SOLAR RICE DRYING IN ACEH

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ABSTRACT

This paper presents the results and observations to date from the solar energy program at the University of Syiah Kuala in Aceh. The solar energy program is starting its second year of projects which include the following: development and construction of a solar water distillation unit, the recording of solar radiation intensity data, the investigation of traditional methods of rice drying and the construction of a one ton solar rice drier, based on an A.I.T. design.

A summary of some of the water distillation project results helps set the background for an examination of solar radiation energy in Aceh and possible new solar rice drying methods. Results and observations from a study on the traditional rice drying methods of bamboo matt and concrete surface drying are given. And, data from a sociological study on rice drying and storage in Aceh are discussed.

A brief description of the A.I.T. solar rice drier is given; and its advantages, place in the UNSYIAH solar energy research program and possible future uses in Aceh are discussed. Comments concerning the long range integration of large volume solar rice drying into the Acehenese culture are also made.

SOLAR ENERGY RESEARCH AT UNSYIAH

In 1982, the University of Syiah Kuala at Banda Aceh contacted the BKS-WUEA educational development project about an instructor to help teach and develop a program in the area of solar energy. The idea was to develop not only a course in solar energy at the under-graduate level that would help train future teachers and researchers, but at the same time, begin some low level solar energy experiments that could be used by extension programs in the province of Aceh. I was applying for a position with the BKS-WUEA project at that time and arrived at my post in January of 1983.

The BKS-WUEA project is administered under a contract from the American Embassy by the University of Kentucky in the U.S.A., with a focus on developing the college of agriculture in eleven universities in Sumatra and Kalimantan. Because of this agricultural focus, we were concerned that the research done at UNSYIAH not only be solar in nature, but also related to the agricultural or rural development problems in Aceh. Several areas of study were discussed, of which, the development of a solar water distillation - salt production unit and a solar rice drying unit were judged as most suitable.

In August of 1983, construction was begun on a 16 m^2 water distillation unit which was completed in November 1983. During this past year, data on the distillation of low salt concentration well water was taken, which is pointing the way towards a more inexpensive design for village use and development. Future experiments are also being laid for the testing of ocean water distillation, which we hope will lead to ways of greatly reducing the energy requirements for salt production in Aceh.

During the past school year we have also considered ways to begin our research in solar rice drying. One student expressed interest in studying the traditional methods of rice drying in Aceh for his senior design project, and at this time, is finishing a sociological and heat balance study of rice drying on bamboo matt and concrete. We are following up on this background work with the construction of a one ton solar rice dryer that was developed at A.I.T. in Bangkok. Construction has begun and should be finished sometime in September. Basic performance in rice drying will then be tested and compared to the results published by A.I.T. and if successful, additional tests on clove drying will be done next year.

In this report, I will present some of the results from the various aspects of our budding solar energy program, and then proceed to describe some of our ideas for future research in solar rice drying for Aceh.

TRADITIONAL RICE DRYING METHODS IN ACEH

In Aceh, most families own less than a hectare of land and harvest an average of 2 metric tons per hectare, per harvest. Harvest times come three times per year, with the first rice season running from August to November, to be followed by an alternate crop from December to March and returning to rice again from April to July. Turn around time between harvesting and planting is around one month, during which all of the post-harvest and soil preparation work needs to be done.

Harvesting is done by hand, using a sycle, as is common in Indonesia. After the grain is cut, it is piled on the side of the sawah and left to dry for approximately 3 to 6 days before it undergoes threshing. The threshing itself is done by hand and is accomplished by simply striking the rice stalks against something. Afterwards, the grain is cleaned by pouring the grain from a 1 ½ meter height to the ground. The wind takes away most of the chaff and the rest is cleaned by hand. The moisture content at this point was measured and found to average around 22%.

At this point in the process, people generally set aside a small portion for reseeding and sell the rest to a cooperative. Sacks of approximately 80 kg capacity are used for this and most family complexes will have several of these sacks stored in a corner. For some households, however, an alternative method of storage is used. This consists of a container of about 2 cubic meters volume constructed of wood. On the bottom is a bamboo matt and along its four sides are pieces of wood or oil-palm branches. These containers many times have their own platform and roof and stand by themselves at a short distance from the house, yet within the family compound. Maximum possible storage time is generally 6 months at which time, the rice begins to be ruined by mold, insects and deterioration.

Whenever a family needs to use some of their rice, they will remove it from storage and then dry it on a bamboo matt for one day before having it milled. The bamboo matt varies in size but averages approximately 2½ m × 3½ m for 8.75 m^2 of drying area. This matt is placed near the house somewhere, with either soil, grass or concrete directly underneath it. The rice has an average initial moisture content of 21% at this time and is placed on top of the matt to a height of 0.5–1 cm. It is then dried for 6–7 hours during which time the rice is turned over twice. Moisture content from samples taken at the end of the day ran between 11½–13%.

Larger cooperatives use a concrete surface located near their milling and storage unit. Rice previously bought from the farmers at 22% moisture content is stored in sacks at the mill until there is time to mill it. One day before the rice is to be milled, it will be layed out on the concrete to dry. Average moisture content of this grain is between 19–21% and the rice is placed on top of the concrete to a depth of 4–5 cm. Drying goes on for about 7 hours and repeatedly the grain is turned over with a flat wooden paddle. The moisture content at the end of the drying process was found to be between 13.5–15%.

The size of drying areas runs between 50 m^2 to 150 m^2 and often the surface of the concrete is not flat but shaped like a sinusoidal curve with about 1 meter between the high points, as given in the following figure. The advantages of this system stem not from its drying ability, but from the advantage of the operator being able to collect the rice on the high points during a sudden rain storm. The operator will cover the rice with plastic if the rain is light and leave the low areas free for rain water runoff. When the rain

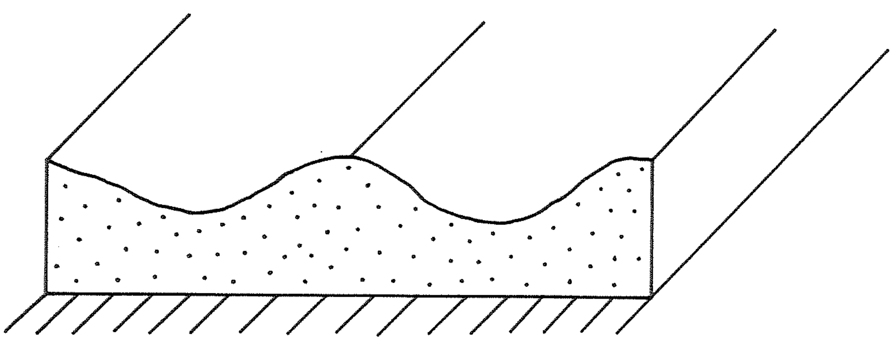

Fig. 1. Sinusoidal Concrete Surface.

passes, the rice is re-distributed over the surface once more and the drying continues.

Rain is a real problem in Aceh in that, even though it rains more in the months November to January, there are no set seasons and the possibility of rain is a daily reality. If the rain is too hard, the operator is forced to put the rice back into its sacks and continue drying the next day. This in turn brings up one of the major disadvantages of this type of drying method - the occurrence of losses due to handeling. It was not the purpose of our research to study the impact handeling losses have on this drying method, but from other studies, we know that they range from 5 to 20%.

HEAT TRANSFER CONSIDERATIONS OF TRADITIONAL RICE DRYING

Six one-day tests were made to study the temperature variations within a layer of rice on bamboo matts and concrete. Testing was done out-of-doors on a drying site in Aceh. Because of the testing conditions, the data taken is not steady state in nature and makes it difficult to address in depth any theoretical heat transfer concepts involved. However, it is possible to look at the overall heat balance and general heat flow mechanisms.

Thermometers were placed at various positions around and in the rice in the following manner. (1), A thermometer was placed in the ground below the bamboo matt and in the concrete to measure the heat flow to the ground beneath the rice. (2), A thermometer was placed on the matt or concrete surface to measure the temperature at the lowest level of the rice. (3), A thermometer was placed just under the surface of the rice so that the temperature of the top layer of rice could be measured. (4), The wet bulb and dry bulb temperatures of the air, about 10 cm above the rice, was taken.

Data on solar intensity, wind velocity and barometric pressure were taken every 30 minutes while rice samples were taken each hour to measure the change in moisture content.

Bamboo Matt

The bamboo matt, as is typically done, was placed on top of grass instead of open ground. An air space of 2 cm was thus formed between the matt and ground. Wind velocity during all of the tests was fairly light at a velocity of 1 ½ m/sec with an occasional period of two hours when wind velocity reached 4 m/sec. Because of this, the air space below the matt tended to act as a layer of insulation.

The ground temperature below the matt was found to vary with ambient temperature, (dry bulb measurement), above the matt, and differences between these two temperatures were nearly always less than 2 °C. Ambient air temperatures ranged from 29 °C at 9 : 30 to 36 °C at 12 : 30 with temperature differences in the morning showing the ambient temperature 1—2 °C higher than the ground temperatures, while afternoon temperatures show the ground temperatures running 1—2 °C higher than the ambient temperature.

Matt temperatures were always higher than the ground temperatures, ranging from 35 °C to 46 °C on a clear day and up to 42 °C on an overcast day. Temperature differences between the ground and matt were 7—8 °C, with an occasional period of 12 °C, as opposed to the 1—2 °C difference between the ground and ambient temperatures. This fact adds to our previous observation of an insulating dead air space below the matt.

Temperatures at the top of the rice layer ranged from 36 °C to 49.5 °C or from 1—4 °C higher the matt temperature. Differences between the top of the rice and ambient temperatures ran between 7 °C in the morning to 10—13 °C by mid-day.

Moisture content started at 22% each time and dropped to 17% by 11 : 30 on an average day and to 14% by 11 : 30 on clearer days. A better indicator was found to be the top and bottom temperatures of the rice layer, which were always 40 °C and 39 °C respectively when the rice reached 17% moisture content. Thus, with a 3—4 °C temperature rise, the rice will drop 5 percentage points of moisture. From this point on, the drying rate changed from 0.9—1.2 percentage points per hour until 13:00, when the rate changed to 0.6—0.8 percentage points per hour. This lasted until either the sun set or the 11.5% moisture level. At this 11.5% moisture level, the rate of drying changed once more to 0.2 percentage points per hour. Final moisture contents for the 6 tests on a 1 cm deep layer ran from 11—13.8%.

Concrete Surface

The concrete slab used in these tests was 8 cm thick and flat. No paint was applied to the surface. For this test a hole was drilled into the concrete and a thermometer stuck tip first into the concrete. The other grain thermometers were again placed at the bottom and top of the rice layer which was 4 cm thick for each of the tests.

The concrete temperature maintained a fairly close range of 38.5—41 °C and was found to be always higher in temperature than the lower level of rice. Generally it was 1½—2 °C higher in temperature, though at times it would have the same value in the middle of the day. The temperature of both the concrete and lower level of rice varied in a similar manner as the ambient temperature, but within a closer range. The ambient temperatures were the same as those in the matt drying tests and varied from 29 °C to 36 °C within a day's cycle.

Because of the high conductivity of the stone compared to the loosely packed rice, heat conduction away from the rice to the ground does happen. However, a basic heat balance across the concrete slab shows that heat loss by conduction amounts to less than 1 % of the incoming solar energy.

The top of the grain temperature varied from 34—46 °C or 3—6 °C higher than the lower part of the rice layer. Temperature differences between the top of the grain and the ambient air ran from 5 °C during the morning to 13 °C around mid-day.

Moisture content started at 22% each time and dropped to 17% by 14 : 00 on an average day (though on a clear day it was accomplished by 12 : 30). A better indicator here for the 17% moisture point was a 45 °C top temperature and a 39 °C lower level temperature. Drying rates do not appear to be constant and vary between 0.7—1.2 percentage points per hour until the grain reaches 14.5% moisture. At this point, the rate drops to 0.6—0.8 percentage points per hour. However, it usually takes the entire day to reach 14.5% moisture, and it is difficult to say whether or not an actual change in drying rate occurs or whether the solar radiation intensity has simply slacked off at the day's end. Final moisture contents at the end of the day for the 4 cm layer ranged from 13.7—14.9%.

Comparison

Except for the physical layout, the methods are quite similar and only four characteristics need to be compared to understand their differences. (1), The volume of the concrete surface method is four times that of the matt method, yet, (2), only the temperatures under the matt and in the concrete differ significantly. The third, (3), characteristic is that the matt drying shows all three textbook stages of drying, (initial, falling and leveling out), while the concrete surface method operates in only the first two stages where most of the water is lost. Thus the matt drying method shows a greater volume of water lost per volume of rice. However, the optimum moisture content is 13—14%, and it is not optimum to dry the rice to the extent that the matt method does. In turn, the final moisture content levels of the concrete surface method need to be a little lower. This could possibly be accomplished by drying more rice at one time with the matt method and less rice with the concrete surface method.

The last, (4^{th}), characteristic is that of an overall efficiency. If we define the efficiency as the energy used to vaporize the water, divided by the solar energy that falls on the rice surface, we can determine the overall performance of each method. Using this definition, the efficiency for the bamboo matt method is approximately 8%, while the concrete surface method has an approximate efficiency of 26%.

If all of the rice had dried at the same performance level as the matt method, we would have expected the concrete surface method's efficiency to be 4 × 8% or 32%. However, because there was a difference in the final moisture contents of the two methods, the concrete surface method had a lower efficiency. Thus, if the height of the grain on the concrete surface is decreased, we expect the moisture content to decrease as well. This suggests that an optimum efficiency for the matt drying method should be approximately 7.5% while $7.5 \times 3 = 22.5\%$ is best for the concrete surface method.

SOLAR WATER DISTILLATION UNIT

About a year ago we built a solar water distillation unit at UNSYIAH, and though it has little to do with rice drying, some of the results cast some light on the concrete surface method. The unit consists of a concrete slab of about 8 cm thickness, with short walls built around it. Two opposing walls are sloped upwards towards their centers at a 10° slope, and support beams placed across their centers. Glass windows were then placed over the entire unit, and the concrete was painted black.

Operation is simple. Water is placed in the unit, which vaporizes in the heat of the sun. The vapor then rises and condenses when it touches the windows. From there it flows down the bottom side of the window to pipes which carry it outside of the unit.

General efficiency of the unit is about 25%. Temperatures of the water rise to approximately 63°C by 13 : 00 and the concrete temperatures average 1—5°C higher than the water temperature, while the glass temperatures run 1—5°C cooler. Average output is around 1.75 l/m^2/day or 20 liter/day for the unit.

A heat up time is necessary before vapor is produced each day and generally it is 11 : 00 before the first liter is produced. After 11 : 00 water is distilled at the rate of 2—3 liters per hour until dark (19 : 00 in Aceh) and continues on through the night until all of the usable energy in the concrete slab is exhausted. Approximately 1/3—1/2 of the unit's output is produced after the sun has gone down.

Looking only at the concrete, we see that because of the black color alone the temperature runs about 15° higher than the top surface temperature of the rice surface mentioned in the traditional methods discussion. Approximately 40% of the usable energy was stored in the concrete to be used after the sun had set. This is a solar passive design concept that is used by architects to store heat in a building for winter heating. Here, there is no winter, but the same concepts should be applicable in future modifications of the traditional solar rice drying methods in Indonesia.

A.I.T. SOLAR RICE DRYER

At this time we are in the process of constructing a solar rice dryer designed by A.I.T. in Bangkok. This unit is made chiefly of bamboo poles and plastic and consists of a solar collector area with an adjoining room containing a drying table. The following figure shows the basic layout. From points AA to BB is the solar collector (which is nothing more than an earthen area covered over with plastic). Air heats up in this area and rises naturally under the plastic to the bottom of the table, at point C. From there it passes through the rice on the table and up out of the chimney at point E. Rice is placed on top of the table by opening the doors at D and simply pouring it out evenly.

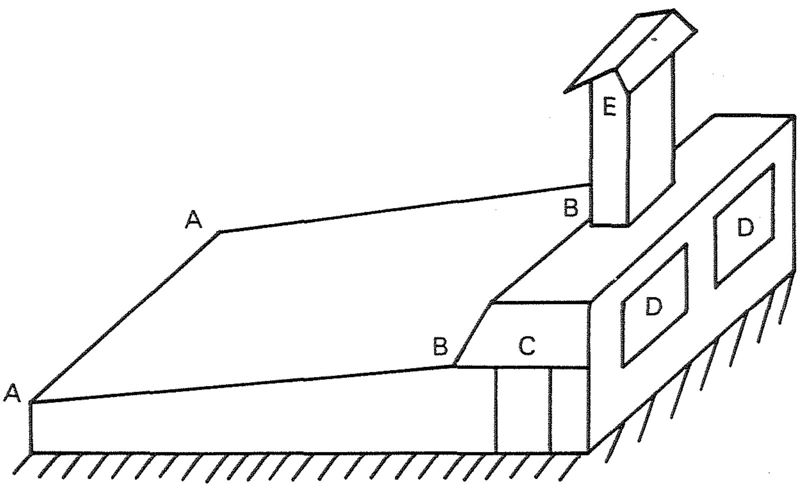

Fig. 2. A.I.T. Solar Rice Dryer.

The solar collection area for the unit is 4.5 m × 7 m, and the drying table area is 1.5 m × 7 meters. Unit capacity is one ton or 1.6 m^3 of rice, and the average time to dry the rice from 22% moisture to 13% is 2 days.

We have selected this unit because it fits both into our solar program as a solar demonstration experiment and because we wanted to demonstrate a rice dryer of medium capacity. As far as performance is concerned, there is no advantage to this unit. The traditional concrete surface method takes the same drying area for one ton of rice as this unit does, and an operator will usually dry for only one day.

Characteristics of handeling and uniformity of drying, however, are much more important with cracking due to dryness greatly reduced and the chance of re-wetting from a sudden rain storm eliminated. The rice is also up off of the ground so that extra dirt from the atmosphere can not settle on the rice, thus improving the cleanliness of the rice.

The cost of the unit, given by A.I.T., is approximately Rp 200,000.— which, at this point in time, is too expensive for most farmers. We are expecting, however, the demand for not only higher quality rice, but higher quality agricultural products in general, to increase in the next ten years. Thus in turn, creating a demand for this unit.

After preliminary studies on rice drying, we will test the unit for clove drying. This is a high cash crop for richer urban dwellers who own property in the country. These people should be willing to not only purchase such a unit for their cloves, but also be willing to use it for rice drying on their rural family property. In this manner, we hope the unit will be accepted in Aceh over a 10—15 year period.

FUTURE RESEARCH

Future research in solar rice drying will have to focus on specific aspects of both solar radiation energy absorption by the rice and heat storage in the drying system before serious alternative designs can be made. The use of either a black surface below the rice or a black plastic sheet on top of the rice, for example, may increase the heat properties by 5—10% while storage of heat in the concrete could provide even higher efficiencies.

Some ideas that I personally have are as follows, (1) Painting the concrete black for concrete surface drying, (2) Using a strip of black plastic with holes punctured in it on top of the rice to increase the amount of energy absorbed into the rice, (3) Altering the A.I.T. design so as to use a black concrete surface as the solar collection area, and (4) Building a water distillation - salt production unit that could readily convert to a grain dryer. Determining whether or not an idea is realistic is the function of a research program, and in the future, we at UNSYIAH hope that some of our ideas can realistically add to the performance of the solar rice drying done in Aceh.