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DEVELOPMENT AND EVALUATION OF A NATURAL CONVECTION SOLAR DRYER

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ABSTRACT

A simple solar dryer has been developed and tested for drying high moisture rough rice at the experimental farm of Rice Mechanization Center (R.M.C), Meet El-Dyba, Kafr El-Sheikh Governorate.

The dryer used solar heated air passing by natural convection through a bed of paddy, and from solar radiation incident on the top of the bed. The results showed that, drying started simultaneously at the top and bottom of the bed, while the middle layer dried slowest. Periodic stirring of the bed of paddy reduced the drying time by about 4 hours and led to a uniform grain moisture content at different layers of the drying bed. The recorded drying times for solar drying with stirred and unstirred bed were 22 and 26 hours respectively as compared with 46 hours for natural sun drying in open mats. A significant improvement in final quality of grain dried by the solar dryer was obvious as compared with the grain dried in open mats specially broken percentage of milled rice which decreased by about 3.59% for stirred bed and 2.41% for unstirred bed.

INTORDUCTION

Due to the steep increase in the price of energy, alternative energy sources have become more attractive. Solar energy is one of these alternative energy sources. The solar energy applications is dependent upon the development of systems that have optimum performance, good reliability and economic characteristics that compare favorable with conventional energy systems and other energy sources (Abdelatif et al., 1993).

Egypt is one of the countries, which has solar energy in abundance. It lies within the tropical and sub-tropical regions. It has a value of about 2.2 to 9.4 kW of solar energy per square meter per day, and sunshine duration per year extended to about 3000 to 4000 hours (Abdelatif, 1989 ; Awady *et al.*, 1993).

In Egypt, natural sun drying is one of the most common ways to conserve agricultural products. Considerable losses may occur during natural sun drying due to various influences, such as rodents, birds, insects, rain, storms and microorganisms. The quality of the dried products may also be lowered significantly (Lutz *et al.*, 1987; El – sahrigi *et al.*,19)

To overcome the existing preservation problems of agricultural crops in Egypt, the introduction of solar dryers seems to be a promising way since the available amount of solar energy is sufficient to provide the heat requirements of the small dryers. The solar drying system for crops drying depends on a temperature rise of only a few degrees in order to dry the crops in an extended period of time. Most of the solar drying systems depend on a forced or a natural convection air for reducing the moisture content of the product (Tayel and Wahby 1989).

Various types of small scale solar dryers have been developed for application in developing countries. Among the various systems described in the literature, the most promising for the purpose of in farm drying are those on which operated using only sun and wind as energy sources and these type of dryers are classified as natural convection type dryers. These types of dryers usually consists of inclined collector which is coupled with a drying chamber hold the product. Air circulation is provided by ascending forces. However, forcing the air even through a very thin layer results in a relatively high air resistance, which cannot be overcomed by natural convection only. Therefore, chimneys or wind powered ventilators have been installed to increase air flow (Sabbah, 1985).

Natural convection type solar dryers offer a means of protecting the crop during the drying process. Also the drying time can be reduced compared with natural drying (El-Shiatry *et al.*, 1991).

Tayel and Wahby (1989) investigated the behavior of a solar drying system using the principle of natural convection. Three products were used in the test. The moisture content of product, ambient temperature, drying air temperature, and air relative humidity were measured thoughout the drying period. It was found that, the system behavior was similar to the convection drying system. The drying rate of the product in the system was affected by the surface area and mass of the product.

Adeyemo (1993) studied the effect of two modifications on the performance of an air convection dryer used to bring wet grain to safe moisture content for storage. The modifications introduced were, floating the heating medium and introduction of a suction fan to increase airflow to the plenum chamber. Results obtained showed that, drying time, drying rate and drying efficiency improved the performance of the dryer but not significantly when compared with those obtained for non-modified dryer.

Ayensu (1997) designed a solar drying system on the principle of convective heat flow. The dryer was constructed from local materials (wood, metals and glass sheets) and used to dry food crops (cassava, pepper, okra, groundnuts, etc.). The obtained results revealed that, it took nearly two times longer to dehydrated crops by open air sun-drying compared to the convective heat flow solar dryer.

The general objective of this study is to develop, test and evaluate a convection solar dryer for drying high moisture rough rice under Egyptian climatic conditions.The specific objectives were as follows:

1- To develop a simple natural convection solar drying system that can be assembled by farmers using a simple tools and local materials.
2- To evaluate the dryer performance in comparison with natural sun drying method.
3- To determine the influence of grain stirring process on drying time and the uniformity of moisture content of the solar dryer.
4- To assess the final grain quality with respect to grain crack percentage, percent of broken kernels, whiteness degree of milled rice and germination percentage of the dried grain.

THEORETICAL CONSIDERATION

Considering the basic energy balance equation for drying process is:

$m_w L = m_a c_p (T_i - T_f)$ ....(1)

Where (m_w) is the mass of water evaporated from rice sample and absorbed by drying air of mass (m_a); c_p is the specific heat capacity of the air at constant pressure; L is the latent heat of vaporization of the water from the grain and (T_i) and (T_f) are the initial and final temperatures of the drying air receptively.

It is assumed that L and c_p are known, and the T_f can be found from the ambient condition with the help of the psychometric chart. The quantity m_w is calculated form the initial moisture content of rough rice (M_i) and the desired final moisture content from the equation;

$m_w = M_i (M_o - M_f) / (100 - M_f)$ ....(2)

Where M_i is the initial mass of the wet rice to be dried and M_f is the final moisture content. Therefore, to dry 1 ton of rough rice at M_o = 24% to M_f = 14%, the (m_w) is 116.28 kg.

Quantity of air needed for drying

Assuming that, the average ambient temperature during rice drying season approaches about 25°C with air relative humidity of 75%. If that air is heated to about 40°C before being used for drying. From the psychometric chart the temperature of drying air will be reduced to (27°C) and the humidity ratio (w) would change from (0.014941) to (0.020397), or Δw = (0.005456) kg/kg air.

Since $\Delta w = m_w / m_a$ = (0.005456) .... (3)

m_a = (21312.32) kg. and

T_f = 300 °K

The corresponding volume of air required for drying process

$V = m_a R T_f / p$ = (18349.5) m^3 ....(4)

Where

p = atmospheric pressure = $1.01325 * 10^5$, and

R = gas constant per unit mass of dry air = 0.291 k Pa.m^3/kg.° K

Alternatively, using eq. (1) with consideration of the specific latent heat of vaporization (L) at grain temperature of 32° C is about (2425.68) kJ/kg and the specific heat capacity (c_p) of the air at constant pressure=(1.02) kJ/kg °C. The corresponded volume of air calculated from eq.(1) is (20206.35) m^3.

In view of the approximate nature of the calculations, this is in satisfactory agreement with the value (18349.5) m^3 determined from the previous calculations.

Considering the mean value of air required for drying process V=19277.9 m^3. From the psychometric chart the quantity of thermal energy required for drying process is (15.01) kJ/kg and the specific volume of dry air required for heating process is (0.8545) m^3/kg.

Suppose that the dryer is required to dry 1000 kg of paddy and the expected drying time is 30 hours or (3 days) with 10 hours of drying per day. According to the calculation of the average quantity of air for the drying process which shows an average value of 19277.9 m^3. The airflow rate should be therefore equalled 11.5 m^3/min.

Assuming the bulk density of rough rice variety (Giza 177) at moisture content of about 24.0% (w.b.) equalled 620 kg/m^3, the volume of 1000 kg rough rice is therefore equalled1.61m^3 and the required air flow rate per unit volume of grain will be (7.1) m^3/min per m^3 of grain or (7.1) complete air change in the bed per minuet.

Pressure difference across the bed

The convection of air through the rice bed is caused by pressure drop across it resulting from the deference between the density of relative cool ambient air and the warm air inside the dryer. As shown in figure (1), let ρ be the density of the ambient air, and ρ' be the density of the warm air inside the dryer, h_1 be the height between the inlet to solar air heater and the rice bed, and h_2 the height between bed and the top of chimney. Since the height of the top of the chimney above the air inlet is (h_1 + h_2) and p represent the air pressure inside and outside the dryer at the level of air inlet, p_2 and p_3 represent the pressure inside the dryer at the bottom and top of the rice bed and p_4 the air pressure inside and outside the dryer at the top of the chimney

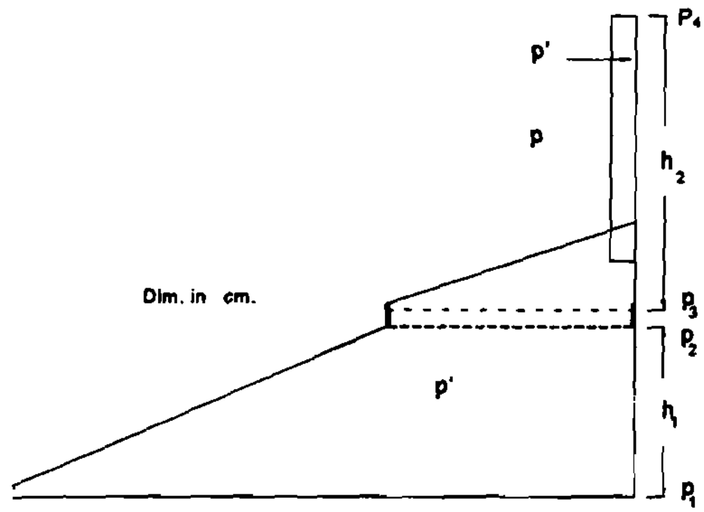

Fig. 1: Cross section showing the changes in air densities and pressure at different heights inside the dryer.

The following equations hold:

$p_2 = p_1 + h_1 \rho' g$

$p_3 = p_4 + h_2 \rho' g$

$p_4 = p_1 - (h_1 + h_2) \rho g$

Where g is the accelerated gravity (9.81 m^2/s). Eliminating p_1 and p_4 we obtain the pressure difference across the bed using equation: (Exeil, 1980)

$p_2 - p_3 = (h_1 + h_2)(\rho - \rho^-)\, g$ ....(5)

The difference in the air densities at atmospheric pressure 101.325 kPa and temperature 25° and 40°C outside and inside the dryer respectively is,

$\rho - \rho^- = 0.05\ kg/m^3$

If $h_1 + h_2 = (1.5 + 3.5) = 4.00$ m. then the pressure difference across the bed calculated from eq.(5) = 1.96 Pa

The dimension of rice bed

In the design of the rice bed the most important dimension is the depth x. It must be so chosen that, the pressure difference across the bed causes the right amount of air flow through.

Since the pressure drop across the bed is (1.96) Pa, the pressure gradient dp/dx in the bed is (1.96) Pa/x.

Considering the flow of the air through the rice bed in a natural convection solar dryer is a laminar flow (Ayensu, 1993) and directly proportional to dp/dx. So, the velocity of the air entering and emerging from the bed (v) can be calculated using the following equation;

$v = k\ dp/dx$ ... . (6)

Where:

k = 0.03 m /Pa.m as obtained from (Shedd, 1953; Calder wood, 1973).

From the calculations, the obtained air velocity (v) through the bed is (0.06 m /min/x).

Considering the air flow through the grain be expressed in terms of the number (N) of complete air changes per unit time. Then we can calculate the proper thickness of grain using the following equation:

$N = v / x$ ....(7)

Where (N) equal to (7.1). Substituting for N and v in equation (7) we find that the depth x of the rice bed should be (8.5) cm. Primary experimental tests have confirmed that, rice can actually be dried satisfactorily in beds of this depth. In fact, since the design of the dryer allows the sun to dry the rice by heating the top of the bed as well as by passing of warm air from below, beds of depth up to 13.5 cm can be dried. If A_b is the area of rice bed, then using bulk density of rough rice equal to 620 kg/m^3 for a bed containing 1000 kg, we have $A_b . X = 1.61\ m^3$. Putting X = 13.5 cm, we find that $A_b = 12\ m^2$.

The area of solar collector

In order to determine the area Ac of the solar collector to collect sufficient solar energy to dry the rice we must know the mass (m_w) of water to be evaporated from 1000 kg of rough rice, the specific latent heat of vaporization of this water (L), the quantity of solar radiation on unit horizontal area per day, and the efficiency of the solar collector.

The daily global solar radiation in Egypt ranges from 2.2 to 9.4 kW/m^2 day according to (Abdelatif, 1989) and may be taken as an average of 6.7 kW/m^2 day. Assume that the efficiency of the collector is about 25%, the total thermal energy provided by a unit area of the collector during drying period (3 days) is 3 * 0.25 *6.7 kW/m^2 day . Considering the total energy required for the drying process is 87.50 kW, which is equivalent to the total heat available for drying or 3 * 0.25 * 6.7 * A. In this case, the calculated collector area (A) = 17.41 m^2.

MATERIAL AND TEST PROCEDURE

Construction of the dryer

Figure (2) shows a side view of the developed natural convection solar dryer and figures (3) and (4) show a front and back view of the dryer. The dryer consists of a first solar collector, a drying chamber, a second solar collector and four chimneys. The first collector was constructed of a flat absorber plate made of black painted iron-sheets (1*2 m) rested on the ground and completely covered by a vinyl plastic sheet fixed on a wooden frame. The front section of the frame was divided into four equal sections each having 3 m long and 1.5 m wide to accommodate the plastic cover. The top of the air inlet at the front of the collector is 0.1 m above the ground. The drying chamber constructed of a wooden frame 0.20 m heigh and a perforated floor made of iron mesh (10% opening) to allow the passage of the hot air and prevent the grains falling down through. The cross section area of the drying chamber floor was12 m^2 and the hight over the collector absorber plate was 1.5 m. The drying chamber was followed by a second solar collector in order to raise the temperature of air and extricate the air naturally from the chamber. The second solar collector was also made of a vinyl plastic cover supported on wooden frame divided into four equal sections each having 1.85 m long and 1.5 m wide with a net surface area of 2.775 m^2. The absorber surface of the second collector was made of a perforated black plastic sheet covering the surface area of the drying chamber. Therefore, the cooled drying air would be heated in the second collector and its density become less than the cold air causing it to rise naturally upward.

Four chimneys each constructed of a hollow cylinder of 0.20 m diameter and 2.0 m high made of iron sheets with matt black paint were fixed at the top section of the secondary collector. A conical shape iron cover was fixed at 0.05 m distance over the top of each chimny to keep out rain.

For loading and unloading, there are four doors at the back of the drying chamber each having1.5 m long and 0.7 m wide with a net surface area of 1.05 m^2. All the wooden components were treated with corrode creosote wood preservative to prevent termite and fungal attack. The dryer was orianted to face southern direction in order to collect the maximum possible of solar radiation flux incident.

Test procedure and measurements

Short grain rice variety (Giza 177) was sacked in plastic bags and stored in the cooler at $-5^{\circ}C$ to supress fungal growth and prevent any moisture reduction. The average moisture content of rough rice was about 24.?? % w.b. Foreign material and unfilled grains were removed through winnowing. At the beginning of the experiments, the rough rice samples was taken out of the cooler and left until it become in equilibrium the ambient temperature before starting the experimental work.

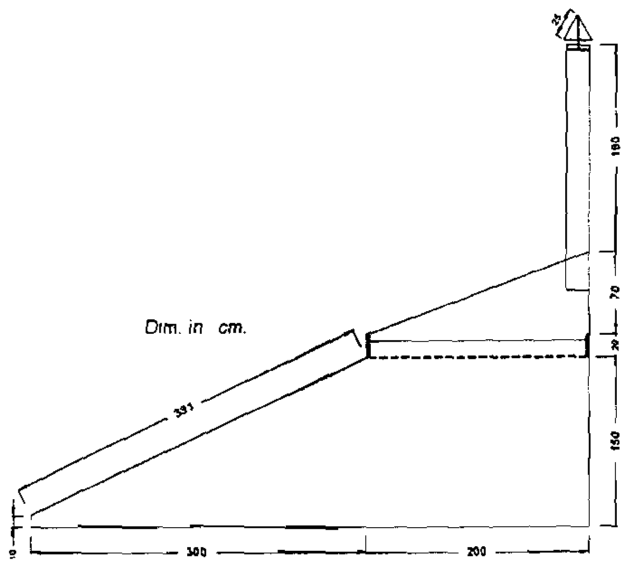

Fig. 2: Side-view of the one ton natural convection solar dryer.

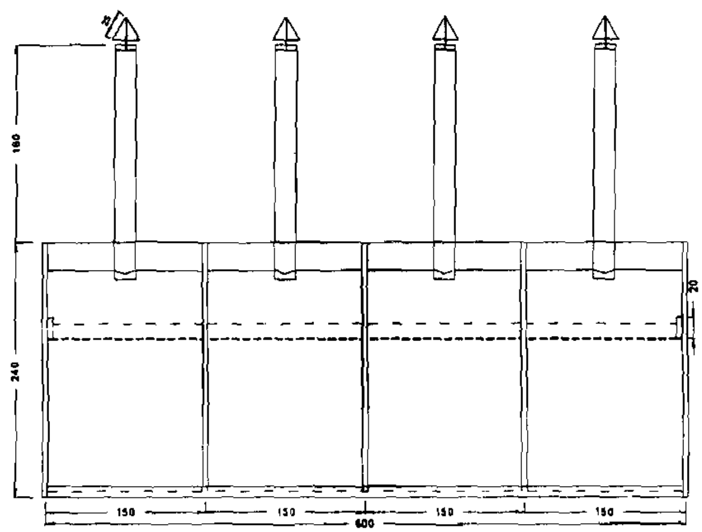

Fig. 3: Front view of the one ton natural convection solar dryer.

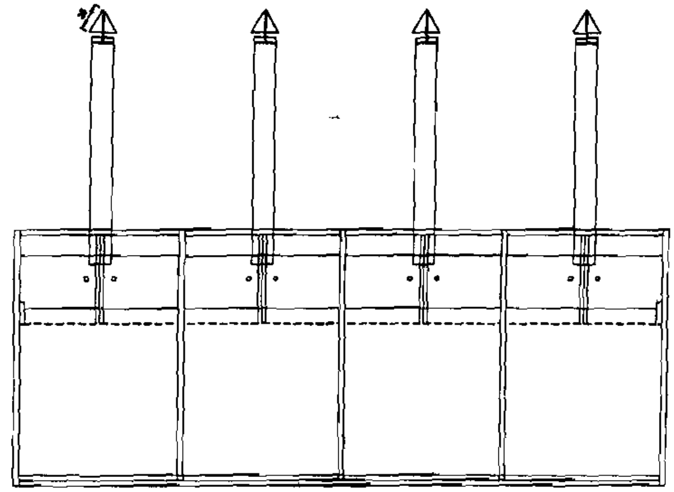

Fig. 4: Back view of the one ton natural convection solar dryer.

MEASUREMENTS

Grain moisture content

Moisture content of paddy samples of each treatment was measured using the standard oven method at 130 °C for 16 h. as recommended by AOAC, 1990. The calculated moisture content was expressed on wet basis unless otherwise specified.

Temperature and air relative humidity

The universal digital measuring system model (kaye Dig.14) connected to 32 channels scanning box with thermocouples sensors distributed at different points was used to measure the air and grain bulk temperature at different points outside and inside the dryer.

The air relative humidity meter model (HN-K) was used to directly measure the air relative humidity.

Air flow rate

A hot wire anemometer model (Kanomax 24-6111) was used to measure the air speed and pressure at different points represent the air movement through the dryer form entrance to discharge and also the ambient air outside the dryer.

Solar energy measurement

The solar energy was measured using the disk solarimeter with a portable recorder model (Y3057-11). The solarimeter was employed to measure the solar energy flux incident on a horizontal surface outside the dryer.

Grain hardness

Hardness of grain was measured using the grain tester model (Kiya 17886). Ten kernels of sound shelled rice were tested, each kernel was oriented on its flattest surface over the bottom plate, and the manual cross head was moved down until failure occurs.

Crack percentage

A total of 100 grains of rough rice sample was manually de-husked. The resulting brown rice was tested using the reflection type crack meter. The grains with fissures were then counted and the percentage of fissured kernels was calculated.

Grain germination

Rice samples of solar and natural sun drying methods were divided into 100 grain sub-samples in three replicates. Samples of each replicate were surface sterilized using 2% sodium and rinsed three times using distilled water. Germination tests replicated three times in petri dishes containing filter paper for a week and grain having both root and shoots considered germinated.

Milling tests

The quality of milled rice samples was evaluated in terrns of percentage broken rice and degree of whiteness. Each of the rough rice samples was passed through a Satake rubber roll model (THU 35A) with clearance adjusted to give about 90% brown rice on one pass. The resulting brown rice was poured into the polishing chamber of the McGill # 2 miller which operated for 1 minute. The broken rice percentage was calculated according to Ibrahiem (1992) as follows:

$$\text{Broken }\% = \frac{\text{Weight of broken rice}}{\text{Total weight of sample}} \text{X100}$$

Degree of whiteness

Degree of whitening of milled rice was measured using the Japanese whiteness meter model C-300.

RESULTS AND DISCUSSION

Grain moisture reduction

Figures (5) and (6) present the change in grain moisture content as related to drying time at different layers of stirred and unstirred rice beds respectively. For the un-stirred bed, the grain dried fastest at the bottom of the bed next fastest at the top and slowest in the middle. The drying at the bottom is by heated air form below in accordance with the design principle, while drying the top is due to direct heating by solar radiation through the clear plastic cover and the presence of the black net over the bed. However, for the stirred bed, stirring process of grain at three-hours intervals increased the drying rate and decreased the variation in moisture content at different layers of the drying bed. As expected, it can be seen that, the drying rate of the stirred bed was increased in the middle layer while the excessive drying in the top and bottom layers was reduced which finally resulted in a uniform grain moisture content and a faster drying rate.

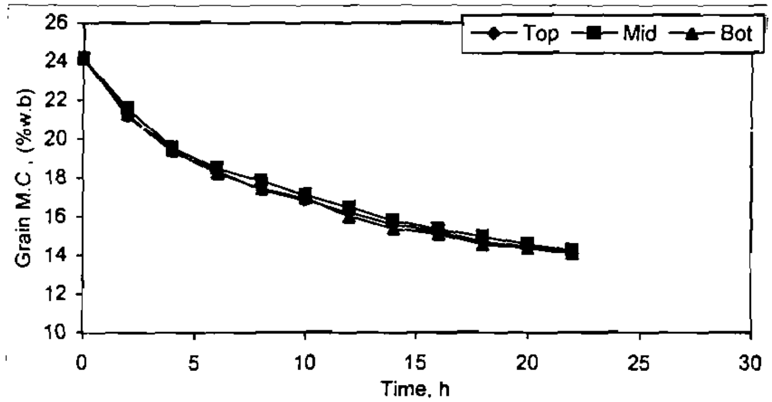

Fig. 5: Grain moisture content as related to drying time at different layers of the stirred bed.

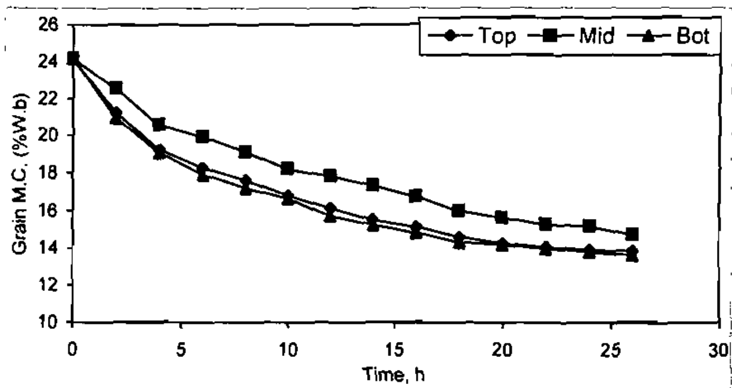

Fig. 6: Grain moisture content as related to drying time at different layers of the unstirred bed.

Figure (7) compares the average change in grain moisture contents for solar and natural drying methods. As shown in the figure, the average grain moisture content were decreased from an initial level of 24.16% (w.b) to a final level of about 14% ±1 (w.b.) in 22, 26 and 46 hours for stirred and unstirred solar dried beds and the natural sun drying respectively. The above mentioned results revealed that, solar drying with the natural convection solar dryer and stirred bed could reduce the drying time by about 4 hours and causes the dried grain to be more uniform as compared with unstirred bed. On other hands, the solar drying method could reduce the drying time by about 20 and 24 hours as compared to natural sun drying method for unstirred and stirred beds respectively.

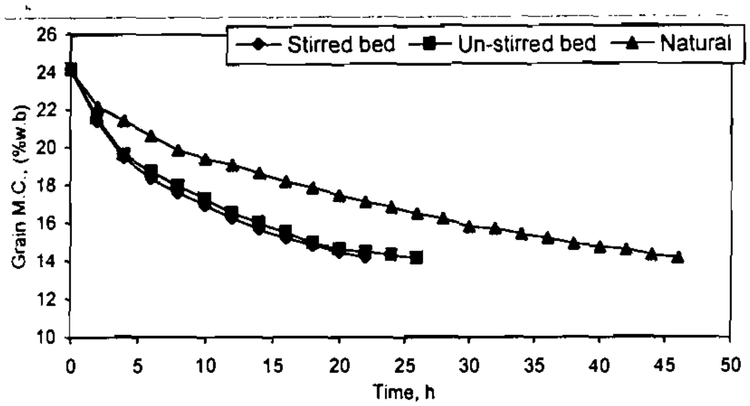

Fig. 7: Average grain moisture content as related to drying time for the solar and natural sun drying methods.

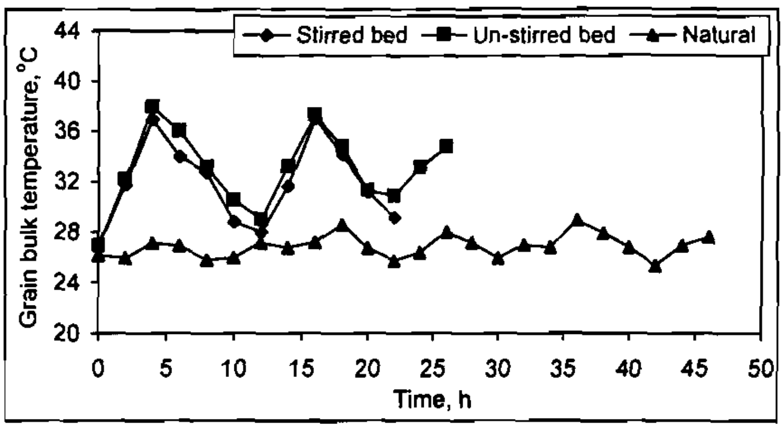

Fig. 8: Average grain bulk temperature as related to drying time for solar and natural sun drying methods.

Grain bulk temperature:

Figure (8) presents the changes in grain bulk temperature as related to drying time. As shown in the figure the average grain bulk temperatures were 31.57, 32.94 and 26.43 °C for stirred bed, un-stirred bed of solar drier and the natural sun drying method respectively. The variation in grain bulk temperatures between solar and natural sun drying methods could be attributed to the variation in drying air temperatures and grain moisture contents during the drying process. On the other hand the lower grain bulk temperature of the stirred bed as compared with the un-stirred bed could be attributed to the temperature loss from grain bulk during the stirring process.

Temperature and air relative humidity profile throughout the dryer

As air pass through the dryer it is first heated in the solar air heater without change in moisture content, then it is cooled and humidified as it rises through the bed of paddy, and as it continues upwards through the bed it is heated again by solar radiation and exhaust out of the dryer through the chimney. Figures (9) and (10) present the temperature and air relative humidity profiles at different positions across the dryer. As shown in figure (9) the ambient air temperature out-side the dryer was fluctuated between 24.35 and 28.26°C with an average value of 26.51°C. While, the air temperature at the plenum chamber of the dryer was fluctuated between 32.19 and 40.86 °C with an average of 36.97 °C. On the other hand, as shown in Figure (10) the air relative humidity outside the dryer was fluctuated between 65.72 and 76.81% with an average of 71.96% while it was 32.91 and 48.97 % with an average of 39.87% at the plenum chamber of the dryer. The above mentioned results revealed that, the solar collector of the dryer could increase the average air temperature inside the plenum chamber of the dryer by about 10.46°C and decreased the air relative humidity by about 32.09%. The observed changes in air temperature and relative humidity reflected the changes in the temperature of the absorber plate of the first collector which fluctuated between 37.63 and 51.36 ° C with an average of 43.89 °C as shown in Figure (11).

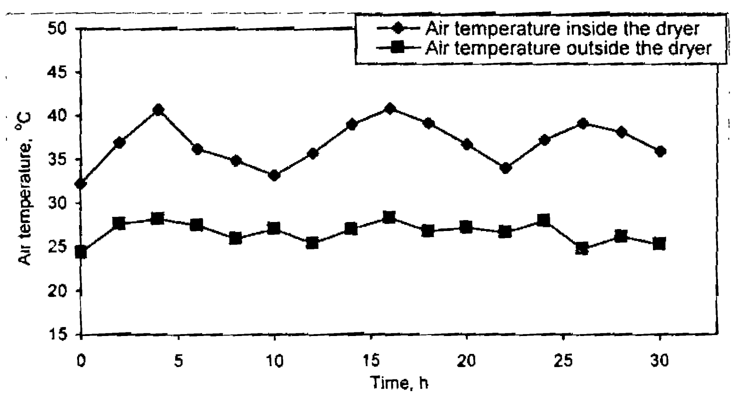

Fig. 9: Temperature of air inside and outside the dryer plenum chamber.

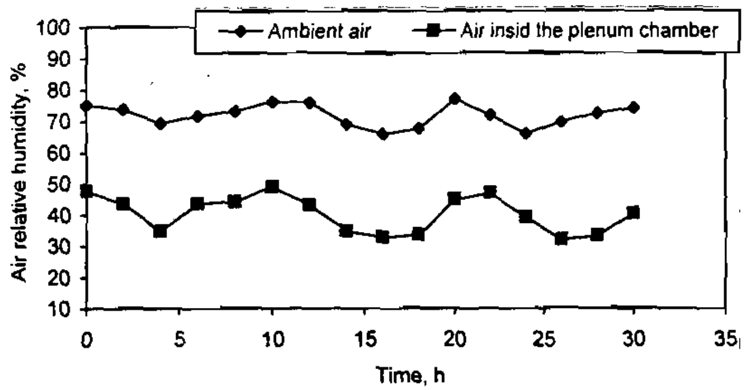

Fig. 10: Relative humidity of air inside and outside the dryer plenum chamber.

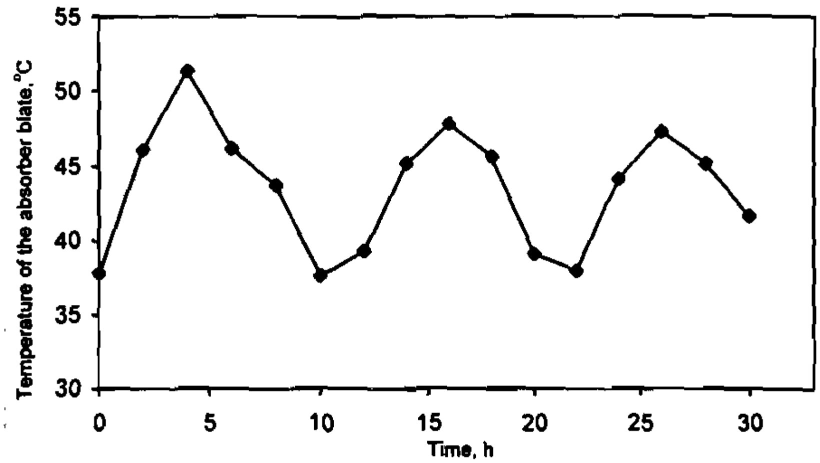

Fig. 11: Surface temperature of the absorber plate of the solar collector.

Air flow through the dryer

The airflow through the dryer was measured by means of a hot wire anemometers, one anemometer was placed over the bottom of chimney with a baffle so that all the air passed through it before going up the chimney was measured. Another anemometer was set over the rice bed to measure the flow up through the bed. The tests showed that, the airflow through the bed was about 0.012 m^3/s per square meter of bed. The measured airflow through the chimney was found to be about 35% greater than the measured airflow through the bed. The theoretical calculated airflow rate for the dryer is about 0.015 m^3/s per square meter of the bed which is very close to the measured air flow mentioned above.

Solar radiation

To study the thermal performance of the solar dryer it is imperative to consider the amount of solar radiation during the drying process. The hourly average solar radiation available during first, second and third days of experiments is illustrated in Figure (12). The hourly average available solar radiation was 700.6, 717.2 and 668.3 W/m^2 for the first, second and third days of experiments respectively. The figure also shows that, the solar radiation gradually increased from sunrise till it reached the maximum value at noon, it then decreased gradually until it reached the minimum value at sunset. The observed variation in solar energy available during the drying period affected the dryer effectiveness in heating air and the differences between air temperature and relative humidity outside and inside the dryer.

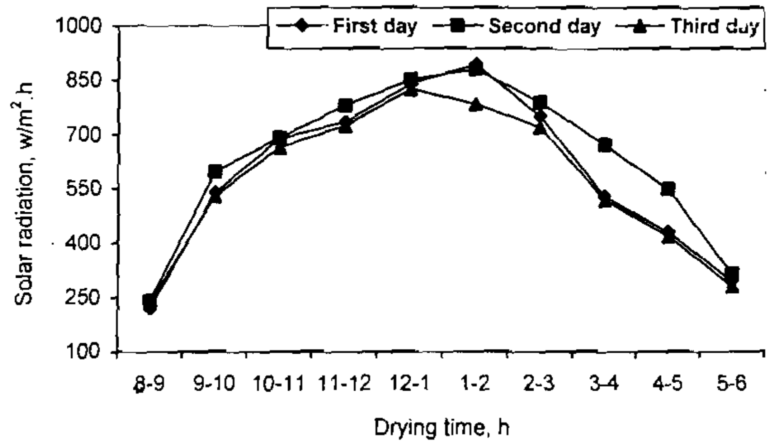

Fig.12: Solar radiation flux incident as related to drying time.

Thermal efficiency of the dryer

Thermal efficiency of the dryer is defined to be the heat of evaporation of the moisture removed from the paddy divided by the solar radiation falling on the dryer during the drying time. The following equation was used for calculating the dryer thermal efficiency (Jindal and Reyes, 1987):

$$\eta = \frac{W_w \times L}{Q \times 3600} \times 100$$

Where:

η = thermal efficiency, %

W_w =water evaporated from grain, (116.28) kg

L =latent heat of vaporization of water, (2668.25) kJ/kg

Q =total energy flux incident on the dryer, 338.90 k.W

The results show that, the overall thermal efficiency of the dryer is about (25.43)% during the period of experimental work.

Grain final quality

Table (1) presents the final quality of dried grain using solar and natural sun drying methods. As shown in the table, a significant lower crack and broken percentages were obtained for the solar drying method as compared with the natural sun drying method. The observed higher crack and broken percentages of natural drying method could be attributed to the longer drying time which gave a chance for grain to alternatively absorb and desorb moisture especially during late night and early morning. When comparing the stirred and un-stirred beds of the solar dryer it clearly revealed that, stirred bed showed lower crack percentage, higher grain hardness and lower broken percentage as compared with the un-stirred bed. This means that, stirring process could improve the uniformity of grain moisture content and also decrease the broken percentage of milled rice. The results also show no significant differences in grain hardness, whiteness degree and germination percentage for both solar and natural sun drying methods.

Table (1): Final grain quality of dried rice grain for solar and natural sun drying methods

Items of grain quality	Solar drying method		Natural drying method
	Stirred bed	Un-stirred bed	
Crack, %	2.33	4.66	7.33
Hardness, N	85.12	84.95	84.96
Broken, %	2.73	3.91	6.32
Whiteness degree, unit	39.76	39.81	39.69
Germination, %	94.00	93.00	94.00

CONLUSIONS

1- The drying time for the developed natural convection solar dryer depends on the weather conditions and can vary from 22 to 26 hours for the stired and un-stirred beds of the solar dryer as compared with 46 hours for natural sun drying method.

2- It is an advantage to stir the bed of paddy during solar dying process to promote uniform drying, reduce drying time and improve final quality of the dried grain.

3- As the difference between air temperature and relative humidity inside and outside the solar dyer is increased, the useful heat gain to drying is also increased and the drying process become more efficient.

4- There was a significant improvement in the quality of paddy dried by the solar dryer as compared with that dried by natural sun drying method.

REFRENCES

Abdelatif, S.M. (1989). Some design parameters affecting solar panel thermal performance. Misr Journal of Agric. Eng. 6 (1):

Abdelatif, S.M; A.M. Matouk and K.N. Abdalla (1993). Solar heat drying of dates.1.Dryer set up.J. Agric.Sci., Mansoura university.,1(8):2365-2374.

Adeymo, T.L. (1993). Modification of a natural air convection dryer. AMA. , 24 (2): 33-36.

AOAC (1990). Official methods of analysis (15 th Ed), Association of Official Analytical Chemists, Washington DC.

Awady,M.N., S.A. Mohamed; A.S. El-Sayed and A.A. Hassanain (1993). Utilization of solar energy for drying processes of agricultural products. Misr J. Agrice. Eng., 10 (4): 794-804.

Ayensu A.(1997).Dehydration of food crops using a solar dryer with convection heat flow. Solar energy.,59 (4-6): 121-126.

Calder wood, D.L. (1973). Resistance to airflow of rough, brown and milled rice. Transaction of the ASAE, 16(3): 525-527,532.

El-Shiatry A.M. J. Muller and W.Muhlbauer (1991). Drying fruits and vegetables with solar energy in Egypt. Agricultural mechanization in Asia., 22 (4): 61-64.

Exell, R.H.B. (1980). Basic design theory for simple solar rice dryer. Renewable Enrgy Review Journal, 1 (2): 1-14.

Ibrahim M.M.(1992). Effect of physicochemical ad mechanical properties of local rice varieties on milling quality. Misr J. of Agric. Engng., 9 (1):1-10.

Jindal,V.K. and V.G. Reyes, Jr. (1987). Conduction heating of rough rice for accelerated drying. Paper No.87-6043, (ASAE) summer meeting, Baltimore, June, 23-July 1st.

Lutz K., W.Muhlbauer; J.Muller and G. Reisinger (1987). Development of a multi-purpose solar crops dryer for arid zones. Solar and wind technology, 4 (4): 417-424.

Sabbah, M.A. (1985). Natural convection solar wind drying system. Alex. J. Agric. Res., 30 (2): 665-673.

Shedd C.K. (1953). Resistance of grain and seeds to air flow. Agricultural Engng. J., 34: 616-619.

Tayel S.A and M.F.Wahby (1989). Drying behavior of a natural convection solar drying system. Misr J. of Agric. Engng., 6 (1): 27-37.

تطوير مجفف شمسى يعمل بخاصية الدفع الطبيعى للهواء

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أجريت تلك الدراسة لتصميم وتصنيع مجفف شمسي لتجفيف الأرز ذو المحتوى الرطوبى المرتفع بسعة ١ طن يعمل بخاصية الدفع الطبيعى للهواء يتميز بسهولة تصنيعه وانخفاض تكلفته وقد تم تصنيع المجفف بمركز ميكنة الأرز بميت الديبة حيث أجريت علية مجموعة من التجارب الحقلية لدراسة إمكانية استخدامه فى تجفيف محصول الأرز ذو المحتوى الرطوبى المرتفع (٢٤,١٦ % على أساس رطب) ومقارنته بالطريقة التقليدية لتجفيف الأرز والتى تتمثل فى تنشير الحبوب فى الجو الطبيعى حتى تمام عملية التجفيف.

أظهرت نتائج التجارب الحقلية أن الفترة الزمنية اللازمة لتجفيف الحبوب باستخدام المجفف الشمسى قد وصلت إلى حوالى ٢٢ ساعة فى حالة التقليب الدورى للحبوب كل ٣ ساعات أثناء فترة التجفيف بالمقارنة بحوالى ٢٦ ساعة فى حالة عدم تقليب الحبوب، فى حين وصلت الفترة الزمنية اللازمة لتجفيف الحبوب بالطريقة التقليدية إلى حوالى ٤٦ ساعة.

أظهرت أيضا نتائج التحليل المعملى لخصائص جودة الحبوب فى نهاية عملية التجفيف تحسنا واضحا فى جودة الحبوب التى تم تجفيفها بالمجفف الشمسى بالمقارنة بالطريقة التقليدية لعملية التجفيف حيث انخفضت نسبة الكسر فى الحبوب بحوالى ٣،٥٩ % فى حالة استخدام المجفف الشمسى مع عملية التقليب الدورى للحبوب بالمقارنة بحوالى ٢،٤١ % فى حالة عدم التقليب الدورى للحبوب. من ناحية أخرى تحسنت أيضا كل من نسبة الحبوب المتشققة، درجة صلابة الحبوب بينما لم تتأثر كل من درجة التبييض ونسبة الإنبات فى كلا الطريقتين.