DEVELOPMENT OF BIO-BASED COMPOSITES FROM WASTE VEGETABLES

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Abstract

Recently, increased attention by many countries has been directed towards the effective recycling of waste products from natural resources, as a means of conserving resources and protecting the environment. In this study, a composite material was developed using waste vegetables as the matrix material, and bamboo pulp as the reinforcement fiber. The bamboo/vegetable composite material was constructed using hot press molding, with the vegetable content varied. Morphological observations and tensile property tests were undertaken on the composite material. The findings demonstrate definite matrix properties associated with the vegetable material. Tensile properties were found to vary according to the kind of vegetables. The bamboo pulp was found to operate as a reinforcing medium for the vegetable matrix, with remarkable improvements observed in the tensile strength and tensile modulus when compared with that of the control samples. The welsh onion composite displayed the highest tensile strength and tensile modulus with the lowest elongation value.

1 INTRODUCTION

In an effort to develop a recycling-based society and to protect the environment, increasing attention is being paid by many countries to the effective recycling of waste products from natural resources. The recognized advantages of using natural fibers include their low density, low cost, high recyclability and bio-degradability characteristics [1,2]. In recent years, there has been an increased focus by researchers on the processes and applications of plastic composites reinforced with natural fibers [3-5]. Another study hotspot is the development of biodegradable resins which are not sourced from petroleum resources. A successful example is Polylactide acid (PLA), a transparent plastic made from natural resources [6], which is now widely applied throughout the world.

Bamboo is a renewable and inexpensive resource, which is very easy to grow with strong durability, stability and tenacity[7]. Bamboo is composed of cellulose fibers, and is a valuable resource in paper making with a history dating back about 1500 years. Because of its many merits, bamboo is also widely used as reinforcement for plastics, a factor contributing to its selection for use in this study.

Large volumes of agricultural refuse are generated each year in Japan, with the effective reusing of this refuse material occurring at very low levels. Vegetable waste is an example of such refuse, where each year approximately 40% of total production are disposed of without reuse. Waste vegetables include vegetables displaying a poor form or trauma, which renders them unsuitable for commodities markets.

Vegetables are comprised of cellulose fiber, protein, fat, carbohydrate, and ash, with the potential to function as a matrix material. To date, there have been few studies investigating vegetable composites. This study was conducted to enrich the body of knowledge concerning the use of waste vegetable materials for composites, and to further efforts in the effective recycling of agriculture waste products. In this study, an onion, bell pepper and welsh onion composites reinforced with bamboo pulp fiber were developed, and the corresponding tensile properties were studied in detail.

2 EXPERIMENTAL METHOD

2.1 Materials

Bamboo fibers were sourced from bamboo pulp with a freeness of 727 ml (CSF). The average fiber length and diameter were 0.43 mm and 11 μm, respectively. Using a mixer, the vegetables were crushed and used as the composite. The bamboo pulp and the vegetables used are shown in Fig.1. The fresh vegetables contained a large proportion of water, around 90 wt%, with a remaining rough fiber content of about 20~30 wt% in the dry material. Also contained in the vegetables are natural polymers of carbohydrates and proteins. The composite materials of the vegetables used here, and the chemical components and contents of the vegetables are shown in Table 1.

(a)Bamboo pulp (b) Onion (c) Bell pepper (d) Welsh onion

Fig.1 Photograph of bamboo pulp (a) and vegetables(b~d)

Table 1. Component of vegetables [8]

(g/100g)

Component	Onion	Bell pepper	Welsh onion
Water	89.7	93.4	91.7
Carbohydrate	8.8		7.2
Inorganic matter	0.21	0.223	0.24
Vitamin	0.008	0.077	0.0003
Rough fiber	1.6	2.3	2.2

2.2 Molding method

The vegetable sheet and bamboo reinforced vegetable composite for this study were produced according to the paper making methods shown in Fig.2.

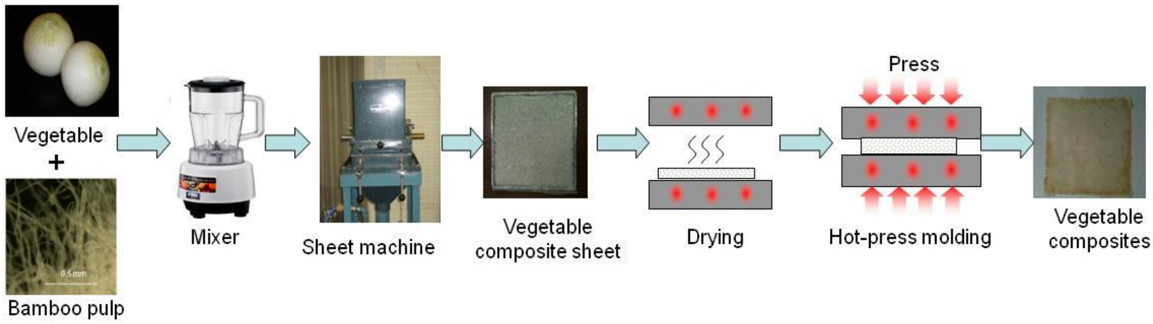

Fig.2 Flow chart of molding method

The poorness of the vegetables was removed, with the fresh vegetables crushed using a mixer, and then combined with the bamboo pulp. Using paper making technology according to the JIS P8222 standard, 25×25 cm bamboo/vegetable composite with different bamboo contents were produced using a PU-401 sheet machine (Tester sangyo. Co., Ltd). The basis weight of the composite was controlled at approximately 300 g/m^2.

2.3 Test method

Morphological observations of the vegetable composite reinforced with bamboo fiber was conducted using a scanning electron microscope (SEM, Hitachi S-3000). The tensile properties of the bamboo/vegetable composite with different bamboo contents were measured using a universal tensile machine (AGS-J, 10 KN, SHIMADZU) according to the JIS K7113 standard. The test values stated are averaged values from five samples.

3 RESULT AND DISCUSSION

3.1 Morphological observation

In this paper, the morphological observation was carried for the onion composite briefly and are shown in Fig.3. The onion composite is characterized by a relatively light color with a smooth broken line.

Fig.3 Images of the onion film sample

SEM image taken of the surface of the onion composite products is shown in Fig.4. In Fig.4, the bamboo fiber combined tightly with the onion matrix, and the surface was relatively smooth. After tensile tests were conducted, the SEM images of composite material was again collected, as shown in Fig.5. As is shown in this figure, the pull out of the bamboo pulp occurs at the broken area.

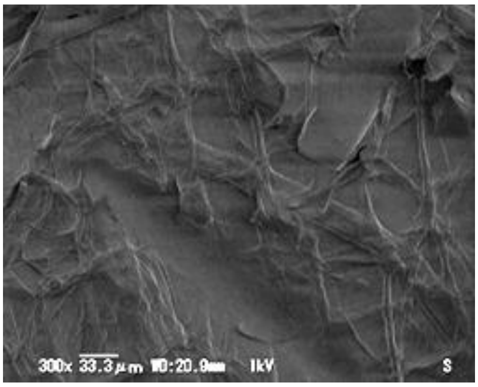

Fig.4 SEM photograph of surface of 23wt% bamboo reinforced composite

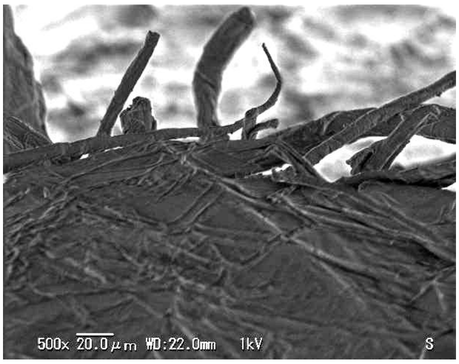

Fig.5 SEM photograph of the broken surface of 23 wt% bamboo reinforced onion composite

3.2 Tensile properties

The tensile properties of the vegetable composites were tested according to the JIS 7113 standard. The tensile strength and tensile modulus are shown in Fig.6 and Fig.7, respectively. The findings indicate that the tensile strength and modulus of vegetable sheet without reinforcement vary largely by the kind of vegetables. The welsh onion has highest tensile strength in the vegetables used here and the fairly larger value of tensile modulus can be seen in Fig.7. It is not clear now which ingredient of vegetables affect the strength and modulus.

The tensile strength and modulus increase with increasing the bamboo content and take a peak value at 10~20wt% of bamboo content. After peak value of bamboo content, the strength and modulus decrease with increasing the bamboo content. This may be caused by the lack of vegetables as matrix material at higher bamboo content.

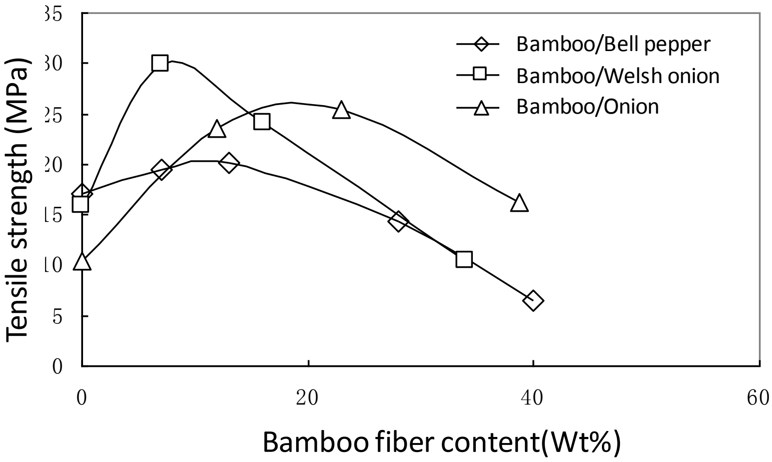

Fig.6 Tensile strength of vegetable composites

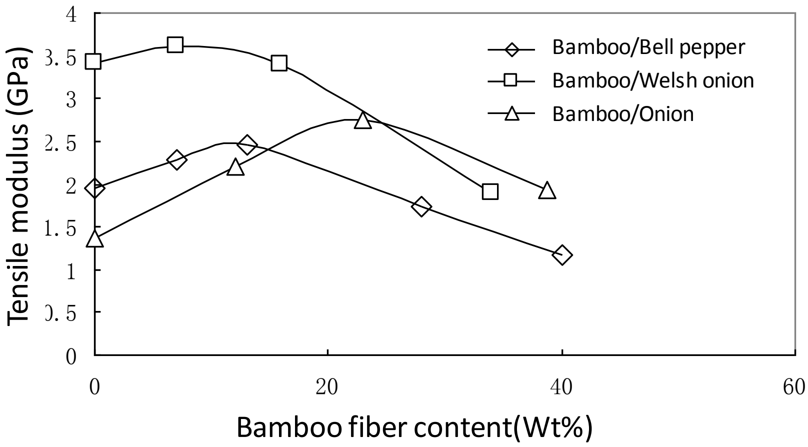

Fig.7 Tensile modulus of vegetable composites

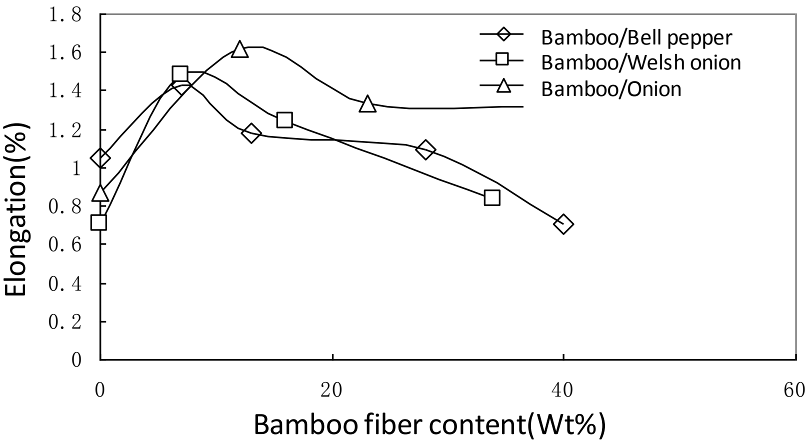

Fig.8 Elongation of vegetable composites

The elongation values of composite materials are shown in Fig.8. The findings indicate that the highest value can be obtained around 10wt% of bamboo content, and the elongation gradually decreases with increasing the bamboo content.

4 CONCLUSIONS

In this study, the construction of vegetable composite material reinforced by bamboo fiber was successfully achieved. The following conclusions are summarized from the analysis of the tensile properties of the vegetable composite materials.

Vegetables composed of differing percentages of ingredient were found to have varying tensile properties. The findings of this study demonstrate that vegetable film is suitable for use as the matrix in a composite, which can be further reinforced by bamboo fibers.

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