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Bio-based seedling pots manufactured from rice hulls and straw by employing the high-pressure steam approach

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The high-pressure steam treatment was successfully employed to fabricate seedling pots from rice straw and rice hulls. While the pots fabricated from rice straw were quite stable with respect to water, pots fabricated from rice hulls absorbed more water upon swelling. Making the pots with ground raw materials significantly reduced thickness swelling for both materials and was an effective means of ensuring water stability. The addition of varying proportions of rice bran as natural binders also ensured the production of durable pots from rice hulls. The addition of rice bran to the rice hulls increased the internal bond strength as well as the nitrogen content of the pots. Pot fabrication was possible with the addition of bran from 10% up to 60% for rice hull while pot fabrication was possible up to 40% of bran addition for the ground rice hulls. Preliminary tests with wheat seedlings yielded quite satisfactory results.

Keywords: Rice hulls, Rice straw, High-pressure steam treatment, Seedling pots

1. INTRODUCTION

Rice hulls and straw are very common agricultural residues generated in large volumes in rice growing countries. As biodegradable raw materials, seedling pots manufactured from such agricultural residues will be much more socially acceptable as eco-friendly materials than conventional plastic pots. Seedlings can be wholly transplanted with the pots thus avoiding root disturbances as in the case of conventional plastic pots. Maximization of crop production can be achieved as transplant failures arising from root disturbances can be eliminated. In addition, organic pots provide nutrients that may be readily available to seedlings. Examples of organic pots made from composts and other agro-industrial wastes have been reported by some authors in recent years [1-3]. Biodegradable pots are already on sale in many countries but the possible use of chemical binders in their production process still discredits them as environmentally friendly materials.

In this paper, we present a report on the use of high-pressure steam to fabricate pots from rice hulls and straw without using chemical adhesives. Our previous work on biomass boards fabricated by the high-pressure steam method revealed that the physical characteristics of boards from rice hulls were very unsatisfactory [4,5,6,7]. In this work, the impact of initially adding varying proportions of rice bran as a natural binder to the rice hulls was investigated. Other objectives also include a determination of the physical characteristics and chemical constituents of the pot materials. Our final objective was to conduct a preliminary test to find out whether the pots had any impact on the growth of wheat seedlings.

2. MATERIALS AND METHODS

2.1 Pot fabrication process

The main raw materials used were rice straw (cut roughly into 1 cm lengths), ground rice straw, rice hulls and ground rice hulls. The particle sizes of the ground materials were below 2 mm. The high-pressure steam method is briefly explained as follows. The raw materials are oven dried at 105℃ for about 3 hours after which 100g are placed in each of the holes shown in the metallic frames in Fig. 1. The frames are covered and placed inside an apparatus (Hisaka made HT-60/250) for steam to be passed at 105℃ for 20 minutes to soften the materials. The softened materials are then compressed while the steam temperature is gradually elevated to 180 ℃ for a 10-minute duration. The pressing component has a capacity of 65MPa. The target density of the pot materials was about 0.7 g/cm^3.

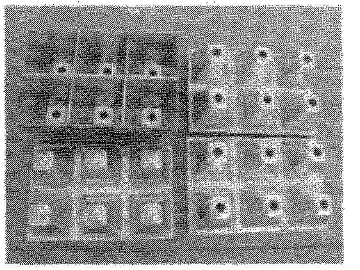

Fig. 1. A photograph of the metallic frames in which samples are compressed

2.2 Testing of samples

In accordance with JIS A5908-2003 specifications, samples were cut from the boards for physical tests such as thickness swelling (TS), water absorption capacities (WA) and the dimensional stability after repeated cycles of soaking in water and oven drying. For the determination of TS, test samples were soaked in water for 24 hours and the percentage increases in thickness measured. WA was calculated as the percentage increase in weight due to the soaking. Samples were also soaked in water for 72 hours to determine the type of ions released into solution. Samples from rice hull pot materials with varying proportions of rice bran were also analyzed for their physical properties as well as total nitrogen and carbon contents.

2.3 Establishment of wheat seedlings in pots

Six pots were used for each material (a total of 24 pots). The pots were filled with the same amounts of soil and three seeds initially sowed in each of them. After sprouting, the healthiest shoot was selected and allowed to remain while the rest were pruned. Water application rate was the same for all the pots. The experiments were carried out in a glass house at the Faculty of Agriculture, Gifu University campus, at the beginning of October 2002.

3.RESULTS AND DISCUSSION

3.1 Thickness swelling (TS) and water absorption (WA)

Fig. 2 shows typical samples of the pots manufactured from ground rice hulls and straw. After soaking the samples in water for 24 hours, an extremely high value of 46.6% was obtained as the TS for rice hulls. The percentage increase in absorbed water was also highest for rice hull samples (Fig. 3). This high water absorbing property meant that the pots fabricated from rice hulls could easily crumble upon contact with water and so extra care had to be taken while handling them. TS value obtained for the ground hulls was 28.6%. The impact of grinding resulted in the ground hull pots absorbing less water with less swelling.

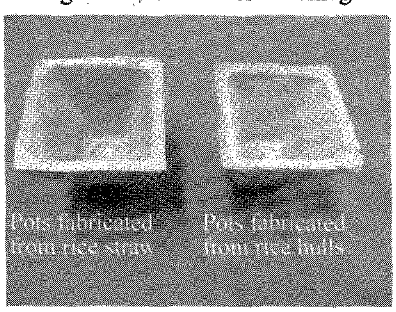

Fig. 2. A photograph showing two of the final products

On the other hand, rice straw and ground rice straw pots had relatively low values of thickness swelling and absorbed less water implying that pots made from these materials were much more water-resistant.

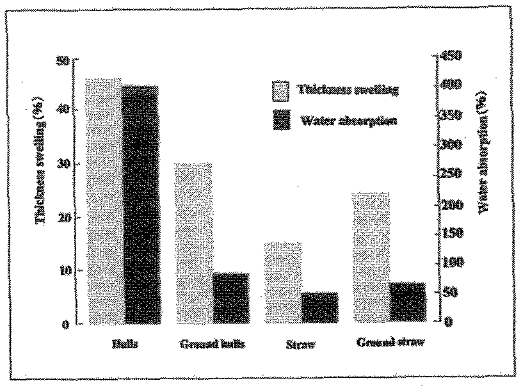

Fig. 3. Thickness swelling and water absorption capacities for the different materials

3.2 Dimensional stability

As shown in Fig. 4, samples from ground rice straw exhibited the highest stability. The samples remained stable even after boiling for 30 minutes. On the other hand, all the rice hull samples crumbled after excessively soaking up water. It was therefore not possible to continue with the dimensional stability assessment for the rice hull samples. It is clear from Fig. 4 that for both materials, the impact of grinding could improve their dimensional stability to water.

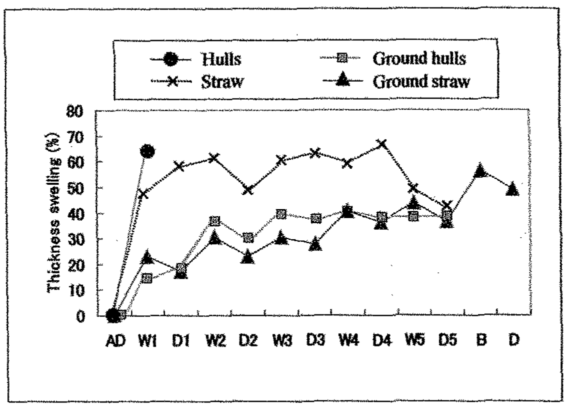

Fig. 4. Changes in the thickness swelling
(AD = Air dry; W1～W5 = 24 hours immersion of samples in water; D1 ～ D5 = Oven drying at 105℃ for 6 hours; B = Boiling)

3.3 Ions released from the pots

Ion chromatographic analyses revealed the presence of potassium, magnesium, calcium and phosphate as the main ions. On the whole, the concentrations of ions were higher for rice straw compared to the values for the hulls (Fig. 5)

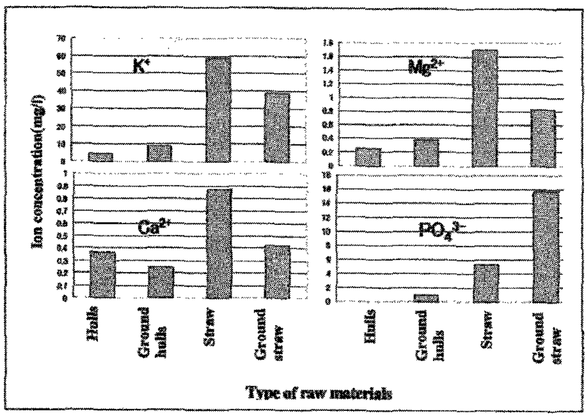

Fig. 5. Concentrations of potassium, magnesium, calcium and phosphate ions extracted from the pot materials

3.4 Effect of adding rice bran on internal bond strength (IB)

Results of internal bond strength upon the addition of varying quantities of rice bran to the hulls and ground hulls are shown in Fig. 6. For the hulls, fabrications of pots were possible with up to the addition of 60% of bran beyond which bran particles, which are very fine, spilled from the sides of the metallic frame after compression. Thus it was impossible to produce pots using only rice bran as the raw material. The peak value for IB was obtained with 50% addition of bran. Pot fabrications were possible for the ground hulls up to 40% with the peak value for IB occurring at 30% bran addition.

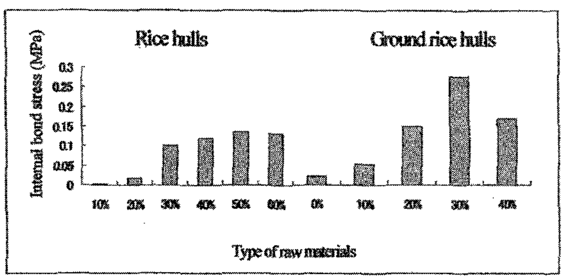

Fig. 6. Effect of adding rice bran on the internal bond strength

3.5 Effect of bran addition on thickness swelling (TS) and total nitrogen (TN)

The addition of varying quantities of rice bran gradually reduced the TS values of the hulls from 43.63% to 9.78% though the addition of 10% bran did not cause any appreciable changes (Table 1). In the case of the ground hulls, the addition of 10% bran resulted in a drastic decrease in TS but the effect of subsequent additions were not conspicuous. The impact of adding bran also increased the total nitrogen content of both hulls and ground hulls. This is seen as a very encouraging result as only traces of nitrogen were released into solution when pot samples were soaked in water.

Table 1. Total nitrogen and thickness swelling for rice hulls and ground rice hulls at varying proportions of bran

Percentage of rice bran added	Rice hulls TN (%)	Ground rice hulls TN (%)	Rice hulls TS (%)	Ground rice hulls TS (%)
0%	0.22	0.19	43.6	28.6
10%	0.37	0.31	44.4	14.7
20%	0.48	0.44	27.4	16.5
30%	0.57	0.57	28.9	12.8
40%	0.96	0.64	19.2	10.8
50%	1.22	*	11.5	*
60%	1.72	*	9.8	*

3.6 Cultivation period and dry matter

The experiment was discontinued after 8 weeks of cultivation and all the shoots were dried and weighed to determine the dry matter content. The reason for terminating the experiment was that the available soil nutrient was unable to support further growth and this reflected in the yellowing of leaves and reduced growth of the seedlings. The experiments were carried out in a glass house from the beginning of October until the end of November (2002). Transplanting was not possible because it was too cold outside. Although there were no significant differences between the dry matter weights, the figure for the control (conventional plastic pots) was the highest while that of rice straw pots was the lowest (Fig. 7). Unlike the plastic pots, the biodegradable pots are porous materials that are likely to allow water and nutrients from the soil to leach out during the application of water. This can affect the available nutrients in the pots and reflect in slight differences in the growth of the seedlings.

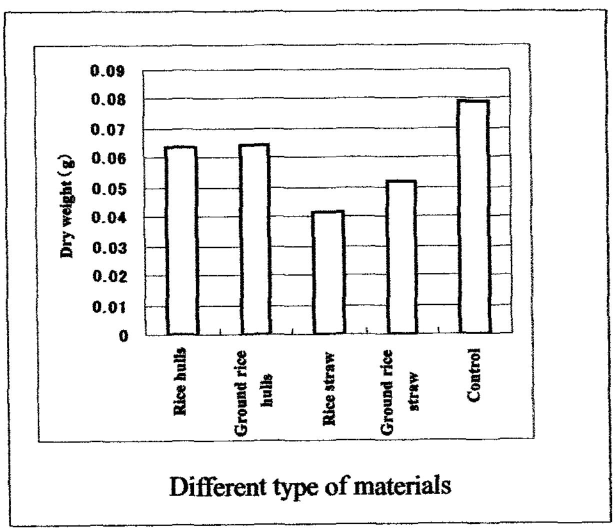

Fig. 7 Dry matter of wheat seedlings after 8 weeks of cultivation

4. CONCLUSIONS

Without using chemical adhesives, it was possible to fabricate seedling pots from rice straw and hulls. Although preliminary tests have only been conducted on wheat, the indications strongly suggest that a wide variety of seedlings can be successfully nursed in pots fabricated by the process described in this paper. Pots fabricated from rice straw were much more durable than rice hull pots. However, the addition of rice bran could decrease the thickness swelling and improve the internal bond strength of the rice hull pots. By using these two agricultural residues, it was also revealed that grinding into smaller particles could result in much more durable pots. Previous studies have shown that particle size could influence the physical characteristics of boards [4]. Further investigations are needed to produce pots or boards from other residues generated during forestry and agricultural activities. It is worth mentioning that the final products were not only made with an eco-friendly process but also economically feasible as the materials used in our studies are all generated during the production of rice.

Further studies are also needed to shed more light on the time required for pots fabricated from different raw materials to completely decompose as well as their nutritional availability to seedlings.

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