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TOPIC: **SOLAR DRYING**

FULL TITLE: **Solar Dryer Systems and the Internet: important resources to improve food preparation**

Author: **David E. Whitfield V.** **Director – Center for Development with Solar Energy**
P.O. Box 738 Cochabamba, Bolivia - Tel. +591 - 4 - 4488187
Emails - dewv@yahoo.com **-** **cedesol@gmail.com**

ABSTRACT

In many countries of the world, the use of solar thermal systems in the agricultural area to conserve vegetables, fruits, coffee and other crops has shown to be practical, economical and the responsible approach environmentally. Solar heating systems to dry food and other crops can improve the quality of the product, while reducing wasted produce and traditional fuels - thus improving the quality of life, however the availability of good information is lacking in many of the countries where solar food processing systems are most needed.

This work presents the performance of several individual, medium and large-scale food processing systems, which incorporate solar drying. Demonstrated achievements through individual medium and large scale commercial applications will be studied, emphasizing technology transfer in rural areas. Works studied are catalogued with summaries, and use of the Internet is featured as a medium to facilitate the availability of this information.

INTRODUCTION

"Drying is an excellent way to preserve food and solar food dryers are an appropriate food preservation technology for a sustainable world." [i] Actually, solar food drying is one of the oldest agricultural techniques related to food preservation, but every year, millions of dollars worth of gross national product are lost through spoilage. Reasons include, ignorance about preservation of produce, inadequate transportation systems during the harvest season (mostly climate related), and the low price the rural farmer receives for products during the harvest season.

Drying of crops can change this trend and is useful in most areas of the world, especially those without a high humidity during the harvesting season. If drying of produce were widely implemented, significant savings to farmers would be achieved. These savings could help strengthen the economic situation of numerous developing governments as well as change the nutritional condition in these same countries. Unfortunately many of the areas that could benefit from solar drying technology lack adequate information related to how to employ this technology and which technology to use under specific conditions. Many of the latest developments in solar drying technology, as well as significant achievements through applying this body of knowledge are not available in libraries or the Universities of developing countries. However, modern science has provided a new resource that helps bridge this information void. The World Wide Web, commonly know as the INTERNET can provide the solution to rapidly spreading new information and applications of known information into areas of greatest need.

1. SOLAR DRYING

1.1 OVERVIEW

Drying preserves foods by removing enough moisture from food to prevent decay and spoilage. Water content of properly dried food varies from 5 to 25 percent depending on the food. Successful drying depends on:

- enough heat to draw out moisture, without cooking the food;
- dry air to absorb the released moisture; and
- adequate air circulation to carry off the moisture.

When drying foods, the key is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavor, texture and color of the food. If the temperature is too low in the beginning, microorganisms may grow before the food is adequately dried. If the temperature is too high and the humidity too low, the food may harden on the surface. This makes it more difficult for moisture to escape and the food does not dry properly. Although drying is a relatively simple method of food preservation, the procedure is not exact. [ii]

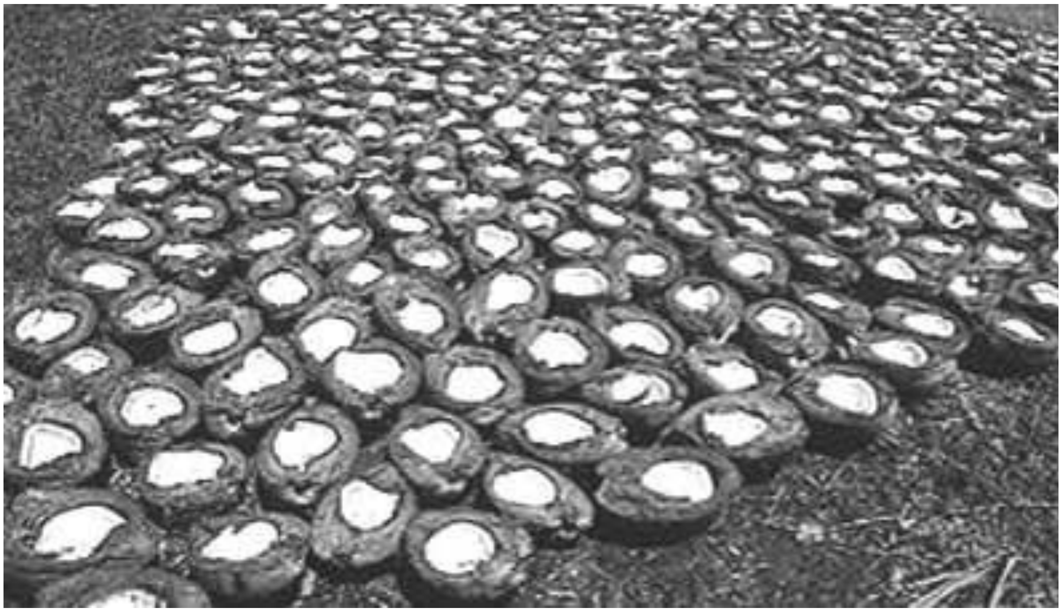
Renowned solar cooker designer and Sustainable Living expert **Barbara Kerr** tells us that, "food drying is a very simple, ancient skill. It requires a safe place to spread the food where dry air in large quantities can pass over and beside thin pieces. Sun is often used to provide the hot dry air. Dry, clean air including dry cold air from any source will dehydrate food. Draping food over branches or spreading it on wide shallow baskets on the roof is an old widespread tradition still in use around the world. Many other arrangements have been used to support a thin spread of food pieces. Some options that have been used are to thread the pieces on a cord or a stick and hang it over a fire, wood stove or from the rafters. Or one can bundle herbs or strawflowers and suspend them from bushes or a door knob or nails in rooms with good ventilation." [iii] Of the many dryer types available, Barbara recommends the downdraft system. What's more, her booklet **A REVIEW OF SOLAR DRYING**, advises that nutritionally, dried food is ranked by the United States Food and Drug Agency as better than canning, and just under freezing. She states that the tastes are related to the food, but there is some uniqueness in their flavor and texture. [iv]

Markus Häuser and Omar Ankila, co-authors of **the MOROCCO MANUAL OF SOLAR DRYING**, inform us that traditional sun drying methods often yield poor quality, since the produce is not protected against dust, rain and wind, or even against insects, birds, rodents and domestic animals while drying. Soiling, contamination with microorganisms, formation of mycotoxins, and infection with disease-causing germs are the result. They assert that the drying equipment used in industrialized countries overcomes all of these problems, but unfortunately is not very well suited for use in developing countries because it requires substantial investments and a well-developed infrastructure. [v] They further maintain that solar drying facilities combine the advantages of traditional and industrial methods, namely low investment costs and high product quality. [vi]

1.2 Applications

For centuries people of various nations have been preserving dates, figs, apricots, grapes, bananas, pineapples, other fruits, herbs, cassava, yams, potatoes, corn, peas, onions, garlic, carrots, peppers, milk, coffee, meat, and fish by drying.

But drying is also beneficial for hay, copra (kernel of the coconut),



tea and other income producing non-food crops. It is worth noting that until around the end of the 18th century when canning was developed, drying was virtually the only method of food preservation.

1.3 Benefits of Solar Dried Food

"Dried foods are tasty, nutritious, lightweight, easy-to-prepare, and easy-to-store and use. The energy input is less than what is needed to freeze or can, and the storage space is minimal compared with that needed for canning jars and freezer containers.

"The nutritional value of food is only minimally affected by drying. Vitamin A is retained during drying; however, because vitamin A is light sensitive, food containing it should be stored in dark places. Yellow and dark green vegetables, such as peppers, carrots, winter squash, and sweet potatoes, have high vitamin A content. Vitamin C is destroyed by exposure to heat, although pretreating foods with lemon, orange, or pineapple juice increases vitamin C content.

"Dried foods are high in fiber and carbohydrates and low in fat, making them healthy food choices. Dried foods that are not completely dried are susceptible to mold.

"Microorganisms are effectively killed when the internal temperature of food reaches 145 degrees Fahrenheit (F)." [vii]

Dennis Scanlin, an expert in alternative energies and instructor at Appalachian State University, Boone, NC informs us, " Food scientists have found that by reducing the moisture content of food to between 10 and 20%, bacteria, yeast, mold and enzymes are all prevented from spoiling it. The flavor and most of the nutritional value is preserved and concentrated. Vegetables, fruits, meat, fish and herbs can all be dried and can be preserved for several years in many cases. They only have 1/3 to 1/6 the bulk of raw, canned or frozen foods and only weigh about 1/6 that of the fresh food product. They don't require any special storage equipment and are easy to transport." [viii]

1.4 Solar Drying Recommendations

The El Paso Solar Energy Association [ix] provides some practical information and links to other resources. They state that their information is prompted by the need for solar dryers in areas where fruit is plentiful in summer months, but because there is no simple and economic method to preserve it, much of it is left to rot, while in the winter there is hunger.

They agree that solar food drying can be used in most areas but clarify that how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity. They provide some basic guidelines to drying food.

Most of the resources researched recommend pre-treatment of the food, such as blanching, (boiling/steaming).
Wash fresh fruits and ripe vegetables thoroughly.
Effective drying is accomplished with a combination of heat and air movement.
Remove 80 to 90% of moisture from the food.
Typical drying times range from 1 to 3 days, again depending on sun, air movement, humidity, quantity, and type of food.
Once the drying process has started it should not be interrupted, do not allow to freeze.
Direct sunlight is not recommended.
Temperature ranges of 100 to 160 degrees F. (37.2 C to 71.2 C) will effectively kill bacteria and inactivate enzymes, although temperatures around 110 degrees F. (43.2 C) are recommended for solar dryers.
Too much heat especially early in the process will prevent complete drying.
Food should be cut into thin slices, less than 1/2" thick (1.25cm) and spread out on trays to allow free air movement.
Rotate trays 180 degrees daily for uniform drying. Move dryer food to bottom racks.
Safe tray materials include Stainless steel rack - wood slats - cheesecloth - Teflon - Teflon coated fiberglass - nylon - food grade plastics
Allow food to cool completely before storing.
Store food in airtight jars or plastic containers, and do not expose dried food to air, light or moisture.
Most fruits taste great dried including apples, apricots bananas, grapes etc.
Vegetables are best reconstituted by covering with cold water until they are near original size. They can be added in their dry form to soups/stews. Vegetables can also be ground into powders and used for instant soups or flavoring.

1.5 Solar Drying Can Improve Agricultural Products

Dehydration of vegetables and other food crops by traditional methods of open-air sun drying is not satisfactory, because the products deteriorate rapidly. Furthermore, traditional methods do not protect the products from contamination by dirt, debris, insects, or germs. A study by **Akwasi Ayensu** from the Dept. of Physics at the University of Cape Coast, Cape Coast, Ghana demonstrates that food items dried in a solar dryer were superior to those which were sun dried when evaluated in terms of taste, color, and mould counts. He asserts, and many others agree that solar drying systems must be developed to utilize this energy resource to improve food preservation.[x]

This translates into quality products that can be stored for extended periods, easily transported at less cost while still providing excellent nutritive value.

2 The Dryer Systems Investigated

For the purpose of classifying the cases studied, categories have been established according to the intended use of each type of system. Conclusions reached are summarized, and links (directions for email or Internet) are given to facilitate additional research by individuals.

2.1 Individual Family Units

Individual family units can be described as those systems designed to dehydrate small quantities of fruits, vegetables or herbs for the purpose of extending the availability of these products at the family level.

2.1.1 Details about family units

Michael Götz [xi] from the Centre Neuchâtelois de cuisine solaire / ULOG Suisse Romande whose web address is www.ulog.ch communicates that ULOG's activity with drying is going on a low level relative to their other activities. They sell plans and kits and finished **'Euro-family-dryers'** which is the small wooden model designed by Uli Oehler maybe 15 years ago (see picture).

Ulog is also know for the famous **A-frame collapsible dryer**. The author's organization, *Sobre la Roca* teaches the use and fabrication of this portable dryer in Bolivia, South America[xii].

According to **Neville Jackson** [xiii], from Tingha, NSW, Australia; for around $50 you can make **a drying cabinet** and enjoy the fruits (and veggies) of your labor all year. He explains that dried foods lose most of their contained moisture, retain most, if not all, of their vitamins and minerals, and take up little space. At his web site http://www.organicdownunder.com/solar_dryer.htm , Neville also provides various procedures for drying.

Allart Ligtenberg suggests that **solar dryers** and water-heaters as an alternative technology are more easily accepted and can serve as stepping stones towards similarly built solar cookers. "They do not have the cultural barriers to overcome, that solar cookers experience," he adds. Follow this link to learn about his experiences teaching family sized solar dryer systems in Nepal, Mongolia and Peru. - http://bali-i.com/fast-solar/milan.htm [xiv]

Dr. Youssef Arfaoui, with the Forum for Energy and Development, INFORSE, Denmark writes, "Solar Dryers make the difference between waste and value of surplus mango fruits in Uganda. They create new possible exports to Europe."[xv] He informs us that the number of the units in operation are still not satisfactory, as the technology is new and people (especially small farmers) must get used to it, even if the system is very simple. He says that, "Often, they do not believe that this one can be effective, because it looks so simple".

Further clarifying that in total 11 units are in operation in Uganda, with about 4 -units operating in Paidha - Nebbi district for 3 years, about 4 - units operating in Masindi - Masindi district for 1.5 years, and about 3 - units operating in Hoima - Hoima district, during 2 years.

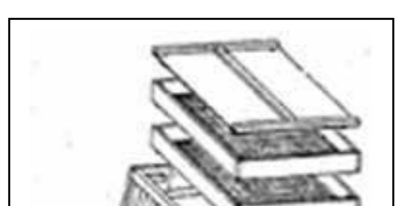
The costs depend of the size of the unit. It is very cheap as the materials are locally available. For the one in the picture, the price is about 20 US$. Increasing the size, increases the prices also (max 50 US$) otherwise, the units will be expensive for the farmers. The prices can be reduced according to the number of units produced.[xvi]

In a direct email communication with the author, Dr. Arfaoui states, "My personal opinion, you should emphasize on the user training and the attitude changing, when starting to use the dryer." He adds "for further clarification, please do not hesitate to contact me at ya@inforse.org ." [xvii]

In two articles published in **Home Power magazine**, **Dennis Scanlin** provides a broad range of information as well as detailed construction techniques for an indirect chimney type dryer system. Some of the topics covered include; factors affecting food drying, recommended drying temperatures, relationships between air flow and dryer temperature, possible temperature related problems, how to get the correct temperature and air flow, collector design, dryer construction and related details. [xviii]

The second article expands on data gathered over 2 years as well as document experiments with design changes, including external reflector use and vent variations.[xix] Both articles are tremendously instructive. It should be noted that the systems detailed in Scanlin's papers are adequate for small-scale commercialization as well as individual family use. Scanlin has also demonstrated considerable proficiency designing and building small solar timber drying systems.

2.1.2 Examples of applications

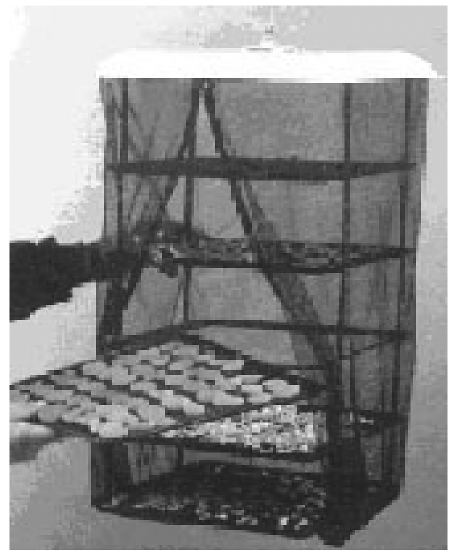


ULOG's A-frame portable dryer system

Ligtenberg System (in Nepal)

Sun Oven and others market a simple device for drying called **The Food Pantry** [xx]

Neville Jackson's cabinet system



Sun Oven's Food Pantry

2.1.3 Benefits

All of these systems provide the benefits required of solar dryers, plus their size permits small-scale food conservation. They have the added advantage of being portable.

2.2 Medium Scale Commercial Applications

Good Export Income with a Good Solar Dryer. Medium scale systems meet the need of individual's and of groups, cooperatives, or associations to supply a greater quantity of product under constant conditions, thus empowering them to reach more markets.

2.2.1 Details about Medium Scale Commercial Applications

The Uganda dryer, believed to be derived from **the Peace Corp** model developed around 1986, [xxi] is our bridge between family scale and village scale. Excerpts from an article of the Sustainable Energy Newsletter provided by Judit Szoleczky demonstrate that the Uganda dryer meets the criteria for both individual and medium scale commercial use.

> Fruits and vegetables are abundant in Uganda. With the right processing, they can provide farmers with a good income. They can be dried using a solar dryer, then

transported and sold in the big cities, exported, or saved to be used during the dry season's food shortages.

The dried fruits processed in the dryers have been tested and exported to the UK. It is now known that they have a big market in the UK and all over Europe. After the introduction of the dried mangoes to the UK, the farmer groups could not meet the increased demand of a UK-based importer and still guarantee the same high quality. Presently, a small-scale export trade has been established. The dried fruit is now produced and exported from Kampala by several farmer groups like the Gukwatamanzi Farmers Association, which has 60 members, the Christian Rural Services of Nebbi West Nile, which has 40 members; and the Uganda National Farmers, Association.

The second-quality selection of the dried fruit, which can not be exported, can be stored for later private consumption. School children are also able to have dried fruit as part of their lunches during the school hours. A large number of fruits and vegetables can be dried, including peas, corn, cabbage, broccoli, peppers, herbs, melon, plums, beets, onions, squash, tomatoes, asparagus, celery, bananas, and, of course, mangoes. [xxii]

For more information on this dryer contact *MS Uganda, 54 B, Kira Road, PO Box 6331, Kampala, Uganda. Ph:+256 41530764, fax +256 41530765 e-mail: co.msuga@ms.or.ug.* or *htdc@swiftuganda.com.*

In the paper, **USE OF A SCALED DOWN SOLAR TIMBER DRYER AS A PILOT FOR COPRA DRYING**, Professor **Oliver Headley**, renown author and investigator specializing in the field of solar energy, describes how a 6 m2 artisanal **solar timber dryer** was developed as a scaled down version of a 30 m2 solar timber dryer so that artisans and small scale operators could dry their timber and improve the quality of the furniture they manufactured. He explains that, "other configurations of crop dryers have been tested in the Caribbean, but this model is designed to be sufficiently versatile to dry several different materials hence it may be used throughout the year and there is no need for a capital item to be idle while the owner is paying interest on the loan used to acquire it." This work informs us that the use of a solar dryer to dry copra was done in an effort to save on the cost of diesel fuel which is used by the large scale copra dryers on the coconut estates in South Trinidad. Copra is the dried kernel of the coconut (Cocos nucifera) and coconut oil is normally extracted from it and used in the manufacture of soap, margarine and glycerol. The paper concludes that, "A dryer of this type should have wide applicability throughout the Third World." [xxiii]

The article, **SOLAR DRIED FRUIT BOON TO KENYA'S RURAL FARMERS,** by **Sam Gonza** acquaints us with the advantages of solar drying of mangoes as practiced by women's groups in Kitui District of Eastern Kenya. **Beatrice Kingori** of GTZ-ITFSP comments that there is a big scope for the business of providing **solar dried fruit in local markets** in Africa. "What is lacking is awareness. Our people need sensitization of the nutritional benefits of solar dried food items," she explains. The dryer has a glass top surface of about 1.5 square meters and is rotated to follow the sun in the course of the day. There are three tiers of racks inside the dryer and they are inter-changed within the solar kiln device to ensure uniform drying. According to Ms Kingori, each solar dryer unit can handle 10 to 15 kilograms of fresh fruit per day, which reduces to 0.75 to 1.5 kilograms of dried fruit per day. This yields a ratio of about 15 to 1. "Ideally, the drying process should take place in a single day. If you leave it overnight there is likelihood of deterioration of quality," she specifies. [xxiv] http://ines.gn.apc.org/africa/afrpre30.htm#APS2796F will provide you with further details as well as information on a nutritious beverage.

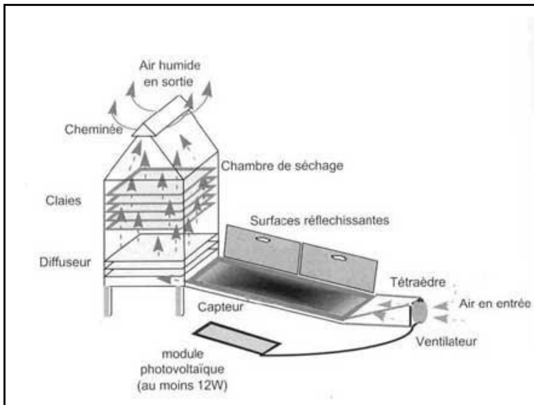
PARAMETER SENSITIVITY ANALYSIS OF A DIRECTLY IRRADIATED SOLAR DRYER WITH INTEGRATED COLLECTOR by **Ajit K. Mahapatra** and **L. Imre**, describe their efforts to examine the effect of different time dependent and time independent input parameters on the various output parameters of a tunnel-type directly irradiated solar agricultural dryer with integrated collector. A prototype consisting of a small radial flow fan and a solar tunnel dryer with an integrated collector part was tested in Hungary, drying chamomile. The drying of 43 kg of chamomile from an initial moisture content of 75 per cent (w.b) to a final moisture content of 7 per cent (w.b) took 57 hours. [xxv]

J. Salom, O. Ortega, and J.J. Felipe provide an important **mathematical model for designing chimney type indirect solar dryers.** This interesting work supports the hypothesis that the introduction of solar dryers in developing countries can improve the traditional methods of food preservation. They state that simulation models of drying systems are needed in the development of solar dryers. And that the knowledge of drying parameters is important to obtain valuable information about the state of the product, the air (temperature and humidity) and the efficiency of the dryer. [xxvi]

Heike Hoedt from the organization **Solarebruecke** has provided details on several dryer types including a solar-dryer called "**Icaro**". In a email communication she states, "among the dryers I very much favor is the Icaro-type. The space is well used, the goods prepared for drying are not exposed to sunlight and I'm quite sure that using a higher chimney one can do without the fan." She adds that, "at our home we have also used our 8sqm Scheffler-dish for drying." But she believes it makes sense only to put it to that use if you have a big dish anyway, as some way of using it more effectively by giving it additional tasks. [xxvii]

2.2.2 Examples of applications

Icaro with PV fan forced convection



2.2.3 Benefits

Medium scale commercial systems have the advantage of allowing the producer to increase the commercial yield of crops by utilizing what is normally lost in spoilage. The products are also eligible for exportation to areas where they may receive a higher price for their goods. Capital outlay for these systems is not as tremendous as in large-scale commercial systems, and studies demonstrate that in many cases the investment can be recuperated in less than 1.5 years.

2.3 Large Scale Commercial Applications

Large-scale commercial applications require greater capitalization, and are designed to dry very large quantities of product with better control of temperature and hygienic conditions. These systems are appropriate for associations or village cooperatives as well as large commercial farming operations.

2.3.1 Details about Large Scale Commercial Applications

Michael Götz with the ULOG organization advises that for larger, commercial dryers, **Jean-Claude Pulver** (in Paraguay: ubc@rieder.net.py) and **Alec Gagneux** (Alecgagneux@hotmail.com) have considerable practical experience.

Jean-Claude taught a course on the Ulog A-frame dryer in Kalamarca Bolivia in October of 1999, in which the author participated. At that time he demonstrated photographs of several commercial dryers including tunnel dryers constructed by him in Paraguay. Through a recent email communication, Jean-Claude informs of building a **shed type dryer with rock heat storage** in the Dominican Republic to dry 200 MT of organic grown cocoa. This hybrid system has the ability of adding another heat source to insure good drying year round.[xxviii]

Dishna Schwarz representing GTZ, communicated that "we promote a solar dryer called "**Höhenheimer tunnel dryer**" developed by a German company. This dryer is rather big and suitable for groups of farmers or farmer collectives. If you are interested in that dryer you can read the details at: http://home.t-online.de/home/innotech.ing

Ms Schwarz also informs us of a solar dryer-mailing list which is set up for sharing experiences in solar drying technologies adding that, "It would be very nice if you all could give some inputs to the list." Her email direction is Dishna.Schwarz@gtz.de [xxix]

Although Oliver Headley and William Hinds title their excellent work - **MEDIUM SCALE SOLAR CROP DRYERS FOR AGRICULTURAL PRODUCTS**, it is included here among the large-scale systems because it describes the design and operation of two **solar agricultural dryers**. One has a capacity of ten tonnes of hay, while the other a capacity of seven tonnes of onions. These systems are compared with two other "medium scale" solar dryers which are used for fruit and timber. The work states that, "Solar dryers of this size need to have mechanically driven fans for air circulation which are powered by mains electricity. In all four cases; they are economically viable so long as they do not have to compete with cheap natural gas." They maintain that, "In isolated communities, solar energy is quite often the only heat source which can be used to dry low cost agricultural products economically."[xxx]

The authors of this paper conclude that, "Solar crop dryers are a cost effective solution to some of the problems of food preservation in sunny climates. In places where fossil fuel is cheap and readily available, such as natural gas in Trinidad & Tobago, the decision to use solar dryers may be based on purely environmental considerations, since the economics of the dryer do not allow it to compete with cheap natural gas. The solar dryer with the least initial capital cost is one which uses an existing farm building or adds a solar air heater to an existing conventional crop dryer." Their results suggest that relating to large scale commercial systems, "while multi-crop dryers may seem to be an ideal solution, the fact is that most operators prefer to have a dryer which is dedicated to one or two crops or to a specific kind of crop, fruit for example, since the compromises inherent in a multi-purpose dryer often result in reduced efficiency for its primary product." [xxxi]

An in-depth study from 1997 titled **FIELD PERFORMANCE OF A SOLAR TUNNEL DRIER,** states that **the solar tunnel drier of the Hohenheim University** has achieved a fair degree of success in many countries and details the performance and economics of this type of solar drier in Thailand. From this investigation it was determined that solar tunnel dryers were developed to eliminate some of the problems related to conventional solar dryers. The authors ascertained that compared to other solar dryers, the capacity of the tunnel dryer is much higher. Adding that significant reduction in drying time, high quality of the dried material and complete protection from rain, dust and insects are the main advantages of the solar tunnel dryer.[xxxii]

What's more, around 150 dryers in 28 different tropical and subtropical countries are now in operation. Prototypes have been produced locally at prices between 1,000 and 1,500 US$ in Sri Lanka, Turkey and Morocco including the PV-drive forced ventilation. In Turkey, mass production of the solar tunnel dryer has already been initiated. In 1995, around 100 tons of dried figs and apricots were produced using 10 solar tunnel dryers. It is estimated that up to the end of 1996 at least 50 solar tunnel dryers will be installed there. In Sri Lanka, local production started in April 1996. [xxxiii]

According to the authors, the experience obtained on solar tunnel dryer operation in Thailand and the performance based on the field shows that;

> The tunnel dryer performs better than normal sun drying and the quality of the product is also better in terms of cleanliness, texture and color.
> Better control of the drying process is possible when compared to other dryers.
> Dried bananas from solar tunnel dryer command a much higher price than the conventionally dried bananas and therefore could be a useful device for the value addition of agricultural products in developing countries.[xxxiv]

Andreas Zoellner, and **Juergen Blumenberg** give us a stimulating example of a variation of the solar tunnel dryer in their excellent document titled **Solar Drying of Apples in Nepal.** [xxxv] Besides describing how they installed an adapted solar drying system at the community of Marpha, Mustang, Nepal, to dry the annual overproduction of 10 tonnes of apples and other agricultural goods of the village; they deal with alternative ways of project management to avoid the well known failures of the conventional and expensive technical aid programs conducted by big organizations.

This report's conclusions are so non-conventional that they are reproduce here in its entirety:

> The experiences made during the realization of this small scale project of technical aid to developing countries showed that it may be more effective to manage such programs with a small financial input including a certain contribution by the partners than to work with enormous budgets like practiced by most of the big aid organizations. Furthermore there are a few suppositions for starting such programs:
>
> · the project should be initiated by the aid receivers
> · the village should be participated financially
> · the project should involve a local experienced partner
> · the technique should be as simple and adapted as possible
> · the system should use only local materials

During the realization-phase it is very important to take the social structure of the area into consideration and to utilize it in favour of the project. Another aspect that should not be neglected is to give the villagers the possibility to participate practically and to follow and influence the project in all the different phases. And if the know-how transfer to the users can be turned out smoothly the project has the best chances to be successful even after the last foreigner left the site.[xxxvi]

Throughout Latin America, the drying of the harvested green coffee beans contributes significantly to the destruction of the remaining rainforests. Conventional **coffee dryers** consume large amounts of wood and electricity to dry the beans after the washing process. In Central America, an estimated 16,000 acres of forest are destroyed to supply the firewood used to dry the coffee production each harvest. **The Solar / Biomass Drying System** developed and marketed by **SUN UTILITY NETWORK INC**. helps to reduce deforestation by using the sun's energy to dry the harvest.[xxxvii]

According to the information they provided, this solar coffee-drying process has several product-quality and economic advantages:

- the low-temperature process, conducted right after harvest, relies on consistent heat, gently circulated across the coffee beans, optimally preserving the quality and taste of the beans;
- the solar drying process gives small growers the capacity to dry their coffee beans themselves, which adds value to the product since dry beans are stable and much more valuable than beans that must be sold wet (as coffee "parchment") to intermediaries for processing.

This sophisticated solar coffee dryer incorporates well-established renewable-energy technologies such as solar thermal collectors, photovoltaics, heat exchangers, and biomass burners. The dryer consists of a coffee bean drying chamber, a solar thermal collector array to generate heat, a solar-electric photovoltaic array and battery bank to power fans and pumps, as well as a small biomass burner/water thermal storage backup system fueled by coffee parchment for nighttime and rainy or cloudy periods. The system has been used in three consecutive harvests, in 1994-1997, in Costa Rica and Honduras, receiving an enthusiastic endorsement from the growers and their cooperatives.[xxxviii]

Enermodal Engineering[xxxix] has developed **solar crop-drying systems** to improve product quality, reduce use of conventional fuels and reduce product wastage. Enermodal offers the following services to crop drying operations:

- design of solar crop-drying systems
- monitoring of crop-drying performance
- technical and economic evaluation of solar crop-drying systems

Their projects include the following:

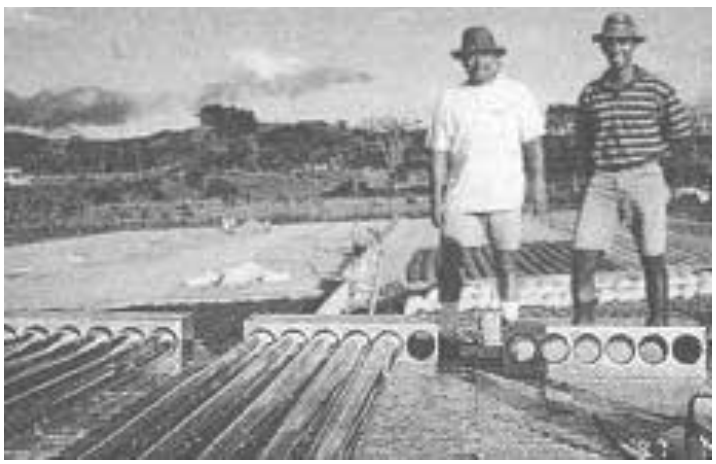
- technical and economic feasibility study of the world-wide potential for solar crop-drying systems (for the International Energy Agency)
- design assistance on solar crop-drying systems in southeast Asia for rubber, tea and fruit
- design of a passive solar drying-shed for seed cones

The drying **system for drying tealeaves** in Thailand was designed and constructed by Enermodal. More information is available through this link: http://www.enermodal.com/solar_drying.html

Innotech Engineering Co. Ltd. [xl] manifests extensive experience in solar dryer technology. They have systems in over 35 countries, principally variations of **the tunnel dryer**. With or with out bio - backup, these dryers are being successfully used to dry bananas in countries such as Thailand. More information, including details of their other activities is available at http://home.t-online.de/home/innotech.ing/

2.3.2 Examples of applications

Drying bananas with a tunnel dryer in Thailand



Roof of a solar coffee dryer in Central America

Drying tealeaves in Thailand

2.3.3 Benefits

Every study analyzed in this section implied the economical desirability of utilizing solar and solar biomass drying systems on a large commercial scale. Benefits are almost immediate compared to other cost intensive methods. The ability to control climate and hygiene add significant value to the product being treated. The apple-drying example in Nepal demonstrated that an overproduction of 10 tonnes of product was recuperated and placed in marketable condition because of this technology. The case of drying bananas in Thailand established that dried bananas from a solar tunnel dryer command a much higher price than the conventionally dried bananas and therefore could be a useful device for the value addition of agricultural products in developing countries. Coffee treated with this temperature and humidity controlled technology considerably increased its value over conventionally cured products.

3. In Real Life

Lack of information through traditional mediums in developing countries impedes the dissemination of valuable and even essential agricultural techniques. Because of this condition, successes are isolated and potential benefits delayed. Malnutrition and poverty persist in areas where during harvest time there is an abundance of food but scarcity between harvests. **Unless actions are taken, no changes will occur.**

4. What This Means

It is necessary to move forward and implement solar food processing programs from family units to large-scale commercial systems. Advances in technology have already been demonstrated. Methodology is proven. **Private enterprises, in combination with Non Governmental Organizations need to acquire and put into practice the technology that exists now.**

As we look ahead to what we can do, let us keep in mind some key points from this investigation:

- Solar food drying is a very simple skill easily assimilated into most cultures.
- The use of solar dryer systems to conserve vegetables, fruits, coffee, and other crops is practical, economical and environmentally responsible.
- Solar dryer systems improve the quality of the product, while reducing wasted produce and traditional fuels.
- Solar dried products reduce storage and transportation costs as well as associated problems from climatic effects.

Solar dryers are a cost-effective solution to food preservation in sunny climates.
Implementing the use of solar drying systems will result in significant savings to farmers and open new markets.
Solar dryer systems improve the quality of life.
Solar dryer system technology now in existence can be adapted to meet almost every agricultural need.
There is an absence of good information about solar dryer technology in the countries where solar food processing is most needed.
Utilization of available resources such as the Internet can fill the information void in developing countries.

5. What we can do.

Those interested in utilizing solar dryer technology can acquire more in-depth information by following the links that have been included with many of the sources cited.
NGOs should form partnerships with Private Enterprises to disseminate and implement this technology in the areas where it is most needed.
Individuals or organizations currently engaged in promoting or developing solar dryer technology should identify themselves and electronically share information.
A database of this technology should be established and publicized.
Governments should give priority to programs that utilize solar dryer technology, as well as develop incentives to encourage implementation and dissemination of it.

Being aware that much of the information cited can not be linked, the author commits to indexing and uploading the resources used in this investigation onto a Solar Dryer section within his web page. Furthermore, he agrees to receive related information from others, link to it or include it there also.

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[ix] **El Paso Solar Energy Association**: http://www.epsea.org/dry.html
[x] **Ayensu, Akwasi:** DEHYDRATION OF FOOD CROPS USING SOLAR DRYER WITH CONVECTIVE HEAT FLOW**;** Dept. of Physics at the University of Cape Coast, Cape Coast, Ghana
[xi] Extracted from email communications with the author and **Michael Gotz** on 11/17/00 and 11/13/00. Michael also provided the pictures and drying related to ULI Oehler's EURO-FAMILY-DRYER.
[xii] **Sobre la Roca** is Spanish for ON the ROCK. SLR is a private organization dedicated to energy conservation and alternative energies. One of their biggest contributions in this area is the elaboration and execution of Robert Chiron's BOLIVIA INTI ecological cooker project in several communities in Bolivia. Email: dewv@yahoo.com or solar1@zuper.net internet web page: http://sobrelaroca.bigstep.com
[xiii] From a web page article by **Nevill Jackson** titled: MAKE A SOLAR DRIER/FOOD DRING FACTS; located at http://www.organicdownunder.com/solar_dryer.htm
[xiv]**Ligtenberg, Allart**: SOLAR COOKING DISSEMINATION STRATEGIES/ EXPERIENCES IN NEPAL, MONGOLIA AND PERU**;** FAST (Friendly Appropriate Solar Technologies) 800 Loyola Drive, Los Altos, California, 94024, USA, Tel/Fax: (650)948-8294 e-mail: aligtenber@aol.com - Internet http://bali-i.com/fast-solar Allart and his wife visited and shared information with the author during December of 2000 and participated in an ecological fair with SLR.
[xv] **Arfaoui**, **Youssef**: MANGO DRYING FOR EXPORT INCOME; Sustainable Energy News, Newsletter of INFORSE, . International Network for Sustainable Energy Gl. Kirkevej 56 8530 Hjortshoj, Denmark Ph: +45 86 22 70 00 Fax: +45 86 22 70 96 E-mail: ove@inforse.org http://www.inforse.org (under construction) http://www.orgve.dk/inforse-europe/news.htm http://solstice.crest.org/renewables/sen/ provided by the editor, **Judit Szoleczky -** through an email communication with the author on 11/13/00
[xvi] Extracted from email communications with the author and **Youssef Arfaoui,** on 11/22/00.
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[xxi] Improved Food Drying and Storage: A Training Manual (**Peace Corps**, 1982, 276 pages) located at; http://media.payson.tulane.edu:8082/cgi-bin/gw?e=b0c10home-fnl-41-C.9.B.183-bl-100-20-00e&q=solar%20%20drying&d=C.9.B.183.1&a=t
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construction) http://www.orgve.dk/inforse-europe/news.htm http://solstice.crest.org/renewables/sen/
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Fax: 260 1 253952, EMAIL: engmahapatra@p3.f1.n761.z5.fidonet.org

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For those wishing to look further, I offer the following links:

http://www.dryit.com/index.html
http://www.eren.doe.gov/consumerinfo/refbriefs/ve7.html
http://www.countrysidemag.com/issues/4_1999.htm#drying
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http://www.panasia.org.sg/nepalnet/crt/photosolar.htm
http://www.solarcook.com/order.html
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http://www.organicdownunder.com/solar_dryer.htm
http://bali-i.com/fast-solar/milan.htm
http://media.payson.tulane.edu:8082/cgi-bin/gw?e=b0c10home-fnl-41-C.9.B.183-bl-100-20-00e&q=solar%20%20drying&d=C.9.B.244.1&a=t