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Short note

A note on Chinese Bamboo paper: The impact of modern manufacturing processes on its photostability



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ABSTRACT

Papermaking has a special place in the cultural heritage of China. Papers made from different types of plant fibers were, and are still used for particular applications. Bamboo paper is a handmade paper that has been traditionally used for book printing and restoration of ancient paper objects since antiquity in China, whereas *Xuan* paper, the subject of recent previous study, is used for traditional Chinese calligraphy and painting. Following our previous approach on *Xuan* paper, four modern Bamboo papers manufactured using traditional or chemically-facilitated techniques were artificially aged by UVA radiation and changes to their optical properties were evaluated by reflectance and 3D-fluorescence spectroscopies. Paper samples produced by different methods displayed different fluorescence spectra and UVA photolysis of paper resulted in decreases in the fluorescence intensities and reflectance values, manifested as differing photoyellowing of the papers. Assays of reactive oxygen species, ROS, revealed that papers made by chemically-assisted pulping methods generally produce more hydrogen peroxide or superoxide radicals than those made by traditional methods, which correlates with their relative yellowing rates. Different spatial distributions of calcium and chlorine were also observed by SEM/EDS analysis in the chemically-manufactured papers, probably arising from the specific pulping and/or bleaching chemicals used in their manufacture.

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1. Research aims

This study reports the fluorescence and photochemical characteristics of Bamboo paper upon exposure to UVA radiation as well as the effects of different manufacturing techniques on the optical properties and photostabilities of paper. Four types of Bamboo paper manufactured using traditional or chemically-facilitated methods were investigated. Their photooxidative stresses associated with the production of hydrogen peroxide and superoxide radicals during irradiation were measured and relative photostabilities were assessed by reflectance and 3D-fluorescence spectroscopies. Scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS) was employed to examine the morphological and elemental characteristics of paper. The objective is to provide fundamental knowledge for how production techniques, especially the use of synthetic chemical agents, determine the relative photostabilities of Bamboo paper. This contributes not

only to the conservation of Asian paper artefacts but also to the preservation of traditional papermaking crafts.

2. Introduction

Bamboo paper, also known as *Liانشi* paper, is a type of Chinese handmade paper of significant cultural and heritage value. Bamboo paper features the qualities of whiteness, softness and thin form, and has been used extensively for printed books throughout history [1]. Today, this paper is still produced in some areas of China to meet needs of artists as well as for the restoration of ancient paper objects. In 2006, the craft of making Bamboo paper was listed as a National Intangible Cultural Heritage of China [2].

Bamboo paper is manufactured from pulped young twigs of bamboo (*Phyllostachys aurea*), a plant that was extensively cultivated in China and has been a major source of papermaking fiber since the 8th century [3]. Traditionally the paper was made using natural materials, hand-tools, utensils and naturally-occurring reagents. Step-by-step processes of the manufacture were well documented by Song Ying-Xing (AD 1587–1666) in his book “*Tian Gung Kai Wu* (The Exploitation of the Works of Nature)” [4] as well as in Needham’s multi-volumed work, “Science and Civilisation in China” [3]. General procedures include: “removing the green” by

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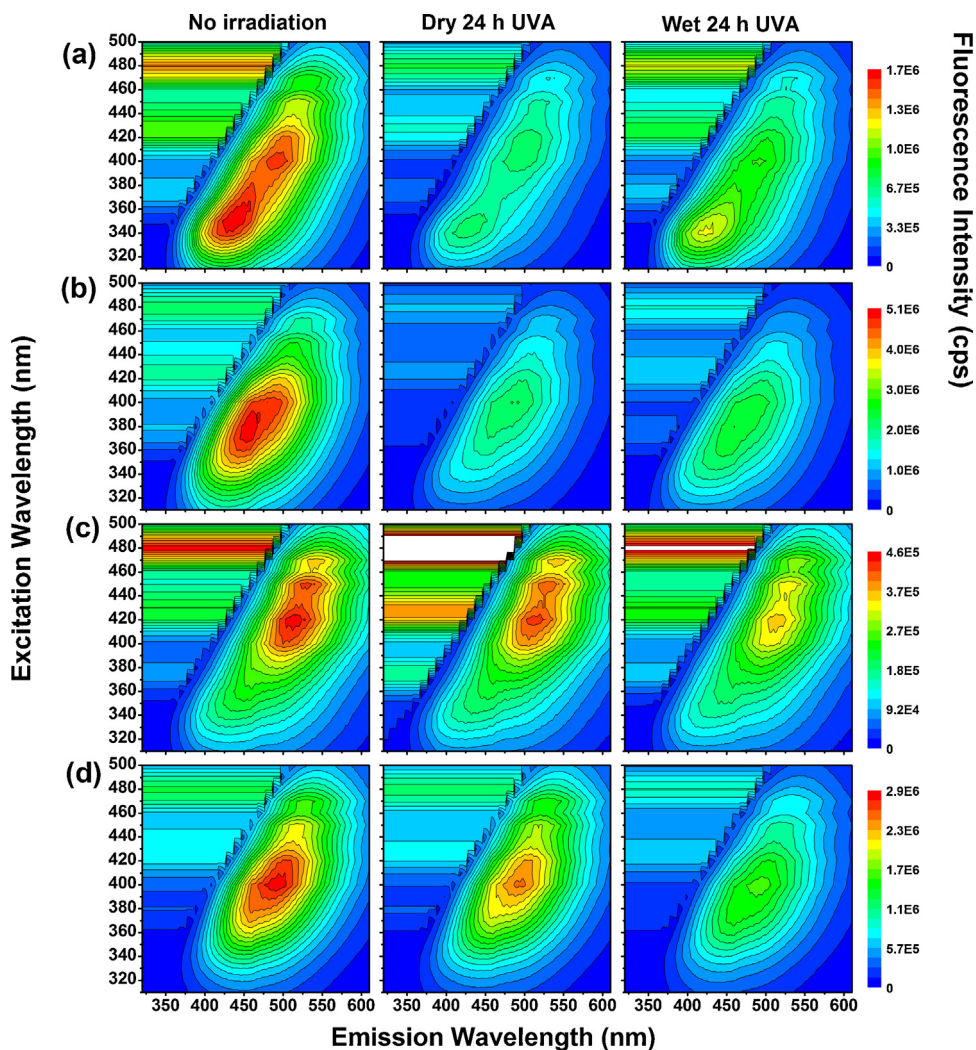


Fig. 1. 3D-fluorescence spectra of four Bamboo papers B1 (a), B2 (b), B3 (c) and B4 (d) before (left side) and after 24 hrs of UVA irradiation, under dry (middle) or wet (right side) conditions.

repeated soaking, pounding, cooking, rinsing, and solar bleaching of the plant materials; forming paper sheets by casting the pulp on a perforated screen; pressing the sheets to expel water; and finally drying on a heated brick wall. The traditional manufacture of Bamboo paper is an arduous and painstaking process, and may take about eight months to one year to produce the sheets of paper [4]. From the 20th century, synthetic chemical reagents have been employed to accelerate the manufacturing process [5,6]. For example, calcium hypochlorite has been used in the preparation of pulps instead of traditional solar bleaching, and sodium hydroxide, in the cooking/thermal hydrolysis stage [1,6]. However, papers produced using these present-day techniques are generally considered inferior in quality, especially with regard to lightfastness, to the traditionally-manufactured paper [7]. Concerns are raised about their appropriateness for paper conservation, and the traditional papermaking crafts are in danger of being lost [6].

Unlike the famous *Xuan* paper [8], reports of scientific research on Bamboo paper are comparatively rare and most have been confined to ethnographic field studies of the paper handicrafts in different regions of China [1,5,6,9]. These reports have contained some preliminary investigations of the relationship between the permanence of the paper and its methods of manufacture. For example, Su's study revealed that Bamboo papers produced by traditional solar bleaching and repeated thermal treatment with alkaline solutions made by dissolving lime or extractions of wood ash in water

retained their whiteness and strength during accelerated thermal ageing better than those made by modern methods [1,6]. However, there has to date, been no quantitative evaluations of the photostability or lightfastness of Bamboo paper nor an elucidation of the underlying mechanisms. Our recent work on *Xuan* paper was the first fluorescence and photochemical study of Chinese handmade paper during artificial photoageing, in which a novel approach was developed to assess the yellowing rate of paper by spectroscopic changes together with assays of the concomitant formation of reactive oxygen species [10].

3. Experimental

3.1. Materials

The Bamboo papers investigated were sourced from Fuyang County, China, where the tradition of making Bamboo paper has been maintained for many years. Paper samples labelled as B1–B4 were manufactured using either traditional or chemically-assisted methods. As stated in Table 1, B1–B2 were of the same origin and were both made from traditional pulps (heating with aqueous extracts of wood ash or lime water), but the latter had been treated with calcium hypochlorite instead of exposure to sunlight. The samples of paper types, B3–B4, were produced from chemical

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