## USO DE LA ENERGÍA EN LA AGRICULTURA
## *USE OF THE ENERGY IN AGRICULTURE*

# Fabrication and evaluation of a Solar Grain Dryer

# *Fabricación y evaluación de una Secadora Solar de Granos*

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**ABSTRACT.** The drying process is a principal activity in postharvest operations in grains; to economize on energy sources and reduce pollution of the environment it is possible to develop solar grain dryers. For that reason the fabrication and testing of a Solar Grain Dryer was done. The following show the main results, the mean moisture content before drying on the surface was 22,51% and after drying was 11,6%, and at the bottom the mean moisture content before drying was 22,78% and after drying was 13,2%, therefore the average mean moisture reduction rate was 0,84%/h, also before drying the mass of paddy was 120,28 kg and after drying was 105,40 kg, therefore 14,88 kg of water was removed and the fuel consumption of the diesel engine during 12 hours operation was 2,75 L. The overall results were impressive; therefore this prototype will help the small scale farmers to improve the quality of grain during the operations of postharvest.

***Keywords:*** drying, solar energy, moisture content.

**RESUMEN.** El proceso de secado es una actividad principal en las operaciones de postcosecha en los granos; para economizar en Fuentes de energía y reducir la contaminación del medio ambiente es posible desarrollar secadoras solares de granos. Por esta razón se realizo la fabricación y la prueba de funcionamiento de una secadora solar de granos. Los principales resultados obtenidos fueron los siguientes, el contenido medio de humedad antes del secado en la superficie fue 22,51% y después del proceso de secado fue 11,6%, y en el fondo el contenido medio de humedad antes del secado fue 22,78% y después de secado fue 13,2%, por lo tanto el promedio de la tasa de reducción de humedad fue 0,84%/h, también antes del secado la masa de arroz cascara fue de 120,28 kg y después de secado fue 105,40 kg, por lo tanto 14,88 kg de agua fueron separados y el consumo de combustible del motor diesel durante 12 horas de operación fue de 2,75 L. Los resultados obtenidos fueron impresionantes; por lo tanto este prototipo ayudaría a los Productores de pequeña escala a mejorar la calidad del grano durante las operaciones de postcosecha.

***Palabras clave:*** secado, energía solar, contenido de humedad.

## INTRODUCTION

Open air sun drying has been used since time inmemorial to dry plants, seeds, fruits, meats, fishes, woods and others agricultural or forest products as means of preservation. However, for large scale production the limitations of open air drying are well known. Among these are: high labor cost, large area requirement, lack of ability to control the drying process, possible degradation due to biochemical or microbiological reactions, insect infestation, etc. (Laszlo, 1974; Mujumdar, 1987)

Energy consumption to dry agricultural crops can exceed the energy required to produce the crop. Since crop drying is a high energy use operation; the cost of drying is directly related to energy availability and its cost. As energy costs rise, energy conservation and the use of alternative energy sources become more important.

The possibility of using solar energy to dry agricultural crops was investigated by Buelow in 1958, and in 1963 Buelow and Sobel present design of solar energy collector for heating air that could be used for drying crops. (Buelow, 1958; Shove, 1977)

In Cuba the rice is the principal crop because the consumption of this product is very high, for this reason Cuba need to increase the rice production and to improve the quality of this product, but the small scale farmers don't have the technology to achieve this, for example they develop the drying of rice manual, on the road and on the house roofs, this can cause losses resulting from bad weather, leading to deterioration of the produce, from animals eating the produ-

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ce, and from contamination or infestation.

The principal objectives of this work are: to improve rice quality, to get environmental and economical advantages, and to disseminate this technology to the Farmers.

## MATERIALS AND METHODS

### Principals Parts

Solar collector
Drying Box
Fan
Diesel Engine (4hp)

### Possibilities Materials

Sheet metal
Sheet punched metal
Steel pipe work
Angle Iron
Plastic cover
Wood
Bearing
Belt

### Methodology

*Air flow per unit time*

To removed water content in the paddy rice it is important to have dry air circulating; this is possible by fan, for that reason it is important to know the air flow that circulate between the paddy rice.

$$Wair\left(m^3/s\right) = S * A$$

Where:
S-Mean wind speed (m/s);
A-Cross sectional area of duct ($m^2$).

### Moisture Content on wet base

It is very important to have the knowledge that products with high moisture content will not keep for extend periods in storage. The moisture content is an index of the probable keeping quality of the product and can be expressed on either the wet or dry basis. Also this parameter is possible to determine using a moisture meter. (Sato, 1994)

$$Mwb(\%) = \frac{W}{Wa + W} * 100$$

Where:
W- Water content (kg);
Wa- Weight after drying (kg).

*Mean Moisture Reduction Rate*

The degree of grain moisture is measured per one hour to observe change in moisture content. In general, the mean moisture reduction rate per hour.

$$Mm\left(\%/h\right) = \frac{Mi - Ma}{to}$$

Where:
Ma–Moisture content after drying (%);
Mi–Initial Moisture content (%);
to–Operating hours (h).

*Mass of paddy after drying*

The mass of paddy rice after drying may be exactly measured because it is not difficult to take out all grains from sheet punched metal, for this reason it is possible to use a balance, if there is no balance it is possible to use the following expression:

$$Wa = \frac{Wb\,(100 - Mcb)}{(100 - Mca)}$$

Where:
Wa- weight after drying (kg);
Wb- weight before drying (kg);
Mca- Moisture Content after drying (%);
Mcb- Moisture Content before drying (%).

## RESULTS AND DISCUSSION

The Performance Test of the Solar Grain Dryer began on the 31 of August (14:10 H) to 2 of September, 2010 (13:30 H). This study was carried out on Tsukuba International Center (TBIC), Japan, with fine weather condition, and using variety of paddy rice IR-28. Initially the total mass of paddy rice before drying was 120,28 kg, also determined was the moisture content % of paddy for each bag in order to determine the mean of moisture content of paddy before drying as shown in Table 1.

**TABLE 1. Moisture Content (%) of paddy before drying**

| Bag | M. C (%) |
|---|---|
| 1 | 21,65 |
| 2 | 23,65 |
| 3 | 24,75 |
| 4 | 22,6 |
| 5 | 19,9 |
| Mean of M.C. | 22,51 |
| Standard Deviation | ± 1,86 |

Also in this study was determined the Air Flow per unit time using the expression (1), beside with the objective of analyzing the drying process and the homogeny in the drying of the grain was to determine the relationship between the change of drying hours and the mean moisture content at the bottom and on the surface as shown in Figure 1.

For to get homogeny in the drying to the grain also was consider the relation between the temperature of grain and Relative Humidity on the surface and at the bottom as shown in Figures. 2 and 3.

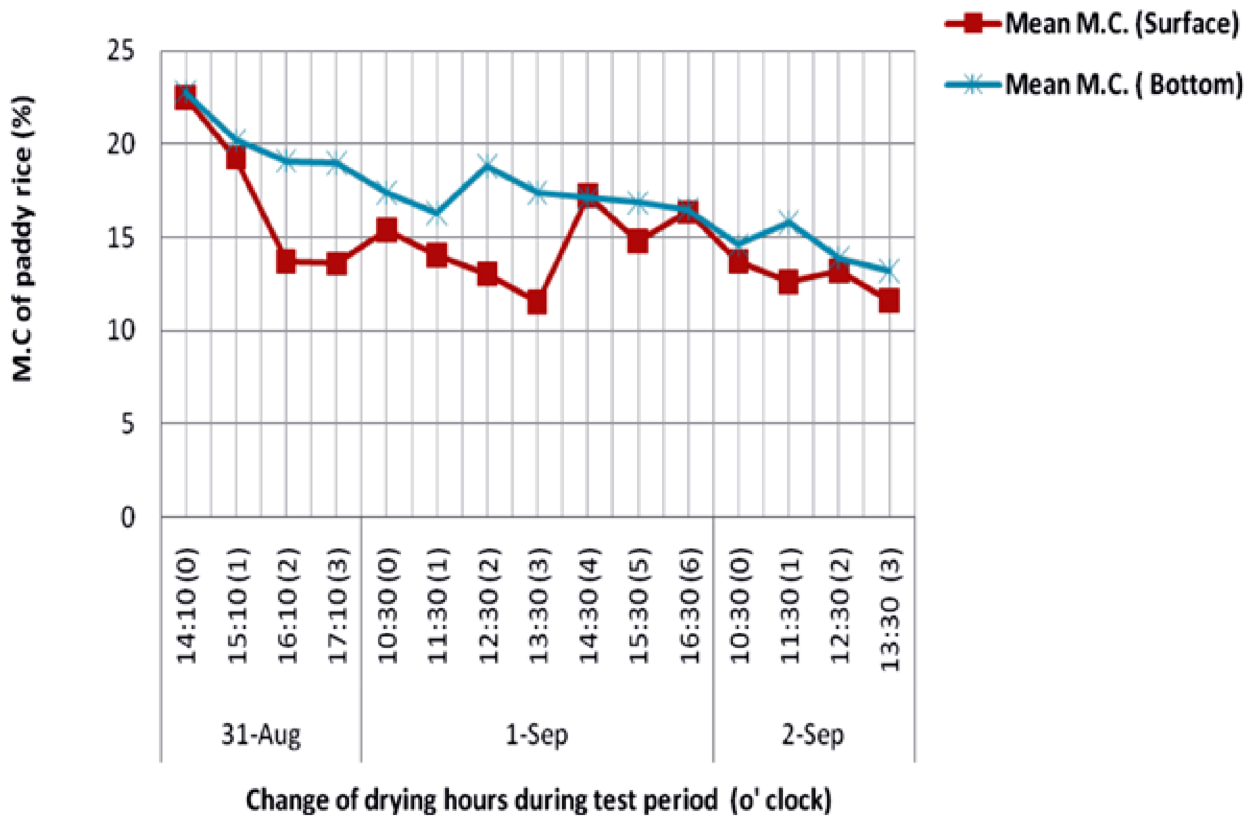


FIGURE 1. Relation between the change of drying hours and moisture content of paddy grain on the surface and at the bottom.

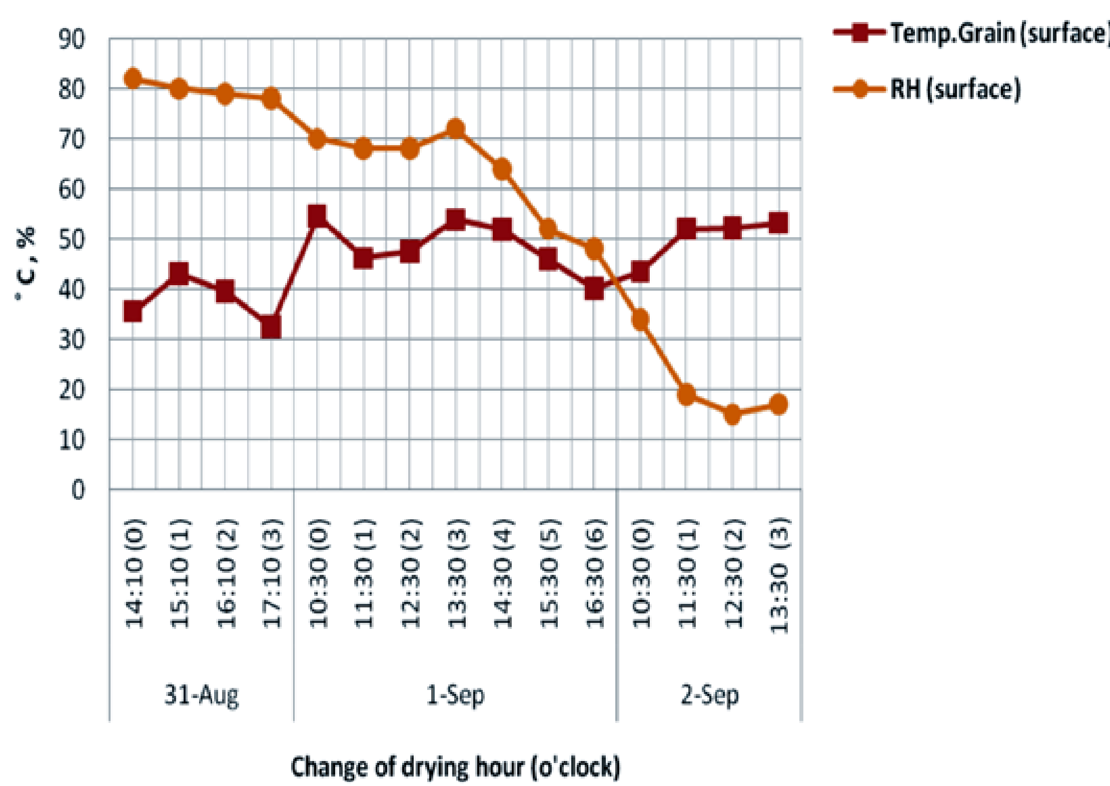


FIGURE 2. Relation between temperature of grain and Relative Humidity on the surface.

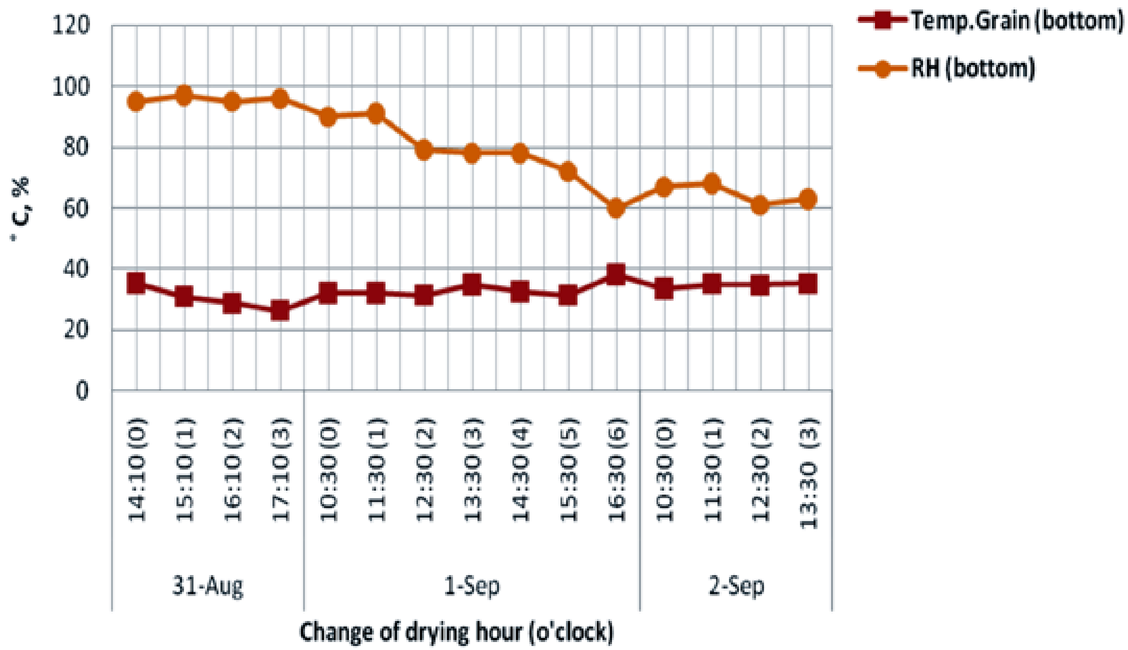


FIGURE 3. Relation between temperature of grain and Relative Humidity at the bottom.

For to get homogeny in the drying, the grain was turned for two times during the drying process, (1/September, 13:30 H) and (2/September, 12:30 H), also in this study was considered the averages of Ambient Relative Humidity (79,3%) and the Ambient Temperature (36,8 ˚C), during days evaluation of the Solar Grain Dryer, besides was measured the solar radiation, the maximum value was obtained the 1/September, 11:30 H.

## CONCLUSIONS

The main results of fabrication were:

- This prototype is relatively cheap to build and do not require skilled labor because this machine has simple structure, the cost of materials used to build the prototype are shown in Table 2.

**TABLE 2. Cost of materials used to build the Solar Grain Dryer**

| Material | Price/unit (USD) | Quantity (unit) | Cost (USD) | Dimensions |
|---|---|---|---|---|
| Diesel Engine | 1200 | 1 | 1200 | 4 hp |
| Sheet metal | 30 | 4 | 120 | 1800 x 900 x 1200 |
| Sheet punched metal | 170 | 1 | 170 | 1800 x 900 x 1200 |
| Angle Iron | 8.5 | 5 (30 m) | 42.5 | 3 x 30 x 30 x 6000 |
| Steel pipe work | 2.4 | 5 (6 m) | 12 | Φ 13 x 1200 |
| Plastic Cover | 100 | 1 (5 m$^{2)}$ | 100 | - |
| Wood | 3 | 1 (5 m) | 3 | 5000 x 35 x 45 |
| Bearing | 8 | 2 | 16 | $\Phi_e$36X $\Phi_i$ 15X10 |
| Belt | 15 | 1 | 15 | Bando V. A-70 |
| **Total** | | | 167.5 | |

- The total weight of Solar Grain Dryer is 115 kg.

The main results of performance test were:

- The air flow determined was 0,098 m$^3$/s with a mean wind speed of 1,4 m/s,
- Revolution of fan was 640 rpm and 1650 rpm for engine.
- Before drying the mean moisture content on the surface was 22,51% and after drying was 11,6%, and at the bottom the mean moisture content before drying was 22,78% and after drying was 13,2%, therefore the average mean moisture reduction rate was 0,84%/h, this value is superior to the standard for dryers machines which is 0,70% /h.
- Before drying the mass of paddy was 120,28 kg and after drying was 105,40 kg, therefore 14,88 kg of water was removed, according Buchinger and Weiss (2001) (Buchinger and

Weiss, 2001), the quantity of water that must be removed of the total quantity of rice to dry is the 10%, in this prototype in this conditions was 12,37%.
- Before Drying the relation between temperature of grain and Relative Humidity on the surface was 35,5 ˚C (82%), after drying was 53,2 ˚C (17%) and this relation at the bottom was 35,3 ˚C (95%), after drying was 35,2 ˚C (63%), these parameters are direct proportional to drying process, in case of bottom the temperature was almost constant, it is cause of air flow for that reason the Relative Humidity didn't decrease so much.
- Fuel consumption of the diesel engine during 12 hours operating was 2,75 Liters.
- To enhance the performance of the Solar Grain Dryer it is recommended that:
- To test this machine with more quantity of grain for drying, to evaluate efficiency
- To realize this study using others crop to check the efficiency of the machine.

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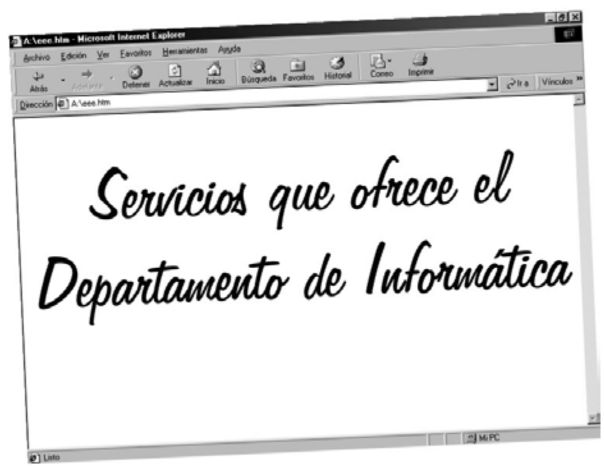


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