Processability and properties of yarns produced from cornhusk fibres and their blends with other fibres

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Natural cellulose fibres extracted from cornhusks have been blended with cotton and polyester and processed on the ring and rotor spinning machines. The processability of cornhusk fibres on the conventional spinning systems, compatibility with cotton and polyester, and properties of the blended yarns have been studied. The properties of cornhusk fibre blended yarns are also compared with those of the similar yarns produced from unconventional fibres, such as pineapple and banana leaves, milkweed and kenaf. It is observed that the blending of cornhusk fibres with cotton does not adversely affect the properties of yarn while the blending of cornhusk fibres with polyester improves the strength and elongation of the yarns.

Keywords: Biofibres, Cornhusk fibres, Cotton, Lignocellulosic fibres, Polyester, Spinning

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1 Introduction

Agricultural byproducts are annually renewable and low cost source for natural cellulosic fibres. Lignocellulosic agricultural byproducts, such as pineapple and banana leaves, coir and sugarcane rind, have been used as a source for natural cellulose fibres for textile applications.1-5 In addition, other agricultural products and byproducts such as poly(lactic acid), cornstalks and rice straw are also being used for textile applications.6-13 Corn is the largest food crop in the world and the United States produces about 40% of the world corn production. The production of corn also generates about 640 million tons of lignocellulosic byproducts every year. Cornhusks, one of the byproducts of corn production, contains about 45-50% cellulose which can be extracted in fibrous form for various industrial applications including textiles. Although textile applications offer a relatively high value addition and a huge market for consumption of the cornhusk fibres, they require fibres of high quality. The potential value addition, however, depends on the fibre costs, quality of the fibres that can be obtained and the end-use applications of fibres. Apparel and other textile applications offer high value addition but demand fibres that have high quality and processability. The primary test of the processability of cornhusk fibres is their spinnability i.e. the ability of the fibres to be spun into yarns. In addition, to be easily processable, cornhusk fibres should not adversely affect the properties or processability of blends with cotton, polyester and other fibres.

Unconventional natural cellulose fibres, such as kenaf, pineapple and banana leaves and milkweed, have already been processed on the conventional cotton spinning machinery. However, these fibres have only been processed either into coarse count yarns or as small proportions in blends with cotton and other fibres, mainly due to the limitations in quality and processability of the fibres. Sugarcane fibres have been reported to be used for nonwovens but there is no literature on the spinning of sugarcane fibres. Pineapple leaf fibres have been processed on
semi-worsted, jute, dref and flax spinning systems and 100% pineapple yarns have been produced in coarse counts of about 70 - 492 tex. A

For the first time, natural cellulose fibres with strength and elongation between cotton and linen have been extracted from cornhusks. These fibres have the potential to be the cheapest available natural cellulose fibres for textile applications and would be the second only to cotton in terms of availability. To realize the value of the fibres and their utility as a textile fibre, it is critical that the fibres should be processable on the conventional textile machinery and be compatible with other common textile fibres, especially the two most commonly used textile fibres, cotton and polyester.

The present work is aimed at examining the processability of cornhusk fibres and studying the cornhusk fibres compatiblity with cotton and polyester fibres on the ring and rotor spinning machines. The effect of cornhusk fibres proportion on the strength and elongation of cotton/cornhusk and polyester/cornhusk blends is also reported.

2 Materials and Methods

2.1 Materials

Dry cornhusks from fully grown corn were collected from the greenhouses at the University of Nebraska, Lincoln and from corn fields in Nebraska. The husks were manually cleaned to remove stubs and other materials collected along with the husk. Cornhusks were then cut into lengths of about 2-3 cm to extract fibre bundles with lengths suitable for blending with cotton and polyester and to make them processable on the short staple spinning machinery. The methods used to extract the fibres are reported elsewhere.

2.2 Methods

Fibre bundles obtained from cornhusks with an average of 40 denier were processed using a miniature spinning machinery according to the 50 g spinning test. Fibres were then hand blended with cotton in the weight ratio of 80/20, 70/30 and 50/50 (cotton/cornhusk). Cornhusk fibres were also blended with polyester in the ratio of 65/35 (polyester/cornhusk). For comparison, 100% cotton yarns were also produced using the same polyester and cotton as used to produce the cornhusk blends. The properties of the cotton and polyester fibres used are given in Table 1.

The fibre blends were processed through a modified card and drawframe as explained earlier. All samples were carded twice for uniform mixing and parallelization of the cornhusk fibres. The 65/35 cotton/cornhusk blend was also spun on an open end (OE) spinning machine to produce a 84 tex yarn. The 80/20, 70/30 and 50/50 cotton/cornhusk blends were processed on ring spinning machine to produce 50, 42, and 30 tex yarns separately (Table 2). Ring spinning was performed on a direct sliver-to-yarn ring spinning machine. The process parameters used for ring and rotor spinning were: ring spinning (30-50 tex)— spindle speed 7000-11000 rpm, draft 103-106.6, traveler #1-#4, & twist multiplier 4.17-5.39; and rotor spinning (84 tex)— opening roller speed 7000 rpm, opening roller type s 21 DN, rotor speed 6000 rpm, rotor type 46U & twist multiplier 5.3.

Yarn strength and elongation were measured using an Instron tensile tester according to ASTM method 1240. A gauge length of 254 mm was used and the cross-head speed was adjusted to obtain the breaking time of about 20 ± 2 s. Forty readings were noted for each type of yarn and the average of strength, elongation and CV% of strength was taken.

3 Results and Discussion

Cornhusk fibre blends with both cotton and polyester are found to be processable on the modified card, ring and rotor spinning machines without any modification to the machines. It is not possible to doff a web of 100% cornhusk fibres from the card. This is mainly due to the low strength of the web, cornhusk fibres being coarse compared to cotton tend to be held by the wire points in the doffer, and also due to the limitations of the modified carding machine. Coarser and longer wire points on the card such as those in...
woollen and worsted cards would be more suitable to produce a web of 100% cornhusk fibres.

Cotton/cornhusk blends are found to be spinnable on the ring frame with up to 50% of cornhusk fibres in the blend. However, blends with higher than 50% of cornhusk fibres are not spinnable due to increased spinning breaks. The polyester/cornhusk blend spun on the ring frame shows a relatively lower end breaks than the cotton/cornhusk blends mainly due to the higher strength of polyester fibres. The 65/35 cotton/cornhusk blend is easily processable on the open end spinning machine at production level speeds.

Cornhusk fibres do not affect the processability of blends on the small scale spinning machinery. However, as shown in Table 2, the properties (strength and elongation) of the ring-spun cotton/cornhusk blended yarns are not proportional to the per cent of cornhusks in the blend. The actual amount of cornhusk fibres in the blends after carding and the inherent variations in the spinning process are the major reasons for the variations in the blended yarns. Therefore, the main aim of this study was to analyze the processability and compatibility of cornhusk fibres with cotton and polyester and not to study the effect of cornhusk fibres on the blended yarn properties.

3.1 Ring-spun Yarn Properties

3.1.1 Counts Spun and Yarn Properties

A 70/30 cotton/cornhusk blend, spun into three counts (Table 2 and Fig. 1), has strength loss ranging from 3% to 13% when compared to 100% cotton yarns of that particular count. The strength loss in the blended yarns is mainly attributed to the lower strength of cornhusk fibres in the blend. However, the elongation of the blended yarns shows higher retention values and the 30 tex yarns show an increase in elongation of up to 50% when compared to a 30 tex 100% cotton yarn.

The increase in elongation and relatively higher strength retention of the 30 tex cotton/cornhusk yarns is mainly due to the higher cohesiveness offered by finer count yarns. It is evident from Table 2 that cornhusk fibres are compatible with cotton and have good strength and elongation retention. The higher extensibility of the 30 tex cotton/cornhusk blended yarn suggests that cornhusk fibres would provide unique properties when blended with relatively inextensible fibres such as linen and jute.
3.1.2 Blend Ratio and Yarn Properties

Increasing the proportion of cornhusk fibres up to 50% in the cotton blend decreases the strength of the yarns by about 20% in a 30 tex yarn (Table 2) but increases the elongation of the blended yarns by up to 36%. It should be noted that even with 50% cornhusk fibres, the blended yarn has more than 80% strength retention indicating that cornhusk fibres are compatible with cotton (Table 2 and Fig 2). The higher elongation of the cornhusk blended yarns is attributable to the higher elongation of cornhusk fibres as given in Table 1. Cornhusk fibres have lower strength than cotton and will break more easily reducing the strength of the blended yarns. However, since fibres are stretched before breaking, the higher elongation of cornhusk fibres makes the yarns to have an increased elongation.

3.1.3 Polyester/cornhusk Blends

Unlike the cotton/cornhusk blends, the polyester/cornhusk blended yarn shows an increase in strength in comparison to a polyester/cotton yarn (Table 2). A plausible reason for the increase in strength of the polyester/cornhusk blended yarns is the comparable elongation of cornhusk and polyester. During testing, both cornhusk and polyester fibres stretch to similar extent before the weaker cornhusk fibres would break. However, in a polyester/cotton blend, the lower strength and extensibility of cotton would make the cotton to break first, leading to a lower elongation of the blended yarn.

The higher moisture regain of cornhusk fibres relative to cotton and the higher strength and elongation retention of polyester/cornhusk blends in comparison to polyester/cotton blends would make cornhusk fibres preferable in polyester blends. It would be very interesting to study the effect of higher proportion of cornhusk fibres in a polyester/cornhusk blend which will be pursued in future.

3.2 Open-end Spun Yarn Properties

A 84 tex cotton/cornhusk blend (65:35) produced on the open end spinning machine is about 35% weaker and has an elongation loss of about 17% in comparison to the 100% cotton yarn produced using the same conditions (Table 2). The lower strength and elongation retention is also due to the structure of open-end yarns that make them inherently weaker than ring-spun yarns and also because of some cornhusk fibre loss at the opening roller in the OE spinning machine. It is important to note that the cotton/cornhusk blends were processed on the open-end spinning machine at production level speeds.

The qualities of the cotton/cornhusk and polyester/cornhusk blended yarns as discussed above demonstrate the utility of cornhusk fibres for textile applications and their processability on the short staple spinning machinery. Cornhusks fibres are compatible with cotton and polyester since the blended yarns have high strength and elongation retention. Cornhusk blended yarns would provide unique properties to the blended yarns due to their higher elongation and moisture regain. The significance of the processability of cornhusk fibres and their uniqueness in a blended yarn is more evident when compared to the processability and properties of blended yarns obtained from other unconventional fibres, such as kenaf, milkweed, and pineapple and banana leaves.

Processing cornhusk fibres of 40 denier on the rotor spinning machines would require large diameter rotors, leading to high power consumption. However, rotor spinning offers higher productivity (than ring spinning) as compared to ring spinning, which could offset the costs due to higher power consumptions, especially in countries with high labor costs. In addition, it would be relatively easier to produce yarns with higher proportion of cornhusk fibres in cotton/cornhusk blends and 100% cornhusk yarns on the rotor spinning machines than on ring spinning machines.
3.3 Comparison of Cornhusk Blended Yarns with Other Unconventional Fibres

3.3.1 Kenaf Fibres

Kenaf is commonly used in the manufacture of sacks, ropes, cordage, nets and paper.\textsuperscript{5,16} Kenaf/cotton blended yarns have already been produced on both the ring and rotor spinning machines and made into knitted textiles and hand woven fabrics.\textsuperscript{5,16} The quality of a 50 tex cotton/kenaf (80/20) blended yarn, which was also produced using the 50 g spinning test, is compared with a 70/30 cotton/cornhusk yarn (Table 3). The cotton/cornhusk yarn has strength and strength CV\% values similar to that of the cotton/kenaf blends. The cornhusk blended yarn shows higher elongation retention than the cotton/kenaf blend, possibly due to the higher elongation of cornhusk fibres. Even though it is arguable that different cottons used in the two studies would influence the properties of the blended yarns, it should be noted that cotton/cornhusk blends have been processed into a finer yarn (30 tex) with higher proportion of cornhusk in the blend (50/50) than the cotton/kenaf blends reported in literature.\textsuperscript{5,16}

3.3.2 Milkweed Fibres

Milkweed was blended with cotton in the ratio of 67/33, 50/50 and 33/67 (cotton/milkweed) processed on the ring spinning to produce 30 tex yarns.\textsuperscript{17} The properties of the cotton/milkweed blended yarn are compared with the cotton/cornhusk yarns (Table 3). The cotton/milkweed blends have a strength loss of about 20-40\% and elongation loss of about 20\% in comparison to 100\% cotton yarn. At 50\% milkweed, the strength of the blended yarn reduces by about 20\% but the strength loss increases to about 40\% with 67\% milkweed in the blend. Cotton/cornhusk blends give higher strength and elongation retention in comparison to the cotton/milkweed blends (Table 3).

3.3.3 Pineapple Leaf Fibres

Of all the agricultural byproducts currently used for textiles, pineapple leaf fibres (PALF) are the most extensively used and widely reported.\textsuperscript{4,18-21} PALF have been processed on the cotton, semi-worsted, DREF and jute spinning machines to produce 100\% PALF yarns and also blends with cotton, wool, viscose and polyester waste in count ranges of about 50-490 tex.\textsuperscript{4,18-21} Properties of the 50 tex cotton/pineapple blended yarn are compared with a similar cotton/cornhusk blend (Table 3). The cornhusk blended yarns have similar strength and elongation retention as the PALF blended yarns. Here again, it should be noted that the PALF yarns produced on the cotton system are either in coarser counts or with low proportion of PALF in the blends.

3.3.4 Banana Leaf and Sugarcane Fibres

Banana plant fibre has been processed on the jute spinning machinery to produce yarns of about 259 tex, suitable for hessian and sacking fabrics.\textsuperscript{19,22} There are no reports available on the spinning properties of sugarcane fibres.

4 Conclusions

Cornhusk fibres are abundant and low cost natural cellulosic fibres with properties suitable for textile applications. It is found that cornhusk fibres are compatible with cotton and polyester and are processable on the conventional short staple spinning machinery. Both the ring and rotor spinning systems are suitable to spin the cornhusk fibre blends. Cornhusk fibres are the only fibres produced from an agricultural byproduct that can be spun into finer counts (30 tex) and with higher proportion (50\%) in blends. Cornhusk fibres have high strength and elongation retention in both cotton and polyester blends. The higher elongation of cornhusk fibres compared to cotton increases the elongation of the cotton/cornhusk and polyester/cornhusk blends. These
properties in addition to the higher moisture regain of cornhusk fibres compared to cotton would provide unique characteristics to products made from cornhusk fibres. It is expected that the higher extensibility, moisture regain and better processability of cornhusk fibres would provide unique properties when blended with linen, jute and other fibres.

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