Natural Cellulose Fibers from Corn Stover

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Natural Cellulose Fibers from Renewable Resources

Keywords

Corn • Husk • Stover • Natural cellulose fiber • Fiber extraction • Lignocellulosics • Fiber properties

Corn or maize is the second largest agricultural crop grown in the world, second only to sugarcane with 875 million tons produced in the world in 2012. Cultivation of corn generates stover (stalk, leaves, and husk) as by-product that has been considered for a variety of uses. In developed countries such as the United States, the recent efforts on producing cellulosic biofuels from biomass have led to the use of corn stover as feedstock for cellulosic ethanol. However, substantial quantities of corn stover are still left unused and are available for industrial use at low cost. Currently, a ton of corn stover baled and ready to be shipped is estimated to cost about $40–$50, making stover one of the cheapest lignocellulosic sources. Corn stover typically consists of about 50 % stalk, 23 % leaves, 15 % cobs, and 14 % husk. The stalks consist of an inner pith and outer rind which is the source for fibers. Cornhusks (ears, shucks) are fibrous structures that can be up to 20 cm in length and have been traditionally used for decoration, food wrapping, and other applications.

Due to the large availability and low cost, the potential of obtaining fibers from cornhusks and cornstalks had been explored. Fibers have been produced from cornhusks and cornstalks for textile and composite applications. To extract fibers from husks or stalks, the raw materials are treated in alkali solutions at high temperatures (85–90 °C) for a desired time [05Red1, 05Red2, 05Red3]. Stalks require more severe chemical and/or physical treatment conditions and produce relatively inferior quality of fibers compared to the fibers obtained from husks. After treatment, the fibers are washed to remove the dissolved substances and short fibers. An additional enzyme treatment may be done to remove hemicellulose and lignin and obtain finer fibers. Typical yield of fibers from husks or stalks varies from 10 to 30 % depending on the severity of the treatment and quality of fibers desired. The long length of cornhusks provides a unique opportunity to obtain fibers with

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Table 2.1 Properties of fibers obtained from cornhusks and cornstalks

Fiber	Length [cm]	Tensile properties		
		Strength [g/den][a]	Elongation [%]	Modulus [g/den][a]
Cornhusk	2–8	2.0 ± 0.3	11.9 ± 1.1	49 ± 3.7
Cornhusk	10–20	1.4–1.6	13–16	36
Cornstalk	3	2.2 ± 1.0	2.2 ± 0.7	127 ± 56

Reproduced from [05Red1, 05Red2, 05Red3]
[a]g/den = grams per denier. 1 g/den is approximately equal to 130 MPa

lengths suitable for processing on both the short and long staple spinning systems and the ability to blend cornhusk fibers with cotton, linen, wool, or other fibers. As seen in Table 2.1, cornhusk fibers with lengths of up to 20 cm were obtained [05Red3]. Longer cornhusk fibers had lower strength but higher elongations, and fibers obtained from cornstalks had similar strength but substantially lower elongation than cornhusk fibers. Interestingly, the cornhusk fibers have high elongations similar to the fibers obtained from coconut and *Borassus* husks, whereas the cornstalk fibers have elongations typical to bast fibers (1–3 %). These differences in elongation are mainly due to the amount of cellulose and arrangement of cellulose to the fiber axis. Rather than using husks from dried stover, green husks were collected and used for fiber extraction at various treatment conditions. Considerable variations in fiber composition and properties were observed with stronger conditions providing fibers with higher cellulose content and strength [13Yil].

Cornhusk fibers were also bleached and dyed and processed on spinning machines to produce yarns. Bleached cornhusk fibers had a CIE whiteness index (WI) of 74 compared to a CIE WI of 80 for cotton [07Sal]. Digital images of cornhusk fibers before and after bleaching are shown in Fig. 2.1. Similarly, cornhusk fibers were found to have higher dye pickup than cotton fibers under similar dyeing conditions [11Red]. Fibers obtained from cornhusks were blended

Fig. 2.1 Fibers extracted from cornhusks before (*left*) and after bleaching (*right*) to a CIE WI of 74

Table 2.2 Properties of yarns made by blending cornhusk fibers with cotton and polyester at various ratios and spun on the ring and rotor spinning systems [06Red]

		Strength		Elongation	
Count [tex]	Blend proportion	[g/tex][a]	[% Retention][b]	[%]	[% Retention][b]
Ring-spun yarn	Cotton/cornhusk				
30	70:30	10.7	97	4.6	150
42	70:30	12.2	90	4.9	72
50	70:30	12.6	87	6.6	92
30	50:50	8.9	81	4.2	136
30	70:30	10.7	97	4.6	150
30	80:20	9.7	88	4.3	140
Open-end yarn					
84	65:35	8.7	64	6.9	83
Ring-spun yarn	Polyester/cornhusk				
27	65:35	17.6	117	15.7	104

[a] g/tex = grams/tex. 1 g per tex is equal to 0.11 g/den
[b] Compared to 100 % cotton yarn of the corresponding count for all cotton/cornhusk blends and to 65/35 polyester/cotton yarn for the polyester/cornhusk blends

Fig. 2.2 Sweater developed from a 50/50 blend of cornhusk fibers and cotton

with cotton and polyester and processed on both the ring and rotor spinning machineries [06Red]. It was found that blending cornhusks with cotton provided yarns with good strength and elongation retention as seen in Table 2.2. Cornhusk fiber-blended polyester yarns had higher strength and elongation retention than corresponding polyester/cotton blends of the same count and proportion [06Red]. The cotton/cornhusk-blended (65/35) ring-spun yarns were knitted into a garment (Fig. 2.2) and dyed with reactive dyes.

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