Solar Food Drying: A Rural Industry*

C. Stuart Clark

Mennonite Central Committee, P.O. Box 785, Dacca-2, Bangladesh.

SUMMARY

A technology, however elegant, finds its fullest expression in its application. Yet in developing countries, for many reasons, it is difficult to reduce nontraditional technologies to practice. This is particularly true if the technology is designed to be used by poor people in rural areas.

This paper describes the work of the Mennonite Central Committees in Bangladesh to apply the principles of modern food drying and solar energy utilization to establish a rural food drying industry. Beginning in 1976, the objective of this project has been the adaptation and development of simple techniques for the solar drying of fruits and vegetables. A simple solar cabinet dryer costing US$ 10 to construct has been developed along with simple techniques for steam blanching, sulphiting, packaging and storage.

On the basis of these techniques women's groups have been established to produce dried grated coconut, a product which has found a ready profitable market. Several other products are in the market testing stage. It is hoped that this work will be a catalyst to the wider application of solar food drying in Bangladesh.

Such simplified techniques have limitations. Product quality and cost may, in some cases, not be competitive with factory produced dried foods. If this opportunity ɟor establishing a rural industry is to be taken the government may have to provide some measure of protection.

1. INTRODUCTION

1. *Food Processing in Rural Bangladesh.*

As in many other parts of the world, in Bangladesh food drying is an established and traditional technique for preserving food-stuffs. Here, however due to the high ambient temperature and more important, the high humidity, the application of food drying has been limited. On sunny days the open air drying of grains, lentils and fish is widespread with some of the minority communities also drying a few selected surplus fruits for short periods of storage. Lack of adequate technology to deal with chemical and microbial deterioration appears to have inhibited the use of drying for a wider range of food products. Traditional drying usually means little more than placing the food material out in the open on roadways, rooftops or other flat surfaces for various lengths of time (3-7 days) during sunny weather. This provides many opportunities for contamination and infestation by blowing fecal dust and parasite eggs, insects, animals and birds. Furthermore the slow drying rate promotes mold and fungus growth and excessive deterioration of colour, flavour and nutritional value. Suitable storage techniques are also difficult. Given the high humidities encountered during most of the year, the traditional storage containers cannot prevent the pickup of moisture by hygroscopic food materials. Dried foods must be frequently redried causing further deterioration of flavour,

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colour and nutrition. Insect infestation is also a continuing problem. If the use of drying in rural Bangladesh is to be expanded it is clear that the following areas need attention.

(1) Contamination during drying must be prevented.

(2) Drying times need to be reduced.

(3) Storage stability needs to be improved.

There are in Bangladesh as in many other developing countries, several factors which kindle interest in expanding the role of food preservation in the rural areas. Firstly, there are some serious seasonal gluts in fruit and vegetable production. These gluts reduce the earnings of farmers thus discouraging increased production. Inevitably such gluts lead to greater spoilage losses. One example may help to illustrate this point. In Noakhali District of Bangladesh the price of tomatoes, on average about US \$ 0.16/kg in season, drops as low as US \$ 0.02/kg at peak season in a good year. At this price the farmer cannot even afford to take the tomatoes to the local market. They rot in the fields and the farmer, hard pressed at the best of times, loses his investment. Similar situations exist for several other fruits and vegetables. The existence of rotting food and discouraged farmers must be avoided as Bangladesh, like other poor developing countries, works towards nutritional self-sufficiency. An expanding rural food preservation industry could help to correct this problem.

The creation of work places in the rural areas of developing countries like Bangladesh is often put forward as the necessary solution to urban drift problems. Already there is massive unemployment and underemployment in rural Bangladesh. The drift to the cities, while not as serious as in other developing countries, is intensifying. Bangladesh's chief resource is its lands. Agriculture and agriculture related activities are and will continue to be the major source of rural employment. In agriculture the possibilities of economically absorbing further labour inputs are exhausted. Already farming families "take turns" in the fields to share this productive activity. Post harvest processing is one of the main hopes for creating additional productive employment in the rural area.

Finally, the role of women in development is an important social factor. In the conservative Muslim society of rural Bangladesh, the keeping of "purdah" seriously restricts the economic role women can play. Traditionally it is the women within the homestead who have processed the grain and carried out the little food preservation which was done. Now with the advent of powered rice mills much of this work has left the homesteads. If rural Muslim women are to maintain or increase their economic role small scale highly decentralized economic activities will be needed.

1.2 *Transferring Technology to the Rural People*

The above arguments for increasing the role of rural food processing, specifically fruit and vegetable drying, will say little to the main participants, the rural people. Theirs is a different world, a world where such "macro" considerations as national nutritional self-sufficiency, urban drift and participation by women in development are of little or no interest. Instead they are interested in "micro" considerations like earning a little more money as safely as possible and avoiding the possibility of ridicule by the neighbours for making a mistake, particularly if the mistake arises from a departure from traditional techniques. Even the idea that by preserving food now they can avoid shortages later has little mass appeal. To persuade the rural poor to try a new technology it is necessary to both reduce the risk and show promise of short-term material gain.

Reducing the risk requires more than protecting against material loss. Peasant perceptions of what technologists view as mainly technical problems are different. Food technologists, because of their shared set of ideas about the purpose and principles of food technology, define food processing problems in a particular way. As long as the people who will use the food technology they develop define the problem similarly the chances of a successful transfer of technology are high. This is rarely the way that rural peasants define the problem. To avoid solving the "wrong" problem it is useful to try to develop new food processing technologies as much "in situ" as possible. This approach is similar to the "on-farm" agricultural research being done very successfully in several developing countries. By such approaches errors in problem definition are not only avoided but some of the mystery that surrounds new technologies is diffused. The author's experience in working with food drying supports this.

A new technology must also promise a substantial return in the near future if the rural poor are to be interested in trying it. In technically advanced societies the economic returns of a successfully adopted new technology may be quite small. In less developed rural societies the inability to withstand economic loss makes people very conservative. The taking of even a small risk must be offset by the promise of a significant reward. Furthermore it is usually not adequate to simply make the rural poor aware of a new technology. Often in the initial stages special arrangements in the form of various insurances against loss must be provided. This is particularly true if the technology is very novel in the rural context or if the economic return, while substantial, is not dramatic. Solar food drying is in this category.

1.3 *The MCC Solar Drying Project*

The Mennonite Central Committee (MCC) is a North American based church-related voluntary organization. Their work in Bangladesh is primarily concerned with agricultural research and extension, rural health/family planning and rural employment creation. In 1977, as part of the MCC (Bangladesh) Agriculture Programme, a project was undertaken "to develop village level food drying techniques which are culturally acceptable, economically attractive to small farmers, safe and efficient" and to "encourage routine utilization of these techniques".

Although the first six months' work of testing the feasibility of solar food drying was carried out at a small research station, the remainder of the project has been closely linked to the rural environment. Initial dryer design development was carried out in a remote area under primitive conditions and dryers were placed into the hands of farmers as soon as possible to get their reactions.

During the technical development phase of the project (December 1977 - January 1980) dryer designs and solar food drying techniques developed by James McDowell of the Caribbean Food and Nutrition Institute and Thomas Lawand of the Brace Research Institute were modified and adapted to fit local conditions in Bangladesh. Locally adapted techniques for blanching, sulphiting and packaging were also developed. These are discussed below. The Food Technology section of the Bangladesh Council for Scientific and Industrial Research (BCSIR) provided technical support in the form of vitamin A and C analyses and advice on dryer design.

Once the techniques developed had been well tested the commercialization and extension phase was begun. Realizing that initially the markets for new food products would be primarily in the urban areas, a market survey of dried foods and related products in the Dacca and

Chittagong markets was carried out. On the basis of the survey findings a range of dried food products was selected for test marketing. In a major coconut growing area the first of twenty producer groups has been established to produce solar dried grated coconut. In a major vegetable growing area ten village women have begun producing test lots of dried fruits and vegetables. In a third location, dried ginger is being produced on a test basis. All of these products are being marketed through a Dacca based dried food marketing group established by MCC.

Interest in this project is growing. Officials of the Bangladesh Agricultural Development Corporation are interested in expanding the solar drying of vegetables. Another private development organization is already marketing a range of solar dried spices. Other organizations, both private and government, are requesting training in solar drying and a training course to be held in October 1980 is in preparation.

The balance of this paper discusses the technical and commercial aspects of rural based solar food drying.

2. TECHNICAL ASPECTS

2.1 *The Technical Problem.*

The basic technical problem addressed in this work was to develop the food drying technology needed to produce food products which will resist spoilage for four to eight months under conditions of high temperature (25-35°C) and high humidity (80-100% relative humidity). While quite easily solvable using modern drying equipment and packaging techniques, this problem is more difficult under the conditions prevailing in rural Bangladesh.

As it is intended that the dryers should be used widely in the rural areas, all materials required must be available locally or, at most, in nearby urban areas. Due to the prevailing economic environment, the materials needed, both durable and expendable, must be cheap. A total investment of US$ 20-30 per producer is a useful guideline. Finally, given the low educational level of most rural people (less than 15% literacy), the techniques developed must be both simple and reliable, requiring a minimum of special training.

The techniques required to make solar food drying possible in rural Bangladesh can be divided into three parts:

a) Preparation of Food Materials for Drying

b) Solar Dryer Design and Operation

c) Dried Food Packaging and Storage

2.2 *Preparation for Drying*

Traditionally no special steps are taken in preparing foods for drying. As a result discoloration, development of off-flavours, reduced nutritional content and reduced storage life are common problems with the few foods which are preserved by drying in rural Bangladesh. Blanching and sulphiting are two relatively simple techniques commonly used in modern food processing. Both techniques are practicable in rural Bangladesh as the former requires only boiling water or steam and the latter only sulphur which is widely available.

Blanching can be accomplished either by immersion in hot or boiling water or by steaming. Both techniques were already known to rural women for uses other than blanching. Using common household and cooking implements both techniques were tested on sliced potato and red amaranth, a dark green leafy vegetable commonly eaten in Bangladesh. Blanching times of four to eight minutes were used. Hot water immersion, while permitting a larger batch to be blanched at a time, resulted in heavy leaching, particularly of the red amaranth leaves. Steam blanching produced a more attractive dried product. The steam blanching technique used consisted of placing cut up food pieces on a screen suspended above boiling water in a closed container. The blancher is shown in Figure 1. This technique is used traditionally to gelatinize rice starch in local cakes. No peroxidase analysis was performed to determine blanching effectiveness. However this process substantially reduced browning.

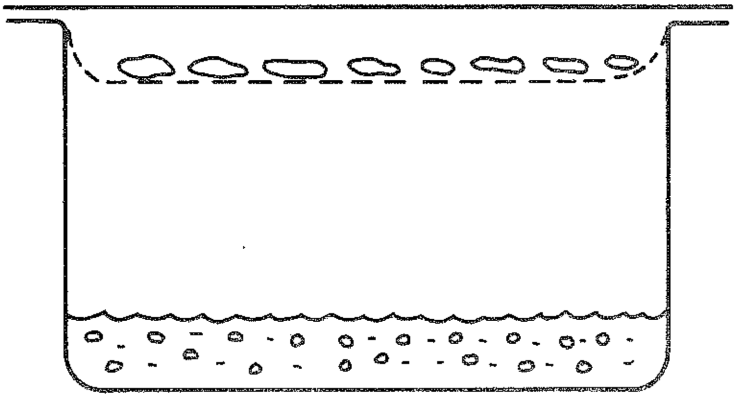

Fig. 1 Simple steam blancher (showing food pieces suspended on bamboo sieve)

Sulphiting by the use of sprays or dips in sodium sulphite and/or sodium metabisulphite is not practicable. Traditionally, however, the same objective has been achieved by burning sulphur to produce sulphur dioxide and fumigating the food with these fumes before drying. In Bangladesh this technique is used to prevent the spoilage of betel nut during storage. To evaluate this procedure, potato slices, pineapple pieces, and grated coconut have been placed on stacked screens in an airtight box and fumigated in sulphur dioxide fumes for periods of 15 minutes, 30 minutes, one hour and two hours. Ten grams of sulphur per kilogram of material to be dried were used. The sulphuring box is shown in Figure 2. The visual appearances of the dried products immediately after drying and after four weeks storage were used as indicators of the treatment effectiveness. One hour of exposure gave the best result in appearance.

These techniques of blanching and sulphuring are simple, they are slso, inevitably, imprecise. The production of a uniform attractive product is very dependent upon the skill of the producer. Fortunately, the quality of the dried product is quickly evident from the appearance and taste after drying. Skillful rural women are quick to observe results and, given sufficient training, to change their techniques to produce the best possible product. None the less there is an element of art on the part of the producer which requires that there be constant careful quality control.

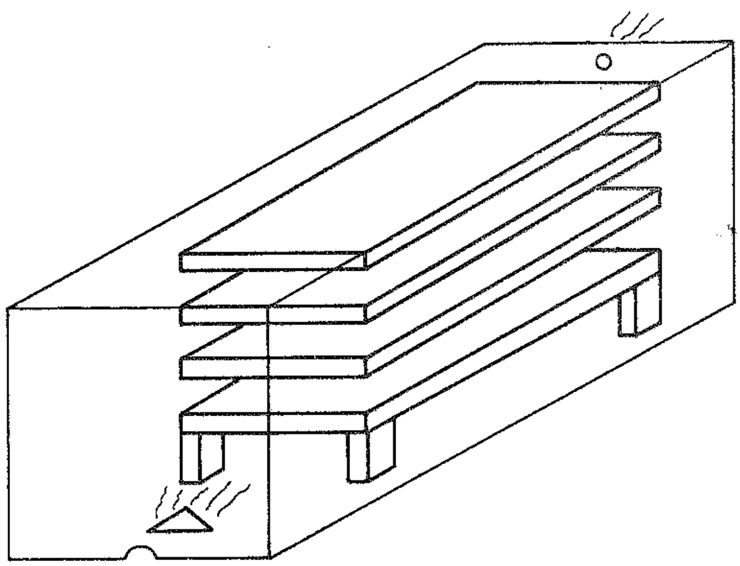

Fig. 2. Sulphuring box (showing food trays inside)

2.3 *Solar Dryer Design and Performance.*

The basic requirements for a solar food dryer for use in rural Bangladesh are:

a) Low cost
b) Simple operation
c) Protection from contamination by dirt and other foreign matter
d) Rapid drying

There has been considerable work done to develop improved sun drying techniques. The Tata Energy Research Institute has prepared a summary of much of this work (Unknown, 1978). However there have been few proposals for low cost practical dryers for drying fruits and vegetables. Three designs have received wide coverage in the past ten years.

(1) The solar cabinet dryer proposed by Lawand, 1973
(2) The solar box dryer proposed by McDowell, 1973
(3) The indirectly heated solar dryer proposed by Exell et al, 1977.

The basic design of these three dryers is shown in Figure 3.

The author conducted preliminary experiments in the solar drying of vegetables for Bangladesh using the dryer proposed by Lawand (Clark, 1976). This dryer proved very effective for drying cauliflower, carrots and tomato puree. These products were blanched and sulphited before drying. Under cool season conditions the dryer produced internal temperatures of up to 60°C. The dryer used in these experiments was too expensive in its original form (wood and glass) to be proposed for widespread use in Bangladesh.

The box dryer proposed by McDowell has been widely extended in East Africa and through UNICEF channels in other developing countries. Constructed of bricks or mud, bamboo and low density polyethylene film it is very cheap to construct. McDowell reports success in drying a range of fruits and vegetables.

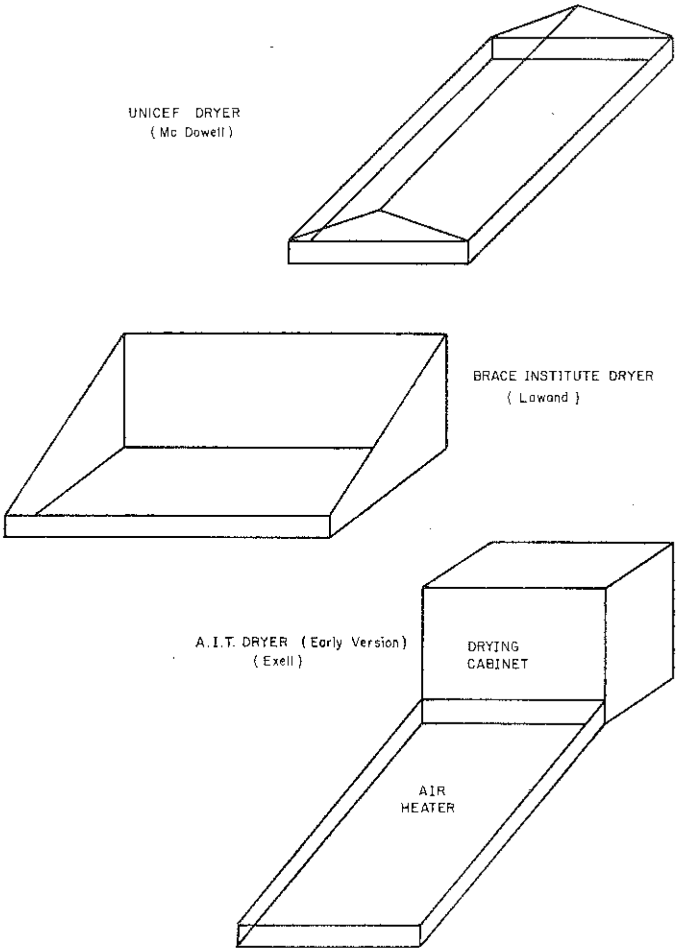

Fig. 3. Solar dryer designs evaluated

Exell and associates at the Asian Institute of Technology have been developing an indirectly heated solar dryer intended primarily for rice drying. However Exell in private communication (1980) reports that a recent version has proven effective for drying vegetables as well. Although more expensive than the other two dryers it has the important advantage of not exposing the drying food to direct solar radiation. This should improve vitamin A retention.

These three dryers and several variations of them were tested at a remote rural testing site located ten miles from the district town of Maijdi in Noakhali District of Bangladesh. The McDowell type dryer and another variation of it were constructed but failed to produce internal temperatures in excess of 60°C. This low temperature problem appeared to be due to the large cover area relative to the size of the dryer causing excessive heat loss. The short vertical distance (15 cm) between the inlet and outlet air vents produced very little air flow through the dryer causing frequent fogging of the underside of the plastic cover. As the dryer was immovable it was not well suited to being placed under protection from rain, flooding and vandals, all problems in rural Bangladesh.

A low cost version of the Lawand dryer overcame most of these problems. Working from a wood, woven bamboo and plastic film modification of the Lawand type dryer proposed by Dr. Quddusur Rahman of the Bangladesh Council for Scientific and Industrial Research (BCSIR) a very low cost design was developed. This dryer has three important advantages over the McDowell design.

(1) The polyethylene cover is placed approximately normal to the solar radiation. Maximum radiation is intercepted by the cover and penetration to the inside of the dryer is maximized. As all other walls are insulated heat retention is also improved.

(2) The air inlets and outlets are 70 cm apart in a vertical direction thus increasing convective air flow in the dryer.

(3) The dryer is light and portable and can be stored inside a building at night or during rain showers. It is also easily dismantled for longer periods of storage.

This dryer is constructed of panels made up of a two inch thick "sandwich" of woven bamboo sheets and rice straw. The dryer measures 2.4 × 1.2 × 0.9 meters. The floor area is 2.9 m^2 with a capacity of 2.5–20 kg, depending upon the food being dried. The internal surfaces of the dryer are painted with a mixture of resinous tree gum and powdered charcoal or, when gum is not available, boiled wheat flour and powdered charcoal. This coating is very effective in generating heat in the dryer. Removable food trays made of woven split bamboo are placed one inch above the floor of the dryer. Holes placed in the low front wall admit cool dry air into the dryer. Holes along the upper back wall release the hot humid air from the dryers. The open top of the dryer is covered with 75 micron low density polyethylene film. The design of this dryer is shown in Figure 4.

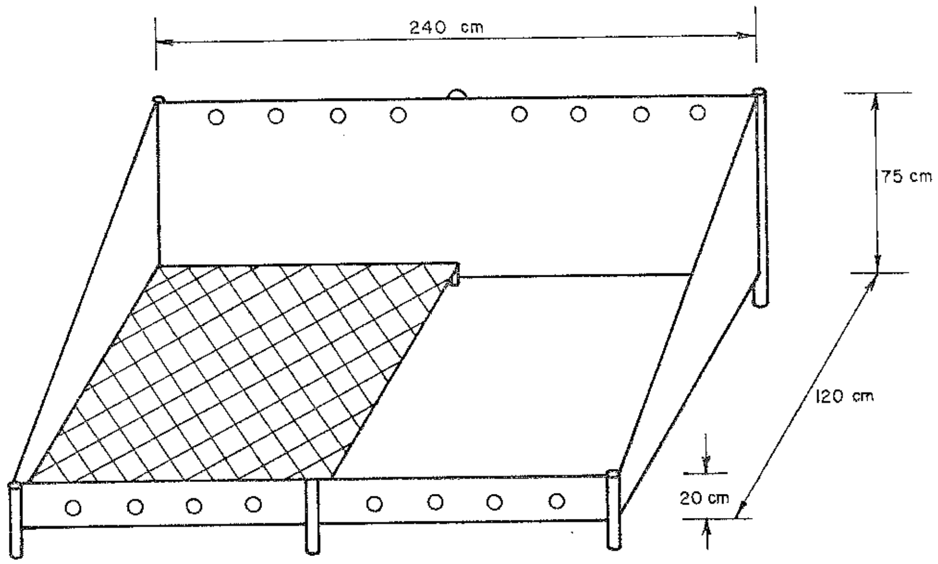

Fig. 4. Brace Institute dryer (shown with polyethlene cover and one tray removed)

The dryer has been used to dry a wide range of locally available fruits and vegetables. Internal temperatures of 56 - 75°C are normal in the middle of the day. Table 1 shows typical dryer performance during the drying of sliced sweet potato.

Tavle 1. Typical Solar Dryer Performance 26 September, 1979

Time of Day	Ambient Temp. (°C)	Insolation (1) ($kW\ m^{-2}$)	Dryer Temp. (°C)
9:30	32	0.41	42
10:00	32	0.55	47
10:30	33	0.66	51
11:00	34	0.74	57
11:30	35	0.76	59
12:00	35	0.77	61
12:30	35	0.85	66
13:00	36	0.71	65
13:30	36	0.62	67
14:00	35	0.56	68
14:30	35	0.55	69
15:00	35	0.49	59
15:30	34	0.21	55
16:00	34	0.07	47

(1) Measured by Model 776 Solar Meter, Dodge Products, Houston, U.S.A.

By calculating the total insolation received by the dryer from the half hourly observations and comparing this to the water evaporated during this time it is possible to compute an approximate overall dryer efficiency.

(1) $$TI = 1.79 \sum_{i=1}^{n} (ARI_i + ARI_{i-1})\ (t_i - t_{i-1})$$

TI = total insolation (MJm^{-2})

ARI_i = average radiation intensity at time i (kWm^{-2})

t_i = time of observation of ARI_i (hr)

(2) $$EP = 0.407\ TI$$

EP = evaporative potential (kg H_2Om^{-2})

(3) $$EFF = 100\ (W_i - W_f)\ /\ (A)\ (EP)$$

EFF = dryer efficiency (%)

W_i = initial load in dryer (kg)

W_f = final weight after drying (kg)

A = dryer area (m^2)

In the example in Table 1 the total insolation is 14.2 MJ/m^2 and the efficiency 18 %.

In drying different food materials it was observed that the dryer efficiency varied widely. Some variation is expected as the surface area to mass ratio of the material being dried is differrent for different food materials. However in drying red amaranth, a dark green leafy vegetable, and grated coconut, both having very high surface area to mass ratios, the efficiencies were 78% and 5% respectively. Similar observations were made in a sorghum drying trial where red and white varieties were dried. These results suggest that radiative heat transfer to the food pieces plays a major role in the drying of darker coloured foods. The drying capacity for dark green leafy vegetables is 15 times greater than that for white grated coconut.

An indirectly heated solar dryer similar to an early design proposed by Exell was constructed to see if the bleaching of green vagetables due to direct radiation could be avoided. Although the temperature in the drying chamber rose to 50°C the drying was very slow. The air flow through this early model was very poor and this combined with the loss of the direct radiative heat transfer, rendered this design impractical. Recent modifications to the original AIT design are said to have largely overcome the problem of sluggish air flow in the dryer. Still the expense and relative complexity of this dryer make it less attractive than the simpler cabinet dryer for drying fruits and vegetables.

2.4 *Dried Food Packaging and Storage.*

One of the major technical reasons why foods are not dried more widely in Bangladesh is the difficulty of packaging and storage. As well as the ever present problems of insects and rodents, the high temperature and humidity will combine to cause heavy storage losses of dried fruits and vegetables. The relative humidity is often in excess of 90% causing moisture pickup to the point where mold growth occurs quickly.

Traditionally dry cereals are stored in unglazed clay pots which have been soaked with mustard oil. This apparently provides an adequate vapour barrier for cereals but is not sufficient for more hygoscopic foods such as dried fruits and vegetables. In some cases tins with press fit lids are available but they are relatively expensive.

Fifty micron low density polyethylene bags in combination with unglazed clay jugs and tins were evaluated as a solution to this problem. Earlier experiments with oil soaked jugs had shown them to be inadequate for protecting cereal grain seeds. As a modification of this process the jugs were heated in the sun and hot molten paraffin was poured inside and allowed to soak into the porous clay. The excess wax was poured off. Dried foods in 100 gm heat sealed 50 micron polyethylene bags were placed inside these jugs. Each jug held 20-30 packets of dried food. The narrow mouth of the jug was sealed with a double layer of heavy polyethylene film and secured with a rope. The results of a seven-month evaluation of these storage methods during the monsoon season are given in Table 2. Storage stability was evaluated on the basis of moisture content after storage and visual appearance.

Polyethylene packets stored in uncoated unglazed clay jugs did not provide adequate protection. The wax lined jugs were more effective. Both the broccoli and carrot slices were well preserved in these jugs. The tomato puree, while picking up some moisture in its tin, showed no sings of mold growth or development of off-flavours.

Polyethylene bags are the only non-traditional material needed to package and store dried fruits and vegetables by this method. However these are available now in most large bazaars in Bangladesh and the majority of rural dwellers are familiar with them. Low density

Table 2. Seven Month Dried Food Storage Test

Material	Packaging Method	Moisture Content Before/After (%)		Appearance After Storage
Broccoli Pieces	50 micron PE film Unlined clay jug	7	15	Brown colour mold visible
Broccoli Pieces	50 micron PE film Wax lined clay jug	7	9	Dark green colour no mold visible
Sliced Carrots	50 micron PE film Unlined clay jug	6	14	Dark orange mold visible
Sliced Carrots	50 micron PE film Wax lined clay jug	6	9	Medium orange no mold visible
Tomato Puree	50 micron PE film Tin with lid	6	13	Dark brown no mold visible

Notes: (1) Broccoli and carrots were blanched and sulphured.
(2) Tomato puree was not sulphited.

polyethylene, while not the optimal dried food packaging because of its high permeability to oxygen, is the only low cost film available in Bangladesh. It does have two important advantages - it is a moderately good moisture barrier and it can be easily sealed in a candle flame.

3. COMMERCIAL ASPECTS

3.1 *Rural Food Processing - "Surjosnato" Food Products.*

Establishing solar food drying as a rural industry requires more than an adequate technology. As discussed earlier special arrangements are often required to make the adoption of a new technology attractive to the rural poor. During the technical development phase of this project it became clear that solar drying technology would not spread automatically in the rural area. People living close to the dryer testing site showed little interest in preserving foodstuffs for their own use. They spoke most often of ways to make a business from the use of the dryers. Other interested people in other parts of Bangladesh also emphasized the trading possibilities of solar dried foods.

A survey of the dried foods and related products market in the two major urban areas of Bangladesh was conducted to determine the market potential for solar dried foods. These urban markets were surveyed because, as well as dealing with the common products available in the rural areas, they were more likely to be interested in new products. This study revealed three major marketing channels for dried foods.

(1) Food Shops in Middle Class Areas - interested in dried coconut, fruits and ground pure spices.

(2) Small Food Shops in Bazaars - interested in traditional dried products such as dried bean seeds and lentil powder. Also interested in flavouring agents made from popular vegetables which are not available in the off-season.

(3) Hawkers - interested in dried foods suitable as snack items (eg. dried fruits, dried coconut chips).

The merchants surveyed expressed interest in marketing solar dried food products. However they stressed the importance of purity (food adulteration is common), attractive packaging and regular supply. This survey and other enquiries showed that any nontraditional dried foods should be sold first in these urban markets. Once the urban market is secure the demand will spread to the rural areas.

Rural dried foods producers working alone cannot reach the urban markets discussed above. Without some intermediate marketing agency they are restricted to producing only the few dried food products which are traditional and can be marketed locally. To overcome this problem MCC established a dried foods marketing group.

This marketing group adopted the name Surjosnato Food Products. "Surjosnato" means "bathed in sunlight" in Bengali. This organization is charged with (a) studying and developing the market for solar dried foods (b) encouraging establishment of small groups of rural women to produce these products and (c) marketing these products in the two major urban areas. Quality control of the dried food products, an important step discussed earlier, is part of the marketing function. This marketing organization is intended to be only a catalyst in the establishment of a rural solar food drying industry. The dried foods market in Bangladesh is much too large for such a limited effort. However by testing and demonstrating the viability of this small scale rural industry it is hoped that other institutions in the private and public sectors of the economy will become involved.

The first producer group has begun to produce solar dried grated coconut. Each producer is equipped with two solar dryers. With these she can dry the grated coconut from twenty coconuts in one day. This grated coconut (2.0-2.4 kg when dried to 2% moisture) is transported by the producer to a central collection point where it is graded, checked for moisture content and packaged in 85 gm (3 ounce) packets. The packets are then shipped to Dacca and distributed to retailers. The coconut husk is used to make coir rope and the shell is used to produce charcoal. It is too early to comment on the economic viability of this product but the initial demand looks promising.

Preliminary work on the solar drying of pineapple slices, ginger, lentil powder and bean seeds is being carried out at two other potential production sites. Samples of these products are being test marketed through Surjosnato Foods. If there is sufficient demand and the products are economically viable they will be produced by new producer groups located close to the supply of the raw materials.

3.2 *The Future of Solar Food Drying.*

Several issues affecting the future prospects of solar food drying as a rural industry remain unresolved at this point. From a technical point of view there are questions about product quality and product cost.

Even assuming that all the producers can be taught to produce a clean and uniformly good quality product two problem areas remain.

(1) *Product Appearance* - the colours of some food materials are unfavourably affected by direct exposure to sunlight. This is particularly true of the green vegetables and fruits. Their chlorophylls are changed to brown pheophytin in sunlight. Solving this problem will require increasing the sophistication of the dryers and/or drying process which will increase costs and may reduce practicality in the rural environment. Competing mechanically dried products in this case will have better colour.

(2) *Product Cost* - the retail cost of the dried coconut is made up of the following elements - materials: 50%, labour: 10%, overheads: 40%. Large scale centralized production using mechanical dryers may be able to reduce these overheads and perhaps the labour cost as well. Even considering the additional energy cost it may be possible to produce a cheaper product by this means. Given the very low cost of natural gas in Bangladesh, future competition from mechanical dryers is likely.

These problems seem inherent in promoting decentralized small scale food drying using very simple equipment. Yet these features are essential if, through food drying, employment is to be created in the rural areas. Under free market conditions it is possible that this otherwise practical rural industry may be undermined by the lower cost of a factory produced item. At this point the future of a rural solar food drying industry becomes a question of social policy. Many developing countries are realizing that in order to solve rural unemploymet problems without massive urban drift it is necessary to take special measures. The reservation of certain sectors of the economy for small scale rural industry is already practiced in India. This may be a vital determinant in the future of solar food drying in the rural areas of the developing world.

4. CONCLUSIONS

The following conclusions can be drawn from the present work.

(1) It is possible to simplify the process of food drying to the point where it can be applied in the rural areas of poor developing countries. Suitable techniques for the preparation, drying, packaging and storage of solar dried food products have been developed.

(2) The solar food drying techniques developed are well adapted to be the basis for a rural industry which is:

(a) Agriculturally based

(b) Labour intensive

(c) Decentralized

(d) Low capital

It has the particular advantage in conservative rural Muslim societies of permitting women in purdah to become involved.

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