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Experimental Determination of the Insulating Ability of Corn By-Products

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This article proposes and experimentally tests a way to better utilize renewable agricultural products that, if successful, will increase revenue for agricultural producers, decrease the amount and cost of disposal of non-renewable products, and decrease the amount of non-renewable products that need to be produced. In this article the insulating ability of ground corn cobs is compared, by experimental tests, to typical fiberglass, cellulose, and Rock Wool insulation. The study found that the insulating ability of ground corn cobs is not as great when compared to typical insulations, but using a greater thickness of insulation made from ground corn cobs or combining this insulation with typical insulations may be beneficial. In conclusion it is valuable to know how the insulating ability of ground corn cobs compares with typical insulations to determine if further research in this area is beneficial and to stimulate other possible ways to use renewable agricultural products.

Keywords: Insulation, corn by-products, waste utilization

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1. Abstract

This article proposes and experimentally tests a way to better utilize renewable agricultural products that, if successful, will increase revenue for agricultural producers, decrease the amount and cost of disposal of non-renewable products, and decrease the amount of non-renewable products that need to be produced. In this article the insulating ability of ground corn cobs is compared, by experimental tests, to typical fiberglass, cellulose, and Rock Wool insulation. The study found that the insulating ability of ground corn cobs is not as great when compared to typical insulations, but using a greater thickness of insulation made from ground corn cobs or combining this insulation with typical insulations may be beneficial. In conclusion it is valuable to know how the insulating ability of ground corn cobs compares with typical insulations to determine if further research in this area is beneficial and to stimulate other possible ways to use renewable agricultural products.

2. Introduction

It is becoming very valuable to utilize material that comes from renewable resources; doing this decreases consumption of non-renewable resources, increases a revenue stream for the producer of the renewable resource, and decreases the amount and cost of non-renewable material disposed of in landfills. It is also becoming very important to utilize energy more efficiently; because utilizing energy efficiently decreases our dependence of non-renewable energy sources and of energy sources from foreign countries, and decreases combustion products, which have been suggested lead to climate change.

One specific way of better utilizing both renewable resources and energy is to create thermal insulation from renewable sources. Thermal insulation is any substance or configuration of materials that resists the flow of heat (Considine, 2002). Common materials that provide varying degrees of insulation (low thermal conductivity) are cork, mineral wool, ceramics, wood fibers, felts or boards, foamed plastics, and cellular glass (Dillon, 1978). Many of these insulation materials work by entrapping and restricting the flow of air, which when stagnant is a good insulator. The most common forms of insulation are batts, blankets, loose-fill, cellular plastic materials, rigid foam boards, and reflective materials.

Insulation has been used for a long time in industries; reducing the flow of heat is valuable to industries that have processes that operate at high or low temperatures, because reducing the flow of heat from high, and to low, temperature processes improves the overall energy and cost efficiency of the process. Insulation in residential homes began to be emphasized in the U.S. after the energy crisis in 1973-1974 (Dillon, 1978). The insulation in the homes reduces heat loss from the home in the winter and to the home in the summer; doing this conserves energy, reduces utility bills, and provides better comfort and more uniform temperatures in living and working spaces.

Because of the advantages of insulation, using material from renewable sources, and using energy more efficiently, a high school student and a college faculty member, who served as a mentor, completed an educational research project that compared the insulating ability of ground corn cobs and of three other typical insulations. The research was completed by constructing an experimental setup, testing the individual insulations, analyzing the experimental results, and drawing conclusions. The remainder of the article will present previous studies that researched various uses of agricultural by-products, describe the experimental setup and testing of the research being reported, and discuss the results of the experiments.

3. Previous Studies

Presently, in the agricultural industry, products are produced which are derived from materials remaining in the farm fields including ingredients in lotions, make-up products, fireworks, and shoe polish. There have been some previous studies that researched making other useful products from renewable agricultural by-products, such as corncobs and rice husks;

therefore the previous studies presented here focus on these types of materials and their uses. Salas and Veras (1986) made insulating panels from cement and rice husk and proposed to use these panels for structural support and insulating ability in residences in developing countries. By doing this they reduced the need for many traditional materials to be imported and wisely utilized rice husks, which are available in most developing countries. They measured the strength and conductivity of the panels and feel like these panels have a promising future for materials used in low-cost housing.

Dasgupta et al. (1991) used rice husks to insulate barns that are used to cure tobacco. They also designed a burner that burned rice husk instead of wood when curing the tobacco. They found that using rice husks for insulation greatly reduced the amount of energy needed for curing and created a much more uniform temperature inside which improved the curing process. Also, they found that burning rice husks instead of wood greatly reduced the amount of forests that were normally cleared and burned for the curing process.

Foley and Vander Hooven (1981) presented many uses of corncobs that were originally reported by them or other researchers. They found that early uses of corncobs were for bedding, mulches, and soil conditioners. They also reported on using finely ground corncobs as fillers in plastics. They also reported many uses of corncobs found from studies by other researchers. Such as, Clark and Lathrop (1950) reported that during World War II the hard, woody portion of the corncob was used to clean pistons in aircraft engines. Schisler and Muthersbaugh (1979) found that using ground corncobs in the soil to grow mushrooms improved the yield. Willner et al. (1979) researched substituting ground corncobs in place of asbestos fibers in roofing paint; they found the corncob granules had similar properties to the asbestos and maintained acceptable weathering characteristics and resistance to crack formation. Foley and Weaver (1981) reported on using ground corncobs in the “soft-grit” blast cleaning process to: (1) remove paint from homes prior to repainting, (2) clean electrical substations and electrical insulators while they are hot, (3) clean electrical motors, and (4) clean gasoline and diesel engines. Vander Hooven (1973) reported on tumbling metal stampings, machine parts, ball bearings, and plastic parts with the woody portion of corn cobs to deburr, polish, and clean them.

An extensive search of international patent applications conducted by A.E. Staley Company in March of 2004, revealed three U.S. title and patent applications dealing with the use of corncobs in insulation. Puhr (1962) proposed using whole corncobs in insulating boards. Eisfeld (2003) mentions making insulation from dried and ground up fruits, plants, and/or corncobs. Olson (1995) discusses using foam, newspaper, and/or corncobs to make blanket-type insulation.

The corn cob conversion industry has expanded as commercially feasible uses for the cobs have been developed. At the present time, four cob conversion plants are operating in the United States (Seinfort, 2005). There have been many studies reported using ground corncobs for many different uses; however, none of the studies reported using ground corn cobs as insulating material. It is valuable to compare the insulating ability of typical insulation products with renewable agricultural products, especially corn cobs as they are plentiful in many parts of the US. If the insulation ability of corn cobs compare very favorably with typical insulation products then more research can be done in this area; if the insulation ability does not compare favorably then additional knowledge has been gained and from this research, possibly other uses for ground corn cobs can be thought of. This article presents the study of using ground corn cobs as insulating material and presents quantitatively how effective their insulating ability is compared to traditional insulating materials.

4. Experimental Setup and Procedure

The corn cobs were obtained from an industry that produces products derived from the cobs and were ground up into small granules measuring 0.5 cm in diameter. The ground corn cobs went through a cleaning process to wash away excess dust and then were dried thoroughly. In addition, three commercial insulation products of fiberglass, cellulose, and Rock Wool in loose-fill form were obtained from a home building store.

Figure 1 shows a diagram of the experimental setup used to compare the insulating ability of the insulating materials. The experimental setup was a box made with 1.27 cm thick plywood, the box was a cube consisting of five sides with no plywood on top, and each side being 60.96 cm. The box was divided into four compartments by using plywood that went between the vertical centerlines of opposing walls. Sheetrock was placed so the top of it was 33.02 cm from the bottom of the box and served as a ceiling upon which to place the insulation being tested; the sheetrock formed an upper and lower compartment from each of the original compartments. The sheetrock was held up by being screwed to additional boxes that were inserted into each lower compartment; these inserted boxes were made of 3.81 cm thick plywood that was 27.94 cm square. The overall box was symmetric so that the insulation in each upper compartment was exposed to the same area of air above and the same area of exterior and interior walls. Six cm thick, rigid, foam board insulation was attached using wood screws and washers to the four vertical sides and the bottom of the box. The foam board insulation reduced the amount of heat transferred from the vertical sides and the bottom of the box and caused more heat to transfer up through the insulation material that was being tested.

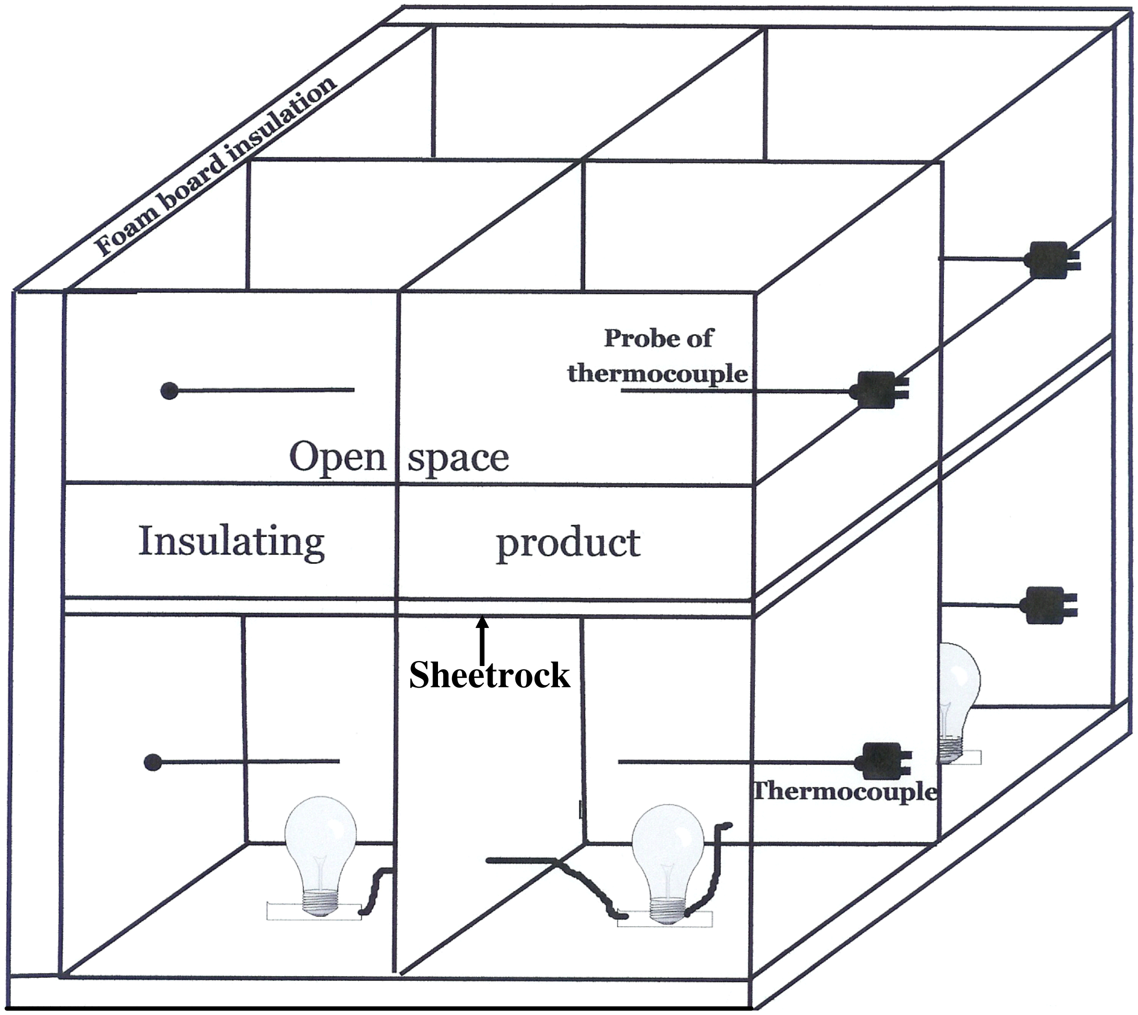

Figure 1. Diagram of the experimental setup

Metal electrical boxes with porcelain light fixtures were placed at the base of each of the four lower compartments of the box and 40 W light bulbs, which were used to produce the heat needed for the experiment, were screwed into each porcelain light fixture. All the holes drilled through the plywood inside the box, and the hole through the exterior of the box that were needed for the electrical to be installed were completely caulked to seal the holes.

Type K thermocouples with 30 cm long probes were inserted through two cm diameter holes that had been drilled into each of the four bottom compartments containing the light bulbs used for the heat source. The holes were 14.5 cm from the bottom and 28.5 cm from the outer side of each section and allowed the thermocouples to extend into the area in which the heat was generated. Holes were also drilled in each upper section, 14 cm from the top and 22 cm from the outer side; this allowed thermocouples to be inserted just above the insulation. The experimental setup had a total of eight thermocouples, one in each of the four lower and upper compartments extending through holes that were caulked shut in order to prevent the loss of heat. The type K thermocouples produced a milli-volt reading that corresponded to a temperature; an Extech Digital Multimeter, Model 22-816, displayed the temperature measured by the thermocouple.

Before an experiment was conducted all four upper compartments were filled with the same insulation to a depth of 5.1 cm, which is the same depth as the other types of insulations tested; also only light bulbs were used that consumed 40 W of power as measured from a Watt meter. An experiment lasted 21 hours and was performed the following way. The light bulbs were turned on and the temperatures in all four upper and lower compartments were recorded by hand after being displayed by the digital multi-meter; temperatures initially were recorded hourly and then at 15 minute intervals during the last 4 hours of testing. The total power consumed by all the light bulbs was also measured at the same intervals as above; the power consumed was measured by a Watt meter and showed that consistently 160 W (4*40 W) of electrical power was used throughout the experiment. The temperature in the testing room was measured with a mercury thermometer and recorded; the room temperature remained constant at all times. In between each insulation material tested, the upper compartments of the box that held the insulation during the experiment was emptied and vacuumed to remove all particles, and then the upper compartments of the box were filled with a different insulation in order to begin another experiment.

5. Results and Discussion

The data collected of temperatures in the enclosed, lower compartments and upper compartments were plotted versus time to determine when the temperatures, particularly the temperatures inside each lower compartment, did not change with time and therefore steady state conditions existed. The temperatures in the upper compartment increased very slightly throughout the experimental run from approximately 19°C to 23°C and at steady state conditions for all tests of all materials, the temperature in the upper compartment was always within 1°C of 22.5°C. The temperatures in the lower compartments became relatively constant between 17.25 and 18 hours after testing began. Figures 2-5 show temperatures measured inside each of the four compartments during testing of each of the different insulations and the solid line shows the time when it appeared that steady state conditions began. Figures 2-5 also show the individual temperature of each compartment to observe the variations between the readings.

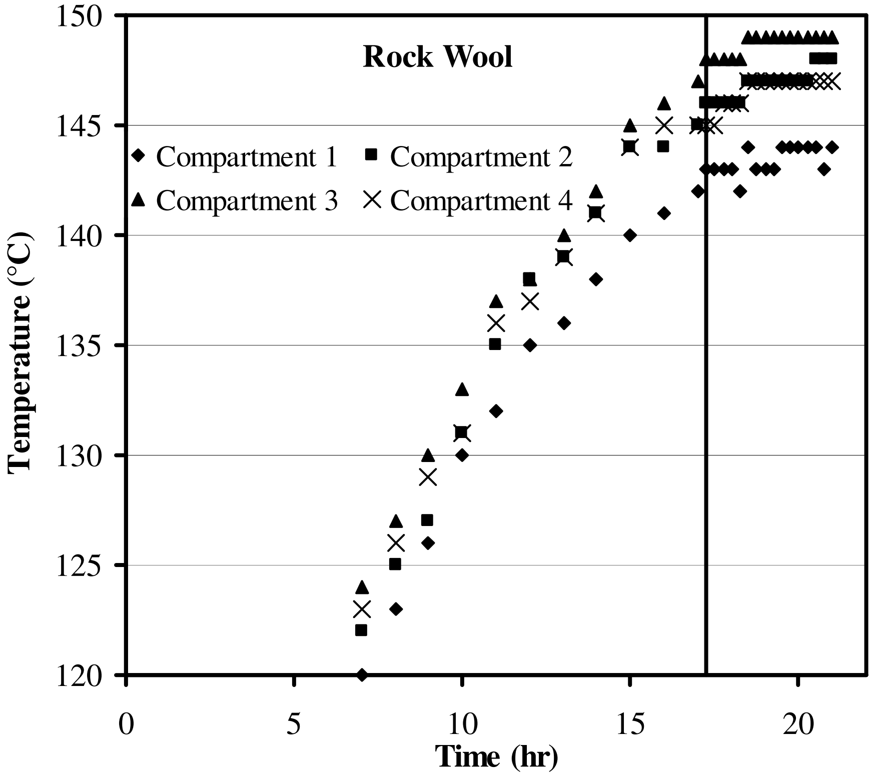

Figure 2 Temperatures measured inside each lower compartment during the testing of Rock Wool insulation

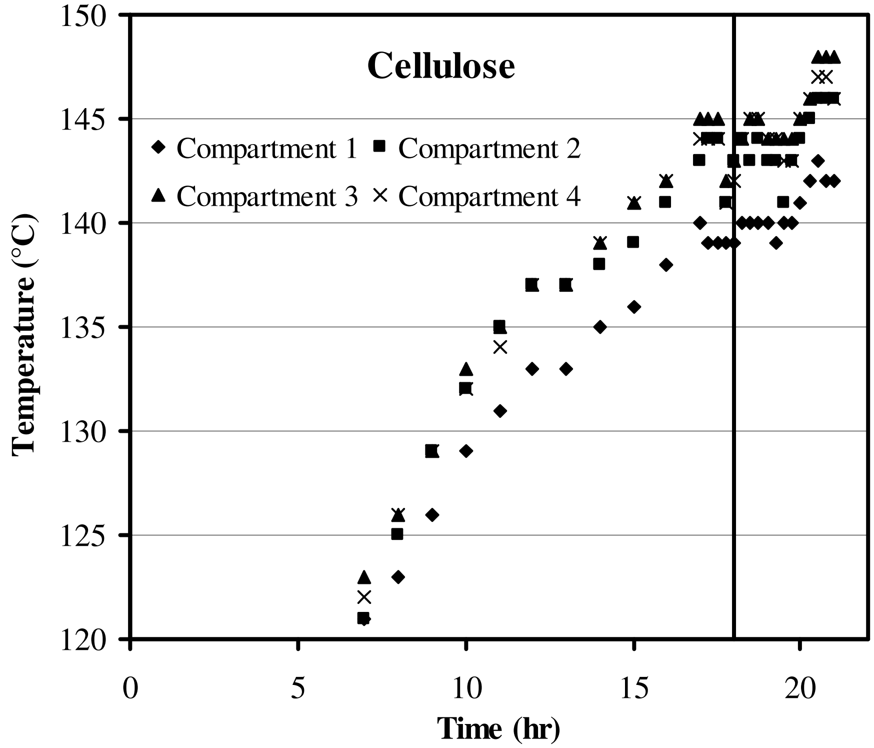

Figure 3 Temperatures measured inside each lower compartment during the testing of cellulose insulation

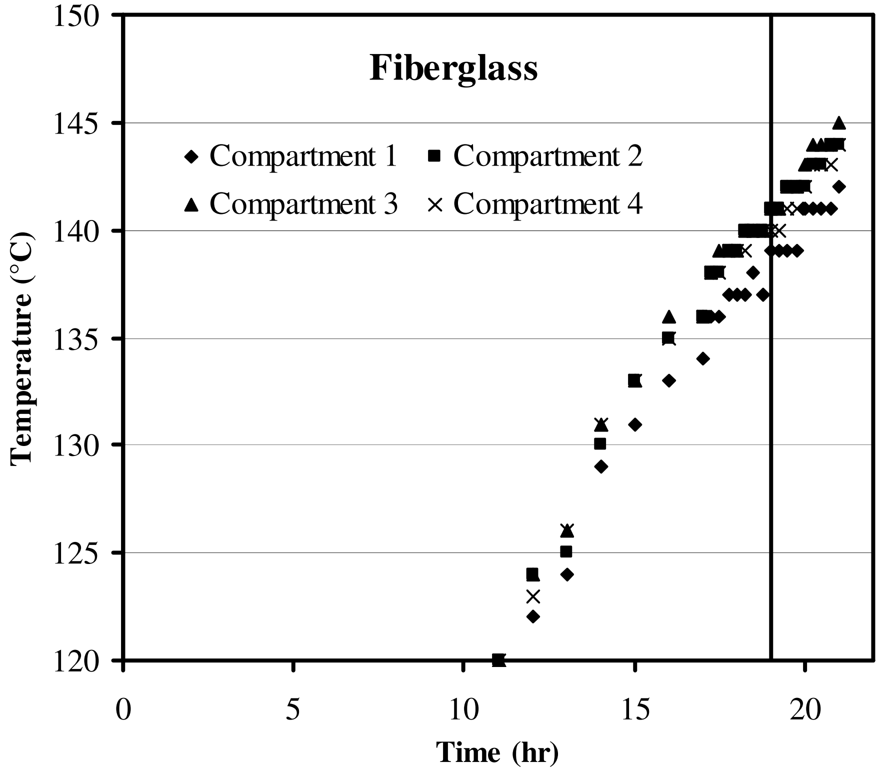

Figure 4 Temperatures measured inside each lower compartment during the testing of fiberglass insulation

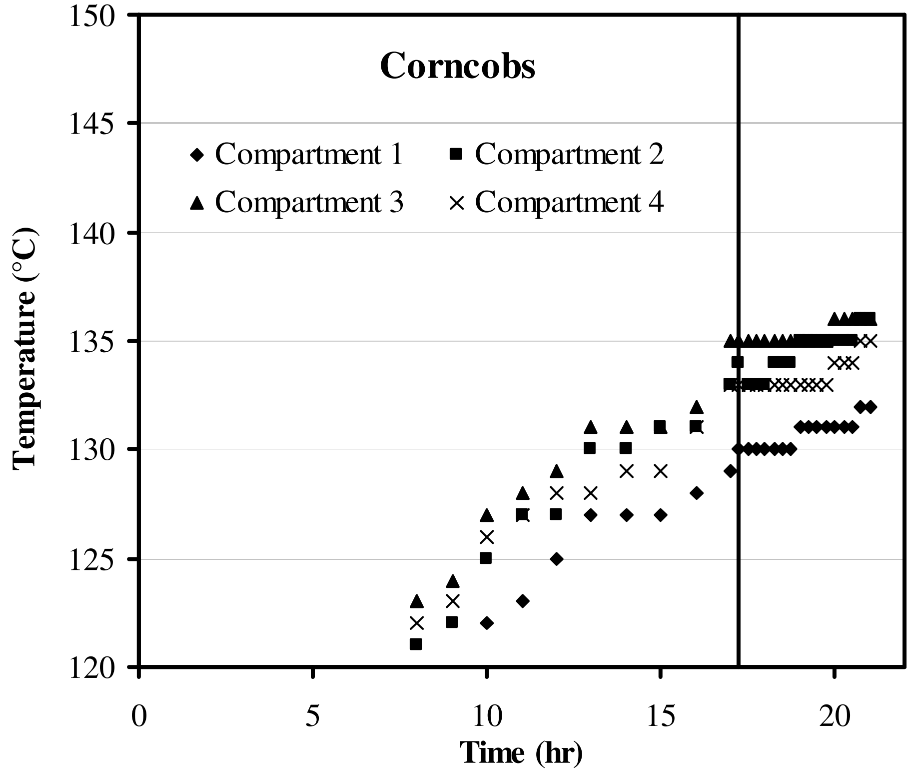

Figure 5 Temperatures measured inside each lower compartment during the testing of ground corncobs insulation

Using the data obtained from steady state conditions, the insulating abilities of the different materials were compared with Fourier's law of heat conduction, shown in Eqn. 1. In this equation, $\dot{Q}$, represents the rate of heat transfer; *A* represents the area available for heat transfer; T_{Lower} - T_{Upper} represents the temperature difference between the lower and upper compartments; and *k* represents the overall thermal conductivity of the insulating material being tested, in this case the combination of sheetrock and insulation; and thickness is the overall thickness of the sheetrock and insulation. Thermal conductivity is the inverse of insulating ability, therefore the material with the smallest thermal conductivity has the largest insulating ability.

$$\dot{Q} = \frac{kA\left(T_{Lower} - T_{Upper}\right)}{thickness} \qquad (1)$$

During all the experiments the heat being transferred from the light bulbs, the area for heat transfer, and the thickness of each of insulations all remained constant. From Eqn 1 and this information, the difference in temperature must be inversely proportional to the thermal conductivity and proportional to the insulating ability of the combination of sheetrock and insulation. Therefore, the sheetrock and insulation tested that produced the largest temperature difference has the lowest thermal conductivity and best insulating ability; since the insulating ability of the sheetrock remained constant throughout all the experimental tests and is small compared to typical insulations, the insulation that produced the largest temperature difference has the best insulating ability.

Figure 6 shows for each insulation tested the average temperature difference between the lower and upper compartment and the 95% confidence interval. The 95% confidence intervals were calculated from plus and minus two standard deviations of the data collected at steady state conditions of each insulating material; the standard deviation resulted from the variation in temperatures in the lower compartments because the upper compartments remained at constant temperature. The results show the average temperature difference between the lower and upper compartments was the greatest during the testing of Rock Wool insulation; the average temperature difference of the testing of cellulose insulation was very close to that of Rock Wool insulation. The confidence intervals from the testing of these two materials nearly completely overlap each other; therefore all that can be concluded is most likely they have very similar insulating ability. The average temperature difference obtained from the testing of fiberglass insulation is slightly less than that from the two materials just mentioned, therefore on average it will have slightly less insulating ability than Rock Wool or cellulose insulation. However, the confidence interval from the experiments performed with fiberglass significantly overlap;

because of the overlap of confidence intervals, the fiberglass may have the same insulating ability as Rock Wool and cellulose but it also may be different, the results are inconclusive. The average temperature difference measured from the experiments with ground corn cobs is noticeably less than the average temperature difference of the other three materials. The confidence interval from experiments with ground corn cobs essentially do not overlap the confidence intervals from the tests of the other three materials, which provides confidence that the temperature difference, and therefore the insulating ability, of the ground corn cobs is not as great as the other three materials. The temperature difference of the ground corn cobs is approximately 90% of that of the Rock Wool and cellulose and therefore the insulating ability compared to the Rock Wool is about the same percentage.

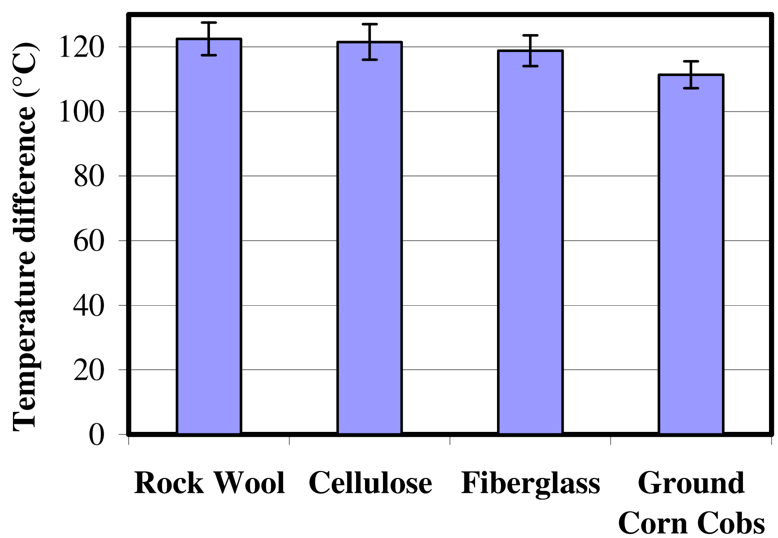

Figure 6. Temperature difference between lower and upper compartments for each insulating material tested

6. Conclusions

From these experimental tests it appears that placing ground corn cobs in a confined space will not have as good as insulating ability as typical insulation; however, if space is not as critical, such as in an attic, the ground corn cobs can have the same insulating ability by creating a greater thickness of ground corn cobs compared to traditional insulation as long as the ceiling can hold the additional weight. Other factors to consider are the use of original and recycled products of the different insulations. Most manufacturers of fiberglass insulation state that 40-50%, by weight, of their product is made from recycled glass. The company that makes Rock Wool insulation states that generally 50% of their product is made from recycled rock. Cellulose has long been known as being made from recycled paper but after adding non-recycled fire retardant the insulation is made from 85%, by weight, of recycled material. Insulation made from ground corn cobs would need to have fire retardant added and therefore approximately 85% of the insulation would be made from recycled materials.

Examining the results it appears that using ground corn cobs as an insulating material may be effective in a couple different possibilities only if the cost of making insulation from ground corn cobs is noticeably cheaper than making other typical forms of insulation. One possibility is to install insulation made from ground corn cobs to a greater depth in attic areas to obtain the same insulating ability. Another possibility is to combine the insulation made from ground corn cobs with cellulose and test the insulating ability of the mixture.

In conclusion it is valuable to propose possible uses of renewable materials so that less non-renewable materials are used and less materials need to be disposed of. These proposed uses can also lead to other uses involving renewable products. From the results of the experimental testing, ground corn cobs are not as good for thermal insulation as typical insulating materials some of which are currently made with a large percentage of recycled material; therefore ground corn cobs used for thermal insulation would be cost-effective if it can be made much more cost-effectively than current material or if the current materials significantly increase in cost.

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