Studies on physical and thermal properties of rice husk related to its industrial application

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The physical and thermal properties namely, bulk density, true density, angle of repose, specific heat and thermal conductivity of both unground and ground rice husk at different moisture contents ranging from 10 to 20%, wet basis (wb) have been found. Except for the angle of repose, the values of the other properties were higher for the ground husk than those of the unground ones. Various possible industrial applications of both unground and ground husk (e.g. production of insulation board, packing material and ceramics) have been discussed.

1. Introduction
A large quantity of husk is available as waste from rice milling industries. This can be used as an industrial raw material, for example, as an insulating material [1], fillers in plastics [2, 3], building material [4], for making panel boards [5, 6], activated carbon [7] etc. Nowadays, production of white ash from rice husk [8–11] is gaining importance as an excellent source of high grade amorphous silica for use in the ceramics, rubber and electronics industries. Exhaustive studies have been carried out on various aspects of rice husk [12, 13] whereas only very limited information on its physical and thermal properties is available.

This paper reports the effects of different moisture contents on bulk density, true density, angle of repose, specific heat and thermal conductivity of unground and ground rice husk.

2. Experimental details
2.1. Materials preparation
Rice husk was obtained by milling an Indian high yielding variety of paddy, namely, Mashuri using a modern Satake rice mill (made in Japan). It was then sieved manually through a BS:25 sieve to remove the broken rice contained in it. The ground husk was prepared by using a horizontal burr mill. It was then sieved manually through a BS:22 sieve to remove the larger size of husk particle.

The husk samples of different moisture content were prepared in the following manner. The moisture content of husk was first increased from an initial value of about 10% (wb) to about 25% (wb) by spraying with the appropriate amount of water. It was then kept in a refrigerator (5° C) inside a sealed polythene bag for about five days to condition the sample. The husks with different moisture contents were obtained by drying the wet husk under shade in a thin layer. The moisture content was determined by standard oven drying method (105 ± 2° C for 24 h).

2.2. Determination of bulk density
Bulk density, BD, was determined by filling uniformly a cylindrical container both loosely and packed. The former one was achieved by slowly pouring the material into the container through a funnel without tapping while in the latter case the container was tapped gently during filling and finally the material was levelled at the edge.

2.3. Determination of true density
The true density of husk was determined by the toluene displacement method [14], using a specific gravity bottle.

2.4. Determination of angle of repose
The angle of repose of husk was determined by a method described earlier [14]. Husk was poured slowly and uniformly on to a circular platform of 6.5 cm diameter to form a cone. The height of this cone was measured using a travelling microscope with a vernier system and a least count of 0.01 mm. The angle of repose (the angle made by the surface of the cone with horizontal) was determined from the geometry of the cone formed.

2.5. Determination of specific heat
The specific heat of husk was determined by the method of mixtures [15, 16], using a flask calorimeter of 500 ml capacity.

2.6. Determination of thermal conductivity
The thermal conductivity of the husk was determined by the transient heat flow method [17–19] using a thermal conductivity probe (Fig. 1) and it was calculated using the following formula

$$K = \frac{0.86 I^2 R}{4\pi(T_2 - T_1)} \ln\left(\frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}\right) \qquad (1)$$

where: K is thermal conductivity (kcal h^{-1} m° C); I is the current input (A); R is the resistance of the heating wire (ohms m^{-1}); T_1 and T_2 are the temperatures at a point close to the line heat source at time θ_1 and θ_2 (° C); θ_0 is the time correction factor (min); and 0.86 is a conversion factor from watts to kcal h^{-1}.

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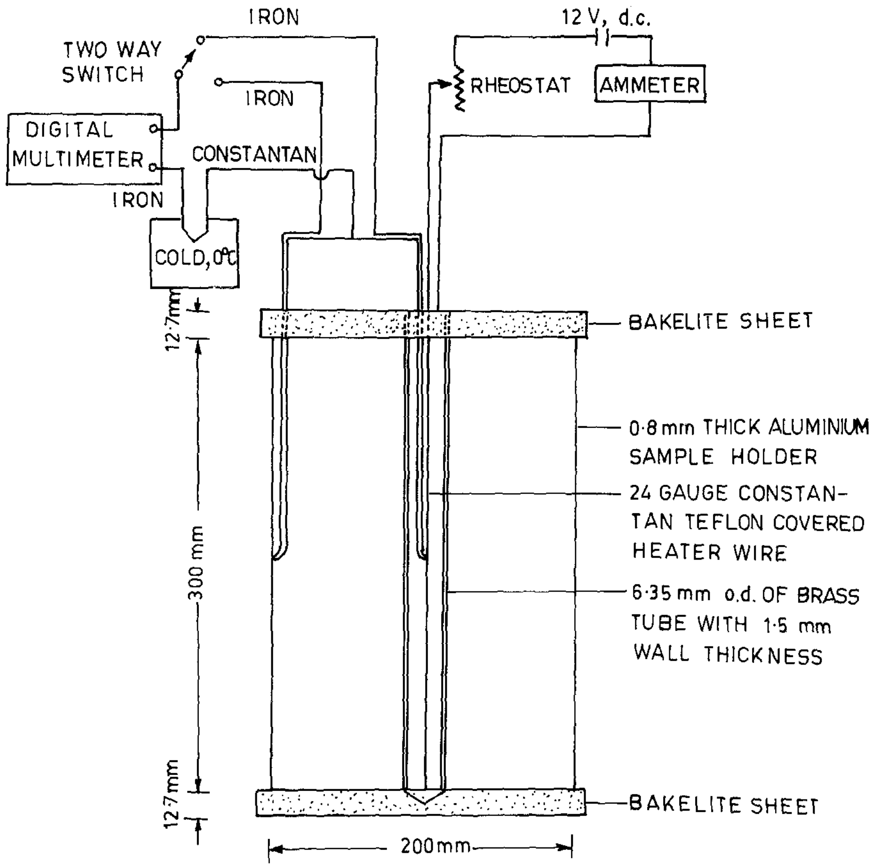

Figure 1 Schematic of thermal conductivity experimental set up.

The time correcton factor "θ_0" was obtained from a time–temperature plot. This is the time allowed for heat production by the probe before the start of measured time.

3. Results and discussion

The bulk density of unground husk increases from 101.7 to 105.5 $kg\,m^{-3}$ as its moisture content increases from 11.4 to 21·.3% for loose filling of the material (Fig. 2). For packed filling, although the bulk density increases with increase in moisture content in the above range it shows a higher value throughout the moisture range than loose filling. This indicates that packing of unground husk is an important factor to be considered if it is to be used as an insulating or packing material.

When ground husk was loosely filled, a decrease in its bulk density from 284.4 to 250.5 $kg\,m^{-3}$ with increase in the moisture content from 11.5 to 21.5% was observed. It was also noticed that the bulk density

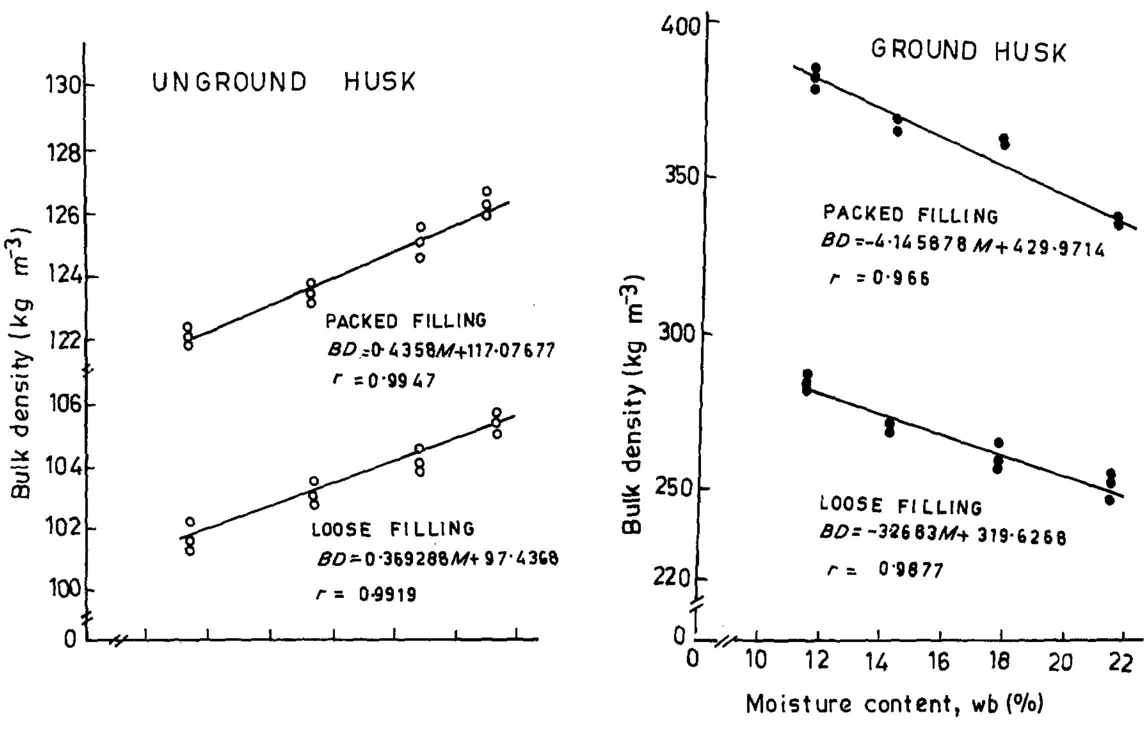

Figure 2 Effect of moisture content on bulk density of unground and ground husk. r = correlation coefficient and M = percentage moisture content, wet basis.

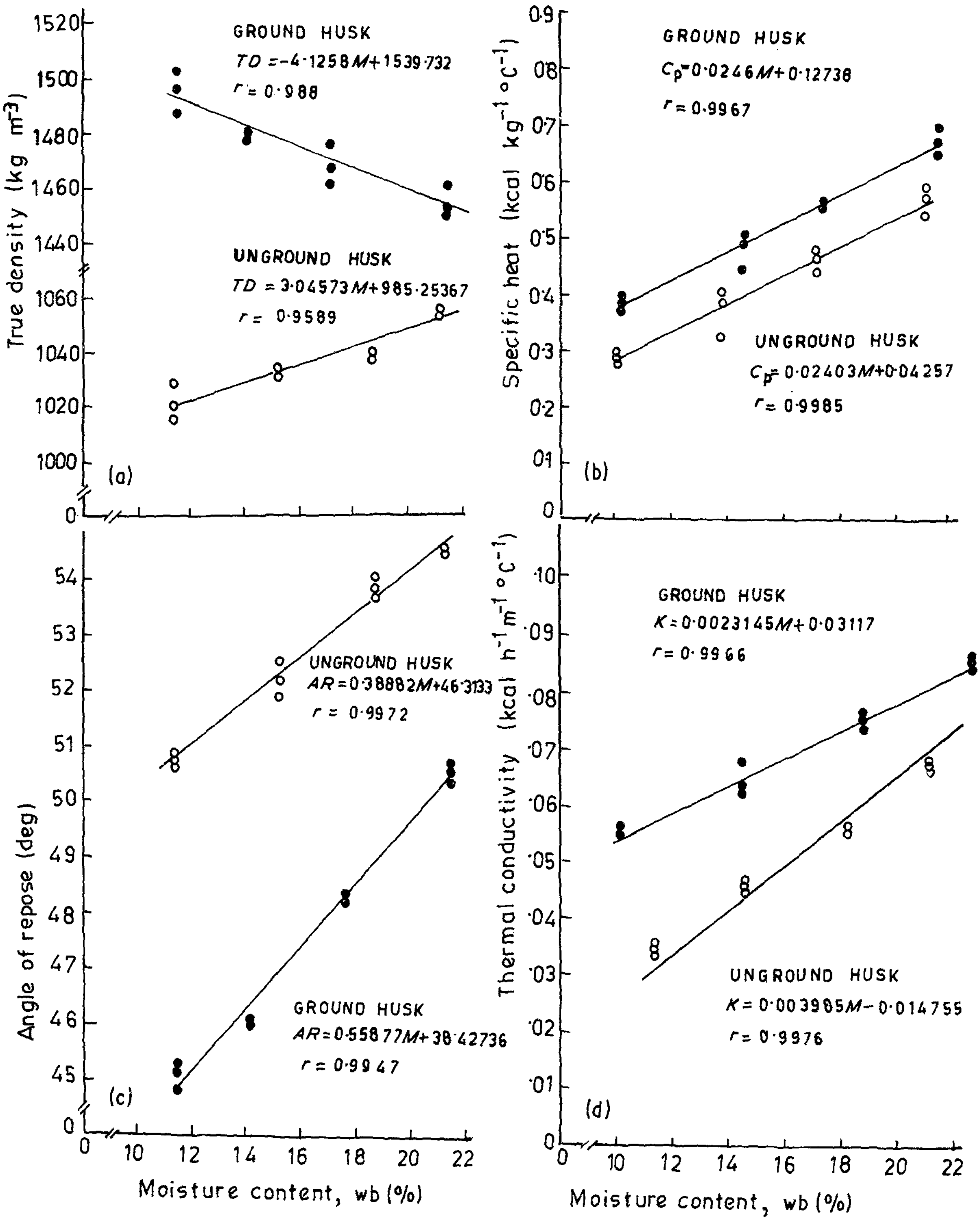

Figure 3 Effect of moisture content on (a) the density, (b) specific heat, (c) angle of repose and (d) thermal conductivity of husk. r = correlation coefficient and M = percentage moisture content, wet basis.

of ground husk increases on account of packed filling. In both the cases of unground and ground husk a linear relationship between the moisture content and bulk density was noticed. The bulk density of ground husk was found to be 2.5 to 3 times more than that of unground husk.

The variation in true density of unground and ground husk is shown in Fig. 3a. The true density of unground husk increases from 1021 to 1054 $kg\,m^{-3}$ as the moisture content increases from 11.4 to 21.3% whereas for ground husk it decreases from 1495 to 1452 $kg\,m^{-3}$ as the moisture content increases from 11.5 to 21.5%. Thus ground husk swells when moist. However, in both the unground and ground conditions of husk, the relationship between the moisture content and true density was found to be linear within the limits of the moisture content. Ceramics are usually fabricated using silica as one of the basic raw materials. Perhaps ground husk could be used as a cheap raw material instead of silica for making the porous ceramics.

The variation in angle of repose with moisture content of both unground and ground husk is shown in Fig. 3b. In both the cases it exhibited a linear increase in angle of repose from 51 to 54° and 45 to 51° as the moisture content increased from 11.4 to 21.3 and 11.5 to 21.5%, respectively. The angle of repose of unground husk was more than that of ground husk.

This may be attributed to greater surface roughness of unground husk which causes an inherent resistance to the flow of the material as compared to the ground husk. This indicates an easiness in handling the husk in ground form.

Fig. 3c shows that the specific heat of both unground and ground husk increased linearly from 0.29 to 0.55 and 0.39 to 0.66 $kcal\,kg^{-1}\,^{\circ}C^{-1}$ as their moisture contents increased from 10 to 21%. This behaviour is expected because of the higher specific heat of water contained in it. The higher specific heat of ground husk than the unground one offers it as a better insulating material for making insulation board etc.

The effect of moisture content on thermal conductivity of husk is shown in Fig. 3d. The thermal conductivity of both unground and ground husk increased linearly from 0.035 to 0.067 and 0.056 to 0.085 $kcal\,h^{-1}\,m^{-1}\,^{\circ}C^{-1}$ as their moisture contents increased from 11.5 to 21.2 and 10.2 to 22.7%, respectively. This behaviour may also be due to the same reasons given for specific heat in the previous paragraph. The thermal conductivity of unground husk was observed to be lower than that of the ground husk. This is because, ground husk provides more dense packing of an available space. In general, the husk can be used as a low cost insulating material for many commercial applications due to its low thermal conductivity.

4. Conclusions

(i) Density (bulk and true) of unground husk increases with moisture content whereas the density of ground husk decreases.

(ii) Angle of repose, specific heat and thermal conductivity of both unground and ground husk increase linearly with increase in moisture content.

(iii) Bulk density, true density, specific heat and thermal conductivity of ground husk are higher than those of unground husk. The angle of repose of ground husk is lower than that of unground husk.

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