



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

22863

UNIDO

United Nations Industrial Development Organization

**“WOMEN ENTREPRENEURSHIP DEVELOPMENT IN THE AGRO-INDUSTRIAL
SECTOR IN MOROCCO ”**

UNIDO Project No. US/MOR/00/A48W

Contract No. 2003/042

Final report

Presented by:

**University of Agricultural Sciences, Institute of Agricultural, Environmental and
Energy Engineering, Division of Agricultural Engineering, Vienna, Austria**

Abstract

fish
A hybrid/drying unit which comprises of an indirect solar drier and a supplementary heating system using diesel as a source of energy, was constructed in Vienna and delivered to the pilot group in Bouadel, Taounate, Morocco. The unit was installed during the mission of 18th May to 15th June 2003. Local artisans (carpenters and electricians) and trainers of the association were successfully trained in the montage and installation as well as in the operation and maintenance of the system. Furthermore, the unit was successfully tested with fruits (banana) and vegetables (tomato and eggplant).

1. Introduction

The objective of the under project US/MOR/00/A48 "Women Entrepreneurship Development in the Agro-Industrial Sector in Morocco" is to disseminate fruit (figs and prunes) hybrid drying technology in selected groups of women entrepreneurs in the north of Morocco.

The objective of the subcontract between UNIDO (United Nations Industrial Organization) and the University of Agricultural Sciences, Institute of Agricultural, Environmental and Energy Engineering, Division of Agricultural Engineering, is to deliver the following services:

1. to conceive and construct in Vienna, in close co-operation with UNIDO, a prototype of a Hybrid Dryer which comprises an indirect solar drier and a supplementary heating system using diesel source of energy; and
2. to arrange the shipment (including special packaging) from Vienna to Casablanca;

This final report covers the installation of the unit at the processing site of the partner organization as well as the training of local artisans and drying personnel.

2. Description and Operating Principle of the Unit

The hybrid drier consists of an indirect solar dryer, a supplementary heating system and photovoltaic system for the generation of electricity.

2.1 Indirect Solar Drier

The indirect solar drier consists of the solar air collector and drying chambers. The electric fan integrated in the indirect warm air generator used to transport the hot air from the air collector to the drying particles in the drying chambers.

Solar Air Collector

The air collector consists of 12 wooden boxes of 2.023m x 0.735m x 0.235m each. Each box contains black painted absorber and insulation material at the base. The latter prevents heat losses through the bottom.

An important component of a solar collector is the absorber that absorbs the incoming radiation and convert it into heat. The absorber in this system consists of two layers aluminum expanded-metal screen and single aluminum foil sheeting below. The latter fulfils two functions: it absorbs the incoming radiation transmitted by the porous absorber, and prevents the air from coming in contact with the glass wool insulation. A 4-mm thick colorless glass (0.74 m x 2 m) covers each box.

Drying Chamber

The unit has two (2) drying chambers. Each chamber is 2.14 m long and 1.02 m wide. The side walls are constructed of brick and the top is covered with 20mm thick wooden board. The interior of each chamber is partitioned with wooden board into four compartments. The partition boards are provided with shelves for the 10 drying trays. The trays with a dimension of 0.5 m x 1m are made of wooden frames and aluminum mesh at the base.

The heated air from the air collector enters the chamber through the opening at the bottom of the side wall, passes upwards through the trays filled with the product, and exits through the opening at the top of the rear wall. Air filters placed at the entrance and exhaust openings protect the product against infestation by insects and contamination by dust.

Photovoltaic system

The Photovoltaic system consists of 6 PV-modules, 4 storage batteries, a voltage regulator and an inverter. The 6 modules (24V and 100 W each) are automatically connected in parallel to give a total performance of 600 W (6 x 100).

Two 12V lead-acid batteries store the voltage generated by the PV-modules. Each battery has a storage capacity of 230 Ah (ampere-hour). They are connected in series to give 24V and then parallel. The power generated by the PV-array is used to charge the batteries during periods of high solar radiation (at night and/or in periods

of less solar radiation, the batteries will be charged with an electrical battery charger). The system loading regulator (30 Amp., 24 V) regulates the array output in order to prevent battery overcharge, overheating and the resulting decrease in battery life.

Supplementary Air Heater

The supplementary heating system uses a diesel-fuelled indirect heater to heat the drying air at night and/or during inclement weather (e.g. low solar radiation). The temperature of the air is regulated with a thermostat. The technical data of the air heater:

| | |
|---|------------------------|
| Voltage | 230 V |
| Motor power | 245 W |
| Fuel consumption at full working capacity | 2.9 kg/h |
| Heating capacity | 32 kW |
| Air flow rate of the fan | 2300 m ³ /h |

2.2 Operation Principal of the Hybrid Drier

The incoming solar radiation (direct and diffuse components) incident on the collector surface is transmitted by the 4mm thick glass cover and is absorbed by the blackened aluminum expanded-metal screen. The part of the radiation transmitted by the aluminum expanded-metal screen is absorbed by the second absorber (aluminum foil) below. Both are thereby heated. The heat is transferred to the ambient air sucked through the air collector by fan integrated in the supplementary heater. The preheated air is conveyed to the drying particle in the drying chamber through the combustion chamber of the hot air generator. In case the of the air from the air collector is below the required drying air temperature, additional heat is provided by the hot air generator. The hot air enters the drying chamber through the entrance opening below. As the air passes through the trays, it picks up moisture from the products spread over the mesh. The moist air exists through the exhaust opening at the top of the back wall.

During cloudy/rainy daytime hours and nighttime the drying air is heated by the diesel-fuelled hot air generator. In this case, the ambient air is sucked by the fan through the air collector and then pumped into the combustion chamber of the generator, where it is then heated to the drying air temperature. In both cases, the temperature of the drying air is regulated by a thermostat.

3 Installation and Training

3.1 Installation

Solar Air Collector

Components:

- wood frames for the 12 boxes;
- blackened aluminum expanded-metal screen (main absorber);
- aluminum foil sheeting (second absorber);
- solar black paint (M40 Li) and special wood paint ;
- glass wool insulation;
- 13 pieces 4-mm thick colorless glass;
- aluminum strip (4mm thick, 4 cm wide).

Assembly:

- ⇒ fabrication of the boxes for the air collector from the wooden frames;
- ⇒ painting of the wooden boxes with protecting paints;
- ⇒ insulation of the boxes with glass wool insulation;
- ⇒ preparation (cutting and painting with solar paint) of the of the aluminum foil (2nd absorber);
- ⇒ arrangement of the aluminum foil sheets (2nd absorber) in the boxes;
- ⇒ arrangement of the aluminum expanded screen (1st absorber) in the boxes;
- ⇒ preparation of the south facing roof of the house for the air collector;
- ⇒ mounting of the air collector on the roof;
- ⇒ glazing of the air collector with colorless glass;
- ⇒ fixing the glasses with aluminum strips ;
- ⇒ fixing of the supports of the air ducts on the outlet openings at the bottom of the boxes
- ⇒ connection on the supports with hot air duct;
- ⇒ connection of the hot air duct to the air inlet opening of the supplementary heater;

Drying chambers

The drying chambers were constructed locally. As a result installation works on the drying chambers consisted of the following activities:

- ⇒ preparation of the board for the partition of the drying chambers;
- ⇒ screwing of the shelves for the drying trays on the sides of the boards
- ⇒ partition of the drying chambers in 4 compartments each;
- ⇒ installation of the hot duct with outlet opening in the drying chambers;

Drying trays

Components:

- ⇒ Wooden frames (1 x 0.5 x 0.04 m : length x width x height);
- ⇒ aluminum mesh;
- ⇒ wooden strips.

Montage at the work site:

- ⇒ screwing of the wooden frames;
- ⇒ screwing of the aluminum screens and wooden strips to the base);
- ⇒ planing of the frames.

Supplementary Heating System

The diesel-fuelled supplementary heater is a normal commercial space heater. It consists of the ventilation unit, combustion chamber, fan, tank, ambient thermostat, spiraled hose for the hot air ducting and aluminum flex hose for gas exhaust. Since the air heater is fabricated ready for assembly, the installation works at the site consisted of the electrical installation (wiring, ground connection, etc), connection of the hot air duct, the exhaust chimney, thermostat and thermometers.

Photovoltaic system:

Component:

- ⇒ 6 PV modules;
- ⇒ charge regulators;
- ⇒ inverter;
- ⇒ batteries;
- ⇒ 3 aluminum u-profile frame;
- ⇒ battery monitor
- ⇒ electrical installation materials (battery terminal connection, cables, etc.).

Installation:

- ⇒ bolting of 2 modules each on the aluminum u-profile;
- ⇒ electrical connection of the modules;
- ⇒ mounting of the panels on the south facing roof of the drying house;
- ⇒ electrical connection:
 - connecting the PV to the charge regulator;
 - connecting the batteries to the charge regulator and inverter;
 - connecting the supplementary heater to the inverter.

3.2 Training and Performance tests

Training

6 artisans (carpenters and electricians) were instructed in the installation of solar air collector and the construction of the roof structure for appropriate integration of the unit on the roof. The electricians were trained in the installation and maintenance of the diesel-fuelled supplementary heating system.

Both training units were done through "Learning by Doing". Prior to the practical implementation of the various installation procedures described above, a theoretical explanation was conducted.

Training in operation and maintenance

An advantage of the system lies in its simplicity in construction, operation and maintenance. The diesel-fuelled heater is also user-friendly.

The training consisted of the following:

1. Washing of the glass cover (air collector).
2. Checking of the wiring and connectors for cracking, rodent damage etc.
3. Switching on and off of the heater with the thermostat.
4. Regulating the drying temperature with the thermostat.
5. Maintenance of the generator viz.: cleaning of the turbo, fuel filter and tank.
6. Filling of the tank.

Performance Tests

The performance of the hybrid dryer was tested with fruits (banana) and vegetables (tomato and eggplant). 10 trainers of the association were trained during the tests.

The content of the training included:

1. operation of the hybrid dryer;
2. drying mechanism;
3. transportation and storage;
4. selection and preparation of the fresh produce;
5. arrangement of the fresh produce in the drying trays;
6. determination of the moisture content of the dried;
7. conditioning, packaging and storage of dried products.

Unfortunately, the system couldn't be tested with the main products (prunes and figs), because of the unavailability of these products during the period. The tests will be conducted during the season. The results of the performance tests will be used for the training the trainers and drying personnel of the association.

4. Conclusions

A prototype of a hybrid fish drying unit which comprises an indirect solar drier and supplementary air heating system using diesel as source of energy was designed, manufactured and delivered to the women Association in Bouadel, Taounate as specified in the contract (contract No. 2003/042) between UNIDO and the University of Agricultural Sciences, Institute of Agricultural, Environmental and Energy Engineering, Division of Agricultural Engineering, Vienna, Austria.

6 artisans and 10 trainers and drying personnel of the association were trained in the installation and maintenance as well as in the operation and utilization of the hybrid dryer. The system was successfully tested with banana, tomato and eggplant.