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Pulverization of rice husks and the changes of husk densities

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Well-dried rice husks were pulverized using a rotating knife cutter, and then classified using sieve separation technique. Most of the milled rice husks, which were screened by a 40-mesh sieve at the bottom of the cutter, were found to be in the range of $-50/+100$ mesh. Morphology of the milled rice husks drastically changed with size from a flake-like shape at $+70$ mesh to a dust-like shape at -325 mesh. Tap density of unmilled raw rice husks was about 0.1 while that of milled rice husks was over 0.4. True densities of milled rice husks were higher than 1.4, and increased with decreasing milled husk sizes. Compared to bulky raw rice husks, the pulverized rice husks can be handled as a powdery material for further industrial processing.

1. Introduction

Research into industrial utilization of rice husk silica has long been continued in rice cultivating and other related countries. Since Lee and Cutler [1] started new materials development using rice husks, reports on powders and whiskers of SiC, Si_3N_4 and SiO_2 from rice husks have frequently been made [2–5]. Despite such research activities, the huge amounts of rice husks being produced all over the world are still treated as bio-wastes. They are simply poured onto rice growing fields or spread on pigpen floors as drying absorbents.

Since rice husks are composed of very elastic and fibrous thin glumes, it is difficult to pulverize rice husks using conventional methods such as ball milling. Thus, most researchers use raw rice husks in their works. Raw rice husks are empty and very low in apparent density, so the amounts of reaction products are very small compared to the volumetric capacity of the reaction equipment. When these hollow raw rice husks are milled into fine powders, the apparent density increases. The amounts of reaction charge can be enlarged and the reaction rates such as chemical treatments, oxidation, and carburization will be enhanced due to the increased specific surface area. Although some pulverizations of rice husks have been reported [6–10], nobody has tried to characterize the pulverized rice husks. A rotating knife cutting method was applied in the present work to pulverize raw rice husks in order to increase their charge density. Changes in morphology and densities of milled rice husks with the pulverization were investigated.

2. Experimental procedure

The most effective method of pulverizing rice husks is to cut them using sharp edges. From this point of view, a rotating knife cutter is one of the best methods for milling rice husks. A schematic drawing of the rotating knife cutter used in the present work is depicted in Fig. 1. Raw rice husks are fed from the hopper into the milling chamber where they are cut into pieces between the stationary and the high revolutionary rotating knives. By repetition of this comminution process, rice husks are cut into fine powders. The size of final milled powders can be controlled by the screen inserted at the bottom of the milling chamber. The rice husks are continuously comminuted in the milling chamber until they become small enough to pass through the inserted screen. In the present work, a 40

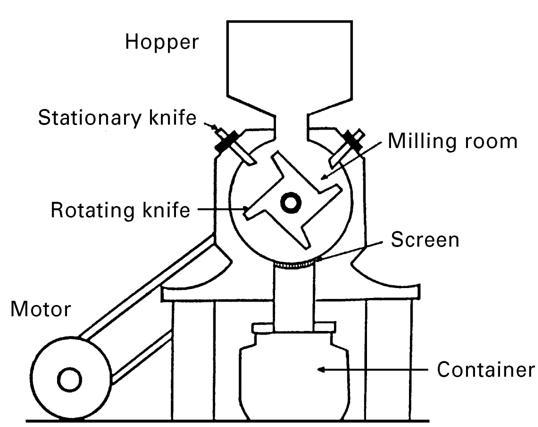

Figure 1 Schematic drawing of rotating knife cutter.

mesh screen was inserted. The cutter used in the present work was a small one, for laboratory usage, having two stationary and two rotating knives. The pulverizing capacity of this kind of cutter can easily be enlarged by increasing the number and size of the knives and the rotating speed.

After pulverization, the rice husks were classified using 30, 50, 100, 170, and 325 mesh standard sieves. The openings of the sieves were 600, 300, 212, 150, 90, and 45 μm, respectively. The morphology of classified rice husk powders was observed by scanning electron microscopy (SEM). Tap and true densities were measured and the silica content of the rice husks was analysed.

3. Results and discussion

3.1. Morphology changes

Well-dried raw rice husks were observed by SEM as displayed in Fig. 2. A well-arranged array of cuticles are observed in the outer epidermal surface, as shown in Fig. 2(a). Higher magnification of the outer surface revealed cuticles and horn-like trichomes, as shown in Fig. 2b. However, the inner surface of rice husks shown in Fig. 2c was very smooth.

The pulverized and classified rice husks were observed by SEM. The shape was drastically varied with the size, as shown in Fig. 3. The largest rice husks at −30/+50 mesh class clearly exhibited the thin flake-like shape. This flake-like shape was well maintained in the large sizes. The rice husks at −50/+70 mesh class looked similar to that of −30/+50 size, but seemed slightly damaged. Rice husks at −70/+100 mesh class seemed like chopped flakes with reduced width and height. However, the rice husks smaller than these classes were not flake-like shaped. The rice husks at −100/+170 and −170/+325 mesh classes were of rather brick- or even rod-like shapes, while the smallest size of −325 mesh class looked like fine dusts showing irregular shapes. A large amount of the horn-like trichomes was mostly collected at the class −170/+325 mesh, as shown in Fig. 4.

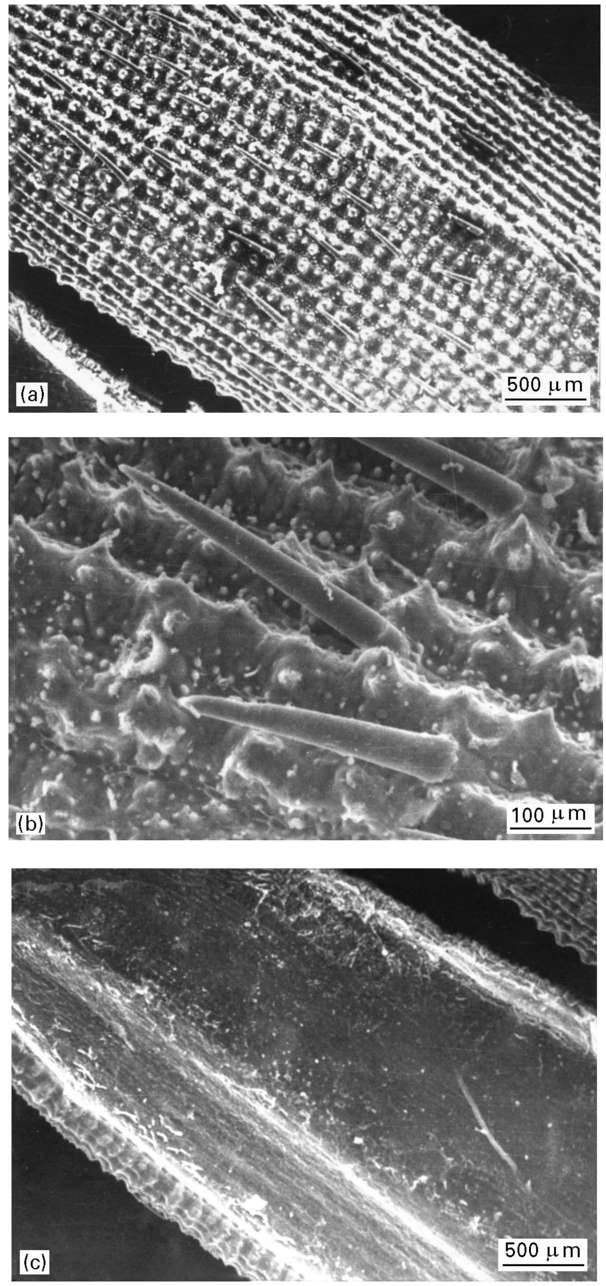

Figure 2 SEM micrographs of raw rice husks; (a) and (b) outer surfaces and (c) inner surface.

3.2. Size distribution

Size distribution of the pulverized rice husks was analysed by measuring the weight of each class. As depicted in Fig. 5, over 66% of powders by weight was found between the size ranges of −50/+70 and −70/+100 meshes. A small amount of husks was found below 100 mesh size. This was caused by either the rice husks being over dried so as to be fragile or the screen inserted at the bottom was not convenient for the properly milled husks to easily pass through. Compared to the grinding disc method [9], the present rotating knife cutting method yielded a more narrow size distribution in milled rice husks.

3.3. Silica contents

The silicon in rice husks occurs as a hydrated amorphous form of silica [7]. This kind of plant silica is called opal phytolith, plant opal, or biogenic opal [11, 12]. Density of this silica is in the range of $1.5 \sim 2.3$. Opaline silica is highly concentrated in the outer epidermis of rice husks [13, 14]. Especially, the horn-like trichomes are mostly composed of this silica [15]. The silica contents of the pulverized rice husks were varied with the size classes, as depicted in Fig. 6.

Taking 170 mesh size as the border, the finely pulverized husks contained a large amount of silica while coarse husks contained somewhat less amount of silica independent of the size variance. This border point of 170 mesh is roughly coincident with the silica content of unmilled raw rice husks of about 11.6%. The high silica contents at the finely pulverized husks smaller than 170 mesh were thought to be caused by the concentrations of the horn-like trichomes for −170/+325 mesh class and the debris of fragile cuticles that contain extremely high amounts of silica for −325 mesh class. This explains why pulverized

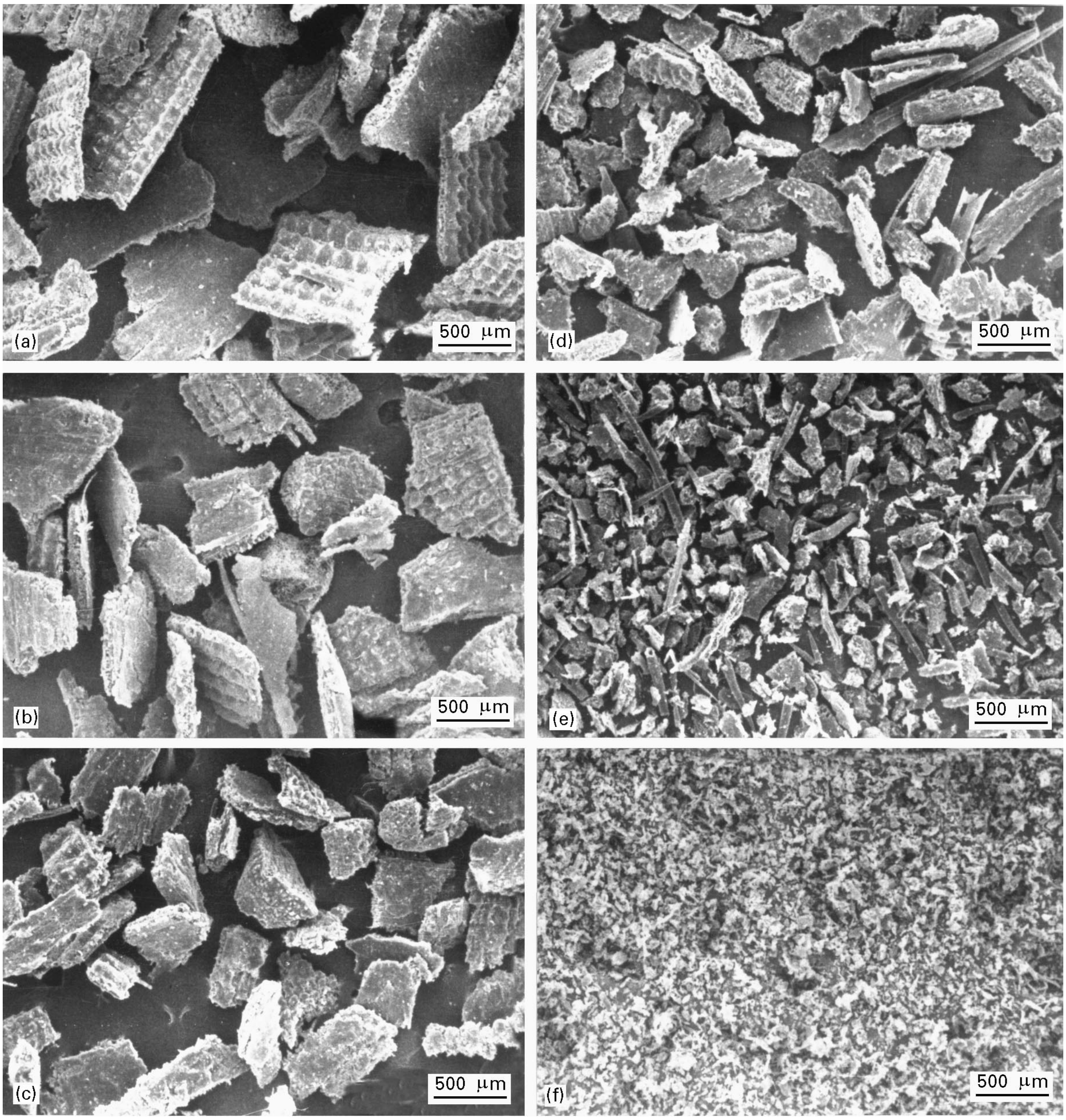

Figure 3 SEM micrographs of pulverized rice husks of various sizes: (a) $-30/+50$, (b) $-50/+70$, (c) $-70/+100$, (d) $-100/+170$, (e) $-170/+325$, (f) -325.

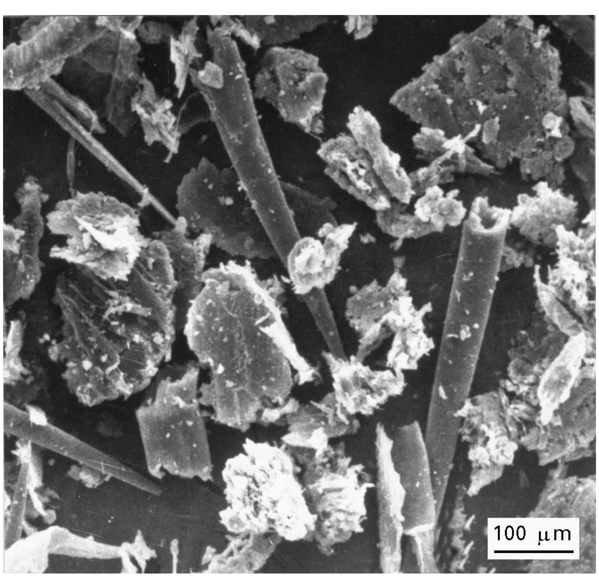

Figure 4 Horn-like trichome fragments at $-170/+325$ mesh class.

husks larger than 170 mesh showed a lesser amount of silica than the raw rice husks. High silica content in small size classes was also reported in grinding disc method [9].

3.4. Density changes

Rice husks are inherently porous in microstructure. Flake-like husk pieces exhibited bundles of channels of about 5 μm in diameter and 1 μm in wall thickness, as shown in Fig. 7. Well-dried raw rice husks showed a tap density of about 0.1 while those of the pulverized rice husks were higher than 0.4, as depicted in Fig. 8. This means that more than four times the amount of raw materials can be put in, so a large amount of reaction products can be expected for a given volume of reaction container when using pulverized rice husks. Tap densities of pulverized rice husks slightly decreased as the husk size reduced, showing the lowest value at -325 mesh class. This was caused by the

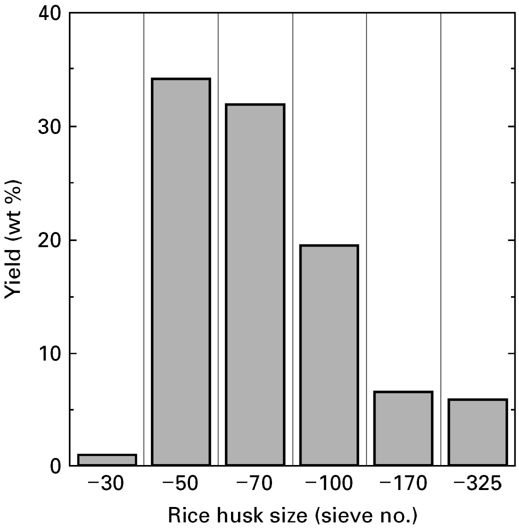

Figure 5 Size distribution of pulverized rice husks.

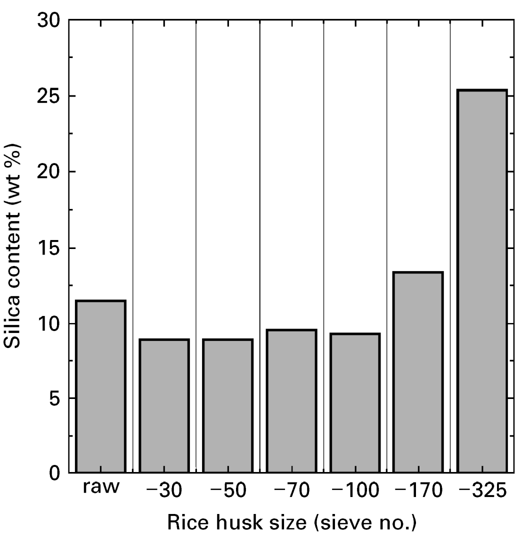

Figure 6 Variation of silica content of raw and pulverized rice husks with their sizes.

increase of friction between rice husks as the husk size reduced.

Although rice husks showed tap densities of less than 0.5, they sank to the bottom of container when poured into water. True densities of raw and pulverized rice husks were measured by using the picnometer method. The rice husks exhibited true densities higher than 1.4, as shown in Fig. 9. Considering the fact that most woods float on water, rice husk is one of the heavier plant materials. This is mainly thought to be caused by the presence of opaline silica in the cell structures, as explained earlier. Figure 9 shows a slight and steady increase of true density as the husk size decreased leaving the highest value at − 325 mesh class. However, this true density change was not well correlated with that of silica content in Fig. 6. This point should be studied further.

The presence of porous microchannels resulted in the low tap density of about 0.5 for the pulverized rice husks although their true density was over 1.4. One way for increasing the tap density is to destroy these

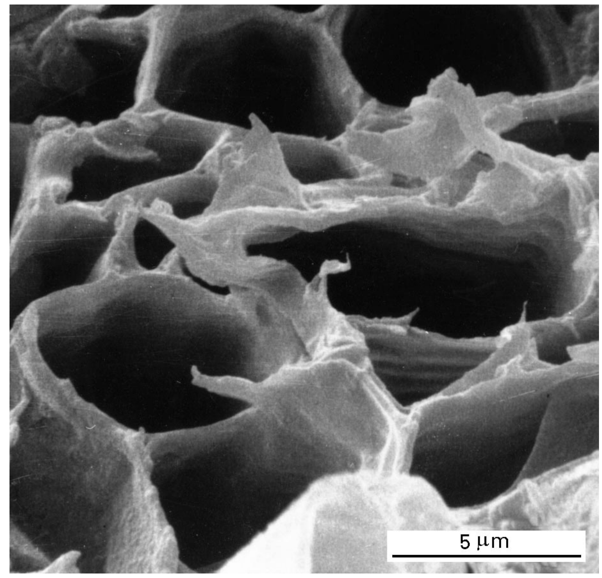

Figure 7 Channels at a cut edge of rice husk.

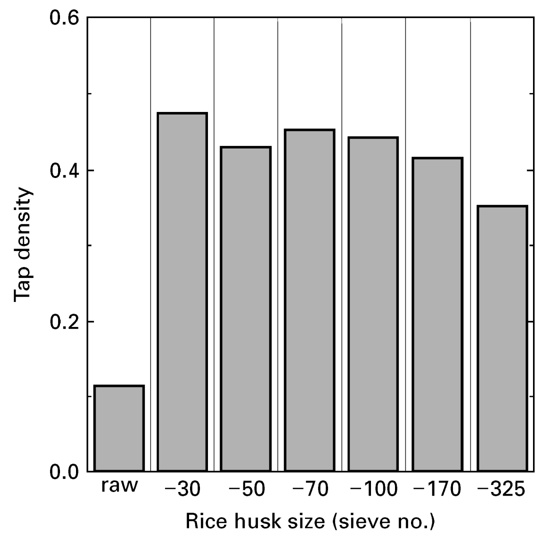

Figure 8 Variation of tap density of raw and pulverized rice husks with their sizes.

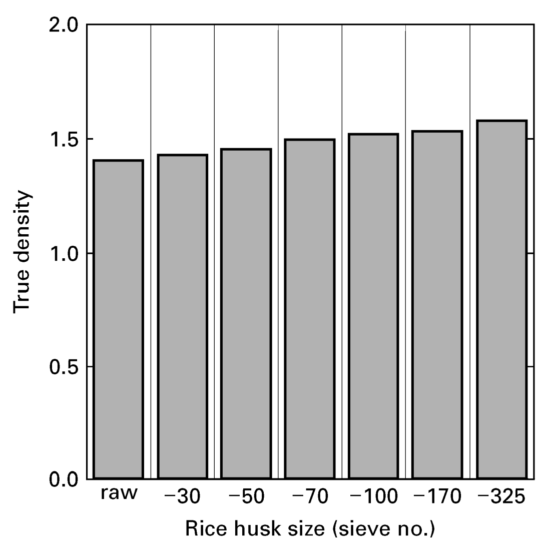

Figure 9 Variation of true density of raw and pulverized rice husks with their sizes.

channel structures into extremely fine pieces down to less than 1 μm. However, such a size reduction is not easy in the rotating knife cutting method. On the other hand, severe reduction in husk size by repeated pulverization might result in disadvantages such as high impurity contamination and decrease of tap densities due to large friction between powders. Thus, the rotating knife cutting method of the present work is thought to be a satisfactory technique for pulverization of rice husks.

4. Conclusions

1. The rotating knife cutting method was found satisfactory for pulverizing rice husks into fine powders.

2. The pulverized rice husks of $+100$ mesh class was flake-shaped, and those of $-100/+325$ mesh class were rod-like shapes, while the smallest size of -325 mesh class showed dust-like shapes.

3. The low tap density of raw rice husks of about 0.1 became greatly increased up to over 0.4 by the pulverization.

4. The true density of rice husks was higher than 1.4. This was mainly thought to be the presence of opaline silica in the cell structures.

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