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Review article

Research and application of kapok fiber as an absorbing material: A mini review

Yian Zheng[1], *Jintao Wang*[1,2], *Yongfeng Zhu*[1,2], *Aiqin Wang*[1,*]

1. *Center of Eco-materials and Green Chemistry, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, China. E-mail: zhengyian@licp.cas.cn*
2. *University of Chinese Academy of Sciences, Beijing 100049, China*

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ABSTRACT

Kapok fiber corresponds to the seed hairs of the kapok tree (*Ceiba pentandra*), and is a typical cellulosic fiber with the features of thin cell wall, large lumen, low density and hydrophobic–oleophilic properties. As a type of renewable natural plant fiber, kapok fiber is abundant, biocompatible and biodegradable, and its full exploration and potential application have received increasing attention in both academic and industrial fields. Based on the structure and properties of kapok fiber, this review provides a summary of recent research on kapok fiber including chemical and physical treatments, kapok fiber-based composite materials, and the application of kapok fiber as an absorbent material for oils, metal ions, dyes, and sound, with special attention to its use as an oil-absorbing material, one predominant application of kapok fiber in the coming future.

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*Corresponding author. E-mail: aqwang@licp.cas.cn (Aiqin Ferrer).

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Introduction

Kapok trees belong to the family of Bombaceae and grow in Asia, Africa and South America. Kapok is a silky fiber that encloses the seeds of kapok trees (*Ceiba pentandra*), and the color is yellowish or light-brown with a silk-like luster. Kapok fiber is composed of single-celled plant hairs, in contrast to cotton, which is lignified and not attached to the seed grains.

Due to their unique features, kapok fiber-based materials have opened up possibilities for various new application fields. Therefore, kapok fiber and its composite materials have been gaining increasing attention in recent years. Conventionally, kapok fiber is used as stuffing for bedding, upholstery, life preservers and other water-safety equipment because of its excellent buoyancy (Zhang et al., 2013), and for insulation against sound and heat because of its air-filled lumen (Veerakumar and Selvakumar, 2012; Xiang et al., 2013). Due to its warmth retention properties, kapok fiber can be blended with other fibers to achieve apparel textiles with desired characteristics (Hong et al., 2012). As an important type of lignocellulosic plant fiber, kapok fiber has been used as a reinforcement material in polyester matrixes *via* hybridization with glass and sisal fabrics (Reddy et al., 2008, 2009). Also, kapok fiber can be added into thermoplastic cassava starch (TPCS) to reduce the water absorption of the TPCS/kapok fiber composite and enhance its stress at maximum load and Young's modulus (Prachayawarakorn et al., 2013). The wax layer on its surface enables this fiber to show excellent hydrophobic-oleophilic characteristics, and accordingly, this fiber is receiving increasing interest as an oil-absorbing material (Wang et al., 2012a,b,c, 2013a,b,c,d; Huang and Lim, 2006; Lim and Huang, 2007a,b; Abdullah et al., 2010; Rengasamy et al., 2011) and in packaging paper requiring strength and water repellency (Chaiarrekij et al., 2012). Due to its natural microtube structure, kapok fiber can also be used as a desirable template material (Zhang et al., 2010) or support candidate, for example as a catalyst carrier (Fan et al., 2012). In addition, this fiber is considered to be a potential starting material for the preparation of versatile activated carbon fibers (Chung et al., 2013) or as a second-generation source for bioethanol (Tye et al., 2012). With a focus on the structure and properties of kapok fiber, this review provides a summary of recent studies on chemical and physical treatments, kapok fiber-based composite materials, and recent applications of kapok fiber as an absorbent material for oils, metal ions, dyes, and sound.

1. Structure and property of kapok fiber

1.1. *Kapok fiber*

Kapok fiber is a highly lignified organic seed fiber and mainly consists of cellulose, lignin and xylan (Fengel and Przyklenk, 1986; Gao et al., 2012). The chemical composition of kapok fiber varies in different reports. One study found that kapok fiber was chemically composed of 64% cellulose, 13% lignin, and 23% pentosan on a weight basis (Kobayashi et al., 1977), while another found that kapok fiber was comprised of 35% cellulose, 21.5% lignin, and 22% xylan, with a high ratio of syringyl/guaiacyl units (4–6) and a high level of acetyl groups (13.0%) as compared with normal plant cell walls (about 2%–4%) (Chung et al., 2008; Hori et al., 2000). The differences might be related to the differences in kapok sources and processing techniques. The crystallization degree of kapok fiber has been determined to be 35.90%, the specific birefringence is 0.017, and the bulk density is 0.30 g/cm^3, considering its large lumen (Xiao et al., 2005a).

Kapok fiber is composed of two major layers with differing microfibrillar orientations. The outer layer is composed of cellulose microfibrils oriented transversely to the fiber axis, whereas the inner layer is composed of fibrils oriented nearly parallel to the fiber axis (Nilsson and Björdal, 2008). Optical microscopy and SEM observation found that kapok fiber shows a cylindrical shape, a surface without texture and thickening groins at the ends (Fengel and Wenzkowski, 1986). The surface of kapok fiber is smooth with a thick layer of wax, and the cross-section is oval to round with large lumen and thin wall (*ca.* 8–10 μm in diameter and *ca.* 0.8–1.0 μm in wall thickness) (Mwaikambo and Bisanda, 1999; Chung et al., 2008). This hollow structure differentiates the kapok fiber from other natural fibers and endows it with a porosity of more than 80% (Xiang et al., 2013). As another unicellular fiber, cotton fiber shows a compressed ribbon-like morphology, rolling in a helicoidal manner around the axis (Chung et al., 2008), as shown in Fig. 1.

Owing to its brittleness, low cohesivity and strength, pure kapok fiber cannot be spun like cotton fiber, but can be successfully blended with cotton fiber to form yarns. With an increase in kapok content, the yarn regularity and tenacity decrease while the yarn extensibility increases, in addition to reduced total cost of production for the yarns (Dauda and Kolawole, 2003). However, the large lumen and waxy surface are not favorable for the access of hydrophilic coloring agents