Preliminary

Application of Wood-rot Fungi Treatment in the Production of Auto-bonding Wood Flour Moulding

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Introduction

Various kinds of synthetic moulded products have been derived from fossil resources such as coal and crude oil. However, these resources are not sustainable and some of them are harmful to the environment. Therefore, production of moulded materials derived from renewable and biodegradable resources such as wood may become important in the near future. Taking into consideration of these facts, the production of moulded products from wood flour without using any additives was attempted. When fine flours (<0.065 mm) from radiata pine wood were compressed in a die, high strength plastic-like moulded products were obtained without the use of adhesives and chemical modification[1]. These products were readily disintegrated when they were immersed in boiling water. Furthermore, the products were recyclable and biodegradable. However, in the production of these products, wood flour had to be moulded at high temperature and high pressure, 220°C and 100 MPa, respectively.

There are a wide variety of wood-rot fungi, which can depolymerize or modify wood components. For example, when wood blocks are colonized by selective delignifying fungi such as *Ceriporiopsis subvermisopra,* lignin is degraded without cell wall erosion by the generation of free radicals *in situ*[2-5]. On the other hand, non-selective white rot fungi like *Coriolus versicolor* decomposes cellulose and at the same time lignin with extensive cell wall erosion. Brown rot fungi preferentially decompose cellulose with partial modification of the lignin structure. Furthermore, the treatment of wood with those wood-rot fungi would be more environmentally friendly than chemical treatments.

Therefore, the plasticization of wood by the treatment with wood-rot fungi was attempted with a view to reducing the energy required for the production of moulded wood products.

Materials and Methods

A preliminary experiment was carried out to select wood-rot fungi, which had the potential to plasticize wood, by using 12 wood-rot fungi of different rotting types. They were *Ceriporiopsis subvermispora* FP-90031, *C. subvermispora* CBS 347.63, *Dichomitus squalens* CBS 432.34, *Phanerochaete chrysosporium* FL-21, *Irpex lacteus* IFO5367, *Coriolus versicolor* K-2073, *C. hirsutus* K-2617, *C. concors* K-1198, *C. vellerus* K-1957, *Bjerkandera adusta* K-2679, *Tyromyces palustris* TYP6137, *Gloeophyllum trabeum* IFO-6268. From the results of a preliminary experiment on the changes, due to the treatment, in thermal softening behaviour of wood specimens in the ethylene glycol swollen condition[6] and the mechanical properties of moulded products, which were prepared from the wood-rot fungi treated wood flour, four wood-rot fungi, *C. subvermispora* FP-90031, *C. versicolor* K-2073, *T. palustris* TYP6137, *G. trabeum* IFO-6268 were selected for this study. The fungal strains were maintained on a potato dextrose agar (PDA, Nissui Co. Ltd.) plate and kept at 4°C until used.

Wood flour of radiata pine (*Pinus radiata* D. Don) was packed in a polyethylene bag designed for the use of mushroom cultivation (200×440×120 mm, NT Kino-Pack, Nissho Co. Ltd., Hyogo) and sterilized at 121°C for 20 min. Fungal inoculum was prepared by homogenizing the cultured PDA plate with 100ml of sterile water in a Waring blender for the duration of 10 sec 4 times. One hundred ml of a sterile CSL stock solution (pH 4.5) containing corn steep liquor (2%, Wako Pure Chemicals Co. Ltd.) and glucose (1.6%) was also added. Then, the fungal inoculum (50 ml) was added to the wood medium (110 g) and incubated at 28°C for 15, 30 and 60 days at 70% moisture content. After cultivation, the cultures were autoclaved at 121°C for 20 min, cooled and used for the following molding experiments. Controls were prepared under the same conditions without fungal inoculation.

Fungi treated wood flour (particle sizes less than 0.09 mm) was added to the untreated wood flour (particle sizes less than 0.09 mm) in the ratio of 1 to 1 (w/w) and well mixed using a mortar and pestle. A preliminary experiment showed that the addition of moisture by 8 to 10% to the wood flour was effective in decreasing the moulding temperature from 220°C to 160°C, however, the bending strength decreased by about 10%. Hence, a mixture of air-dried wood flours (approximately 12g, 8-10% moisture content) was put into a stainless steel cylindrical die (70 mm inner diameter) and hot-pressed at 130°C or 160°C and 30 to 100 MPa for 10 minutes, to prepare a moulded product of approximately 2 mm thickness. The press was cooled to 20°C over a period of 8 minutes, from which the die at approximately 20°C was

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removed and allowed to cool to room temperature and the samples were removed from the die. Two samples of moulded products were prepared from each processing condition. For comparison, the wood flour treated under the same condition without fungal inoculation was moulded under the same conditions. From each sample two test specimens (50 mm by 12 mm by 2 mm) were obtained for evaluations of their mechanical properties. The specimens were subjected to three-point bending test at a displacement rate of 5 mm/min and a span of 40 mm.

Results and Discussion

The weight loss of wood flour due to the wood-rot fungi treatment is shown in Table 1. The weight loss also increased with an increase of the incubation time. The degree of weight loss was more remarkable in the brown rot fungi treatment, where the weight loss reached around 60% after an incubation time of 60 days. On the other hand, the weight loss due to the white rot fungi treatment was small compared to the brown rot fungi treatment and the maximum weight loss was only 13.5%.

Table 1. Percent weight loss of radiata pine wood due to wood-rot fungi treatment.

Fungal strain	Incubation time (day)		
	15	30	60
C. subvermispora FP-90031	5.5	7.6	11.0
C. hirsutus K-2617	4.5	9.2	13.5
T. palustris TYP6137	1.0	7.8	28.5
G. trabeum IFO-6268	9.5	30.5	57.9

The mechanical properties of moulding products prepared from the 30 days fungi treated wood flour are compared in Fig. 1. The moulding pressure, temperature and time were 100 MPa, 130°C and 10 minutes, respectively. Modulus of elasticity (MOE) of 2 to 3 GPa higher than those of control samples were obtained at any fungi treatments. The modulus of rupture (MOR) of the samples prepared from the white rot fungi treated wood flour were in a range of 50 to 60 MPa. These values were about 10MPa higher than those obtained by the control samples and were comparable to the values of moulding which compressed oven-dried untreated wood flour at 210°C and 100MPa for 10 minutes in this study. Therefore, it can be said that the treatments using *C. subvermispora* and *C. hirsutus* are effective in reducing the moulding temperature at lower weight loss. On the other

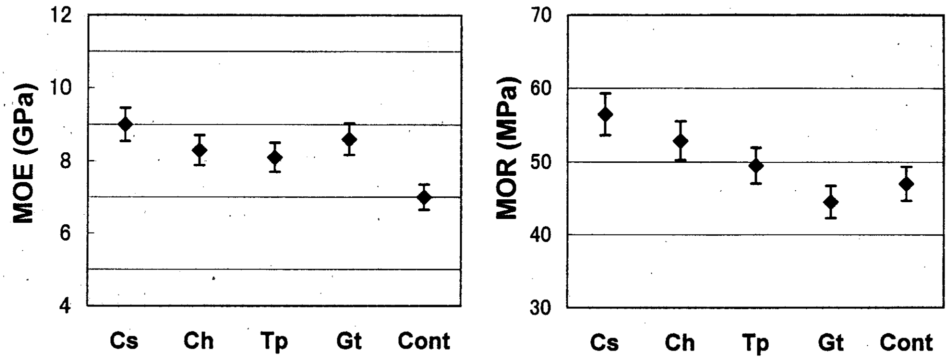

Fig. 1. Mechanical properties of moulding products compressed at 100 MPa and 130°C for 10 min. Air-dried radiata pine wood flour with fungal treatment for 30 days. Results are average value of 4 tist samples with 95% confidence interval. Cs : *C. subvermispora* FP 90031, Ch : *C. hirsutus* K-2617, Tp : *T. palustris* TYP 6137, Gt : *G. trabeum* IFO 6268, Cont : autoclaved with CSL/glucose medium.

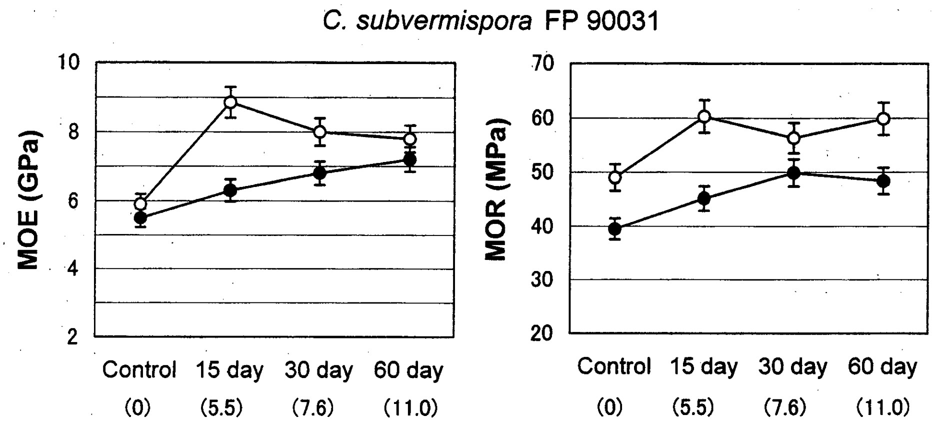

Fig. 2. Mechanical properties of moulding products made from radiata pine wood flour treated with *C. subvermispora* FP 90031 for 15, 30 and 60 days. Values in parentheses refer to percent total weight loss. Results are average value of 4 test samples with 95% confidence interval. —●— 130°C, —○— 160°C, 30 MPa, 10 min.

hand, the MOR of the samples prepared from the brown rot fungi treated wood did not differ significantly from that prepared from the control wood. The difference in MOR between white rot fungi treatment and brown rot fungi treatment may be attributable to the difference in the degree of damage caused to the cellulose, which is a framework of cell walls.

The relationships between mechanical properties and incubation time for the moulded samples treated by *C. subvermispora,* which gave the highest MOE and MOR amongst the four fungi treatments in Fig. 1, are shown in Fig. 2. The moulding temperature, pressure and time were 130°C and 160°C, 30 MPa and 10 minutes, respectively. As is seen in Fig. 2, the MOE and MOR of the samples moulded at 130°C increased with an increase of the incubation time, however, those of the samples moulded at 160°C almost reached maximum values in 15 days. Therefore, it can be said that the increase of temperature from 130°C to 160°C is effective in reducing the incubation time.

Consequently, it can be concluded that the wood-rot fungi treatment is a promising pretreatment for the moulding of wood flour, since it decreased the moulding temperature and is environmentally friendly.

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