PN-AAW-866 1420
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Cha-Chel's Solar Crop Dryer

A Report on Solar Drying of Fermented Cassava Residue

Prepared by:

Chandra Joshi, Nepal
Rachel Polestico, Philippines

For the 3rd Session of the
Training in Alternative Energy Technologies Program

9 December 1981

Solar Drying of Fermented Cassava Residue

1. Objective

The main objectives of this project are:

a) to design and construct a simple and inexpensive solar crop dryer for drying the fermented cassava residue,

b) to test its technical performance, and

c) to explore its social and economical feasibility for the economically and technically less developed communities of rural areas in the developing countries.

2. Introduction

Drying of farm crops is one of the most important parts of agricultural activities. It is done either through simple sundrying or with the use of artificial dryers. The traditional method of sun drying on mats, concrete pavements, side streets, etc., is the most popular method because of its low cost requirements. However, uncontrolled weather conditions, lack of specialized structures to protect crops from animal and insect attacks and spillage due to handling lead to product loss and quality deterioration. These problems can be overcome by using artificial dryers, but with the spiraling cost of fuel, the use of such dryers is becoming more and more impracticable (1).

This necessitates some other type of dryer which is both free from the disadvantage of the traditional sun drying method and conservative in its energy use. Such a solar dryer is presented in this report which bears the name "Cha-Chel's Solar Crop Dryer."

It is designed specifically for fermented cassava residues. It can, however, be used for drying fresh cassava chips and other farm produce which

has about the same initial moisture content as the fermented cassava residue (70%).

Cassava, a root crop grown in a large number of developing countries, has been chosen to be the object of the design because of the problems associated with its drying and the benefits that are attendant to the removal of up to 80% of its moisture.

Cassava has traditionally been grown for food but is recently being considered as a substrate for fermentation because of its 2.5% starch composition (2). It offers a potential of yielding a high volume of alcohol per unit area of land.

The production of alcohol from cassava is however beset by a number of problems, one being that cassava does not have by-products that can contribute to the energy input in the alcohol production and extraction. Any step taken, therefore, in this fermentation process that can preserve the integrity of cassava or provide useful by-products will favour the cost benefit balance of alcohol production from cassava (3).

There are two opportunities for solar drying to contribute favourably to cassava technology. One is preserving the integrity of cassava while in storage and second in drying the fermented residues left after fermentation.

In both cases what solar drying prevents is the fungal contamination of the cassava chips which in the first case uses up the starch needed for alcoholic fermentation and in the second case endangers the health of the livestock for which the residues are intended.

It is for these two purposes that the "Cha-Chel's" crop dryer is designed for.

3. Description of Dryer

Cha-Chel's solar crop dryer used in this project is shown in Figure 1. It is composed of two components namely the solar collector and the drying cabin. The collector (4 ft. long and 2 1/2 feet wide) consists of a black painted sheet of mm thickness, which acts as an absorber plate. It is enclosed in a wooden frame heavily insulated with fiberglass sheet of 2 cm thickness. The whole box is covered at the top by a window glass sheet of 3 mm thickness. It is clamped with extruded aluminum profiles. The air space between the absorber plate and glass cover is 15 cm. Two long slits, cm long and cm wide are cut in two of the shorter sides. One is being used as the inlet for cold air and the other as the outlet for the heated air. The inlet slit is provided with two shutters to regulate the flow of ingoing cold air. The collector is inclined at an angle of 37° to the horizontal.

The drying cabin, 150 cm in height 88 cm in width and 52 cm in depth, looks like a wooden tower. It has a glass cover on the top and air inlet hole in the bottom. On it rests the top of the collector. Inside are three wooden racks, on which the trays slide while loading and unlaoding. All vertical walls are insulated from inside with 2 cm thick fiberglass insulation. On the back wall of the drying cabin eight holes of 6 cm diameter are drilled at regular distance. These holes are provided with lids. Through these the outflow of hot air is regulated. The trays are made of synthetic mech with five holes held firmly by the wooden frames.

4. Instrumentation

Figure shows the location of the thermocouples inside the drying cabin. These copper constantan thermocouples are connected to the data acquisition system for resulting the records every few minutes during the experimenting period.

The air flow was measured with the help of a hand-anemometer held in front of the holes on the back wall of the cabin.

The horizontal solar radiation was measured with the pyranometer. Humidity and all other meteorological data were read from the meteorological station at the centre.

5. Experimental Procedure

The fresh cassava residue obtained from the alcohol distillation contained a large portion of water. Part of this moisture was removed by pressing the cassava in a piece of thin cloth. A sample of it is taken to determine its initial moisture content. This is then spread on the tray in a thin layer. No usual pretreatments with hot water or chemicals were carried out before it was put into the cabin for drying.

Several samples were removed from the cabin at regular intervals to determine the drying rate of cassava residue and thus the efficiency of the dryer. The results are tabulated in Figure .

The final moisture content of the sample is determined by drying it at 75°C for 48 hours, then at 182°C for another 24 hours and then taking the final weight.

Several tests were conducted with different air flow rates that produced different temperature ranges inside the dryer. The drying conditions resulting in the shortest possible drying time were determined from those different results.

If:

W_o = initial weight of cassava sample

W_d = weight of bone dry cassava sample

and M_o = initial moisture content

$$M_o = \frac{W_o - W_d}{W_o} \times 100\%$$

7. Designing of Dryer

Following assumptions are made for designing the dryer (collector and cabin):

Average ambient temperature at November in Gainesville	20°C
Boiling temperature of water	100°C
Collector efficiency	25°C
Average insolation	800 Btu/ft^2-day

The efficiency of a solar dryer can be defined as the "thermal energy utilized for drying" over the "thermal energy available for drying."

In the numerator, the thermal energy utilized for drying should include the following terms:

a) sensible heat used to raise the temperature of the food = $\dot{m}C_p(\Delta T)$

b) sensible heat used to raise the temperature of the water in the food = $\dot{m}C_p(\Delta T)$

c) latent heat used to vapourize the water in the food = $\dot{m}L_v$

where,

$\dot{m}$ = weight of food, (g/hr)

C_p = heat capacity (cal/g/°C)

ΔT = temperature rise from initial temperature t_{o1} to t_{o2}, °C

L_v = latent heat of vaporization.

In the denominator, the term thermal energy available for drying is the available solar insolation.

7a. Collector Area

Amount of energy required for drying:

$$Q_{required} = Q_{(25 - 100°C)} + Q_{vaporization}$$

$$= \dot{m}C_p\Delta T + mL_v \text{ [(a) neglected]}$$

$$= 2100\ (100 - 20 + 540)$$

$$\sim 5200 \text{ Btu [1 kcal = 3.9685 Btu]}$$

Weight of the sample = 3 kg/batch.

Calculations

1. Collector

$$\text{Collector efficiency} = \frac{\text{thermal energy utilized for drying}}{\text{thermal energy available for drying}}$$

$$\text{efficiency} = \frac{Q_u}{Q_a}$$

$$Q_u = Q_{20 - 100°C} + Q_{vaporization}$$

$$= \dot{m}C_p\Delta T + mL_v$$

$$= 3 \times 7\ (100 - 20 + 540)$$

$$= 5200 \text{ Btu}$$

$$Q_a = A_{collector} \times I_s$$

$$A_{collector} = \frac{Q_u}{I_s \times efficiency}$$

$$= \frac{5200 \text{ Btu}}{0.25 \times 800}$$

$$= 26 \text{ ft}^2$$

Drying time = 3 days

$$A_{required} = \frac{26}{3} = 9 \text{ ft}^2$$

Size of collector chosen: 4' x 2.5'

$$A_{collector} = \frac{Q_{required}}{\times I_s}, \text{ where}$$

= efficiency of collector

I_s = solar insolation

$$A_{collector} = \frac{5200}{0.25 \times 800} = 26 \text{ ft}^2$$

$$Arequired = \frac{26}{3} = 9 \text{ ft}^2$$

No. of days drying, estimated = 3

Size of the collector chosen: 4' x 2.5'

7b. Drying Cabin

The quantity of sample to be dried and the permissible weight or thickness of it (see handbooks) determined the size of the tray, which comes out rather too large to handle. Therefore, this area of the tray is divided into several small trays. The number of trays thus obtained gives the size of the drying cabin.

Assumptions made for calculations

Average ambient temperature (Gainesville, November)	20°C
Boiling temperature of water	100°C
Collector efficiency	25%
Average insolation	800 Btu/ft^2-day
C_p	1
Initial moisture content	80%
Final moisture content	10%

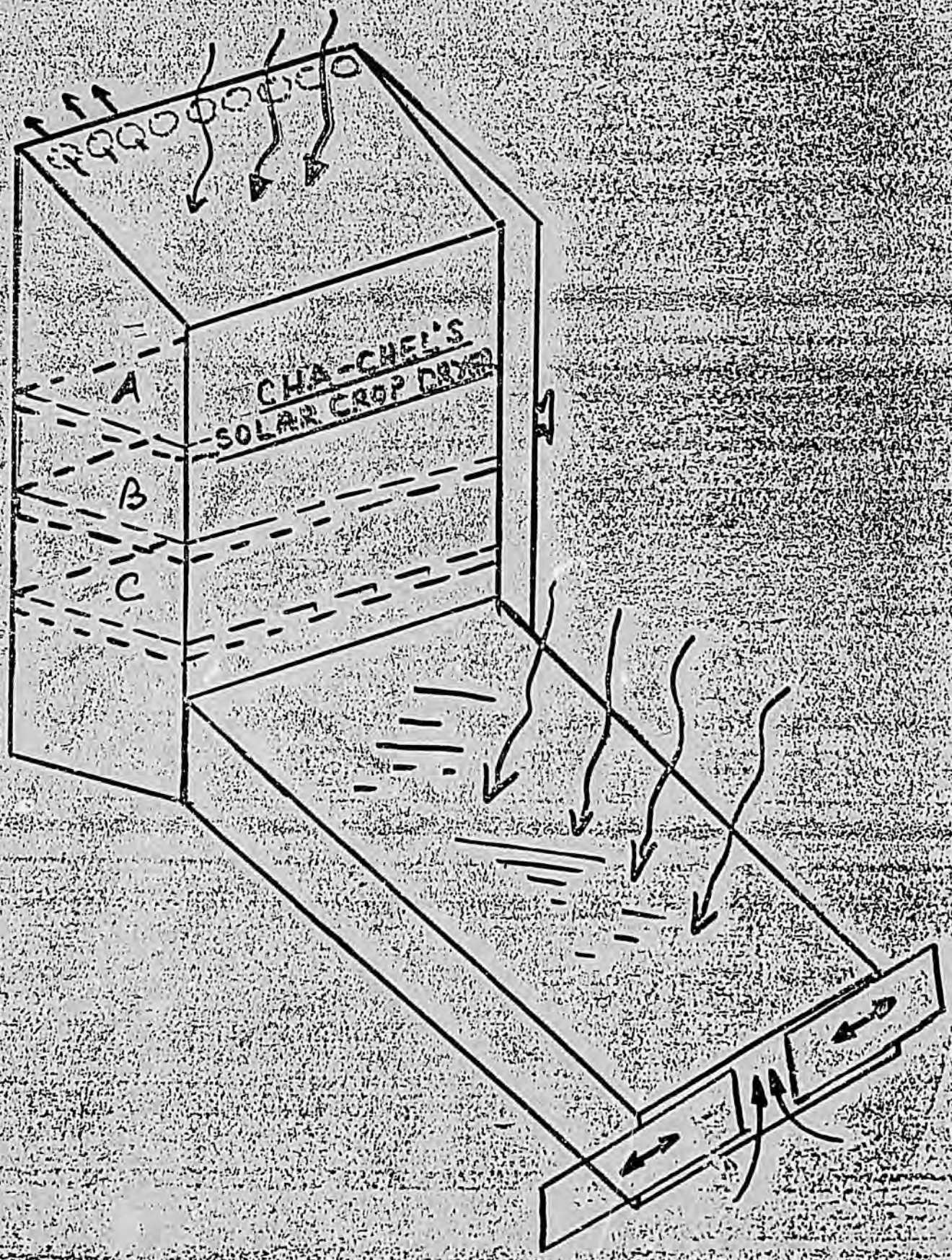

Fig 1. CHA-CHEL'S SOLAR CROP DRYER.

52
88
150
85
42
7.5

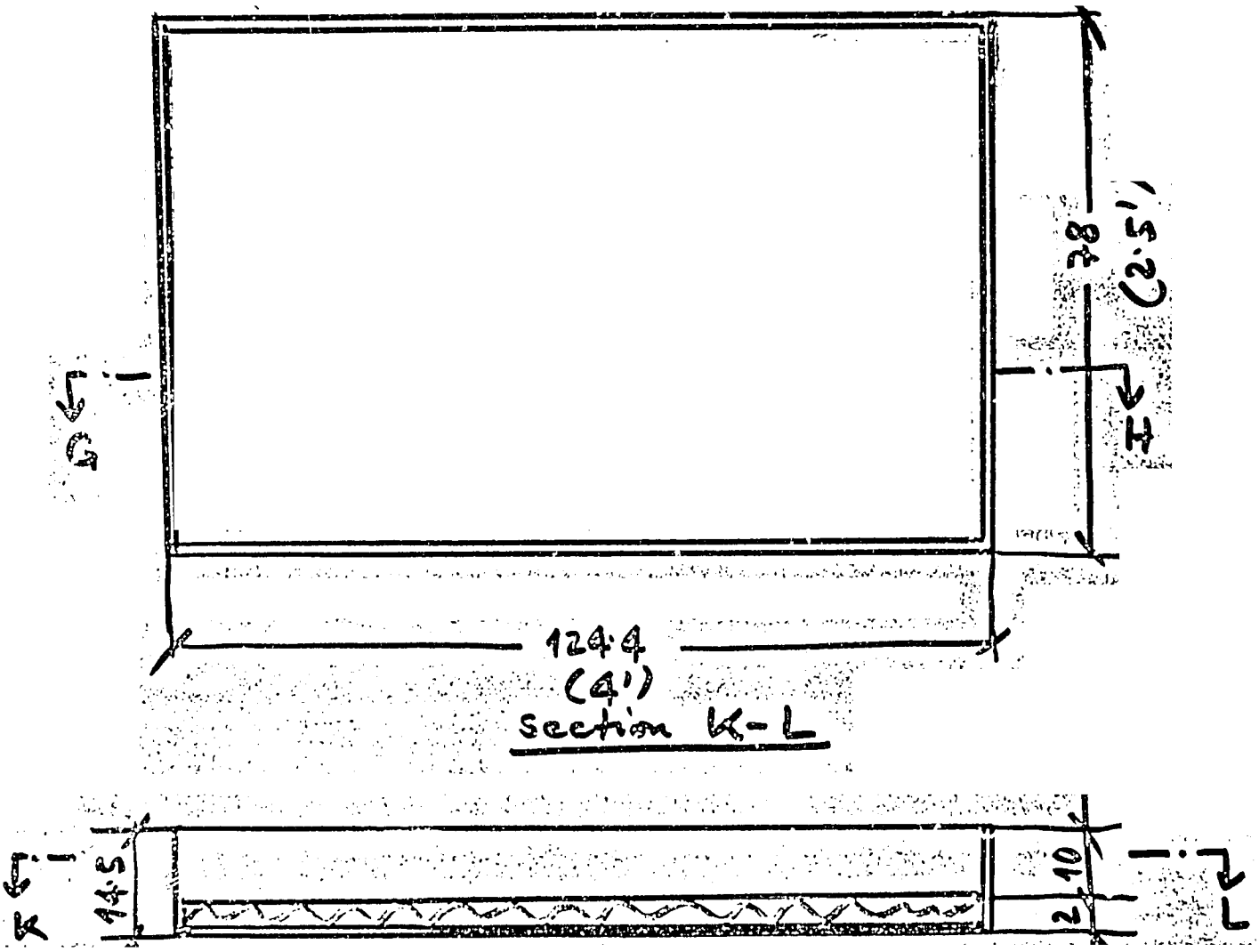

Fig. 3. Details of Collector

WEIGHTS OF CASSAVA CHIPS DRIED IN CHA-CHEL'S SOLAR DRYER

TRAYS	A	B	C	D
HOURS	(TOP)	(MIDDLE)	(BOTTOM)	(CONTROL)
9:00 AM	1000 gm	1000 gm	1000 g	1000 g
.5 11:30 AM	772	850	762	888
.5 3:30 PM	545	600	500	666
7 12:00 (Next day)	409	450	404	555
% Weight Loss in 27 Hrs	59.1 %	55.0%	59.6%	44.5%
% MOISTURE Removed	84 %	78.6%	85.1%	63.6%

Fig 4

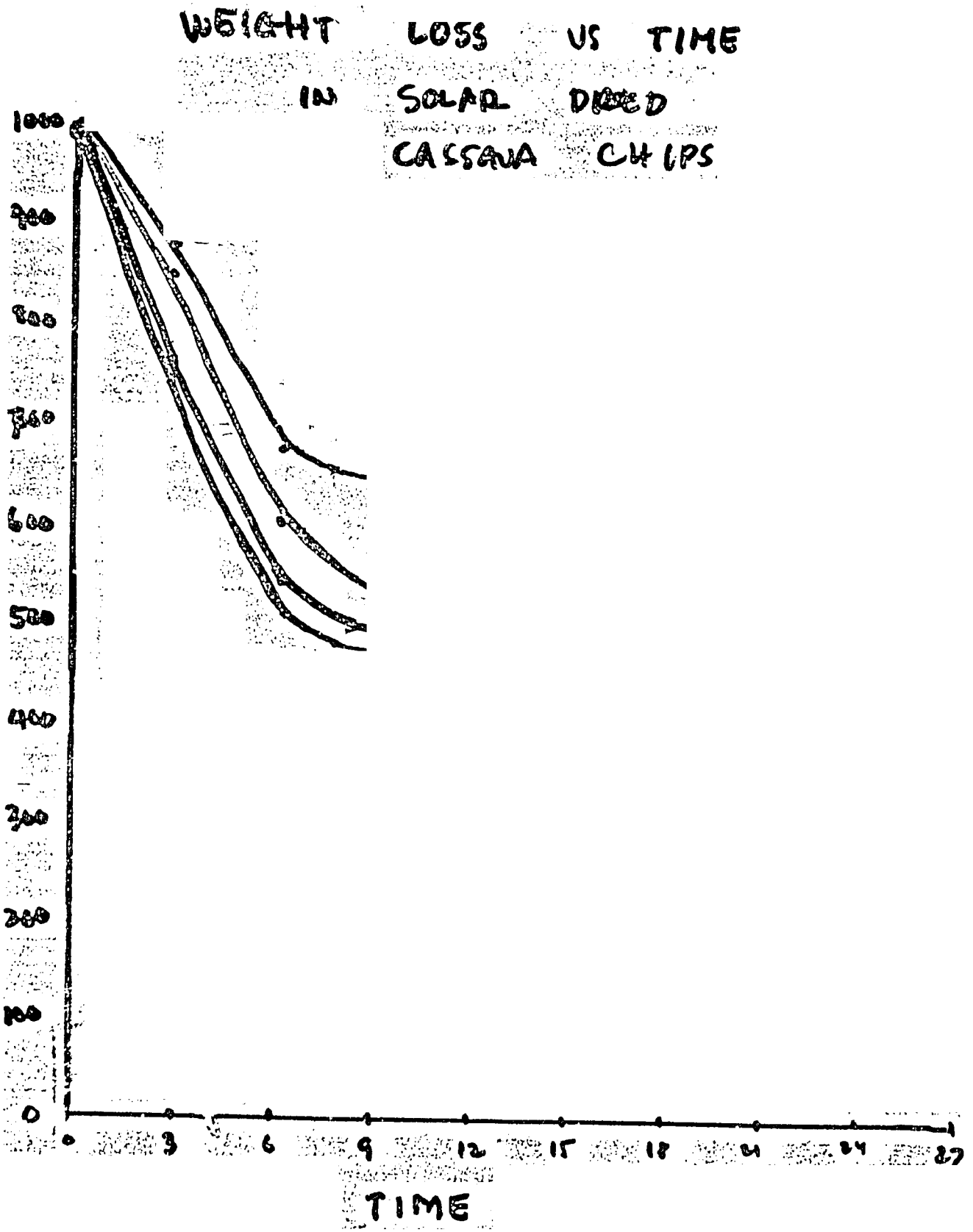

Fig 5

NIGHT

PM

AM

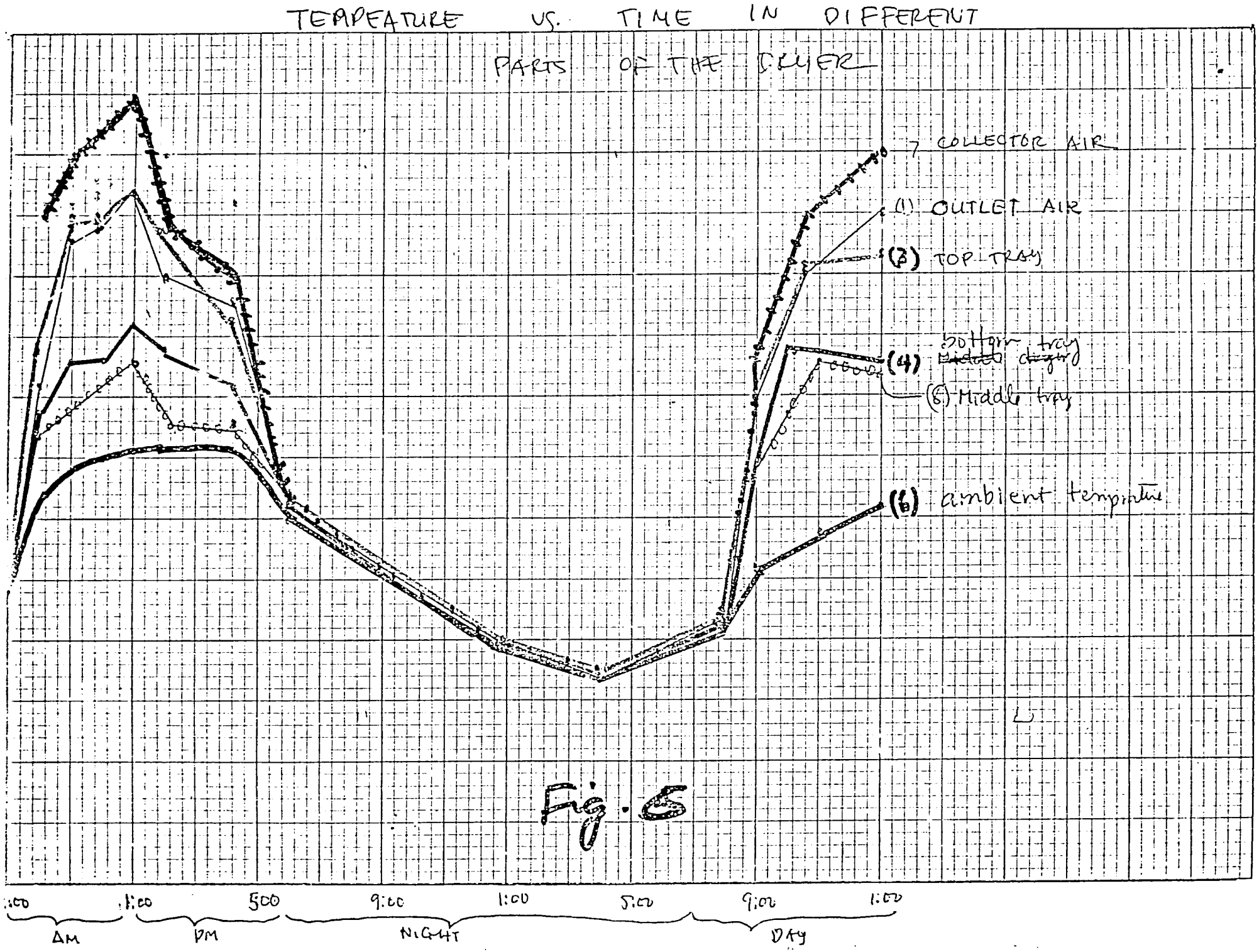
TEMPERATURE VS. TIME IN DIFFERENT
PARTS OF THE DRYER
COLLECTOR AIR
(1) OUTLET AIR
(3) TOP TRAY
(4) bottom tray
(5) Middle tray
(6) ambient temperature
1:00
1:00
5:00
9:00
1:00
5:00
9:00
1:00
AM
PM
NIGHT
DAY

Fig. 6