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PRACTICAL EXPERIENCE WITH SOLAR CROP DRIERS IN THE CARIBBEAN

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ABSTRACT

Solar crop driers have been used in the Caribbean territories for the past twelve years. Crops dried have included sorrel, bananas, grass, nutmegs, ginger and screw pine. Several types of drier have been employed, varying from the simple wood-and-plastic wire basket drier to the metal-and-glass rock bed drier with chimney-assisted air circulation. Practical experience indicates that the most cost effective design is the wire basket drier with a plastic cover of UV stabilised polyethylene. For crops which require higher or more stable temperatures, the open cycle natural convection rock bed drier may be used. Rock-bed driers have been built in Barbados, Jamaica, Dominica, Grenada and Trinidad & Tobago, wire basket driers have been used in St. Lucia, Dominica, Guyana and Trinidad and Tobago. Simple cabinet driers have also been used, but they lack the simplicity of the wire basket drier and the heat storage capacity of the rock bed driers.

RESUMEN

Durante los últimos doce años, se ha utilizado secadores solares en el Caribe para secar cultivos tales como la acedera, los bananos, la hierba, la nuez moscada, el jengibre y la pandánea. Se ha empleado varias clases de secadores, del sencillo secador de madera y plástico con red de alambre hasta el secador de vidrio y metal con lecho de piedras y circulación de aire por chimenea. La experiencia práctica indica que el diseño más rentable es la red de alambre con una tapa de plástico hecha de polietileno estabilizado contra los rayos UV. Para los cultivos que necesitan temperaturas más altas o estables, se puede utilizar el secador de lecho de piedras de ciclo abierto y convección natural. Se ha construido secadores de lecho de piedras en Barbados, Jamaica, Dominica, Granada, y Trinidad y Tobago. Se ha utilizado tambíen los secadores sencillos en forma de gabiente, pero éstos son más complejos que la red de alambre y no tienen la capacidad de almacenamiento calorifico de los secadores de lecho de piedras.

Keywords: Solar Crop Driers, Caribbean

The solar energy available in the Caribbean region varies from about 25 MJ m^{-2} day^{-1} during the dry season to about 10 MJ m^{-2} day^{-1} during the rainy season. Crops which ripen during the dry season are therefore ideally suited for solar drying since about 2.5 MJ are required to remove 1kg of water from the drying crops.

Solar dryers may vary in complexity from the very simple, such as the drying floor, to highly complicated systems using pumps, heat exchangers and microprocessor controls. Over the past 12 years, experiments have been conducted on a large variety of driers (Headley and Springer, 1973; Headley, Bryan and Hoogmoed, 1976; Headley and Singh, 1979; Harvey et al., 1985) whose design has depended on the type of crop and the economic cost which can be incurred during its drying.

A wide variety of crop materials have also been dried such as grass *(Panicum maximum)*, nutmeg *(Myristica fragrans)*, sorrel *(Hibiscus sabdariffa)* and yam *(Dioscorea alata)*. In terms of cost effectiveness, the simplest driers have been the most suitable.

Drier Types

The following types of solar drier have been tested in the territories listed after them.

(a) The closed-cycle natural convention drier - Trinidad and Tobago.

(b) The rock bed drier - Barbados, Dominica, Grenada, Jamaica, Trinidad and Tobago.

(c) The wire basket drier - Dominica, Guyana, St. Lucia, Trinidad and Tobago.

(d) The cabinet drier - Trinidad.

The closed-cycle natural convention drier

Work on solar driers was begun using the closed cycle natural convention drier. This design was chosen because it did not require fans for air circulation. Tests were conducted on root crops to see if they could be dried by farmers for incorporation into animal feeds. To maximise air circulation rates, a high temperature difference between the top of the solar collector and the bottom of the dehumidifier was required. With a doubly glazed collector, one could reach 110°C at the top of the collector with the dehumidifier at 65°C. This gave a maximum air velocity of about 50cm $sec.^{-1}$ when the unit was unloaded.

Because air at over 90°C was admitted to the drying chamber, this unit was only used to dry root crops such as cassava *(Manihot esculenta)* sweet potato *(Ipomoea batatas)* and yam *(Dioscorea alata)*. Because of the presence of muco-polysaccharides (Santo, 1967), yams had to be sliced to about 3mm thick before they could be dried satisfactorily. Partial cooking of the dried product was not a disadvantage.

During the rainy season, the insolation available was inadequate to maintain suitable air circulation, so the dryer gave problems such as fungal infestation due to the presence of spaces in the drying chamber where the relative humidity reached 100 per cent. During the dry season, drying times varied from 20 hours for yam to 8 hours for grass.

The rock bed drier

The rock bed drier was developed from the closed cycle natural convection drier by removing the dehumidifier and allowing the air from the solar collector to move through the drying chamber before being exhausted to the ambient air. Air was not re-cycled so humidity control was much easier. The rock bed was in series or parallel with the drying chamber and reduced the air temperature from the 105°C at which it left the doubly glazed solar collector to about 65°C in the drying chamber. Figure 1 shows the efficiency curve for a rock bed drier (Singh, 1979). The heat storage capacity of the rock bed drier is an advantage in that it keeps the drier above ambient temperature during cloudy or rainy periods and allows the drier to continue to operate after sunset. Examples of this drier have been built in Barbados, Dominica, Grenada, Jamaica and Trinidad. Figure 2 shows a cross section of the Grenadian drier which has 7.8m² of collector area and is used to dry spices while Plate 1 shows the Jamaican drier which has 2.2m² of collector and a chimney. This drier is used as a demonstration unit. The chimney aids air circulation.

The Barbados drier is 21m² and was originally designed to dry sugar-cane pith. Its rock bed contains 1600kg. of rocks of 5 to 7cm in diameter. The Trinidad rock bed drier was usually operated in tandem with a wire basket drier which is described in the following section.

The wire basket drier

This is the simplest of the movable driers. It consists of a wooden frame covered in wire mesh to retain the crop over which is draped a transparent cover of of UV-resistant polyethylene. Alternatively, one may use a removable cover to keep the polyethylene over the crop. This transparent cover keeps the rain off and the open wire mesh sides allow free access of ambient air so air circulation is excellent and fungal contamination of the drying crop is usually absent. A mosquito mesh liner keeps out insects.

Figure 3 shows the dimensions of the wire basket drier while Plate 2 shows one being loaded with sorrel. Figure 4 is a drying curve for sorrel which shows that one can get moisture contents as low as 0.13 kg. moisture kg⁻¹ of dry matter after three sunny days.

However, it was usually the custom to remove the sorrel from the wire basket dryer after the moisture content dropped below 2kg water kg⁻¹ of dry matter and transfer it to a rock-bed drier where drying conditions are much better controlled.

During drying trials on sorrel, three wire basket driers with a total area of 5 m² were used to feed a 3.3 m² rock-bed drier. This allowed much better utilisation of the higher-cost rock-bed drier since the large amounts of water that have to be removed during the initial stages (sorrel is about 90% moisture, wet basis) were removed in the cheaper wire basket dryer. A 2.2 m² wire basket drier can be built for as little as $50 US if the farmer builds it himself.

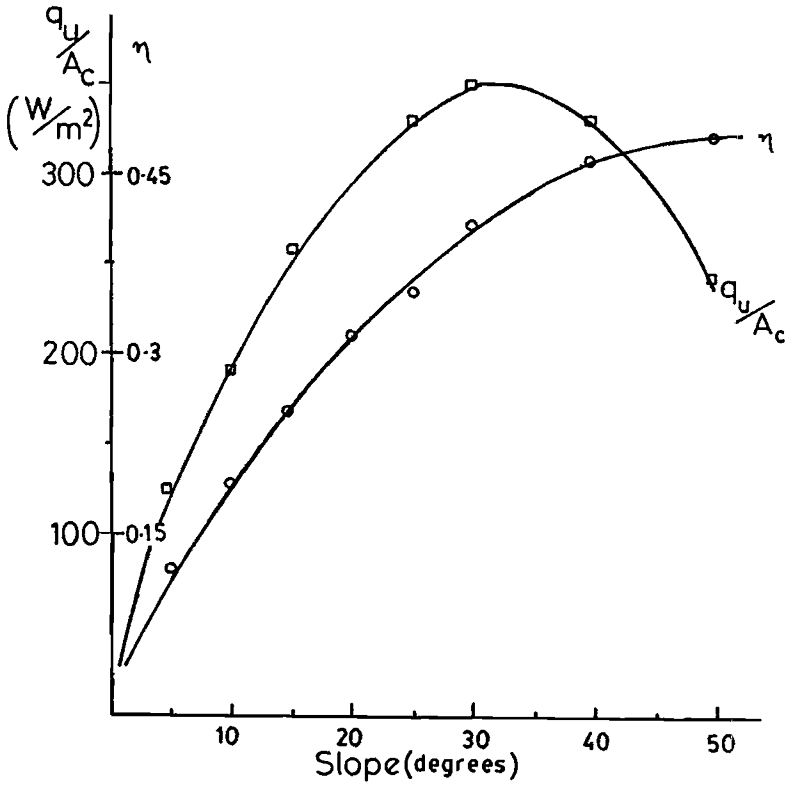

Figure 1 : The Efficiency Curve of a Rock Bed Dryer (After Singh, 1979)
q_u = useful power (watts)
A_c = area of collector (m^2)

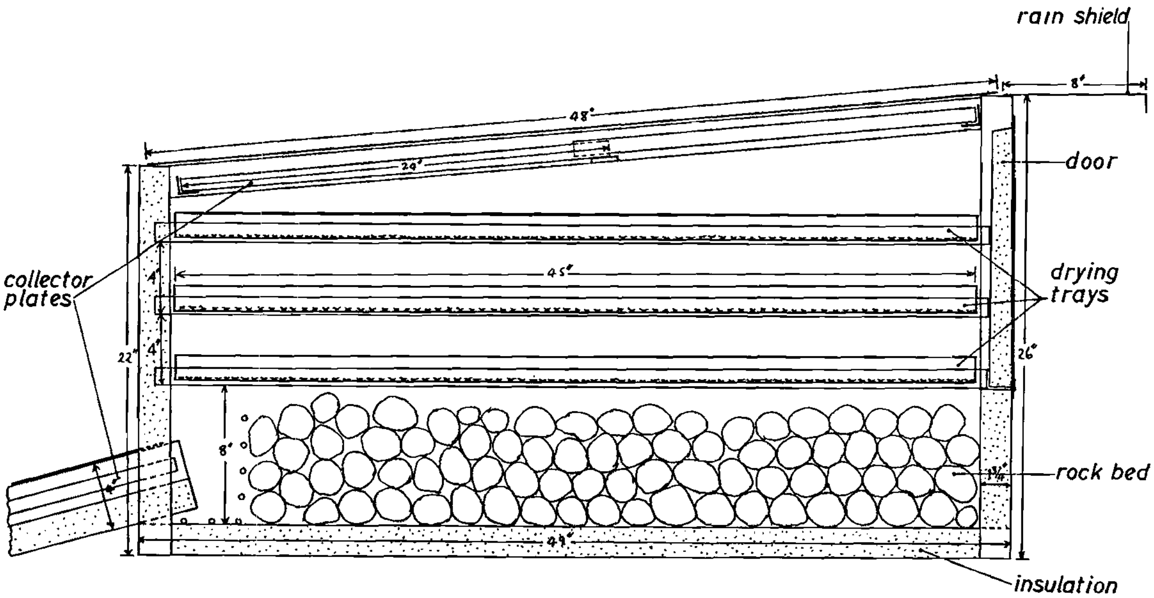

Figure 2 : Cross Section of the Drying Chamber of a 7.8 m2 Rock Bed Dryer in Grenada

The cabinet drier

This design is very suitable for housewives and other small-scale users. It is usually built of wood and plastic to reduce cost (Lawand, 1975) although metal-and-glass units have a longer life expectancy. Plate 3 shows a 2.2 m^2 metal-and-glass cabinet drier which has been used to dry ripe bananas and pomeracs for use in cake making. These dried fruits may be used as substitutes for imported products such as raisins, currants, prunes etc.

Plate 1: The 2.2m^2 Rock Bed Dryer with Chimney Assisted Air Circulation at CAST in Jamaica.

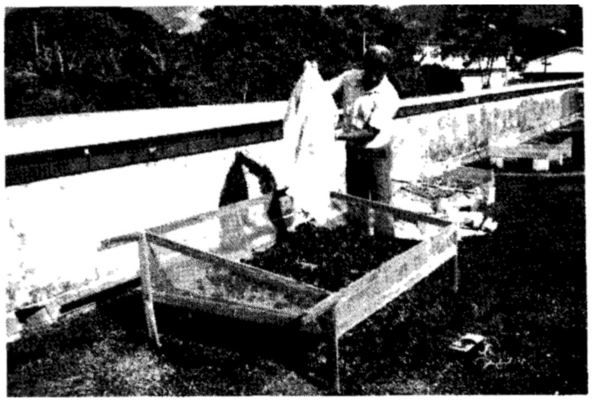

Plate 2: Loading Sorrel into a Wire Basket Dryer

The cabinet drier illustrated in Plate 3 also has provision for a 300 kg rock bed which enables much more steady drying conditions to be maintained in the drier. This drier also has metal collector vanes in its roof underneath the glass cover so that the material to be dried is not exposed to the bleaching effect of direct solar radiation.

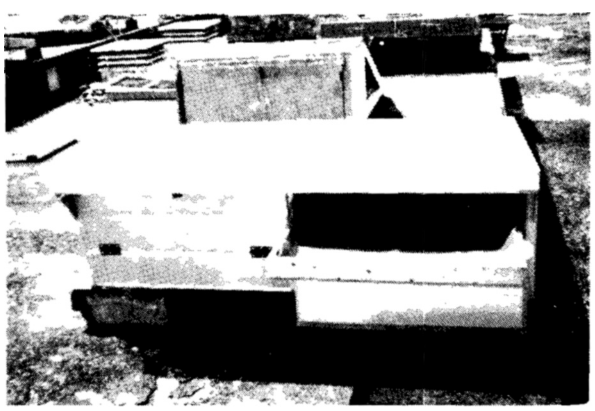

Plate 3: A 2.2m^2 Solar Cabinet Dryer

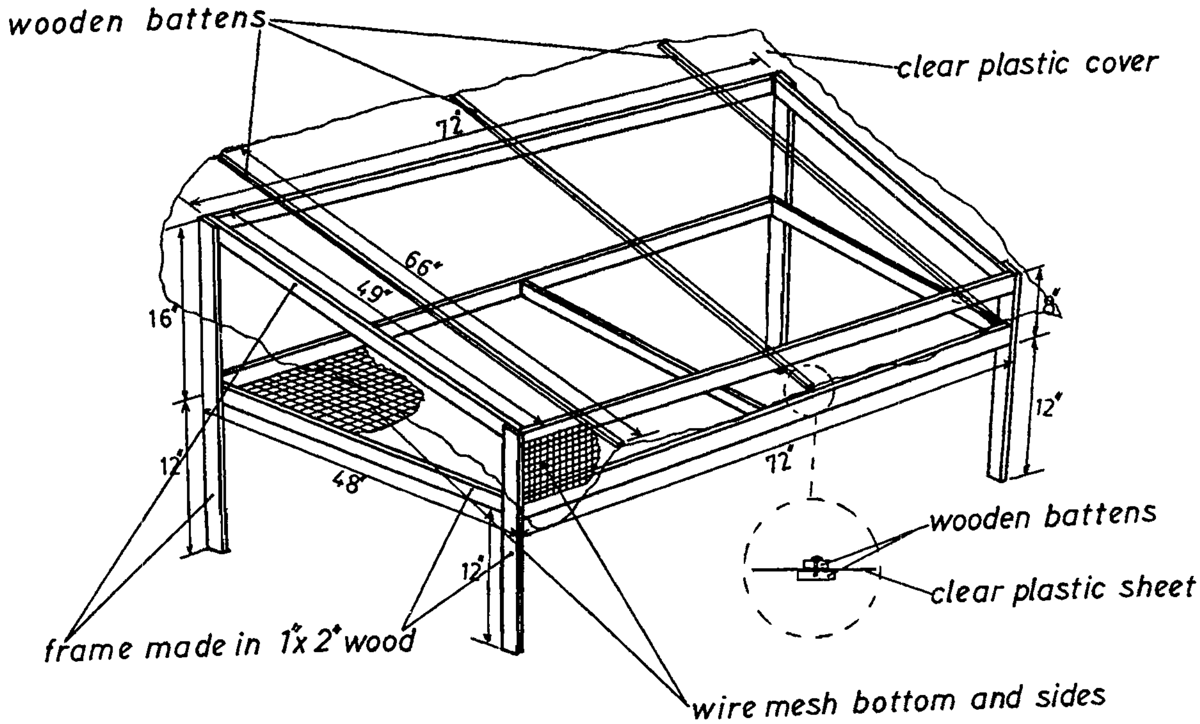

Figure 3 : The Wire Basket Dryer

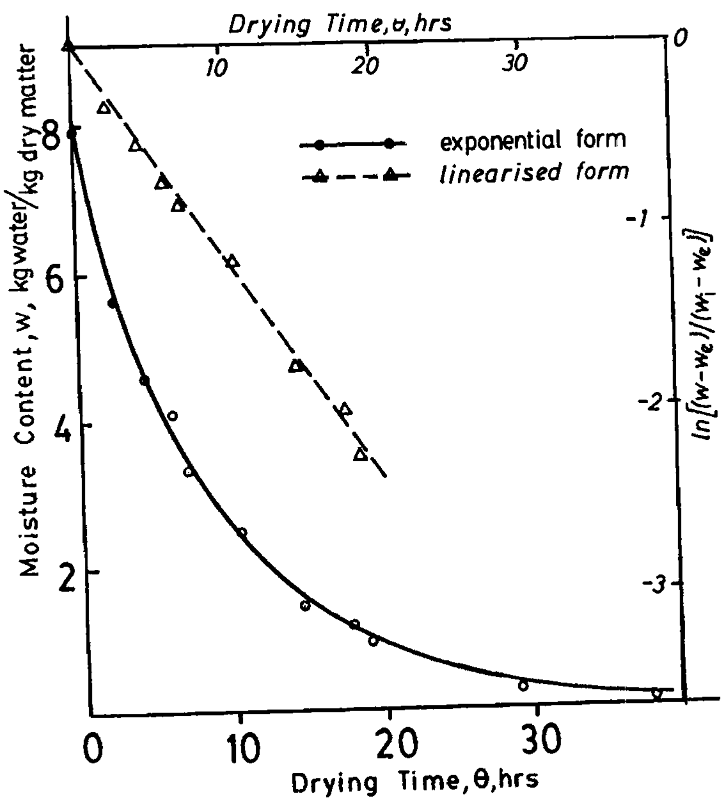

Figure 4 : Drying Curve for Sorrel

The roof air preheater

This is usually designed for large scale usage. A false ceiling in an existing farm building is used to create a hot-air chamber in the space just beneath the roof and a suitable extractor fan pumps air from this space into a drying bin where crop material is dried. It is a design which is very suitable for mixed-mode operation where one can use solar heat from the roof as well as fossil fuel burners or electric resistance heaters. The Brace Research Institute of McGill University and the University of the West Indies are currently designing one of these units for a cocoa drier in Trinidad (Papadopoli *et al.*, 1984).

Performance

The average daily efficiency of a solar drier may be evaluated from the following equation:

$$n = \frac{M_w H_v \times 100}{I_H A} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where n is the efficiency expressed as a percentage, M_w is the mass of water removed in kg.
H_v is the latent heat of vapourisation of water in MJ kg^{-1}.
I_H is the insolation on the horizontal surface in MJ m^2 and A is the area of the solar collector in m^2.

With glass or plactic covered solar collectors, tne heat and mass transfer relationships and the optical characteristics of the solar collector may be used to derive a series of equations to give the instantaneous efficiency. Textbooks on solar engineering (see for example Kreith and Kreider, 1978) cover these topics in the required detail.

Of more immediate interest to the farmer is how much drier area he will require to dry crops at a given rate. For most solar crop driers, n is between 15 and 40% with 25% being a reasonable figure. Knowing M_w, I_H and H_v, A is readily calculated.

For certain crops, the drying rate and temperature may be critical. For example, nutmegs should not be taken above 45°C or loss of some of the aromatic volatile compounds may result. The crop is therefore dried under laboratory conditions and its fundamental drying characteristics determined. The type of solar drier which is suitable can then be decided. Most crops show an exponential curve when the fractional moisture content (dry basis) is plotted against the drying time. McGaw (1979) obtained this type of curve for nutmegs and a similar one has been obtained for sorrel. The relevant equation is:

$$(W - W_e) / (W_i - W_e) = a \exp(-k\,\Theta) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where W is the moisture content, dry basis, at time θ. W_i is the initial moisture content, dry basis, W_e is the equilibrium moisture content, dry basis, with a and k being constants.

The drying rate usually increases when one increases the temperature, hence a family of drying curves is obtained, one for each temperature.

Most crops have an equilibrium moisture content under ambient conditions and if they are dried beyond this point they resorb water from the atmosphere until they regain equilibrium. For sorrel, this is about 10 to 12% under Trinidadian conditions i.e. 60-90% relative humidity, 25 to 30°C.

Conclusion

Solar crop dryers may be used successfully in the Caribbean territories so long as their cost and complexity are not beyond the ability of the average farmer. Of all the dryers tested, the wire basket dryer meets these criteria best (Headley, McGaw and Sankat, 1985). This dryer is therefore being deployed in the rural areas of the Caribbean for use as a total drying system or as a pre-dryer where moisture contents of less than about 12% are required for safe storage.

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