30 flax/cotton) blend has the least thickness value while sample E (100% cotton yarn) has the highest thickness. This shows that as the percentage of flax fibre in the blend is increased, the fabric thickness reduces. However ,it would also be observed that the thickness of sample A and D are the same even though the percentage flax is higher in sample A.

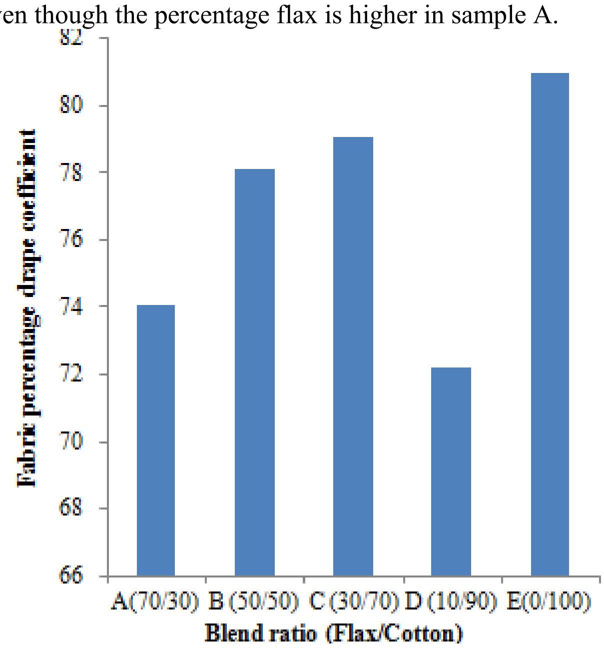

Figure 4: Fabric Percentage drape coefficient versus blend ratio

From the results of fabric drape obtained in Figure 4, it is evident that sample E with the highest fabric thickness recorded the highest drape coefficient of 81.01% and hence has the lowest drapability. This is closely followed by sample C with a drape coefficient of 79.07% , sample B which has 78.14%, sample A with drape coefficient of 74.04% and sample D with the lowest value of 72.21%. From the above results it is clear that fabric thickness has significant influence on the draping quality of a given fabric. It would be realized from the result that the drape coefficient shows higher values as the flax content in the blend is increased for samples A, B, and C. The increase in drape coefficient with increase in the flax content is a direct reflection of reduced bending stiffness for fabrics, which have high flax content. It is evident that as picks per centimeter increase , drape coefficient will increase. The reason being that higher picks give lesser space for yarn movement in fabric giving tighter and stiffer fabrics.

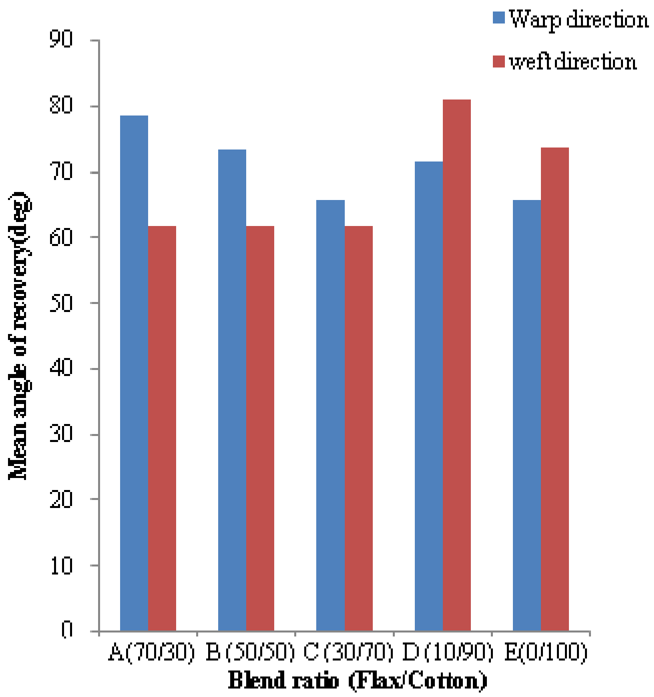

Figure 5: Fabric Angle of Recovery versus Blend ratio

From the result obtained as shown in Figure 5 , it can be seen that sample E with the lowest flax content in the blend has the highest crease recovery angle in the weft direction. Samples A (70:30 flax/cotton) and B (50:50 flax/cotton) with higher percentages of flax, recorded the least crease recovery angle when tested in the same weft direction. This means that as the flax content is increased, the crease recovery angle is reduced. One of the major reasons is the molecular structure of flax which is more ordered than that of cotton and posseses greater susceptibility to creasing (Peters, 1963). The result of the crease recovery angle in this reaserch is equally in agreement with the findings of Irish, 2005.

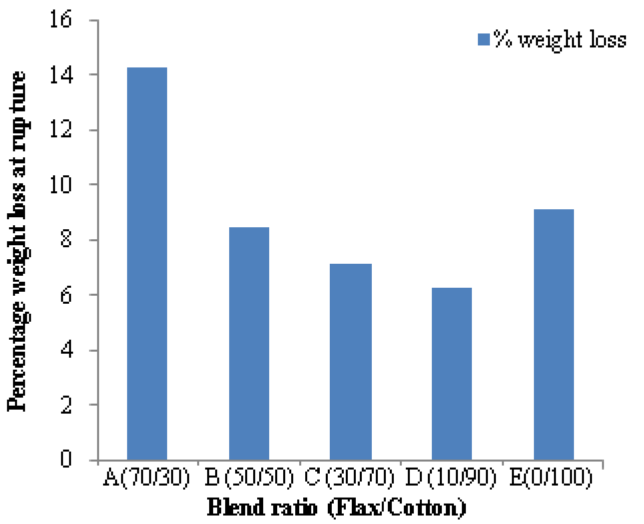

Figure 6: Percentage weight loss on abraded fabric versus Blend ratio

The result obtained in Figure 6 shows that sample A with the least ends x picks per centimeter recorded the highest weight loss with percentage weight loss of 14.34 %. This is because there were fewer number of threads to be abraded during rubbing action. Sample E is second in terms of weight loss with percentage weight loss of 9.21 % respectively.

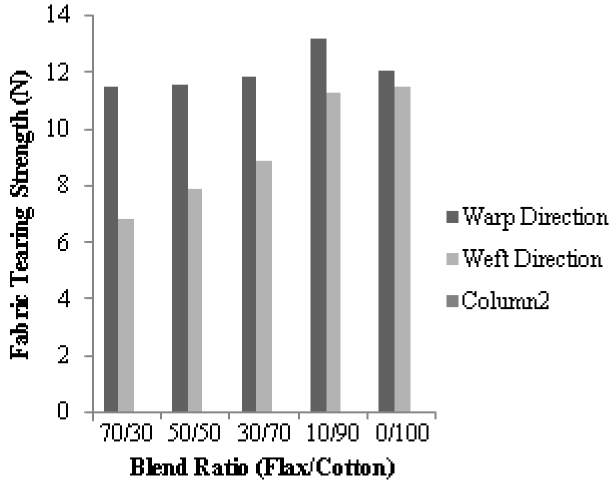

Figure 7: Fabric Tearing Strength Versus Blend ratio

It is evident from the results shown in Figure 7 that warp and weft way tearing strength decreases with increase in the flax content in the blend fabric due to lower strength of the constituent yarn. This is in agreement with the results on the tenacity of the blended yarn (Lawal, 2008) which gives the tenacity in cN/tex of the blended yarn in the following order;

Sample A (5.89cN/tex) < B (9.86cN/tex) < C (10.18cN/tex) < D (12.62cN/tex)

From the result obtained from the fabric analysis on tensile strength as shown in Figure 8 , it would be realized that the same pattern was recorded i.e. tensile strength increases with decrease in the flax content in the blend.

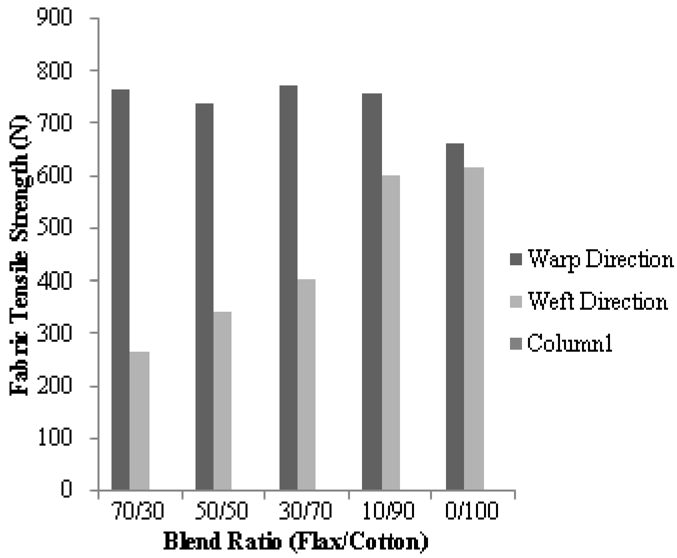

Figure 8: Fabric Tensile Strength versus Blend ratio

The result obtained in this research work shows that tensile strength in weft direction generally decreases with increase in the flax content in the blend. While sample A (70:30 flax/cotton) has the least tensile strength of 265.06 N, sample D (10:90 flax/cotton) recorded 603.86 N. Sample which serves as the control sample comprising of 100% cotton recorded 619.38 N. It is therefore evident that with increase in the flax content in the blend ,there would be a corresponding decrease in both the yarn tenacity and the fabric tensile strength. It would be observed that warp tensile strength in all the fabric tested is higher than the weft tensile strength. This is in accordance with single yarn strength result as presented (Lawal, 2008).

6. Conclusion

The following conclusions can be drawn out as follows:

The tenacity of the yarn with higher flax content in the blend is lower and the resultant fabric from such yarns gave material with lower fabric tensile behaviour. The properties of the blended fabric analysed show that fabric with more cotton component has higher strength than the less cotton, such material can be used where strength is paramount important. The fabric creasing properties is affected by the amount of flax content in the blended fabric, thus increase in the flax content of the blend gave a corresponding decrease in the crease recovery of the material.

From the fabric draping point of view, it would be concluded that fabric with higher flax component in the blend gives lower drape coefficient. On the fabric thickness however, it would be concluded that as the percentage of flax is increased, the fabric thickness tends to reduce. The yarn crimp results show that percentage crimp reduces greatly as the flax content in the blend is increased. This is supported by the results obtained which showed lower crimp percentage as the flax content of the blend increased.

It would be concluded that sample A (70:30 flax/cotton) blended fabric had the highest percentage weight loss of 14.3 %. However, sample D (10:90 flax/cotton) with the lowest flax content in the blend recorded the lowest percentage weight loss of 6.1%.

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