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RECENT DEVELOPMENT OF GHE SOLAR DRYING IN INDONESIA -GRASS ROOTS PROJECT

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ABSTRACT

Study on greenhouse effect (GHE) solar dryer was initiated since early 1990's in our laboratory. From several test results conducted using different type of GHE solar dryers, it was found that such system was applicable to a wide variety of tropical products from grains such as black pepper, rough rice, coffee and cocoa beans, to seeds, timber and sliced fruits. The latest experiment with the GHE solar dryer using mechanical stirrer to dry fermented cocoa beans, for example, was capable to reduce the total specific energy (solar and commercial energy) from about 12 MJ/kg of moisture as reported elsewhere to 6.2 MJ/kg moisture. For the case of coffee drying without any mixing device but with relatively high loading capacity the recorded specific energy was 5.5 MJ/kg of moisture.

Therefore, under the current stage of R/D activity will be focused on the dissemination of appropriate GHE solar dryers through action research to promote the development of small scale industries in the rural areas so that they can help the farmers in processing their products. This paper presents some results of drying performance with GHE solar dryer including the introduction of several action research program to disseminate the technology in Indonesia.

INTRODUCTION

After a long research and development effort at CREATA (Center for Research on Engineering Applications in Tropical Agriculture) of IPB, some prototypes of renewable energy driven thermal systems are now ready for dissemination. The Greenhouse Effect (GHE) solar dryer, for example, was found to be far less expensive than the conventional solar dryer using solar heat collector. Several types of drying bins had been tested namely, the stationery rectangular bin, vibrating racks, stationary racks, and cylindrical bin with mechanical stirrer. If such system can be applied in the eastern part of the country where solar radiation is high and available almost all year round, it can help the farmer in processing their product and stored them for longer period.

In 1994 dissemination of the technology was initiated by applying the GHE system for seed drying. For the same purpose, since August 1998, a joint project with the Research and Development Center for Calibration, Instrumentation and Metrology of the Indonesian Institute of Sciences (LIPI), was started. In the latter undertaking two GHE solar dryers, one for coffee berry with 6 ton wet capacity and another having a capacity of 1 ton wet were installed in East Java and Sumbawa Island, respectively. The main objective of the project was to apply appropriate technology to help the people in the rural area to increase added value of their products and hence may lead to the improvement of economic condition in the area. Starting 1999, a grass roots project was granted by the government of Japan to install 4 GHE solar dryers one each in East Java and Bali and two in Sumbawa island. One of the dryer in Sumbawa is used to dry coffee berries.

This paper presents the results of laboratory as well as field tests of several models of a GHE solar dryer.

DESCRIPTION OF A GHE SOLAR DRYER

Previous study using Lagrange multiplier (Kamaruddin, 1993) have shown that the initial cost of a solar drying system can be further reduced by using a greenhouse effect mechanism since the function of solar collector unit can be substituted by transparent structure which also simultaneously function as the drying chamber.. From structural and functional point of view a GHE solar drying system, as shown in Figure.1, is basically similar to a greenhouse. The entire wall is made of transparent materials such as fiberglass, UV stabilized plastic or polycarbonate sheets. The transparent sheets are fixed on steel frame support or pillars with bolts and nuts and rubber packing to prevent humid air leaking into the chamber other than those introduced from the inlet opening. A blackened steel plates is provided to enhanced solar radiation absorption within the structure and are located either on the upper section of the structure or at both sides near the wall. According to the type of commodity to be dried, the racks, cabinets or drying bin can be placed at the center section of the transparent structure so that maximum access to drying air can be obtained. Inlet and exhaust fan are placed at proper position within the structure to ensure even distribution of the drying air within the chamber. To reduce further the cost of air handling system a PDID unit (Vo-Ngoc and Srivastava, 1993) can be installed. Whenever necessary, auxiliary heating system using biomass or kerosen stove with heat exchanger unit can also be installed.

Figure1a. GHE solar dryer for cocoa bin with mechanical stirrer

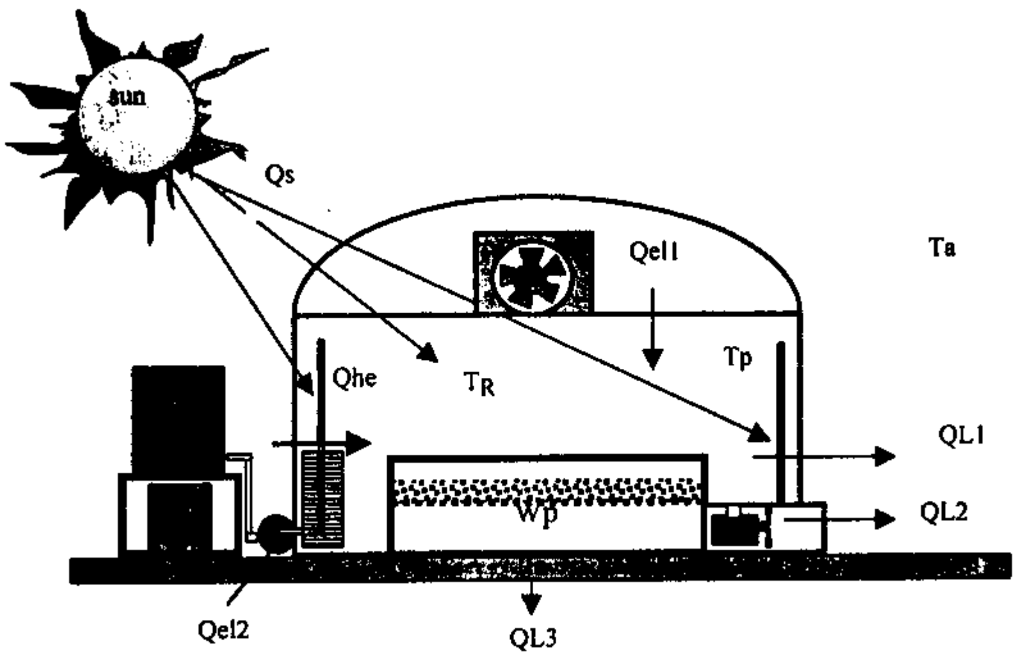

Figure1b. Energy balance in a GHE solar drying system

DRYING PERFORMANCE

Figure.1. shows how a combined solar and biomass energy is used in a drying process in a GHE solar dryer (Manalu,1999). Several types of GHE dryers have been constructed and tested and the results are described below. Figure.2. shows an example of simulation results of a GHE solar dryer for coffee berry drying. For this purpose the capacity used was 3 t wet coffee berries. In this simulation hot water was also supplied during the day as indicated by Tw, and the achieved room temperature was slightly above 40 C while the black plate temperature peak lied about 70 C . This indicates the need to operate full capacity of the blower to re-circulate the drying air within the chamber and at an appropriate interval the air may be disposed to the outside environment.

Vibrating Racks

A prototype tested for fermented cocoa beans drying in Bogor. Indonesia had used vibrating racks with the main purpose to provide mixing action so that the sticky beans can be separated one from another to improve drying (Nelwan,1998). The dryer had a floor dimensions of 3.27 m x 3.27 m, equipped with an auxiliary heating unit and three 80 W blower unit. two at inlet and one at the outlet. The height of the structure was 1.98 m on one side and 2.73 m on the other. In addition a blackened steel plate was installed at the upper position inside the structure leaving 0.47 m clearance for inlet air ducting to enhance the thermal performance

Test results showed that using this system with an initial loading of 228 kg (60.4%wb) of wet cocoa beans could be dried to 6.7%wb in a total of 40 hrs, with some resting time during the night. Under this condition, the average temperature and RH were 45.2 C and 35% respectively. The total drying efficiency, η_d as calculated using eq.(1) 18.4%.

$$\eta_d = \frac{m_p Cp_p (Tc_f - Tp_i) + m_w \Delta Hfg}{[P_w + I(t) A_f]\theta_d + (dm_f / dt) C_f} \qquad (1)$$

Where m_p, is the mass of the product dried (kg), Cp_p, heat capacity of the product (J/kg K), Tp_f, is the final temperature of the product (K), Tpi, initial temperature of the product (K), m_w, total amount of evaporated water from the product (kg), ΔHfg, latent heat of evaporation (kJ/kg), P_w, electric power input (kW), I(t), solar irradiation (kW/m^2), θ_d drying time (h), dm_f/dt, combustion rate (kg/h), C_f, calorific value of fuel (kJ/kg), and .A_f, effective drying floor area (m^2)

The total specific energy, Es, a parameter defined as the ratio between the total input energy both from solar and commercial energy and the total amount of evaporated moisture from the beans can also be used to compare the drying performance of artificial dryers.

$$Es = \frac{\left[P_w + I(t)\,A_r\right]\theta_d + \left(dm_r / dt\right)C_r}{m_w} \qquad (2)$$

Using this parameter it was found that for the above GHE solar dryer test, the total energy required to evaporate moisture from the beans was 12.90 MJ/kg.(Kamaruddin *et al.* 1997, Nelwan, 1998).

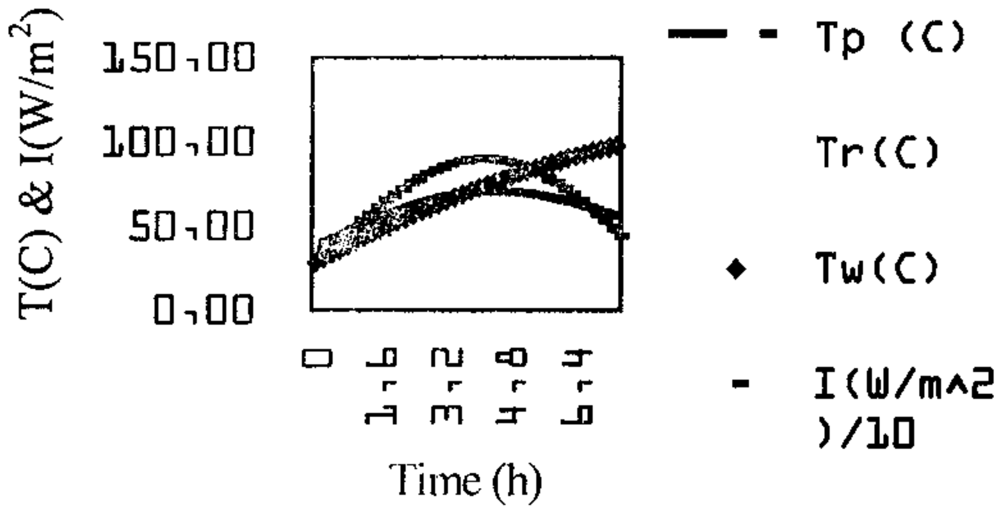

Figure.2. Simulation results of Robusta coffee berry drying at 3 t wet load.

Drying Bin with Mechanical Stirrer

Using the same GHE dryer as described above, a trial test to overcome the sticky beans by means mechanical stirrer had been conducted (Manalu, 1999). In this test a cylindrical drying bin made of perforated aluminum sheet was installed at the center of the chamber (see Figure.1). A rotating arms made of steel was used as stirrer which rotate at 2.5 RPM intermittently. The stirrer was driven by 1.5 HP electric motor equipped with a reduction gear unit to reduce the rotation down to a required RPM level. From this test it was found that the new drying method using stationary bin with stirrer had improved the specific total energy for drying to 6.2 MJ/kg moisture and total drying efficiency of 46% as also shown in Table 1. (Kamaruddin, *et al.* 1998). The drying time of the latter design was between 32 to 33 hours.

Quality test results indicated that the dried beans fell into the first quality of AB grade which means the A grade and B grade were mixed to form one AB grade, a common practice in grading system of Rajamandala Cocoa plantation in Bandung, West Java. The quality achieved was better than the drying test using rectangular bin of the previous study conducted by the authors (Nelwan, 1998).

Table 1. Comparison between the conventional solar drying and the GHE system

Commodity	Drying Temperature (C)	Drying time (h)	Load (kg)	η_d, %	ηe (MJ/kg water)	Auxiliary heat source	Source:
A. GHE System							
1. Cocoa							
a. Lab test 1	50	40	228	18.4	12.9	kerosene	Nelwan(1997)
b. Lab test 2	49.2	32	400	55	5.2	kerosene	Manalu (1998)
c. Field test	45.8	43	190	18	14.4	charcoal	Kamaruddin(1998)
2. Robusta coffee	37	58	1114	57.7	5.5	none	Dyah (1997)
3. Vanilla pods	51	52	52	7.5	-	charcoal	Mursalim(1994)
4. Seeds							Kamaruddin (1995)
a. Chilli	40	4	1.6	-	-	none	
b. Cucumber	40	9.5	5.4	-	-	none	
5. Fruits							
a. Papaya	39	33	40	10.5	-	none	Tahir(1998)
b. Banana	40.6	11	18	9.7	-	none	Mirza(1997)
c. Banana 2	n.a.	57	25	11.1	19.2	none	Somchart (1997)
6.Woods							
a. Bayur	39.3	158	728	8.1	25.8	Charcoal	Suhdi(1996)
b. Kemiri	48.5	96	780	-		none	Efrida(1995)
B. Conventional System							
1. Coffee berry	44	70	773	21.1	11.6	woods	Tryono(1996)
2. Cocoa	38	108	5000	10-20	n.a.	woods	Utomo(1996)
3. Banana 1	n.a.	44	360	15.8	14.9	LPG	Somchart (1997)

Coffee Berry Drying

The GHE solar dryer for coffee drying was made of UV stabilized plastic sheet, 1.5 mm thickness with 70% transmissivity (Wulandani,1998). The sheet was fixed on the steel angle frame supported by 1.24 cm x 1.24 cm mesh wire net with 0.8 mm in diameter. The floor size was 6 m by 2.2 m and height and height of 2.8 m. The side walls had 2mm length and were inclined to produce trapezoidal cross section connected to triangular roof top. A wooden bin having a dimension of 3 m x 2 m x 1 m was placed right at the center of the structure and was provided with partition so that simultaneous test at different bed depth, respectively, at 0.1 m,0.2 m,0.3 m and 0.4 m can be accomplished. Blackened steel plate was located at the top close to the ceiling but with ample clearance to allow inlet air to flow into the chamber. The whole unit was equipped with a 0.5 HP exhaust blower.

Table 2 . Cocoa drying at Rajamandala estate, Bandung, West Java (Utomo and Tarigan, 1997)

Type of bin Parameter	Flat bed (Vertical cylinder)	Flat bed (rectangular)		Flat bed (rectangular)
	Wood fuel	Wood	coal	*255 m^2 solar collector with heat exchanger*
1. Initial load(kg)	10000	5500	5500	5500
2. Initial m.c. (%wb)	68	74	74	66
3. Drying temperature (C)	60-55-50	50	55	43-48
4. Average RH (%)	50	50	50	50
5. Drying time (h)	33	57	66	42.5
6. Dried product (kg)	3500	1870	1870	1870
7. Dried cocoa/initial load (%)	35	34	34	34
8. Electricity (kWh)	134	85	82	65
9. Additional heating				
a. Fuel wood (m^3)	11.3	5		-
b. Coal (kg)			900	-
c. IDO (liter)				884
10. Energy efficiency(MJ/kg)*	16.8	19.57		16.9

* The specific energy is the ratio of total input energy (including solar energy) to the total amount of water evaporated from the product.

Test results with several bed depths had indicated that the highest drying efficiency was attained at 57.7% when the bin was loaded with 1.1 tons, 0.3 m in bed depth, of wet coffee berries. When the specific energy was calculated using eq.(2) in terms the total input energy, the resulting value was 5.2 MJ/kg water evaporated and reduced to 0.15 MJ/kg water in terms of only electric energy input. During this test the average solar radiation of 525.2 W/m^2 producing average chamber temperature during of 38 C, and RH of 45%. The total drying time was 72 hours when the final moisture reached 11.2 % wb. Table 1 shows reported performance of solar dryer in Indonesia and for comparison data from Somchart et al (1997) is also presented. The above results can also be compared to the current drying practice and solar drying activities in Rajamandala estate plantation in Bandung West Java as shown in Table 2.

Accroding to Somchart et al.(1997), test result for banana drying using tunnel dryer developed by Hohenheim University (Muhlbauer *et al*,1997),had shown that the specific energy achieved was 19.2 MJ/kg water. The value was lowered to 14.9 MJ/kg water when a forced convection dryer with LPG fired auxiliary heating was used.

DISSEMINATION OF THE TECHNOLOGY

The basic idea of technology dissemination under the grass roots program was to provide the drying facility to local entrepreneurs or cooperatives so that they are capable in constructing . operating and administrating the facility. The beneficiaries of the facility were requested to set aside a portion of benefits gained during the operation of the facility. Such accumulated funds will be used later to construct new facility and installed in other areas for similar purpose.

In disseminating the technology it was necessary to conduct the training of local technician to construct the drying unit. With adequate supervision, these technicians were capable to follow the drawings and finally completed the construction. Most of the construction materials could be purchased locally except for the poly-carbonate sheets and the blowers. Such training programs including the operation, maintenance of the facilities and the management aspect of the project should be provided to ensure continuity of the program.

One important aspect in the dissemination of the technology is on how to provide further guidance in creating motivation so that the manager could generously find the consumers. Probably an initial working capital should also be provided so that they can start using the facility and to demonstrate to usefulness of the facility to the would be consumers. Further assistance was also found necessary in finding the market of their products.

Simple break even analysis had shown that the GHE solar dryer was ready for adaptation test. Preliminary test result of the joint project with LIPI had indicated that the one ton solar dryer was capable to dry sliced meet or fish within two days. The installed unit which was it was equipped with auxiliary heating system is gaining its popularity since it works day and night and even during the rainy days.

Currently, in Indonesia, the government is looking back to agricultural sector as the only means to accelerate the national economic recovery. For this purpose there are 17 credit schemes are made available with low interest rates of 14% per annum to promote the application of technology at the village level. With better access and availability of fund at the village level as described above it is expected that the dissemination process for GHE solar dryer in Indonesia can be accelerated.

CONCLUSIONS

A GHE solar drying system have been tested for coffee berries, cocoa beans, sliced meat, fish and other tropical products and was found to be potential for its application in the rural area of Indonesia. Newly installed GHE dryers had shown satisfactory results for sliced meat and fish drying. Available credit scheme provided by the government and further guidance is still necessary, however , to keep the current project going.

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REFERENCES

Bakker-Arkema, F.W. and H.M. Saleh. 1985.In-store drying of grain: the state of the art. Preserving grain quality by aeration and in-store drying. ACIAR Proceedings, No.15.pp.24-30.

Dyah W.,1998. MSc thesis, IPB Graduate Program, Bogor, Indonesia.

Efrida,B. Dan D.Rochadi,1995. Prospect of solar energy applications for wood drying (in Indonesian).. Proc.. Workshop on approapriate Technology of Non-conventional Energy for Development in Indonesia, Bandung. Halawa, E.E.H and Arjuno B., 1996. Proceedings, Workshop on Monitoring, Evaluation and Adoption Strategy. ASEAN-Canada Project on Solar Energy in Drying Process.

Kamaruddin A. 1993. System Optimisation in Solar Drying. Paper No.30-1. Proceedings of the 5th International Energy Conference, Energex'93.Seoul, Korea.Vol.III. pp.86-102.

Kamaruddin A., Armansyah H.T. Tamrin, F. Wenur and W. Dyah. 1994. Heat and Mass Transfer Within a Fiberglass House Solar Dryer Proceedings of International Conference on Fluid and Thermal Energy Conversion, FTEC'94. Vol.II. pp.179-191.

Kamaruddin A., Tamrin, F. Wenur and W. Dyah.1994. Drying of black pepper using solar Energy,. Proc. International Drying Symposium, IDS'94, Gold Coast, Australia.

Kamaruddin A.,Sri Endah A. 1995. Application og GHE solar dryer for seed dying (in Indonesian) Energy Workshop, World Energy Council. Jakarta, July.

.Kamaruddin A. 1998. Greenhouse Effect Solar Dryer for Coffee and Cocoa beans.Final Report. University Research for Graduate Education. Contract No.032/HTPP- II/URGE/1996. Directorate General of Higher Education, Indonesia

Manalu, L.P., 1999. MSc thesis, IPB Graduate Program, Bogor, Indonesia.

Mirza, M., 1997. Graduation thesis Department of Agricultural Engineering, IPB.

Mursalim, 1994. Graduation thesis Department of Agricultural Engineering, IPB.

Muhlbauer W., J.Muller and A. Esper, 1997. Agricultural Crop Drying and Storage, F.WW. Bakker-Arkema and D.E. Maier Ed. Marcel Dekker Inc. (in press).

Nelwan. L.O. 1997. MSc thesis. IPB Graduate Program, Bogor. Indonesia.

Somchart, S. and Nathakaranakule. A., Limtrakool,W., Nathakaranakule. S. 1997. Drying of Banana Fruit. Abstracts of paper presented in ISES 1997 Solar World Congress, Seoul.]

Tahir, M.1998. Graduation thesis Department of Agricultural Engineering. IPB.

Utomo,Y.S.,I.I. Tarigan, E.E. Halawa and A Brojonegoro,1996. Monitoring and performance evaluation of Rajamandala solar cocoa dryer. Proc. Workshop on Monitoring, Evaluation and Adoption Strategy. ASEAN-Canada Project on Solar Energy in Drying Process.

Utomo Y.S. and I.I. Tarigan, 1997. Cocoa dying using three modes of drying. Proc. 5^{th} Energy Seminar, Jakarta.

Vo-Ngoc. D. and N.K.Srivastava,. Evaluation and application of a simple pressure differential inducer device (PDID) for post harvest drying and storage. Report from Wind Engineering Center Universite de Moncton, Moncton, N.-B. Canada (without date of publication).23 pp.