

Investigation of Rice as an Absorbent and Degradable Material for Personal Hygiene Applications

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Abstract

This research explores the uses of natural materials in personal hygiene applications. In order to maximize the use of materials for personal hygiene, they must be absorbent, but should also be biodegradable to minimize their impact on the environment. Rice was prepared for testing by increase the porosity. The material was ground into three size distributions and tested to determine its ability to absorb moisture under both ambient and body temperatures. Research goals address the percentage of moisture absorbed by weight, the absorption as a function of temperature, and the optimal particle size required for the selected application. Results indicate that the amount of moisture absorbed by the material increases as the temperature approaches body temperature. Furthermore, the time required for the material to reach equilibrium, as also defined by the amount at which the material will no longer absorb moisture, varies by particle size.

Introduction

Each month, young women in developing countries miss out on a portion of their academic studies due to a lack of available options for personal hygiene, and the average young woman misses 10 to 20 percent of school days per academic year [1,2]. In an attempt to solve this problem, and therefore expanding the accessibility to educational opportunities, many companies have investigated the development of materials and other technologies that would mitigate the impact of menstrual cycles [3-8].

While some researchers have investigated the uses of natural materials for a sustainable application, there has been minimal data reported on the uses of these materials and their effectiveness in personal hygiene applications [9-13].

The design specifications for this project include two greater challenges. First, to synthesize an absorbent polymer, and second, to synthesize a degradable polymer. As polymeric materials were considered for this project, there were two recurring questions. The first was related to the manufacturing processes required by developing countries to produce usable products. It was unclear whether developing countries would have access to certain chemicals or processes. The second question was related to the chemicals that the polymer would create in the degradation process [14,15].

These design challenges led to the consideration of rice as a potential material for personal hygiene applications. Rice is among the most abundant food staples around the world and is available in diverse developing countries from Africa to Asia to South and Central Americas. Greater than 70% of caloric intake in some countries comes from rice alone [16]. Because it is readily available, the use of rice for personal hygiene applications may eliminate the need to manufacture polymeric material. This will also further enable women in developing countries to take ownership of this world-wide issue.

Therefore, if rice were to be considered a viable option as an absorbent, degradable material, three research questions must be answered. First, what is the percentage of moisture that can be absorbed by rice? Second, does the absorption of water change as a function of temperature? Third, what are the optimal physical dimensions of the rice grains that will provide the greatest benefit to users?

Materials and Methods

Rice was prepared in order to increase the material porosity through cooking processes in water alone with no food additives. The rice was cooked in a ratio of 2.5:1 water to rice and for 35 minutes. The rice was allowed to air dry for a minimum of 4 hours, and until there was no moisture left in the material.

To create grains of rice in three distinct sizes, a PULVERISETTE 6 planetary ball mill was used. The duration of the milling process was changed to create grains of small and medium sizes. Whole,

long grain rice was used as the largest grain sized sample. The size of the rice was measured using Scanning Electron Microscopy. Ten samples were imaged and measured from each size distribution.

To determine the amount of water absorbed by the rice, a weighing test was performed. To perform this test, the rice on each of the three size distributions was weighed and placed into a moist tea bag. The grains were allowed to soak in water and the mass was measured every two minutes until the mass reached a point of equilibrium. This point is defined as the point at which the weight no longer increased to a minimum of ten minutes. This test was repeated fifteen times for each grain size sample and at 18°C and 37°C, which simulated both ambient and body temperatures.

Results and Discussion

Two different dimensions of rice were obtained from the milling process and were characterized using scanning electron microscopy. The first was small, measuring less than 1 mm; the second was medium, measuring 2 to 5 mm, see Figure 1; and the third size used was not milled and left whole, measuring 5 to 8 mm. The weight of the three sizes was measured. The whole grain rice weighed an average of 15 mg per grain. The medium sized grains weighed an average of 8.5 mg per grain. The smallest sized particles formed a powder and individual grains could not be weighed accurately. An image representing the three different sizes is given in Figure 2.

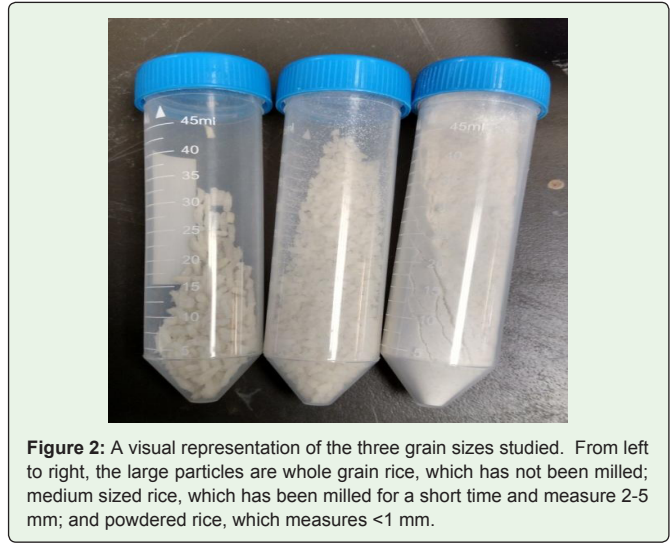


Figure 2: A visual representation of the three grain sizes studied. From left to right, the large particles are whole grain rice, which has not been milled; medium sized rice, which has been milled for a short time and measure 2-5 mm; and powdered rice, which measures <1 mm.

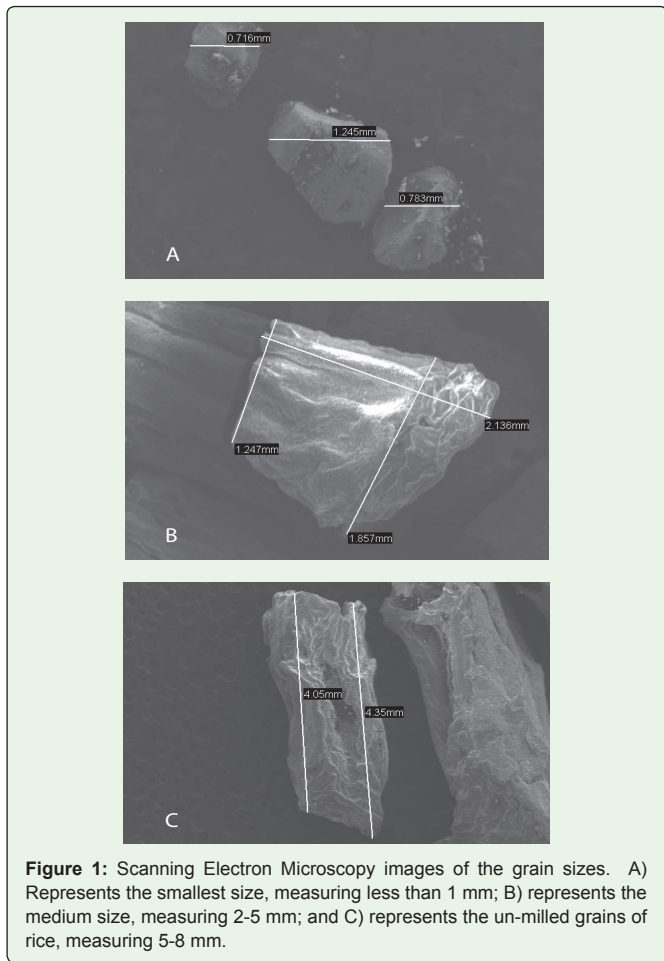


Figure 1: Scanning Electron Microscopy images of the grain sizes. A) Represents the smallest size, measuring less than 1 mm; B) represents the medium size, measuring 2-5 mm; and C) represents the un-milled grains of rice, measuring 5-8 mm.

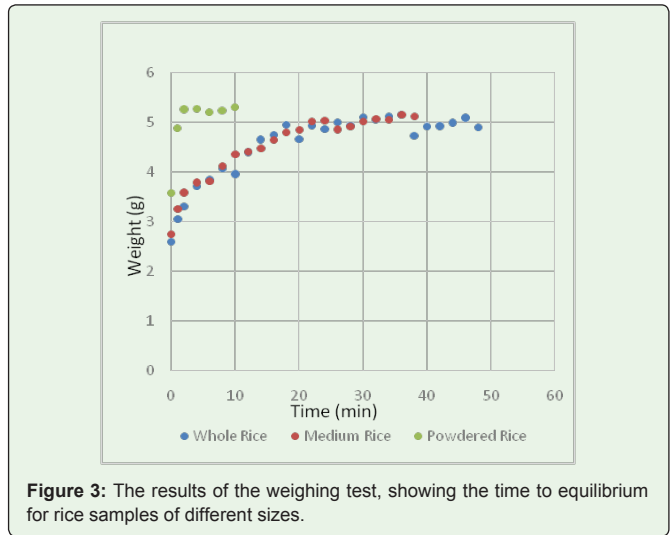


Figure 3: The results of the weighing test, showing the time to equilibrium for rice samples of different sizes.

The data collected and plotted from the weighing test reveals that rice is an absorbent material. The data presented in Figure 3 demonstrates the time at which one sample of each size reached equilibrium. As shown in the Figure 3, the ground rice reached equilibrium between 2-4 minutes, while both the medium and large grain sized rice samples reached equilibrium after nearly 30 minutes.

To answer both the first and second research questions, the data presented in Figure 3 demonstrated the percent change in weight after the samples reached equilibrium. The powdered rice samples absorbed 257% of their original weight in water, while both the medium and whole rice absorbed in the same range 218% and 216% respectively.

The second research question was to determine whether the amount of water absorbed by the material was a function of temperature. Since hygiene items are used in close proximity to the body, the two temperatures compared with this project were at ambient temperature (18°C) and body temperature (37°C). The results are also given in Figure 4 where the percent change in weight is compared. The percent change in weight of the powdered samples

was higher at body temperature, 280%. Furthermore, the medium sized samples were able to absorb a higher percentage of water at body temperature as compared to room temperature (261% compared to 218%).

The third research goal was to determine the optimal physical dimensions of the rice for use in personal hygiene applications. While the powdered rice was able to absorb the highest amount of water, it also absorbed the full potential within 3 to 4 minutes when completely submerged in water. While these conditions do not fully simulate the conditions of use, there was an indication that the powdered rice would reach a saturation limit much faster than other physical dimensions.

Conclusion

The data presented in this project demonstrate that rice can be used as an absorbent material, and has been known to degrade under ambient conditions. In terms of research goals, rice absorbed more than 200% of its original weight of water. Furthermore, rice absorbed a higher volume of water at body temperature, and the physical dimensions played a vital role in the response kinetics of the material.

Because the powdered rice reached equilibrium saturation within 3 to 4 minutes, the data presented suggests that to achieve the optimal physical dimensions for moisture absorption, it would be ideal to use a variety of rice particle sizes. This would optimize the swelling response through the rapid response of the powdered samples and create a sustained absorption profile to ensure the personal hygiene items can be used under normal use conditions. Furthermore, the use of precooked rice not only increases the porosity of the material, but also provides a sterilization step that will be required for the designed applications of the material.

Future research will determine the degradation profile of rice as an absorbent material. Furthermore, future research will explore other natural materials that can be layered into personal hygiene products that are both naturally occurring and readily available in developing countries, but is also minimally processed and degradable under environmental conditions.

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