SOLAR ENERGY CENTER DENMARK

DANISH TECHNOLOGICAL INSTITUTE

Survey on solar dryers for drying of food and wood in Ghana

Danish Technological Institute
Danish Institute of Agricultural Sciences

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Foreword

The survey is part of the project "Test and Research Project into the Drying of Food and Wood Products with Solar Heat" financed by Danida (Danish International Development Assistance) via the Danish Embassy in Ghana. The project was established based on an initiative by the Energy Commission of Ghana.

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Energy Commission of Ghana, Executive Secretary
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Ghanaian consultants
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1. Introduction

The survey was conducted as a part of the project “Test and Research Project into the Drying of Food and Wood Products with Solar Heat”. The aim of the survey was to investigate the need for drying of food and wood in Ghana and the already existing experience on solar drying in order to form a basis for the initial decisions within the project concerning the location of three demonstration solar dryers for crops, fish and wood, which species to dry and the type of solar dryers.

The project deals with transfer of knowledge in the field of drying of crops and wood and solar air heating systems from Denmark to Ghana. The aim of the survey was, therefore, also to give the Danish experts an impression of the conditions in Ghana in order to facilitate an appropriate design of the solar dryers. Three of the four Danish partners participated in the survey. The fourth Danish partner - the manufacture of solar heating systems Aidt Miljø – are already familiar with the conditions in Ghana due to an earlier project in Ghana.

The survey was planed by the Energy Commission of Ghana, the Ghanaian partner and consultants: DENG, University of Science & Technology, Kumasi and Econkoad. The time schedules for the survey - one for crops/fish and one for wood - are found in Annex A. The schedules were very well prepared and the sites to visit were well chosen. The visits gave the Danish experts a good overview of the situation in Ghana in the field of post harvesting of crops, handling of fish, drying and manufacturing of wood and existing experience on solar drying. The schedules included a large variety of different information and impressions e.g. ranging from large sawmill to small carpenters and workshops.

Although tight schedules the consultants manage for stick very close to the time schedules shown in Annex A.

The authors of the report would like to thank the Energy Commission of Ghana, the Ghanaian partner and consultants for the well prepared time schedules for the visits as it is believed that the survey based on this will form the best possible basis for the further work within the project.

The collected information and impressions are described in the following chapters - each chapter concentrating on one topic: drying of crops, drying of wood, drying of fish, experience on solar dryers and weather data - ending up with at conclusive chapter with recommendations for the further work within the project.

2. Sun drying of crops in Ghana

Food Research Institute
Deputy Director: Dr. W. A. Plahar
Head of Dep. of Processing and Engineering: Dr. Wisdom Amoa-Awua
Solar dryer expert: E. C-T. Tettey
Mr Sam Johnson

The Food Research Institute has carried out tests concerning drying tents and sun drying plants. The solar dryers were based on convection and not on forced ventilation by means of fans. The crops included in the drying tests were cassava and pepper. In order to obtain good and effective drying, the pepper has to be blanched or steamed before drying. A test plant was installed at the test station, "Cassava Production Station", in Pokoasi. The Food Research Institute managed the test station

The Food Research Institute seems to have good experience and is willing to co-operate. There seems to be a possibility for installation of an experimental crop drying plant at the test station in Pokoasi.

Mr. E. Tettey presented the following data from of his experience on solar drying:

Meat
For 500 kg of meat dried over five days, a reduction in moisture content from 65 to 12% was obtained.

Pepper
After a drying period of 3-4 days, a moisture content of 12% was obtained. In few cases drying a period of 1 day was sufficient.

Cassava
10-15 mm thick chips are used for drying. Reductions in moisture content from 60-70 to 10-12% have been obtained. The drying temperature was 40-50°C and the humidity 30% RH. Ideal drying temperature is about 50°C, and temperatures higher than 80^{o}C may reduce the quality of the crop.

Ministry of Food and Agriculture. Post Harvest Division
Deputy Director: Joseph Kwasi Boamah
Mr Mensah
Mr H. Anyane

On harvesting and storage there is a general crop loss of 20-25% due to insufficient drying or maltreatment of the crop.

For crops such as maize, grain and rice, which will normally have a moisture content of 18-21% at the time of harvesting, moisture content reductions down to 12-14% should be obtained. In the northern part of Ghana the crops will dry while standing, whereas in the southern districts the moisture content of crops may be as high as 60% at the time of harvesting. Traditionally, crops are spread on the ground in a layer of 15 cm (½ ft.) and sun-dried. Under favourable weather conditions drying can then be obtained within four hours.

Cassava and yams are also sun-dried, however they are chopped before drying. During the drying process the crops will be turned over or mixed. Sun drying of these crops is difficult to manage and quality problems often occur. When sun-dried the quality often is insufficient for the production of high-value products as for example cassava flour. Whole cassava may be stored for up to about two weeks without the risk of quality reductions.

Pepper is another crop relevant for drying in a sun-drying plant. Other crops applicable for drying in solar dryers may be soybeans and other leguminous plants.

The above-mentioned crops will be ripe for harvest at approximately the same time. For drying of maize a drying plant with a daily capacity of 2-3 t will be needed. Today, the most common mechanical drying method is continuous drying in plants with heated air. A drying capacity of 2 t within four hours will typically be obtained with this type of dryers.

Weija farm

The Weija farm produces vegetables. Drip irrigation is used. 20 acres (8.1 ha) of land are used for cultivation of pepper. Two types of pepper are grown namely sweet pepper and chilli pepper. For drying purposes, only chilli pepper will be of interest.

Chilli pepper plants will be fruit bearing for periods of up to one year, and harvesting can be done every 4-5 days. For export purposes, it will usually be most profitable to harvest the chilli pepper before it is ripe. Green pepper fruits are filled into in small cardboard boxes of about 15 × 15 × 25 cm with vent holes. The boxes are transported to the airport and exported within the same day. In periods with low prices, the fruits are harvested when ripe (red fruits), after which they are dried and sold on the local markets. In periods of bright sunshine a drying period of about 2 days will be sufficient.

In this area the market for fully ripe dried chilli pepper is rather low, but in other districts of Ghana, drying of chilli pepper is more common. The best prices, i.e. 7,000 Cedis per box, will be obtained for green pepper, whereas fully ripe peppers will only amount to 4,000 Cedis per box. The time from the green pepper fruits are harvested and distributed and until fully ripe (red) will be 90 days.

Onions was another of the crops mentioned where drying is needed. A potential drying capacity might improve the possibilities for effective and rapid harvesting.

Other crops grown on Weija farm: Aubergines, Carrots, Cucumbers, Tomatoes and Cabbage.

Agona Asafo

At Agona Asafo there is a sun-drying plant for drying of pepper and maize. The drying plant consists of two individual drying units. Each unit has a drying capacity of 1 t of pepper within 4-5 days. The drying temperature was about 50°C.

The capital cost was 12,000,000 Cedis per dryer. In the area the fee for drying in mechanical dryers is 800 Cedis per bag (50 kg) corresponding to 16,000 Cedis per ton. Calculations based on these prices showed a very good economic for such a solar dryer – reference: "*Prospects for Solar Crop Drying in Ghana"*.
The drying plant has been overtaken by a private company, "CACHPRO", who are now in charge of the running of the plant. There were serious problems with the durability of the solar collector coverings.

Crop Research Institute, Kumasi
Dr E. Otoo
Dr Petr Salla
Dr Danquah
Dr J. K. Twumasi
Dr E. Moses

The scientists at the Crop Research Institute pointed out the following crops as relevant for processing in solar dryers: Maize, rice and yam as well as other vegetables, e.g. onions and pepper. Of cereals, the main species grown is maize, and therefore the most important.

The crops are harvested in periods with unfavourable weather, and open air sun-drying of crops is difficult due to rain.

One problem involved when using mechanical dryers will be that of unstable electricity supply. Therefore, a system, which is not dependent of external electricity, will be needed.

Maize will be harvested at a moisture content of 18-26%, and after three days of drying a reduction to 10-12% will be obtained. Some years the moisture content before drying will be even higher, about 30%, due to the wet/rainy season.

Dried maize grown for seeding purposes may be sold at a higher price, thereby improving the profitability of a solar dryer plant. For human consumption the maize price is 54,000 Cedis for 100 kg. For seed the price is 250,000 Cedis for 100 kg, an increase in value at about 2,000 Cedis per kg.

The conditions mentioned for maize will also apply for drying of rice.

Another important crop for which drying possibilities are needed is the cocoa.

Cassava is also an essential crop. However, the marketing of cassava chips involves problems. Apparently, no purchasers want to buy the chips, or maybe the reason could be that the farmers are unwilling to sell at the prices offered. I was mentioned that purchasers had contacted a large number of local farmers and made contracts on sale and delivering of cassava chips. The farmers had started the production of the chips, but had never been contacted again by the purchasers. At present the farmers could not catch sight of a market, and therefore they were negative towards production of cassava chips.

In the period from July to November, drying plants with a daily drying capacity of 1 t will be needed. The price of 10 mill Cedis may be too high for the individual farmers, but for co-operative farms it might be possible to pay that price for a drying plant.

In this area the present price for drying of maize and grain in mechanical dryers is 10,000 Cedis per ton.

University of Science & Technology, Kumasi (KNUST)
Head of Mechanical Engineering Department: Professor Fred O. Akuffo
Head of Animal Science Department, Faculty of Agriculture: Proffessor Okai

At the University of Science & Technology a number of experimental plants for drying of crops and meat were presented. For most of the plants a drying temperature of 45-50^{o}C was used, however, in some cases temperatures up to 60^{o}C could be achieved. Two types of solar dryers had been examined for use in the drying of meat strips. The solar cabinet dryer proved to be more effective than the solar tent dryer in the rate of moisture reduction. The price of a German solar cabinet dryer (Type Hohenheiem) was 10,000$ which seemed to be very expensive. The results from the drying of meat are described in the report "*Meat drying in a hot and humid climate using convection type solar dryers"* by E. C-T. Tetty (Food Research Institute), M. J. Jones and D. E. Silverside.

Cassava production. Ashanti Region, Atwima District
Farmers' organisation Ashanti Region

Many of the farmers in Atwiam District are smallholders with land areas of 1-2 acres (1 ha). Often, their crops are grown in "integrated farming" systems, where several crops, e.g. maize, cassava and bananas, will be grown at the same field. The crops will then be harvested in the order in which they ripen (maize → cassava → bananas).

The Atwiam District is one of the most important areas for production of cassava. Cassava is planted during the rainy season from March to June and harvested 6-9 months later. The harvest season may last up to one month. After harvest, the cassava roots can only be stored for three days before fermentation will start. If not dried, the roots should therefore be harvested concurrently with demand and consumption. According to the experts at the Post Harvest Division the whole cassava roots may be stored for about two weeks without reduction in quality.

When chopped, the cassava will be spread on a table or a plate and dried in the sun. The drying process will last from 1 to 2 weeks, and fermentation will have started before the drying is completed. Therefore, the quality of the dried crop will be insufficient for production of flour. Now the dried cassava is used for the production of gari or flour used for local consumption. Fresh cassava will be used for local consumption as well or it will be sold on the marked. Several years ago, a production plant based on cassava chips was established in the area, but it was left unused, due to unfavourable sales prices.

Figure 2.1. Sun drying of chopped cassava.

The most important sun-dried crop in the district is cocoa. The kernels were distributed in a thin layer (2-5 cm) on bamboo mats. The mats are elevated 0.5 m from the ground. The kernels are turned over at regular intervals to ensure good and uniform drying.

Figure 2.2. Sun drying of cocoa on drying tables.

Sunyani. Demonstration farm with crop dryers
Director: Mr. Krampa
Head of Project: Stephen Awit-Kuffour

The overall objective of the research on solar drying has been to increase the value of cultivated crops by improved treatment and expedient marketing. Experiments with low-technological sun drying plants without mechanical ventilation were made on local farms. A project on solar drying of chilli pepper had been conducted. Within this project trails which evaluated the use of solar dryers for the production of dried chilli pepper under real farmer conditions had been undertaken.

Improved drying tables consisting of plastic tents placed on top of existing drying tables could be constructed at a price of 20,000 Cedis. 25 such drying plants were included in the study, but more than 60 were actually being used, because the farmers discovered the economic benefits by investing in such plants.

Figure 2.3. Improved drying table. Traditional drying tray covered with a simple solar collector made from timber and polythene sheet.

Depending on the type and materials chosen, the production price for regular drying plants equipped with four 1-1.5 m^2 drying trays placed in a wooden plastic covered drying chamber will be 130,000 or 250,000 Cedis. Those prices are considered acceptable.

Figure 2.4. Cabinet dryer with 4 drying trays

The price of fresh chilli pepper per rubber full ranged between 3,000 and 6,000 Cedis. The price per rubber full of solar dried pepper was 10,000 Cedis as compared to 7,000 Cedis for open-air sun dried pepper. In some cases there had been no difference in sales prices. However, the solar dried pepper sells faster on the markets due to the god quality. This is to be considered as a great advantage.

Another important advantage by solar dryers compared to the traditional open-air sun drying of pepper and other vegetables is saving of labour. The waterproof nature of the dryers allows the farmers to leave the products being dried unattended. All the farmers were highly impressed by the labour savings in terms of non attendance to the products for stirring in open air sun drying as opposed to non interference with the solar drying process.

During the rainy season it was a general problem to get enough sunshine to complete the drying process. Often the drying process would last up to six days, but under favourable conditions, drying could be completed in as little as three days.

The conclusion of the project was that solar dryers have a very bright future in the region for the processing of vegetables, especially pepper.

Cassava Production Station. Food Research Institute, Pokoasi.
Mr. Ernast Ablo

The Cassava Production Station disposes of all necessary equipment for drying tests with cassava, including peeling, rinsing and chipping equipment and equipment for drying of the crop. Drying cabinets for determination of moisture content are also available at the production station.

The production of cassava flour involves rinsing and peeling and subsequent pressing of cassava to remove water. Thereby, reductions in the moisture content down to 50-45% will be obtained. The cassava roots are cut into thin slices or chips and dried in an oven for 14 hours at 60-70^{o}C. Finally, the dried material is ground down into flour. The roots may be dried in the sun, and under favourable conditions the drying process may be completed within one day by use of a drying tent. Normally, a process of sun drying will last up to three days.

The test station has a plant for sun drying of crops, consisting of a large tent with plastic foil covering. The quality of the film is insufficient, and it has to be changed twice a year. At the moment the drying tent is not capable of functioning due to damaged covering.

Conclusion

The visits to the research institutes, the University of Science and Technology in Kumasi, the demonstration farm in Sunyani and farms as well as further information given by the consultants from Econkoad showed that there is a great need for drying of crops in Ghana.

A very important issue is the economics for both the farmer and the person or company who buys the product. How much value can be added to the crops by drying in a solar dryer compared to the investment cost and the cost of running the plant? For the demonstration project it is thus of the greatest importance, beside a good technical solution, to choose crops with a high economic benefit by drying.

From the investigations the most promising crops seem to be chilli pepper and maize (especially maize for seed). These crops have added value by drying and are suitable for drying in a solar drying plant. Also cassava and especially cassava chips used for cassava flour might be a relevant crop. There is a very great interest in cassava drying by solar dryers, but there seem to be some marketing problems for the cassava chips.

In Ghana there is already some knowledge and experience concerning use of solar dryers and drying tents for drying of crops. Most of the solar dryers are based on ventilation through natural convection. This knowledge should be used in the construction of the demonstration plant for this project.

A problem with most of the existing solar dryers is low capacity and a long processing time for the crops in the dryers. To speed up the rate of drying and thereby ensuring improved product quality and a high capacity, the demonstration plant must use forced ventilation caused by a fan. The fan should be driven by electricity produced by a solar panel.

In this project the solar dryer is a demonstration plant. For such a plant the documentation of production results and running conditions is essential. To achieve success the interest and enthusiasm among the people involved is of great importance. Choice of location for the plant and selection of the staff to run and maintain the plant is, therefore, very important. These decisions should be made in corporation with the Energy Commission of Ghana, DENG Limited and other local experts.

3. Sun drying of wood in Ghana

Introduction

The purpose of the visits was to collect as much data from a wide spectre of trade organisations and wood processing companies as possible. The collected data will be used in the design phase of the project, in which a prototype of a drying kiln with utilisation of solar energy will be dimensioned and developed.

Hereby follows a brief description of the visited companies and institutions.

Ministry of Lands and Forestry
Mr. Siisi Wilson, Acting Technical Director

Factual Information
Mr. Siisi Wilson informed that in Ghana there is a major interest in advancing the use of kiln dried wood and a recognised need to extend the drying kiln capacity essentially. The knowledge and understanding of a good drying quality of timber are recognised by the wood processing companies and the suppliers of wood. The participants of the wood trade will thus understand and appreciate the effect of a project like this.

Large wood companies already now dry the wood and a number of small wood processing companies is on their way to build drying kilns and thereby increase the drying capacity.

Mr. Siisi Wilson presumed that pre-drying – drying from a green condition to the fibre saturation point approx. 25% wood-moisture - would be a reasonable utilisation of solar energy.

The investment in a drying kiln is a very extensive problem, while the value increase and the profitability in drying the wood clearly are positive.

Informed export shares ranked according to extent in Ghana:

1.	Gold	45%
2.	Agricultural crops	30%
3.	Timber	15%

The export share constitutes the same amount as the total donation to Ghana.

"Furniture and Wood Products Association of Ghana"
Mr. Frank Nana Enos, Ag. Executive Secretary

The solar drying project is of major interest. Mr. Frank Nana Enos would clearly recommend the demonstration drying kiln to be placed in the "Wood village" in Kumasi, in which the Furniture and Wood Products Association will gather their activities and some wood producing companies. "FORIG" would then be able to perform all documentation measurements. Mr. Frank Nana Enos would in all circumstances like to be informed about the course and results of the project.

Mr. Frank Nana Enos was going to have a meeting the following week with Jørgen Karlsen from the Danish Embassy, in which a joint workshop should be planned. Mr. Frank Nana Enos would at this occasion express his support to the project.

Novatex Ltd.
Mr. Peter Sauerland, Manager

Photo 1: Administration Building

Photo 2: Production at Novatex Ltd.

The sawmill is situated approx. 2-hour's drive south of Kumasi. The sawmill is not equipped with any drying kilns, it does, however, air dry a small amount of timber in open air, while the main part is sold as green lumber to a.o. East Asiatic Company. The sawn planks that were produced at the time of the visit should be used for picture frames for the German market. The sawmill also had a production of particleboards and veneer, these premises were not inspected.

Wood Denzines
Mr. Kofi Antowi, Managing Director

Photo 3: Production premises

Photo 4: Showroom at Wood Denzines

Manufacturer of doors of a.o. teak. Mr. Kofi Antowi informed that the raw timber price constitutes 5 US $/m³ in logs and 9 US $/m³ in planks. Mr. Kofi Antowi was very interested in reducing the storage time for air drying of planks from 4-6 months to approx. 4-6 weeks by using solar drying and/or forced air drying with solar energy to pre-dry the wood. The level of interest at 35% per year reduces, however, the interest in investing!

Forestry Research Institute of Ghana, FORIG
Dr. J. Ofori, Specialist in Wood Drying

The department has in the past twenty years had some experience in greenhouse drying by solar energy. They have succeeded in drying the wood from green to a level of 6-8% moisture content in a pilot plant, but they have not been able to get finances to implement the system for commercially use. Mr. J. Ofori had measured the air velocity in the greenhouse dryer to 0.5 m/s. The department at FORIG would like to participate in the actual project but only if funding was granted. Otherwise specific information might be purchased from FORIG.

Photo 5: Greenhouse drying kiln erected by FORIG

Paul Sagoe Sawmill Ltd.
Mr. Tony Abu Jawdeh

The sawmill cuts only Wawa and has 4 drying kilns from Nardi each with a capacity of 100 m^3 and one smaller with 25 m^3. Mr. Tony Abu Jawdeh was of the opinion that as long as there is enough oil and conventional energy, there is no need for solar dryers. He was also of the opinion that the handling costs for wood would be too high, if the solar energy was utilised in pre-drying.

Gasoop Sawmill
The Manager

Gasoop Sawmill is a minor sawmill, which cuts Wawa for export to the German market in 50 x 100 x 5,000 mm used for shuttering. They have no drying facilities so to avoid fungus attack they have to preservative treat the wood by dipping in fungicides, before shipment and pay the duty for export wood with high moisture content.

SI Amanqua Sawmill
The manager

SI Amanqua Sawmill cuts 35 m^3 of trunks a day, which gives approximately 15 m^3 of goods. Wood species cut at the sawmill are both Mahogany and Wawa. The Mahogany is mainly exported to the USA and the sawmill has had some bad experience with some shipments being rejected by the customers because of a too high moisture content and degradation by fungus.

Kumi & Company Ltd.
Mr. Osei Kumi, Managing director

Very well managed sawmill that also cuts veneer. They have 4 Vanicheck kilns with a capacity of 100 m^3 each. They dry the wood to a moisture level of 4 %, but after kiln drying they store the wood in a warehouse with no moisture control. The equilibrium moisture content in the wood will under these conditions be in the range of 20 %. The total energy expenses for having the kilns rounding was for this sawmill 14,000 US $ a month. Mr. Osei Kumi explained that they use air drying to enlarge the capacity of kiln drying of wood, either by pre-drying or by drying the wood totally.

A look into one of their kilns revealed that the batch of wood was not stacked properly, which will lead to non-uniform and ineffective drying of the wood and thereby following quality problems.

The sawmill was looking for a partner for manufacturing the wood in a new built production site.

Mr. Osei Kumi expressed that large scale pre-drying utilising solar energy would be of tremendous benefit to the whole wood industry in Ghana.

Asamankese Sawmill
The Managing Director

Photo 6:
Office and production facilities.

Photo 7:
Vascular Immersing.

Photo 8:
Storage square.

The sawmill cuts the following wood species Wawa, Odum, Mahogany in the following thicknesses: 27, 48 and 75 mm, which are exported to Italy, France and Germany. The wood is not dried and the sawmill therefore has to pay a penalty duty of 15%. Some of the wood is dried in the open air for the domestic market. Examples of wood prices: Wawa 400 DM/m³ for open air dried wood with a wood moisture content of 18% and 450 DM/m³ for kiln dried wood with a wood moisture content of approx. 10%.

Wawa is dipped into fungicide against blue stain and mould fungus. It is dried in the open air under an open shed for 3 months. The managers of the sawmill are very interested in getting solar drying facilities.

A drying facility will mean that they will be able to cut the "red wood" species and other more exotic wood species. It is impossible to obtain an export license without drying these wood species.

Kutkom Wood Processing in Oda
Mr. D. P. Rotzel, Consultant for the Timber Industry.

Photo 9:
Drying kiln and store room

Photo 10:
Protection Premises

Photo 11:
Timber yard

Dr. D.P. Rotzel is at the moment consultant for 3 sawmills.
Mr. D. P. Rotzel was of the opinion that the wood industry in Ghana most of all needs drying kiln facilities. The company was building a new drying kiln at this sawmill, which already has 3 pieces of Vanicheck drying kilns each of 80 m³. Another of the sawmills, which Mr Rotzel manages, was at the moment building 3 drying kilns each of 100 m³.

Mr. Rotzel's opinion on conventional drying kilns is that pre-manufactured drying kilns are the only ones that work and not the drying kilns that are built at the site.

He proposes that the drying process should be a "downstream process":
1. Forced air drying from green condition to the fibre saturation state approx. 25% wood moisture with solar heat for approx. 4 weeks
2. Thereafter drying in a conventional drying kiln for approx. 2 weeks to remove the fibre latent moisture from 25% wood moisture to a final moisture level of approx. 10%
3. Finally, 1 week in a solar heated conditioning chamber for relaxation and equalisation of the moisture gradients in the wood

Mr. Rotzel informed that the waste rate at normal drying kiln without conditioning constitutes 20-25%, while this spillage at conditioning after the actual drying process can be reduced to only 5%.

The market situation is now far heavier requirements to the drying quality when exported, but also to the wood for the domestic market. Nobody will any longer accept initial shrinkage cracks, material flaws and malfunction of the timber after 2-3 years.

D. P. Rotzel stated that there are increasing problems with complaints on the exported kiln dried wood. This is due to lack of quality assurance on the kiln dried wood. Too often it is not assured that the moisture content of a batch is uniform. Often half or more of a batch is attacked by mould at arrival to the export customers. This is one of the major problems for wood export Ghana is facing at the moment.

Clipper Design Ltd.
Tonny Larsen

Photo 12: Production premises

Photo 13: Example and product

Clipper Design has since 1992 made order production of furniture and interior fixtures, however, after a stagnation of this market, now mainly doors in series production is manufactured.

The production conditions at Clipper Design are fairly modern, but due to lack in the water and electricity supply, the production capacity was not utilised optimal.

Clipper Design dries the wood in the open air and stores the wood for at least 3 months.

Informed key figures:

- Prices of raw timber cut with a chain saw: 160,000 Cides/m³ (is not permitted any more due to the large spillage in the forests)
- Price of raw timber cut at a sawmill: 350,000 Cides/m³
- Uses 1 m³ wood for manufacture of 6 doors
- Has capacity to 200 doors per month
- The electricity capacity for processing machines approx. 600 kWh/month
- Social contribution: Employee 5%, company share 12%

Akuba Toy and Furniture Ltd.
The Technical Manager, Mr. Mono Herbstein.

Akuba Toy and Furniture Ltd. manufactures kitchens, cupboards and furniture. The company has formerly manufactured wood toys, but this market has been taken over by Asiatic manufacturers. The company has itself rebuilt a 40-foot container into a drying kiln by installing ventilators and a condensation surface.

Photo 14: Container rebuilt into a drying kiln

Due to poor drying efficiency and high energy prices the container is only used occasionally. In stead the wood is dried in the open air. The company has purchased "hardware" for 3 drying kilns, but has no funds for the construction of the drying kilns.

Photo 15: Mobile covering for timber

Failing covering to avoid moistening from rainwater is not rectified by mobile units built as frame constructions with metal lining, it does, however, seem to be too inadequate.

Photo 16:
Stack of timber with deformations

Photo 17: Far too small sticker dimension will result in too poor ventilation through the stacks

The timber is stored outdoors and air-dried. A lot of the timber will be deformed during drying.

The assembly of machines seems to be well-maintained and functional with relatively modern machines. They could produce timber with a far higher quality by using kiln-dried wood. The company is order manufacturing, and in quiet periods it stores the production. The company is looking for designers, who can give them a new concept. At the moment e.g. drawer members with fastened "fake" fronts are produced. The company delivers e.g. to state institutions e.g. school desks and school chairs for the Ministry of Education and bunk beds for children's homes.

L & L or Elminor in Accra
Mr. Larry Yoofi, Technical Manager

See chapter 5

Conclusion

The main impression of the visits was that Ghana has a major need for a better value and quality increase from the wood as a raw material. To enable this the primary goal should be to establish profitable drying kiln facilities.

Kiln dried wood is the key to better timber and prices, this means less transport damages, less amount of export complaints, better exploitation of the timber, better wood assemblies, better surface finish, higher quality of finished timber etc. However, there is a major need for a quality assurance policy, when using the kilns.

To use the solar energy to dry the wood seems obvious, and test plants e.g. at the university in Kumasi and at a sawmill have been initiated. Characteristic for these drying plants is that the construction and mode of operation has been very simple – perhaps too simple – to keep the establishment costs low.

Photo 18: Drying kiln at the university

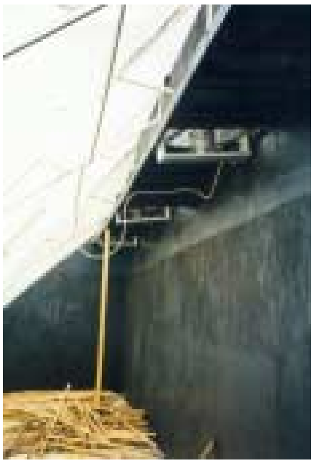

Photo 19 and 20: Commercial solar dryer from the USA

A goal of this project is to make use of a known technology for optimisation of the efficiency and profitability of solar driven drying kilns.

The drying kiln demonstration plant to be constructed and established by the contractors in this project should as far as possible be based on solar cells (pv). The demonstration plant should be made independent of the electricity grid, as the supply conditions and supply safety are very poor, and the price of electricity is increasing.

The location of the demonstration kiln should be harmonised with the local consultant and DENG, but the following competence and conditions should be considered to get an optimal implementation process and project result:

- Knowledge about wood and drying kiln quality
- Knowledge about solar energy

- Knowledge about electricity and electronic
- Test and measurement planning
- Interest in pilot experiments and tests
- Need for drying kiln in batch sizes of 10-20 m^3

An immediate solution could be to place the demonstration kiln at Clipper Design, whose wood quantity, interest and knowledge of wood are present. The employees at DENG in Accra can contribute with technical know-how and the consultant K. S. Nketiah from the Forestry Research Institute of Ghana could possibly be in charge of test and measurement planning and carry out the measurements in the test period.

Please also see the overall conclusions of this survey report.

4. Sun drying of fish in Ghana

A visit to the Directorate of Fisheries, Ministry of Food and Agriculture, Accra, a visit to Apam and further investigations by Econkoad reviles the following information on preservation of fish by sun drying in Ghana.

400,000 ton of fish are yearly caught and brought ashore in Ghana. About 20% of this is wasted. 60% of animal proteins come from fish in Ghana.

80% of the preserved fish is smoked. The rest is either salted and sun dried or only sun dried. Anchovies are e.g. normally sun dried. Salted and sun dried fish are preserved at a water content of 35%, while preserved at a water content of 12% if only sun dried. The Ghanaians love according to G.H. Anyana, Director of Fisheries the taste of smoked fish. The marked is very conservative - new/different tasting fish cannot be sold.

5% (20,000 tons) are sun dried. 10,000 tons of the sun dried fish are used for human consumptions.

Figure 4.1. Traditional drying of fish on the ground at Apam.

G.H. Anyana stated that if the fishermen in stead of sun drying the anchovies on the ground would put the anchovies on nets above the ground so that the anchovies would be dried on both sides simultaneously the quality of the dried anchovies would be increased considerably. The fishermen are starting to put a mat between the anchovies and the ground by request of the mills producing feed for e.g. chicken. Half of the sun dried anchovies are now dried on mats while the other half still is dried directly on the ground. Anchovies are dried on the ground within 2 days.

The value of anchovies dried in a solar dryer is not likely to be higher that anchovies dried on nets above the ground. In order not to decrease the nutritional value of the fish the drying temperature must not exceed 40°C. The ambient air in e.g. Accra reaches during daytime a temperature of around 30°C, which means that the surface temperature of fish directly exposed to the sun will be close to 40°C. The benefit of a solar dryer will thus mainly be that the fish are in an enclosure where it is possible to keep e.g. insects and larger particles from polluting the fish. If a solar dryer is used for drying of fish there is a need for a rather precise control system in order not to exceed an air temperature of 40°C.

The amount of fish being sun dried is not constant throughout the year. About half is dried during the fishing season in July-September.

Other spices than anchovies are dried in Ghana, however, the amount is low. Shark meet cut in pieces of 5 x 20 x 20 cm takes around a fortnight to be dried in the sun on the ground.

Conclusion

It seems based on the performed survey that the benefit of solar dryers for drying of fish would be limited.

5. Existing experience on solar dryers in Ghana

Research has been carried out in Ghana during more than a decade in the field of solar dryers for crops and wood. Several of these solar dryers were visited during the survey. The present chapter summarize the impression and information obtained on these solar dryers.

Food Research Institute, Ministry of Food and Agriculture, Accra

E.C-T. Tettey explained the activities at the Food Research Institute in the field of solar dryers. They have carried out research in different types of solar dryers: Tent dryers (or green house dryers), dryers with external solar air collector and combinations of these two types of solar dryers. They have mainly been involved in buoyancy driven solar dryers.

The tent dryers consist most often of a wooden skeleton covered with transparent plastic foil made of polyethene. One of the shown examples had a food print of 15 x 30 ft and was man high. The drying capacity was 500 kg. The air flow through the dryers are established due to the stack effect created by the heating of the air inside the dryer.

The problem with the above type of dryers is that the used plastic foil is not durable. It has to be replaced twice a year. Experiments have, therefore, been undertaken where the plastic foil were replaced with rigid plates of transparent polycarbonate. With these plates the dryers are assumed to last 2-3 years. The polycarbonate plates are, however, considerably more expensive than the foil. The price of the polycarbonate sheets is 27,000 Cedis/m² while the price of the foil is 500 Cedis/m². The price of a tent dryer with at foot print of 3.7 x 2.44 m² and mounted with ploycarbonate sheets is around 2 million Cedis ≈ 750 US$.

500 kg meat can be dried down from a water contents of 65% to 12% in 5 days. Drying of pepper down to 12% takes normally 2-3 days – however, a drying time of one day have been obtained.

A comparison between drying of meat in a tent dryer and a cabinet dryer (external solar air collector connected to a drying chamber with opaque surfaces) has been carried out (*Meat drying in a hot and humid climate using convection type solar dryers.* Tettey, Jones and Silverside, 1993). The paper concludes that the cabinet dryer is more efficient than the tent dryer.

Agona Asafo, Central Region

Two large dryers (financed by the Ministry of Mines and Energy) – each with a capacity of 1 ton – have been erected in Agona Asafo. The solar dryers were erected in 1992. The dryers are identical and are tent dryers with external solar air collectors to preheat the incoming air to the drying chamber. Figure 5.1 shows a picture of one of the dryers.

The food print of the drying chamber is 8 x 6.75 m². Two solar air collectors are connected to the drying chamber – one facing south and one facing north each with a tilt of 6°. The total collector area is 152.5 m².

The cost of on solar dryer was 12,000,000 Cedis ≈ 4,500 US$ according to the document "*Prospects for solar crop drying in Ghana*".

Figure 5.1. One of the solar dryers in Agona Asafo. The top photo shows the drying chamber while the bottom photo shows one of the collectors.

Drying of 1 ton of pepper takes 5 days in the rainy season and 3 days in the dry season. The crops are located on two layers of shelves made of wooden frames with nets in the bottom.

The document "*Prospects for solar crop drying in Ghana*" give only very few measured data and only in the form of mean values for longer periods and some maximum values. It is not possible based on these data to determine the efficiency of e.g. the collectors. However, it is stated that the "average velocity of heated air at exit of collector" is between 0.5 and 0.6 m/s.

The dimension of the area of the inlets from the collectors to the drying chamber is 6.2 x 0.2 m^2. This give an average flow rate of around 5,000 m^3/h equal to 33 $m^3/hm^2_{collector\ area}$. The flow rate per $m^2_{collector\ area}$ is a bit low (resulting in a lower efficiency of the collector) and is caused by the fact that it is a buoyancy driven system. In a forced system it is possible to use at more efficient collector with a higher pressure drop across the collector. It is thus possible to reduce the necessary collector area.

A private company CASHPRO has purchased the dryers in May 1999 for a price of 10,000,000 Cedis for both dryers.

The used plastic - polycarbonate - in the two dryers cannot withstand the operation conditions in the solar air collectors as shown in figure 5.2. The plastic sheets are not coated with at UV filter. The sheets did, therefore, quickly turn brown which increases the absorption of solar radiation by the sheets. This results in a so high temperature of the plastic that the sheets deform. A more durable material has to be used in the prototypes - e.g. polycarbonate coated with at UV filter of acrylic.

Figure 5.2. Deterioration of the cover of one of the collectors in Agona Asafo.

The Department of Mechanical Engineering of the University of Science & Technology, Kumasi has prepared a plan for renovation of the solar dryers at Agona Asafo. It has been realised that there is no need for such a large collector area. Two collectors facing opposite directions further create problems during windy conditions as the wind pressure may force air through one collector and out the other instead of the air going up through the drying chamber. So only the South-facing collector will be maintained and further split in to two separate collectors - an East facing and a West facing collector. Only the South facing part of the drying chamber is intended to be used in the renovated dryers. The drying chamber will further as the collector be split in an East and a West facing chamber each connected to one of the South facing collectors.

The owner will pay for the renovation of the dryers.

University of Science & Technology (UST), Kumasi

Department of Mechanical Engineeringand and Department of Agricultural Engineering

Proffessor F.O. Akkuffo guided a tour round the campus of the Mechanical Engineering Department. The Department of Mechanical Engineering has during many years performed research in utilization of solar energy especially in solar air drying. The two solar air dryers at Agona Asafo were designed by the Department of Mechanical Engineering.

A ten-year-old solar air collector with a cover of glass fibre reinforced polyester was inspected - figure 5.3. Although turned yellow the collector are still operational. The collector was used in experiments concerning drying, however, no files on the experiments are unfortunately available. The collector is of the forced air flow type.

Figure 5.3. Old solar air collector at the Department of Agricultural Engineering.

Also a resent small forced flow solar air collector was presented. The fan is powered by a small solar cell panel as shown in figure 5.4. The collector was erected as part of a student project. The collector has been connected to a small tent dryer for drying of cassava. However, the experiment with drying of cassava was unsuccessful. The experiment was carried out in the rainy season. The cassava chips got mouldy.

The Department of Agricultural Engineering has two drying chambers. One batch dryer with a capacity of 1 ton and one tray dryer with a capacity of 200 kg. The necessary flow rate for the two dryers has not been measured

The Department of Mechanical Engineering has a weather station for detailed measuring of solar radiation - global and diffuse horizontal radiation - see the chapter on weather data.

Department of Agriculture (farms)

The Department of Agriculture (farms) is in position of four solar dryers of which two are in operation. The solar dryers was presented and explained by Mr. Annan.

The Hohenheim (H-type) solar dryer is a German dryer often referred to as a tunnel dryer where the crops are dried directly in the collector. At the Department of Agriculture (farms) the collector is, however, connected to a drying chambers of 1.4 m³ with opaque surfaces (cabinet dryer). The collector area is 27.75 m². The H-type dryer is shown in figure 5.5. The dryer is a forced flow type with two small fans driven by a solar cell panel. The price of the dryer is 10,000 US$.

Figure 5.4. Small fan driven solar air collector.

Figure 5.5. German solar dryer - type H.

Based on the principle of the H-type dryer another dryer (type K (K for Kumasi)) has been erected using materials available in Ghana - figure 5.6. The price of this dryer is 1,000 US$. The volume of the drying chamber is 1.6 m^3 and the absorber area is 17.25 m^2. A solar cell panel power the two fans in this dryer.

Figure 5.6. Ghanaian dryer - type K - based on the principle in the German dryer.

The collector of both systems has a cover of suspended polyethene foil. There are holes in the cover of especially the type K dryer which if not repaired will decrease the performance of the collector considerably.

The two dryers have been used for drying meat, blood and crops. 10-20 kg sliced meat can be dried in 2-3 days.

The collector area seems rather big compared to the rather low drying capacity.

The Department of Biochemistry

Mr. Oldham, head of the Department of Biochemistry, Mr. Elis Williams and Dr. Oduro explained the experience with solar dryers by the Department of Biochemistry. The Department of Biochemistry works with low tech/low cost tent dryers for small farmers. The dryers shown in figure 8 have a capacity of 10 kg. The concept is similar to the dryers which have been part of a research project at the Demonstration Farm in Sunyani and an On-farm Trial in the Sunyani and Tano Districts of the Brong Ahafo Region of Ghana - see later. Figure 5.7 shows the solar dryers at the Department of Biochemistry.

When drying cassava chips the Department of Biochemistry has experienced problems in the rainy season. The cassava chips get easily mouldy.

Forestry Research Institute

At the campus of the university a 10 year old solar kiln (solar dryer for wood) was inspected - figure 5.8. The solar kiln has a capacity of about 6 m^3 wood.

The solar kiln has a glass covered roof with a slightly tilted south orientation and glass walls to the East and West. Under the glassed roof is a suspended ceiling forming the absorber of the collector. Air is circulated between the drying chamber and the collector by several grid powered fans. Fresh air intake and outlet is manually operated dampers.

Figure 5.7. The solar dryers at the Department of Biochemistry.

Figure 5.8. The solar kiln made by the Forestry Research Institute at the campus of UST.

Demonstration Farm, Sunyani

A demonstration project has as explained under Biochemistry, UST been undertaken at the Demonstration Farm in Sunyani with simple low tech/low cost solar dryers. The results from an On-farm trial were successful. The farmers involved in the trial are happy with the dryers and several other farmers have purchased solar dryers. See the chapter on crop drying for further details.

The trial was on drying pepper. For the simple dryers no problem was experienced during the rainy season. However, the more advanced dryers with two trays on top of each other gave problems with mouldy peppers in the lower tray.

L.+L. Wood Processing Ltd, Accra

The sawmill L.+L. is in position of two large American solar kilns. The capacity of each solar kiln is estimated to be around 40 m³. The solar kilns are 6 and 4 years old. One kiln is facing East while the other is facing West. The solar kilns are shown in figure 5.9.

Figure 5.9. The two solar kilns at L.+L facing opposite directions.

The covers of the solar kilns are made of a rubber foil (possibly EPDM) which is suspended on at steal skeleton which can be lifted by at truck so that the wood can be put in and taken out by at truck. The cover consists of two layers of foil. The two foils are during operation kept from each other by at small fan, which blows air into the gap between the foils as shown in figure 5.10. The foil should last 5 year, however, L.+L. have replaced the foil more often as the foil is easily torn by the wind if it is not mounted very carefully. The cover of one of the solar kiln is presently completely demolished. The price of the foil for one kiln is 500 US$. The foil can be replaced in one day.

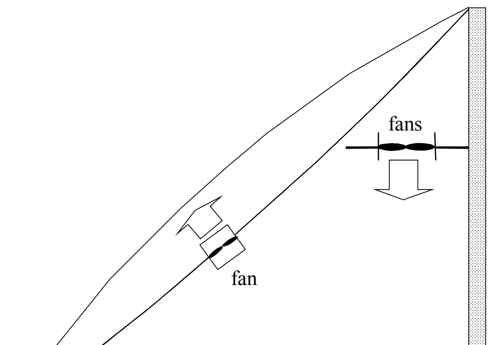

Figure 5.10. The principle of the solar kilns at L.+L.

There are 4 fans located in the top of the kilns for circulation of the air in the kilns. The fans are powered from the grid. The kilns are manually operated.

The price of the steel skeleton for carrying the cover, the cover, fans and insulation for the back wall and East and West walls is 10,000 US$. To this comes the prise of the foundation, the load bearing construction and the external surfaces of the walls, L.+L. is happy with their solar kilns and would recommend them to others. They claim that they at economical. The impression was, however, that this statement is more based on an emotional feeling than on facts.

The solar kilns are not being used at the moment. L.+L. has presently no contracts which involve drying of the wood. L.+L. has no conventional dryer but has a vacuum dryer.

The solar kilns are manufactured by Wood-Mizer, Indianapolis, USA.

Conclusion

The existing experience with solar air dryers in Ghana falls into two groups: one being the often simple convection driven tent dryers while the other is fan forced cabinet dryers with external solar air collectors.

Concerning the first group: the simple tent dryers fall outside the scope of the DANIDA project. Only the experience from the tent dryers with external convection driven solar air collectors is of interest for the present project.

The experience from the other group is on the other hand of major interest for the present project as the experience from the visits point towards fan driven systems as also was the initial intention with the project. However, it seems that the documentation of the obtained experience is rather poor and difficult assessable.

The visits to the existing solar dryers reviled that a major area for the DANIDA project is to investigate more durable covers for the solar air collectors. For crop/fish drying where fresh air is sucked in through the collector the cover may be polycarbonate with at UV-coating of acrylic. Aidt Miljø already supply DENG with this type of covers in the form of double walled ribbed polycaponate plates with an UV-coating of acrylic. The price of the cover from Aidt Miljø is 44,000 Cedis/m² for the size DENG receives for their water collectors. Not cut the price would be below 40,000 Cedis/m² - e.i. not much more expensive that the covers used in Agano Asafo. However, this type cover cannot be applied in solar kilns, as very humid air from the drying chamber will be circulated in the solar air collector. Polycarbonate decomposes when exposed to hot humid air. A solution to this may be covers of acrylic. However, only cover types available in Ghana for a reasonable price has to be chosen.

The external solar air collectors used in the visited solar air dryers are all of a low efficient type. The heat transferring area between absorber and air stream is often small. This in combination with a low air flow rate leads to a poor heat transfer between the absorber and the air stream. The heat loss of the inspected collectors is further high as the air stream often is between the absorber and a single pan cover and there is often no backside insulation. It is hoped that a combination of a higher fan forced air flow rate in combination with a more efficient

collector will lead to a more cost efficient system as the collector area may be reduced considerably while increasing the performance of the total system.
The visited solar kilns are very simple e.g. with manual control. The impression from the visits to sawmills with kilns is that there very often is a lack of quality control to assure that all of the wood is dried down to the desired water content before exported. Such a quality control will of course also be necessary for solar kilns which further means that manual control of the kilns is not sufficient - except maybe for smaller carpenters supplying the local marked.

Many different types of solar kilns have over the years been designed. It is the intention based on already existing designs in combination with thermal simulations to come up with a suitable design for a demonstration solar kiln. However, the design of the demonstration kiln will highly depend on the chosen location of the kiln. A solar kiln for pre-drying at a larger sawmill will be different from a solar kiln for complete drying at a small sawmill, which again may be different from a solar kiln for a carpenter. The price of the solar kiln will also be highly dependent on the location, as the size of the kiln will differ very much between a kiln for a large sawmill and a kiln for a carpenter.

It will hopefully be possible to power the fans of the kiln entirely by electricity from solar cell panels. However, as the fans also have to run during the night there will be a need for battery back-up and a larger area of solar cell panels than required by the fans in order to produce enough electricity for charging the batteries.

The design of the different solar dryers/kiln can first be determined when the exact location and drying purpose of the dryers/kiln has been chosen.

6. Weather data

When designing solar heating systems including solar dryers it is essential that the systems are designed to match the climate where they are going to be located. In order to be able to optimize the different components and the interaction of these components in a solar dryer it is important to know several climate parameters: Solar radiation (global (or direct) and diffuse radiation), ambient temperature, ambient humidity and wind speed. These data should preferably be on data files in the form of hourly data for a whole year.

Hourly data for a whole year is preferred in order to test the design under different weather conditions which it is likely to operate under and also to test the system under dynamic conditions where the climate change from hour to hour and from day to day.

Climate data from different locations in Ghana are available in the report: "*Solar and Wind Energy Resources Assesment - Preliminary Data Analysis and Evaluation. Final Report - Volume 2*" by Professor Fred O. Akuffo. 1991. The following data are available:

- Global radiation:	Hourly monthly mean values for the twelve months
- Diffuse radiation as a percentage of global radiation:	Daily mean values for the twelve months
- Ambient dry bulb temperature:	Three hourly monthly mean values for the twelve months
- Ambient relative humidity:	Three hourly monthly mean values for the twelve months
- Wind speed:	Daily mean values for the twelve months

The above-mentioned data are available for de following locations:

Location	global radiation	diffuse radiation	dry bulb temperature	relative humitity	wind speed
Kumasi	x	x	x	x	x
Wenchi		x	x	x	x
Akim Oda		x	x	x	
Akuse		x	(x)	x	x
Koforidua		x	x	x	x
Accra	x	x	x	x	x
Tema			x	x	
Bole		x	(x)	x	x
Tamale	x	x	x	x	x
Yendi		x	x	x	x
Navrongo	x		x	x	x
Wa		x	x	x	x
Akatsi			x	x	x
Ho	x	x	x	x	
Kete Krachi		x	x	x	x
Axim		x	x	x	x
Sefwi-Bekwai	x	x	x	x	
Takoradi	x	x	x	x	x
Saltpond		x		x	x
Abetifi				(x)	
Ada		x		x	x
Sunyani					x

(x) means not all data are available

From the table it is seen that all data are only present for 4 locations. However, the wind speed is not the most important parameter, which means that sufficient data are available from 6 locations: Accra, Ho, Kumasi, Sefwi-Bekwai, Takoradi and Tamale. The locations of these six sites are shown in figure 6.1.

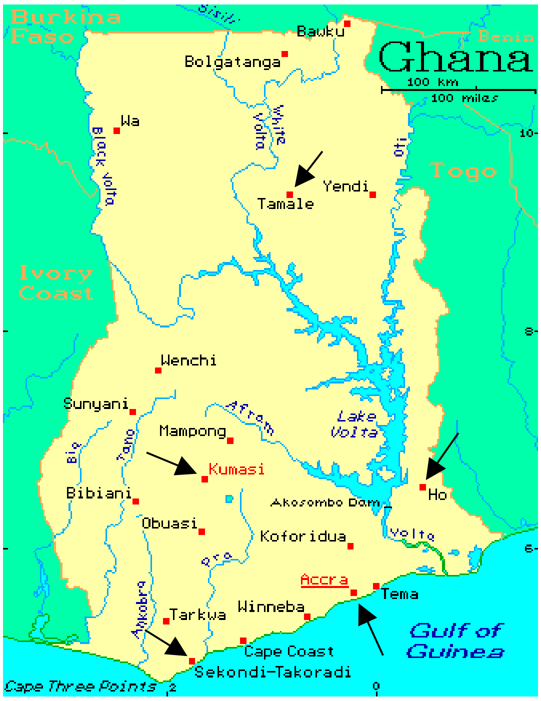

Figure 6.1. The location of five of the sites where all the climate data from the above-mentioned report are present – Sefwi-Bekwai which is not shown is located next to Kumasi.

The six locations are considered to well represent the different climate types in Ghana.

The above weather data are mean monthly data which means that it is possible to determine the average performance of the systems month by month. However, the data do not allow for parameter studies where e.g. the performance for a really good or really bad day may be investigated nor do the data allow for an investigation of the performance under dynamic conditions where the weather changes from day to day.

The Department of Mechanical Engineering, University of Science & Technology, Kumasi has a weather station for detailed measuring of the necessary weather data. Professor Fred O. Akuffo has supplied samples of data from the weather station. However, the measured values for the diffuse radiation seems to be wrong. The values are almost identical to the measured global radiation. This indicates that the shading ring of the pyranometer measuring the diffuse radiation is not screening of the direct radiation.

Kumasi is on the other hand situated in the region of Ghana with the lowest radiation level and may, therefore, be of less interest for the project. The low radiation level was, however, used as an argument by Dr. J. Ofori from the Forest Research Institute, University of Science & Technology, Kumasi for placing the solar kiln in Kumasi. His argument was that if the solar kiln works in Kumasi it will work all over Ghana. In contradiction to this it could also be stated that if it does not work in Kumasi we would not know if it would work elsewhere in

Ghana. And the likelihood of success of the project is greater in regions with a higher insulation level.

Conclusion

It is preferred to have more detailed weather data from several locations in Ghana. However, such data was not expected to be available as high quality detailed weather data are difficult and expensive to obtain. In fact the available data are of a higher quality than expected.

The parameter studies may instead be performed with artificial weather data generated based on the available data so that it after all will be possible to test the designs under more extreme weather conditions than possible with the available climate data.

7. Conclusions

It is the general impression that the conducted survey will form the best possible basis for the further work within the project. It is also the impression that the accomplished visits of the survey gave the Danish experts a good and true picture of the situation with regard to the need for drying of crops, fish and wood in Ghana. It further gave a good impression of what can and what cannot be done in the field of solar drying.

There is definitely a need for drying of food and wood in Ghana. 20-25% of the crops is lost due to insufficient drying or maltreatment of the crops. In order to increase the value of the wood cut in Ghana and decrease complaint from the export market on mould fungus on the wood it is very important to be able to dry the wood properly.

The supply situation for electricity is poor in Ghana. Often the supply of electricity is cut meaning that it is necessary to have emergency generators for keeping the fans of the dryers running. This means large investments in generators and expensive electricity. The prices of energy in Ghana further keeps on increasing.

There is, thus, a market for solar dryers where the fans are PV driven if the solar dryers can be produced at a reasonable price.

Several solar dryers were inspected as part of the survey. The conclusion from this is that the project should focus on fan forced dryers made of durable materials with low maintenance – i.e. especially more durable cover material for the collector part of the dryers.

Crops

The survey revealed a need for drying of maize, rise, chilli pepper, cassava, cocoa, ... - with maize, chilli pepper and cassava being of most interest for the present project. These crops achieve an improved quality by an effective and quick drying process. Furthermore, the drying increase the sales price of the crops.

A dryer with a capacity of 1 ton and fan forced air flow seems to be the target of this part of the project.

However, the economical part of using solar dryers for drying of crops still have to be evaluated – i.e. what is the maximum price for the dryer in order to make it profitable and thereby make it feasible for drying of crops in Ghana.

Wood

The survey revealed a major problem in Ghana on the quality of dried wood. There is major focus on kiln drying of wood including a penalty on several spices if exported undried. This has to some extent increased the installation rate of conventional kilns. However, the quality of the kiln-dried wood varies very much often due to improper operation of the kilns and lack of quality control. Improper operation can be bad stacking of the wood in the kilns and wrong sensor location on the wood.

Introducing solar kilns cannot solve the above problem. If not being careful identical quality problems will arise when using solar kilns.

It is believed that the inspected solar kilns are too simple – i.e. manual control of the drying process. In order to obtain a suitable and a homogeneous quality within a batch and between batches a minimum of automatically control – like in conventional kilns - is important.

The survey reviled demands for different types of solar kiln mainly dependent of the size and type of the company:

- Larger sawmills would benefit from a simpler pre-dryer to be used before drying in conventional kilns.
- Smaller sawmills would profit from a larger solar dryer for complete drying of the wood from green down to a water content of 10-12%.
- Larger manufactures could use the above kiln or a conditioning chamber for tempering of the wood before manufacturing in order to reduce the percentage of wasted wood.
- Smaller carpenters would profit from a smaller solar kiln for drying of green wood down to a water content of 16-18%.

When choosing the type of kiln for the demonstration system the cost of the kiln has to be considered due to a limited budget of the project. The price of the above-mentioned kilns increases when going up the list.

Drying of fish

The survey showed that there is a need for improved methods for drying of fish. However, if the fish is lifted up from the ground on a net (instead of being dried on the ground) this will increase the quality of the dried fish so much that drying in a solar dryer would not add further value to the fish.

It is, therefore, proposed to leave the demonstration plant for drying of fish out of the project and instead concentrate more on the two other types of solar dryers in order to increase the possibility of success here.

Location of demonstration plants

The success of the project is major dependent on the location of the demonstration plants. In order to ensure success the below listed demands have to be fulfilled by the demonstration site:

- need for drying also after the end of the project
- enthusiasm about the project
- profit from the solar dryer
- knowledge on drying of crops or wood
- knowledgeable about the theory behind the solar dryer
- knowledgeable about the ideas behind the construction and running of the solar dryer
- able to perform smaller reparations and modifications to the solar dryer
- willing to allow tests and measurements on the solar dryer
- willing to show and explain the solar dryer to others

It is further preferable that the hosts of the demonstration plants are willing to pay part of the solar dryers, as this will increase the enthusiasm of the host in making a profit out of the solar dryers and thereby make the project a success. The hosts should, however, only pay part of the solar dryers thereby making it possible to require a certain amount of work of the hosts for the project.

No site has as yet been pointed out as location for a solar dryer:

For crops the “Cassava Production Station” in Pokoasi is a candidate if the economical calculations points at cassava as the target for the solar dryer for drying of crops. The people at the test station have the needed knowledge of drying of cassava and on solar dryers, however, it should be assured that the dryer also will be in operation after the end of the project.

For drying of wood the small the firm Clipper Design Ltd. in Mankoadze is a candidate. From the visit it is seems that the need for drying, the enthusiasm, knowledge, ability to run and perform modifications on the dryer is present, however, it should be investigated if the location also is good for demonstrating the technology for others. Another candidate would be the Wood village” in Kumasi where many carpenters will benefit from the kiln.

The Danish partners cannot alone decide on the location of the solar dryers due to too little knowledge on potential candidates for the solar dryers. DENG and the Ghanaian consultants should investigate and propose candidates based on the above-mentioned demands. Candidates among which the location of the dryers may be chosen in agreement among the involved persons of the project.

Annex A

Time schedules for the survey in Ghana October 4-8, 1999

TEST AND RESEARCH PROJECT INTO THE DRYING OF FOOD AND WOOD PRODUCTS WITH SOLAR HEAT

PROGRAMME OF ACTIVITIES FOR VISITING CONSULTANTS (CROPS) AND ECONKOAD
October 3-10, 1999

DATE	ACTIVITY	TIME	PARTICIPANTS
Sunday 3-10-99	Arrival in Accra		Visiting Consultants
Monday 4-10-99	• Meeting at DENG • Meeting at Energy Commission (EC) • Meeting at EC	• 9:00 a.m. • 11:00 a.m. • 3:00 p.m.	• DENG Cons. (Crop & Wood) • EC, Cons. (Crop & Wood) • EC, DENG, Cons. (Crop & Wood), KNUST, FORIG & Econkoad
Tuesday 5-10-99	Meetings: • Food Research Institute (FRI) Ministry of Food and Agriculture • Post Harvest Division • Fisheries Division • Weija, (CR) • Visit Agona Asafo – Central Region (CR) – Solar Crop Dryer	• 9:00 a.m. • 10:30 a.m. • 11:30 a.m. • 3:00 p.m. • 5:00 p.m.	• FRI, Cons. (Crop) & Econkoad • MOFA, Cons. (crop) & Econkoad • - do - • Cons. (Crop) & Econkoad • - do -
Wednesday 6-10-99	Depart from Accra Kumasi, Ashanti Region (AR) • Crop Research Institute (CRI) • KNUST (Agric. Faculty, Agric and Mech. Engineering Depts) • Atwima District (AR) – 2 Cassava production centres	• 5:30 a.m. • 9:00 a.m. • 10:30 a.m. • 2:30 p.m.	• Cons.(Crop) & Econkoad • CRI, Cons.(Crop) & Econkoad • KNUST, " • Cons. (Crop) & Econkoad
Thursday 7-10-99	Depart from Kumasi Sunyani • Demonstration farm with a Crop Dryer Accra	• 7:00 a.m. • 9: 00 a.m. • 5:30 p.m.	• Cons. (Crop) & Econkoad • Cons. (Crop) & Econkoad • - d0 -
Friday 8-10-99	• Ada, (GAR) - Fish drying • **Meeting at EC (Debriefing))**	• 6:00 a.m. • **3:00 p.m.**	• Cons. (Crop) & Econkoad • **EC, DENG, Cons. (Crop & Wood), KNUST, FORIG & Econkoad**
Saturday 9-10-99	FREE		
Sunday 10-10-99	Departure		

TEST AND RESEARCH PROJECT INTO THE DRYING OF FOOD AND WOOD PRODUCTS WITH SOLAR HEAT

PROGRAMME OF ACTIVITIES FOR VISITING CONSULTANTS (WOOD) AND KNUST
October 3-10, 1999

DATE	ACTIVITY	TIME	PARTICIPANTS
Sunday 3-10-99	Arrival of visiting Consultants		
Monday 4-10-99	• Meeting at DENG • Meeting at Energy Commission (EC) • Meeting at EC	• 9:00 a.m. • 11:00 a.m. • 3:00 p.m.	• DENG Cons. (Crop & Wood) • EC, Cons. (Crop & Wood) • EC, DENG, Cons. (Crop & Wood), KNUST, FORIG & Econkoad
Tuesday 5-10-99	Meetings: • Ministry of Lands and Forestry • Forestry Department • Forestry Research Institute, Kumasi	• 9:00 a.m. • 10:30 a.m. • 3:30 p.m.	• MLF, Cons. (Wood), KNUST & FORIG • FD, Cons. (Wood), KNUST & FORIG • Cons. (Wood), KNUST & FORIG
Wednesday 6-10-99	Visit: Kumasi • Ghassoub Sawmill Ltd. • Ashanti Curls and Lumber Co. • KNUST • Working Lunch with GTMO & FAWAG • Paul Sagoe Sawmill (Kiln Dryer) • Kumi & Co. Ltd. (Kiln Dryer • Sunstex Company	• 8:30 a.m. • 9:30 a.m. • 10:30 a.m. • 12:30 p.m. • 2:30 p.m. • 3:30 p.m. • 4:30 p.m	• FORIG, Cons. (Wood) & KNUST • Cons. (Wood), KNUST & FORIG • Cons. (Wood), KNUST & FORIG • - do - • - do - • - do - • - do -
Thursday 7-10-99	Leave Kumasi • Asamankese Sawmill • Akim Oda • Mankoadze • Accra • Visit to 2 Furniture Companies	• 6:00 a.m • 9:00 a.m. • 10:00 a:m • 1:00 p.m. • 2:30 p.m • 3:00 p.m	• Cons. (Wood), KNUST & FORIG • - do - • - do - • - do - • - do - • - do -
Friday 8-10-99	• Report preparation • **Meeting at EC (Debriefing)**	• 8:00 a.m • **3:00 p.m.**	• Cons. (Wood), KNUST & FORIG • **EC, DENG, Cons. (Crop & Wood), KNUST, FORIG & Econkoad**
Saturday 9-10-99	FREE		
Sunday 10-10-99	Departure		