RP-328

Recent Advances in the Processing of Cocoa Beans

by
Biswa N. Ghosh
Project Engineer
Advanced Development & Engineering Center
Gulf + Western Industries, Inc.
101 Chester Road, Swarthmore,
Pennsylvania 19081, USA

UNESCO Expert in Agricultural Engineering
Guyana School of Agricult.
Mon Repos, E.C.D.
Guyana, S. America.

Introduction

The cocoa (Theobroma cacao L.) crop is processed to a considerable extent at the farm after harvesting to produce the dry cocoa beans, which are used by the manufacturers of chocolate or other secondary industries. Processing at the farm consists of pod-breaking, fermentation and drying followed by storage, along with some cleaning and grading during or after drying and storage. The equipment used for the farm processing may vary from the simple cutlass to a sophisticated automatic temperature regulator. The cocoa beans undergo a drastic change in their physical appearance and properties like shape, size, color, density and flavour during the processing, and they need to be handled with extreme care in order to retain the characteristic properties associated with good quality chocolate.

The basic operation of drying cocoa, the most difficult part of processing on the estate, is the reduction of moisture in the freshly fermented beans to such a level that micro-organisms cannot grow and the beans can be stored safely for a number of months (1). During drying a considerable reduction in weight and volume of the material takes place, along with certain chemical changes inside the bean which gives rise to the typical aroma or flavour associated with good quality chocolate. The freshly fermented beans, with a loose surface coating of mucilage, have a maximum initial moisture of approximately 55% (w/w) and are dried down to an average of 7% to ensure good keeping qualities during storage. However, the initial moisture content is subject to considerable variation (2) and can be as low as 39%. It depends to a large extent on the type of fermentation box used (number of holes in the wooden box to drain the mucilage), the amount of mucilage drained for preparing cocoa jelly as a byproduct before fermentation and the number of days necessary to complete the fermentation process. It is also affected by the rainfall in the area during the few days preceding the harvest of the cocoa pods.

The common method of drying cocoa beans in Brazil, a major world producer of cocoa, is by exposure to the sun in *barcaça* or a drying platform constructed above ground level, where the beans are spread out in a thin layer of 4-5cm and a sliding roof is provided over the platform to protect the beans during rain and also at night. The drying floor dimensions usually vary between 50 and 72 sq.m and the number of platforms in a farm between one and 16-20, depending mainly on the quantity of cocoa produced by the farm.

The sun-drying method for cocoa beans in Brazil has a great disadvantage in that frequent rain and showers are experienced during the processing season, which extends from April to January, when drying on the *barcaça* is either slowed down to a considerable extent or rendered impracticable. An alternative artificial drying system is therefore necessary to maintain the volume of production, and most *fazendas* or cocoa farms in Brazil have an artificial dryer in addition to sun-drying platforms or *barcaças*. The different types of artificial dryers commonly used for cocoa beans, along with their shortcomings, have been described elsewhere (3-6).

Article was presented as ASAE paper No. 12-13, section 12, at the First International Conference on Engineering and Food University of Massachusetts, Boston, Ma., August 9-13, 1976. Sponsored by A.S.A.E., St. Joseph, Mich., USA.

Problems in Cocoa Drying

A large number of problems are associaqed with the drying of cocoa beans, after fermentation, at the farm level. These have been discussed in detail elsewhere (3—8) and summarized below:

1. Frequent rain and showers experienced during the processing season slows sun drying to an impracticable level, requiring up to 3—4 weeks at certain times of the year.
2. As the beans have to be spread out in a thin layer of 4—5cm for sun drying, a large number of *barcaças* are necessary if drying is carried out only by sun.
3. The cost of constructing a *baracaça* is rather high and its drying efficiency is low.
4. The labour requirements is sun drying is high as the beans have to be turned frequently on the drying floor.
5. During bad drying weather prolific amounts of mould quickly develop on the surface and also inside the bean, which may seriously affect its quality.
6. Good quality, cheap, dry firewood for artificial dryers in some cocoa-growing areas is already in short supply, while in other areas transport of the bulk firewood over rough or mountainous terrain is difficult and expensive.
7. The difficulty in maintaining the heat exchangers in a trouble-free condition for the wood-burning type of artificial dryers gives rise to a smoky flavour in dried beans.
8. With certain types of artificial dryers (*eg* Ferraz) the minimum amount of cocoa bean necessary for a satisfactory batch operation is sometimes too big even for a large producer except during the peak season.
9. Lumping and excessive breakage of beans during drying by mechanical dryers.
10. Too much separation of dried mucilage from the bean surface, which is lost as a dry powder due to excessive mechanical mixing in artificial dryers.
11. High capital cost of a mechanical dryer; also, the need for electrical energy (which may or may not be available at the farm) or an internal combustion engine to operate the driving mechanism.
12. The need for expert mechanical supervision for the operation and maintenance of the equipment.

Experimental Scope

A comprehensive study of the existing drying systems used for cocoa beans (1) clearly indicated that none of them were basically designed to meet the various specialized requirements of the crop; hence, it was considered that it would be easier to incorporate these requirements in a new design rather than try to modify and improve any one of the existing systems. In developing the new system, the following design parameters were laid down:

a. The dryer should be flexible in design, using a repeatable unit module, so that the requirements of any farm size can be easily met.

b. The dryper should be dual purpose, so that it can be used either as a solar dryer and/or as an artifical dryer, in order to economize on the construction and operational costs.

c. The physical effort required by the farm operators in drying the crop should be as little as possible. In the existing *barcaça* they have to stand over the bean on the drying floor and bend down to reach them; also, the operator's feet are affected by the acidic mucilage in the beans while the beans are contaminated by the dirty, usually bare, feet of the operator. An elevated drying platform at the normal working height would minimize the physical effort required by an operator and also avoid contamination of either his feet or the beans from each other.

d. The drying house should utilize as much as possible locally and easily available wood as a material of construction; also, the design should be simple for the farm carpenter to follow and execute.

e. The roof over the drying platform should be fixed and be built of a material which will easily allow the heating rays of the sun to pass through while praventing the rain or dew at night to come in contact with the beans.

f. Ventilation and circulation of air inside the dryer should be preferably by convection rather than mechanical, for simplicity in design and ease of operation.

g. The charging and discharging of the beans on and from the drying platform should be easy; a platform raised to the working height would achieve this objective.

h. A central passage with a drying platform on either side would facilitate the movement of both the operator and the material.

i. The height of the roof above the drying platform should be low to minimize the volume of air to be heated during solar drying, yet should be enough for operators to walk through the central passage; a roof sloping down on either side from the central passage would be desireable.

j. The plenum chamber for artificial heating should be located under the platform to facilitate passage of the heated air through the layer of drying beans.

k. The artifical heating system

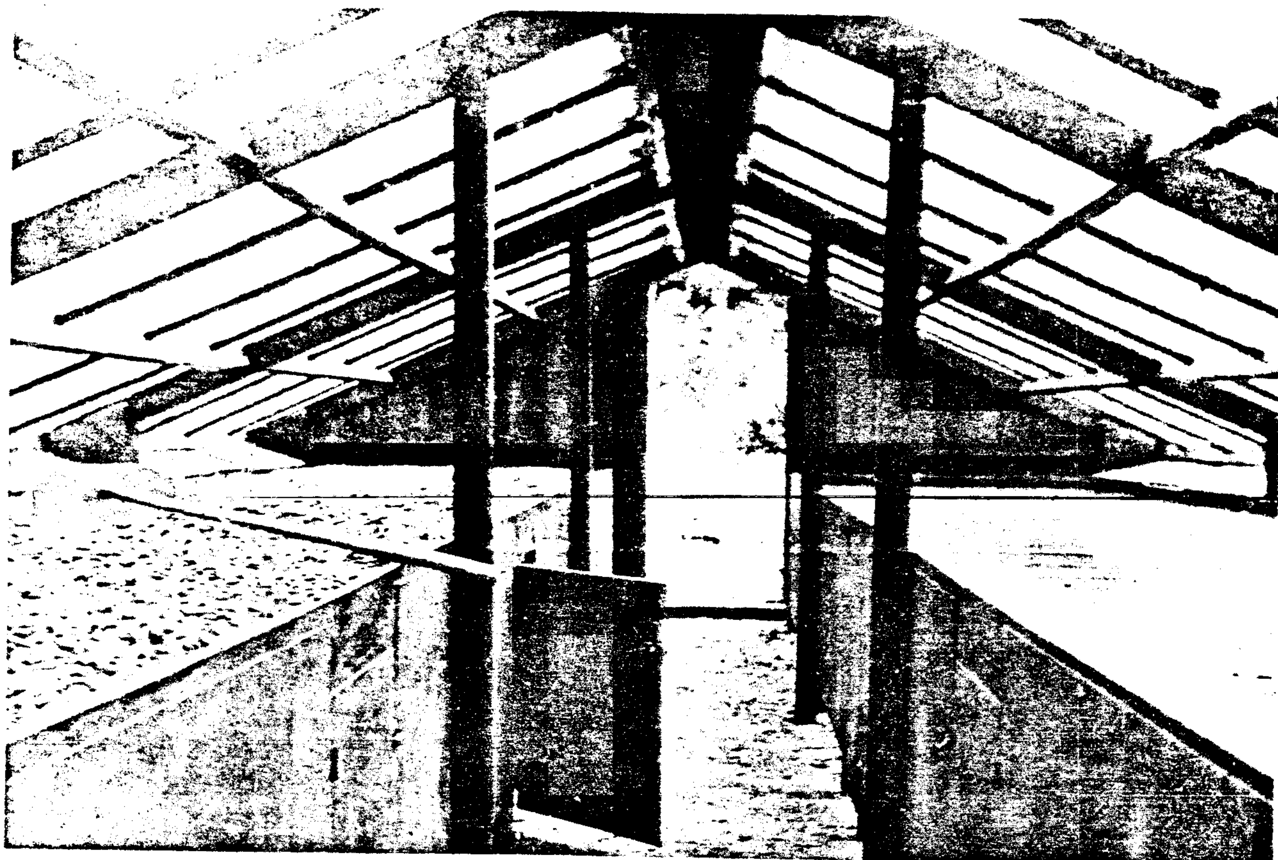

Fig.1. Glass-roof dryer—inside view.

should preferably use a smokeless fuel, as contamination from smoke is one of the most objectionable aspects of practically all the existing artifical drying systems even when equipped with a heat exchanging device.

1. The heating fuel should be easily available at a reasonably low cost, even in the outlying cocoa farms which may or may not be connected by a road to the nearest highway.

A Solar-Cum-Artificial Dryer

A new type of sun drying platform was designed and developed by the author to meet the above-mentioned design parameters at the Cocoa Research Center of Brazil (CEPEC), located at the heart of the Brazilian cocoa region at Itabuna in the State of Bahia. The prototype glass-roof dryer (**Figure 1**) is light in construction and is covered by a fixed glass-roof like a green house instead of a sliding roof used in a *barcaça*, which is expensive to build and heavy and cumbersome to operate. The prototype dryer has been described in detail in a recent paper (7); it basically consists of two parallel rows of drying platform (each 12 m long, 1.76 m wide and 0.8 m high) with a central passage 1 m wide for an operator to facilitate the loading of either platform with the beans for drying, turn during drying by a rake provided with a long handle and transfer the dried beans directly to sacks after cooling on the platform. The overall width of the drying house including the outer supporting pillars is just over 5 m, while the length can be made to suit the needs of the individual farm; for lengths more than 15-20 m it would be better, however, to construct a second, separate unit. The top of the platform is provided with a ridge 10 cm high along the edge and the drying surface is made of galvanized iron wire-mesh laid over wooden beams fixed across the platform at a pitch of 0.5 m, so that the heating rays from the artificial heaters (**Figure 2**) located underneath the platform can easily pass through the wire-mesh. A strong metal wire laid over the wooden beams and under the wire-mesh along the length of the platform at a pitch of 0.4 m provide additional strength to to the wire-mesh against sagging under load. A fixed glass roof (3 mm thick, commercical quality, 1 m x 1 m panel) above the drying platforms allow the heating rays of the sun inside the dryer but prevent the rains or the dew at night to come in contact with the beans. All surfaces inside the drying house are painted black to facilitate the absorption of heat from the sun.

For artificial heating, a plenum chamber is provided under and along the length of the drying platforms. Each platform is pro-

Fig.2. Gas burning infra-red heater (note : the write-mesh protective cover avoids incineration of falling cocoa particles.)

vided with three small doors opening out to the central passage for entry into the plenum chamber where infra-red heaters using low-cost commercially available gas are located in a central furrow on the floor. The equipment is fairly simple and there are no moving parts like fans or electric motors, as natural convection forces set up by cold air entering at the bottom of the plenum chamber through a vertical space of 12 cm at the lower edge of the platform wall force the heated air to rise through the layer of drying beans. The heat is available for drying immediately on starting the heaters without any elaborate or time-consuming preparations or smoke, as is the case for starting wood fires. For artificial drying, the adjustable shutters under the lower edge of the sloping glass roof are also closed, so that the flow of ambient air is routed through the plenum chamber.

Each heater is located 120cm below the platform, as at this distance a desirable maximum drying temperature of around 70°C can be maintained for the beans on the platform. The temperature at the platform can be easily regulated by a valve provided with each heater and also with the gas cylinder. By this configuration each heater can effectively heat an area of 2 sq. m of the drying platform, the total number of heaters used for a particular installation being dependent on the capacity needed. The system is therefore highly flexible and can equally serve the needs of the very small farm using only one or two heaters to the very large farm with 16-20 or more heaters. Approximately 75 kg of beans can be dried per batch for each square metre of the drying platform.

The gas is supplied in the cocoa-growing region of Brazil in cylinders of either 13 kg (household) or 45 kg (industrial) capacity, the cost of gas per kilogramme being the same in both cases. The smaller cylinders are generally preferred by the farmers, mainly due to their ease of handling and transport, which in some instances has to be by mules over rough terrain, and their interchangeability with existing household clyinders. The number of smaller cylinders used in a multiple-heater installation is equal to the number of heaters. They are located outside the plenum chamber in two groups, so that only half the number of cylinders are used at a time, while the other half is kept connected to the system in readiness for switching over instantly when required during a drying operation.

Results

Sun Drying

Experimental evidence obtained from continuous recording thermohygrographs (7) clearly illustrate the advantage of the glass-roof dryer over a common *barcaça*. The mean maximum temperature inside the dryer, at around mid-day, is approximately 20-25°C higher than ambient, while the mean minimum relative humidity at the same time of the day inside the dryer is around 15-20% lower than the ambient. A combination of these two factors produces a condition which is highly conducive to a faster drying rate for the cocoa beans.

The drying rate of cocoa beans inside the glass-roof dryer has also been compared with that in a common *barcaça*, located some 30 m from the dryer. The drying rate inside the dryer is consistently faster than that in the common *barcaça* (**Figure 3**), and the end point is reached in the glass-roof dryer one day before that in the common *barcaça*; the saving in time of 1 day in 8 days correspond to a saving of approximately 12%. Also, the initial moisture content of the cocoa beans after fermentation, at the start of drying, was higher for the beans in the glass-roof dryer than in the common *barcaça*. Such differences of moisture in cocoa beans during and after fermentation, carried out in batches, is attributable to a number of factors (2). Also, the beans in the dryer with a higher initial moisture content had proportionally larger amount of water to evaporate than those in the common *barcaça*, to dry the beans to the same level of moisture content, indicating a higher drying efficiency for the glass-roof dryer over the common *barcaça*.

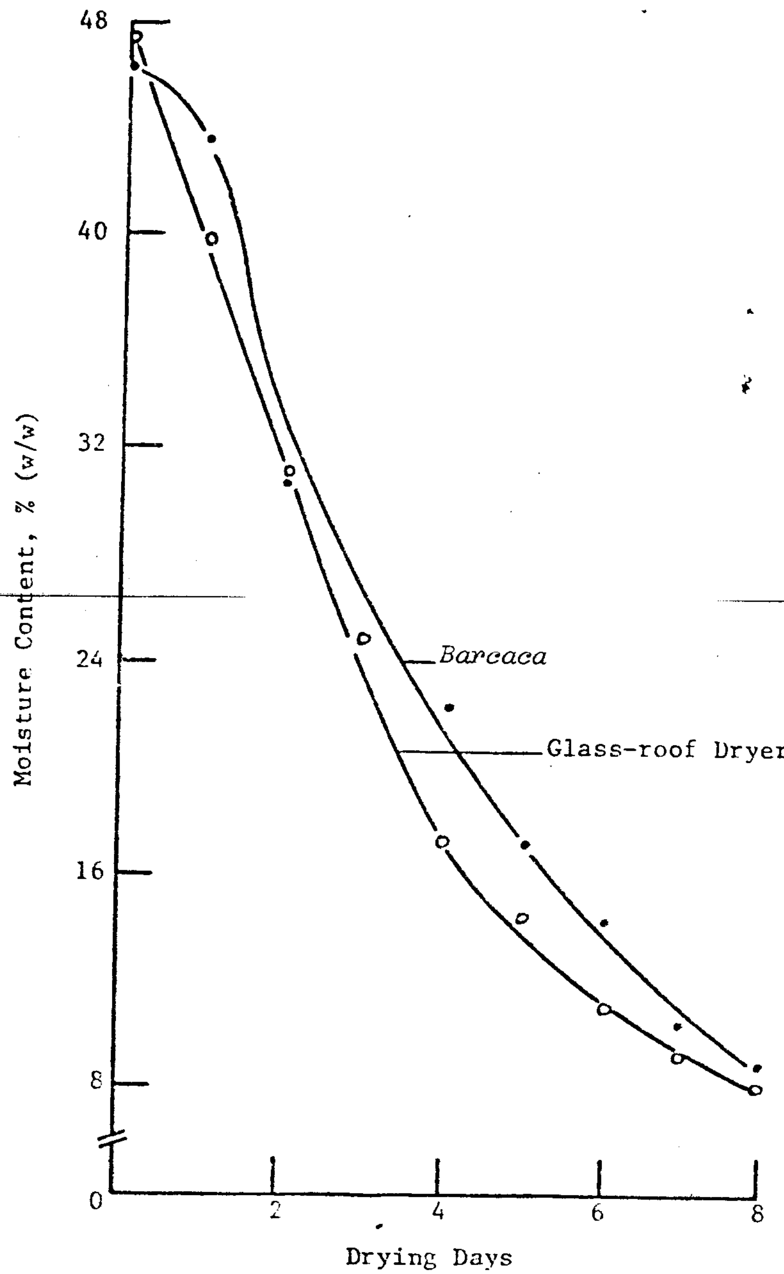

Fig.3. Drying rate of cocoa beans with solar energy.

Gas Drying

The maximum drying temperature for cocoa beans for gas drying maintained at around 70-75°C in the initial stages and is gradually lowered as the moistre content is reduced to around 15-12%. This is easily achieved by the simble but effective temperature control equipment described in a recent paper (1), where factors affecting the cost of gas drying along with the total drying cost has been considered in detail.

The main advantage of using the same installation for both solar and gas drying is in the possibility of switching from sun to gas drying or vice-versa instantly, in view of inclement weather, nightfall or daybreak before drying is complete. In the traditional system, a considerable amount of time and energy is needed for transferring the beans from the drying platform to the artificial dryer, the transfer usually being in one direction only, which also gives rise to the possibility of bean damage or breakage through mechanical handling during the transfer.

Experiments carried out with gas drying of beans initially dried by sun and/or with beans immediately after fermentation indicated that a highly satiscactory end product could be obtained without any loss in product quality. The characteristic drying rate obtained by using the infra-red heaters under the platform (**Figure 4**) indicate that the drying time varies from 18 to 34 hours, with the moistre content of the beans at the start of gas drying varying from 30 to 46% respectively. The typical falling rate curves obtained in **Figure 4** closely resemble the theoritical drying rate of a vegetative material like cocoa beans (3).

The overall performance of the prototype dryer over a period of two seasons has been satisfactory, and a number of farm installations have since been carried out in the cocoa region of Brazil. Also, adaptation of the gas dry-

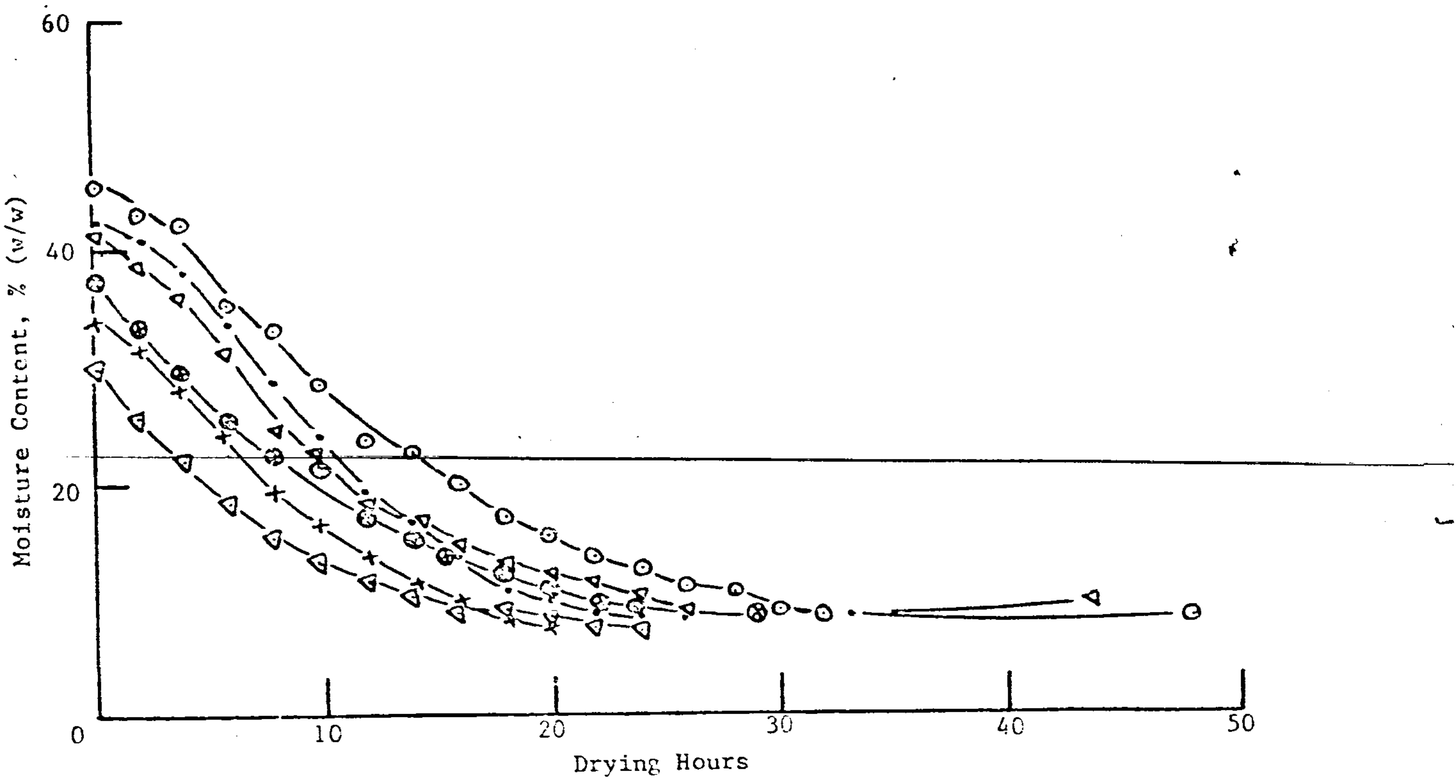

Fig.4. Drying rate of cocoa beans with infra-red heaters.

ing system to traditional *barcaças* and to wood burning artificial dryers have been successfully carried out (1).

Conclusions

The new drying system designed and developed for cocoa beans has helped to solve the most difficult problem encountered during the farm processing of the cocoa crop in Brazil, where the main requirement for maintaining quality of the end product is that drying should be a continuous operation without interruption or slowing down and that the crop is handled with extreme care to avoid bean damage.

The newly developed glass-roof dryer uses solar energy and/or artificial heat in the same installation to produce an excellent product. Also, the gas drying system can be used to adapt traditional *barcaças* and wood burning artificial dryers. Further, the dryer can be easily modified for drying practically any other crop on the farm.

Acknowledgement

The design and development of the solar-cum-artificial cocoa drying system and its adaptation to existing *barcaças* and wood burning artificial dryers were carried out by the author during his former assignment with the Cocoa Research Center of Brazil, under the Directorship of Dr. Paulo de T. Alvim.

LITERATURE CITED

1. Ghosh, B.N. (1973) : Drying Cocoa Beans by Gas. World Crops. 25 (5) : 232-237.
2. Ghosh, B.N. (1973) : Physical Properties of Cocoa Beans, Turrialba, 23 (4) : 438-443.
3. Ghosh, B.N. (1972) : Engineering Aspects of Cocoa Drying in Brazil, Revista Theobroma. 2 (4) : 23-37.
4. Howat, G.R., Powell, B.D., and Wood, G.A.R. (1975) : Experiments in Cocoa Drying and Fermentation in West Africa, Tropical Agriculture (Trinidad), 34 (4) : 249-257.
5. Maravalhas, N. (1968) : Novos Tipos de Secadores. Cacao (C. Rica). 13 (1) : 13-21.
6. The Samoan Cocoa Drier (1958) : Cadbury Brothers Ltd., Bournville, U.K.
7. Ghosh, B.N. (1973) : A new glass-roof dryer for cocoa beans and and other crops. The international Congress "The sun in the service of mankind", Paper V-30. UNESCO, Paris.
8. Allison, H.W.C., and Kenton, R.H. (1964) : Mechanical Drying of Cocoa, Tropical Agricultuure (Trinidad), 41 (2) : 115-121. ■ ■