DESIGN FABRICATION AND TESTING OF A FOLDABLE SOLAR DRIER

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PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology in Agriculture Engineering

Faculty of Agricultural Engineering
Kerala Agricultural University

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Kelappaji College of Agricultural Engineering & Technology

Tavanur - 679 573 Malappuram

1992

DECLARATION

We hereby declare that this project report entitled **Design, Fabrication and Testing of a Foldable Solar Drier** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Tavanur,

10th Dec. 1992

Shiny Lukose

C E R T I F I C A T E

Certified that this project report entitled **Design, Fabrication and Testing of a Foldable Solar Drier**, is a record of project work done jointly by **Miss. Helen G. Varghese, Mr. Reji Emmanuel** and **Miss Shiny Lukose** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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ACKNOWLEDGEMENT

We have great pleasure to express our sense of gratitude, indebtedness and respect to **Mrs. Santhi Mary Mathew**, Assistant Professor, Department of Agricultural Processing and Structures for her professional guidance, valuable advices, constructive criticism and constant encouragement, during the course of this project, in the preparation of manuscript and in the preparation of final report.

We express our sincere thanks to **Mr. George Mathew**, Junior Assistant Professor, Department of Agricultural Processing and Structures for his help for the work.

We are grateful to **Shri. T.P. George**, Dean In-charge, KCAET, Tavanur, **Shri. K. John Thomas**, Professor and Head, Department of Agricultural Processing and Structures, **Shri. Joby V. Paul**, Associate Professor, Department of Agricultural Processing and Structures, **Shri. Sathyajith Mathew**, Junior Assistant Professor, Department of Farm Power and Machinery, for their valuable suggestions offered during the study.

We also extend our heartfelt gratitude to **Dr. K.Anilakumar**, Associate Professor, Department of Chemistry, RARS, Pattambi, for his guidance during the work. We also gratefully acknowledge the help and co-operation rendered by the workshop staff, KCAET Tavanur, especially **Mr. C.S. Krishnan**, Technical Supervisor, Workshop , KCAET, in completing the fabrication of the work.

We consider it as a pleasure to express our profound gratitude to **Mr. Jigimon T.**, Final year B.Tech (Agrl) Student, KCAET, for his sincere help and co-operation extended towards as for the completion of this work.

We are greatly indebted to all the staff members and our friends for their tireless co-operation and enthusiastic help from time to time for the completion of this work.

A word of thanks to the staff for efficient typing and prompt service of **M/s. Copy Catch**, Trichur, for the preparation of this manuscript.

At this moment we do remember our loving parents, whose help on this work we thankfully acknowledge.

Above all we bow our heads before God and Almighty for His blessings.

Helen G. Varghese

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SYMBOLS AND ABBREVIATIONS

Agrl	Agricultural
AoAc	American Association of Analytical Chemists
AMA	Agricultural Mechanisation in Asia, Africa and Latin America
°C	Degree Centigrade
cm	Centimetre
Co	Company
db	Dry basis
EMC	Equilibrium Moisture Content
ETC	Evacuated Tubular Collector
et.al	and others
g	gram
IIT	Indian Institute of Technology
ISAE	Indian Society of Agricultural Engineering
ISI	Indian Standard Institution
J	Joule
Kg	Kilogram
KW	Kilowatt
Ltd.	Limited
m	Metre
MC	Moisture Content
ml	millilitre
mm	millmetre

m^3/sec	Cubic metre per second
MJ	Mega Joule
pp	Page
Pvt.	Private
Publ.	Publishing
wb	Wet basis
%	Percentage
°	Degree
$\therefore$	Therefore
=	equal to
$\approx$	Approximately equal to
/	per

INTRODUCTION

India is a developing country where major portion of the domestic energy needs are met from non-renewable sources like fire-wood, cow dung, saw dust, rice husk and other agricultural wastes. The environmental degradation of the earth due to burning of fossil fuels, depletion of ozone layers etc. the atmosphere is getting poluted every minute. Also the reserve of fossil fuels are being consumed at a very fast rate. So source of light, oil and gasses may not last for more than 30 to 50 years. So for the survival of man-kind, we may have to shift our dependance from fossil fuel based economy to renewable energy and nuclear power based economy. But according to researches, societies will reject nuclear power because of its economics, political and environmental liabilities. The concern for economic developments among nations has drawn considerable interest to tap new and renewablle energy sources.

Man has been drying food to preserve it since the beginning of the recorded history. Drying process involves the removal of water from the material, requiring an amount of heat equal to the latent heat of vapourization of water plus a current of air moving past the surface to carry away the water vapour produced.

The sun has been used to dry food for preservation, or to increase its value, for centuries. Sun drying, the use of the sun's energy to dry agricultural produce without the use of a special structure, is the most widely practised form of drying because it s cheap, easy and convenient. The simplest method of sun drying is to lay the produce on a suitable surface in the sun.

Even though sun drying requires little capital or expertise and can produce a product of sufficiently high quality, it has many limitations

As sun drying is dependant on weather, the rate of drying can be slow and irregular, there by increasing the risk of spoilage from mould growth and de- colouration.

In humid countries the final moisture content of the product can be relatively high, which increases the risk of spoilage.

Condamination with dust and infestations by insects is likely.

Sudden rain storms can soak the produce and set back the drying process

The produce is prone to damage ie. Animals and birds can damage the produce, and direct sunlight will destroy vitamins and can remove flavour

Large land areas are required

In correctly dried produce may make further processing difficult

Drying under controlled, conditions of temperature and humidity helps the crop to dry reasonably rapidly to a safe moisture level and to ensure a superior quality of the product. To obtain a good quality product, reduce post - harvest food losses, and save labour and time, conventional fuel fired and electrically heated driers are also used in technically advanced countries, where both, combustion fuels and electric power are cheap. However, this option is not open to most developing countries because of limited availability of combustion fuels, non-availability of technology and limited crop volumes with the farmers. Under the circumstances, solar driers are the most viable option for most developing countries, especially those endowed with good solar insolation.

The energy sources which are renewable or in exhaustible such as wind energy, solar energy wave energy, geothermal energy etc. are termed as renewable energy sources. Solar energy is the illuminate source of most form of energy used now. Sun is the biggest fusion reactor known to mankind, which supplies to earth daily free of charge about ten thousand energy needed by world population.

Solar energy is a clean, non polluting non depleting energy available, almost everywhere, reaching the earth in the form of electromagnetic radiation which consists of 3% ultraviolet, 52% visible and 55% infrared. The intensity of electro-magnetic radiation is 1.94 calories/cm^2/min or 1.353 KW/m^2 on a surface normal to solar beam. The peak clear sky intensity at a horizontal surface is 1 kilowatt per square metre and integrated daily average could be as high as 6 to 8 KW/m^2 in India.

The problems with sun drying and Mechanical drying can be reduced by using a solar drier, a structure that enhances the drying power of the sun and protects the crop from dust, dirt and insect attack. The structure used can range from little more than a simple box with a polythene film over the top, to a complicated unit with solar collectors and chimneys.

Solar driers operate by raising the temperature of the air by 10 to 30°C, so reducing the relative humidity. This air then moves through the drier by natural convection. The higher temperature, the movement of air and the lower humidity together combine to increase the rate of drying. This means that the crop can be dried faster, the risk of mould growth and discolouration is reduced, dust and dirt are kept off the crop, and a lower final moisture content can be reached. Solar drying produces a higher quality product and less of the crop is lost.

For a farmer who driers large quantities of crop every year the equipment and operating costs required for drying could be economically justified But it is very difficult for a farmer having a small crop volume to afford an expensive system, that requires not only new design information but also assistance for its construction & operation. For a practically all useful device, a balance between high efficiency & low cost is always desirable.

The foldable solar drier is a simple but highly efficient unit which can help in preservation of foods through drying. This solar dryer will be invaluable to house wives in urban areas and farmers in rural areas and to small scale industries as well post harvest drying of produce in rural area for storage, preparation of raisins from grapes, drying of any other extended food products, drying papads, wafers etc. for household use or for small scale industries. Since it is a foldable device, it is easy to maintain and is convenient to keep while not in use.

"Design and Construction of a foldable solar drier and study of its performance" was undertaken with the following objectives.

a) To design a foldable solar drier.

b) To fabricate a foldable solar drier.

c) To evaluate the performance of the drier.

REVIEW OF LITERATURE

A brief description of the general drying phenomenon and solar drying, solar insulation data measuring equipments and available literature of past works done by different people are discussed here.

2.1 Drying

Generally the term drying refers to the moisture removal from a solid or nearly solid material so that an unfavourable environment is present for the growth of yeast, mould and bacteria which may cause spoilage. Therefore drying involves both heat and mass transfer operations.

According to the mode of operations drying method can be divided into conductionn drying, convection drying, and radiation drying. Radiation drying is based on the absorption of radient energy of the sun and its transformation into heat energy by the product. Moisture movement and evaporation is caused by the difference in temperature and partial pressure of the water vapour between the product and the surrounding air. The effectiveness of drying depends on temperature relative humidity of the atmospheric air, velocity of air, type and condition of the product.

A number of physical mechanisms have been proposed to describe transfer of moisture within a material, liquid movement due to surface forces (capillary forces) moisture concentration differences (liquid diffusion) diffusion of moisture through the surface pores (surface diffusion), vapour movement due to moisture concentration differences (vapour diffusion) and water or vapour movement due to total pressure differences. After completion of the surface moisture phenomenon further drying depends on the rate at which the moisture within the product moves to the outer surface by diffusion. Depending on the type of material being dried this may be slow or rapid.

Drying is one of the important unit operations in the primary processing of agricultural produce. It permits long time storage without deterioration. Extended storage periods are becoming increasingly important with the large amount of product being stored and carried over through another storage year by the Government and industry. It also permits the farmer to take the advantage of higher price a few months after harvest.

2.2 Drying Process

Drying process involves the removal of water from the material requiring an amount of heat equal to the latent heat of vapourization of water plus a current of air moving over the surface to carry away the water vapour.

The drying process is characterised by two major periods of drying, they are (1) the constant rate period (2) The falling rate period. In the constant rate period drying takes place from the surface of the material and is similar to evaporation from a water surface. The magnitude of the rate depends upon the area exposed, the difference in humidity between air stream and wet surface, the coefficient of mass transfer and velocity of the drying air.

The falling rate period is entered after the constant rate period. In this phase the rate of moisture decreases may due to migration of liquid boundary into the material with the vapour being formed moving to the surface by diffusion. The critical moisture content occurs between the constant rate period and falling rate period.

The critical moisture content is the minimum moisture content of the product that will sustain a rate of flow of free water to the surface of the product equal to the maximum rate of removal of water vapour from the product under the drying condition.

The moisture content of the product when it is in equillibrium with the surrounding atmosphere is called equillibrium moisture content. It will vary with relative humidity and temperature and may be expressed in either wet or dry basis.

2.3 Equations of Drying

Lewsi suggested that the rate of removal of moisture from a material was proportional to the difference between average moisture content and EMC of the material.

$$\frac{dm}{d\theta} = -K(M - M_e)$$

Where $\frac{dm}{d\theta}$ = rate of moisture removed

M = average moisture content of the material at a hours % (DB)

M_e - EMC of the material (%DB)

K - empirical constant

In 1949. Page determined that the falling rate period in the drying of shelled corn could just be described by the following equations.

$$\frac{M - M_e}{M_o - M_e} = e^{-K\theta}$$

Where M = Moisture content of the corn at time 0 hours (% D.B.)

M_o - initial moisture content of the corn (% D.B.)

M_e - EMC of corn (% D.B.)

K - Drying rate constant

U - empirical constant

It was found that U varies with relative humidity of drying air and K and U were not affected by initial moisture content.

According to simmonats et al. the equation is

$$\frac{M - M_d}{M_o - M_d} = e^{-K\theta}$$

Where M - M_c of the material at a hours (% D.B.)

K - Drying rate constant h^{-1}

M_o and M_d are the initial and dynamic EMC (% D.B.)

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Using Gibb's absorption empirical equation Henderson (1952) developed the following equation to express the EMC curve mathematically.

$$1 - RH = \exp(-CT M_e^n)$$

Where RH = equilibrium relative humidity in decimals

M_e = EMC (% D.B.)

T = Temperature K

c & n = product constants

Heat supplied by the drying air

$$q_a = (0.24+0.45 H_1) G^1 (t_2 - t_3) \Theta$$

Heat required for evaporation of moisture from the product

$$q_1 = W_d (X_1 - X_2)$$

Sensible heat required to raise the temperature of grain and its moisture q k cal.

$$q = W_d C_g (t_{u_2} - t_{u_1}) + W_d C_w (t_{u_2} - t_{u_1}) X_1$$

$$q_a = q_1 + q$$

$$G^1 = \frac{W_d (X_1 - X_2) + C_g (t_{u_2} - t_{u_1}) + C_w (t_u \; t_u) G}{(0.24 + 0.45 H_1)(t_2 - t_3) O}$$

$$P \times G = G^1 R T$$

G = Air flow rate m^3/minute

H_1, H_2 = humidities of ambient and heated air Kg/Kg

t_2, t_3 - dry bulb temperature of heated and exhaust air.

W_d = Total Wt of bone dry product in the drier.

X_1 & X_2 = initial & final moisture content of the product (Kg/Kg)

t_u , t_u = Initial & final product temperature °C

P = atmospheric pressure

R = specific air constant

T = atmospheric temperature

G^1 = rate of air supply Kg/min.

θ = total drying time min.

λ = Average value of latent heat of vapourisation of moisture from the product KCals/Kg

C_g, C_w = Specific heats of product & water respectively KCal/Kg°C.

2.4 Uses of Solar Energy

Solar energy could be used for

1) hot air heating
2) space heating and crop drying using solar heated air
3) solar distillation for producing potable water for human and animal consumption from brackish water.
4) solar pumps for rural irrigation

5) Energy conservation in green house design

6) solar refrigeration etc.

2.5 Status of Solar Energy in India

Only in a few places in India do we have the solar water heating units, solar drying unit and solar distillation units. Solar cells generate electricity directly when sun light falls on them. A 10KW solar power station has been constructed by Indian Institute of Technology Madras and Bharath Heavy Electricals Bhopal.

Solar energy is potentially very important for India which has a large number of villages. The use of solar energy for air conditioning and pumping may become economical soon. The large scale use of solar pumps has the potential to lower the electricity demand by 500MW. Recently a high performance solar hot water system using UTR 371 ETC has been installed at Madras. The system efficency is about 60 percent while is designed life of the tube is claimed to be ten years. The system can supply 3000 litres of hot water (80°C) per day.

Availability of solar energy is not constant. It various from region and even in the same region

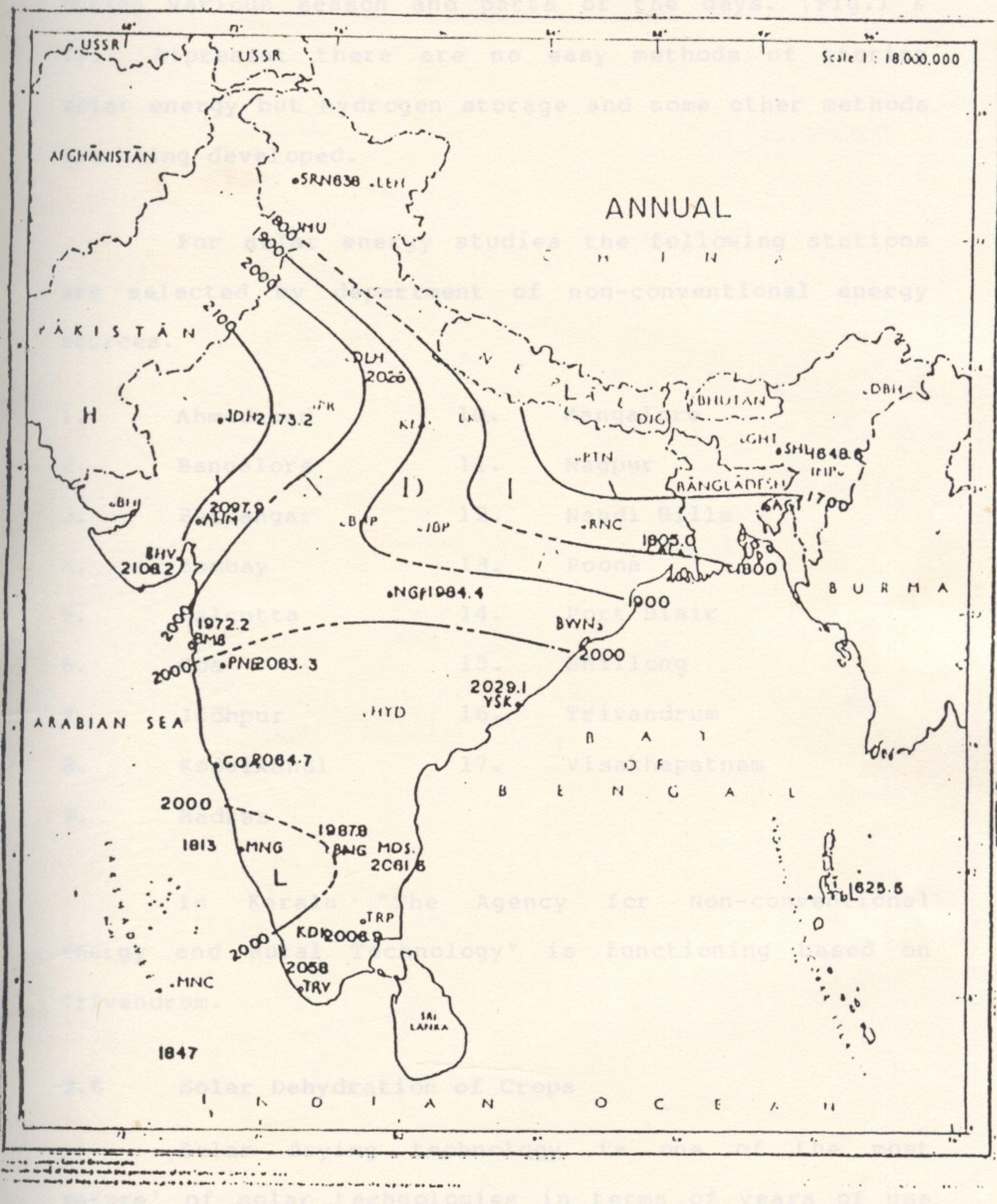


Fig. 1 Distribution of global solar radiation - Annual Unit $Kwh.m^{-1}.year^{-1}$

during various season and parts of the days. (Fig.1 & 2). Atpresent there are no easy methods of storing solar energy but hydrogen storage and some other methods are being developed.

For solar energy studies the following stations are selected by department of non-conventional energy sources.

1. Ahmedabad
2. Bangalore
3. Bhavangar
4. Bombay
5. Calcutta
6. Goa
7. Jodhpur
8. Kodaikanal
9. Madras
10. Mangalore
11. Nagpur
12. Nandi Hills
13. Poona
14. Port Blair
15. Shillong
16. Trivandrum
17. Visakhapatnam

In Kerala "The Agency for Non-conventional Energy and Rural Technology" is functioning based on Trivandrum.

2.6 Solar Dehydration of Crops

Solar drying technology is one of the most mature' of solar technologies in terms of years of use and has the potential to alleviate some of the more

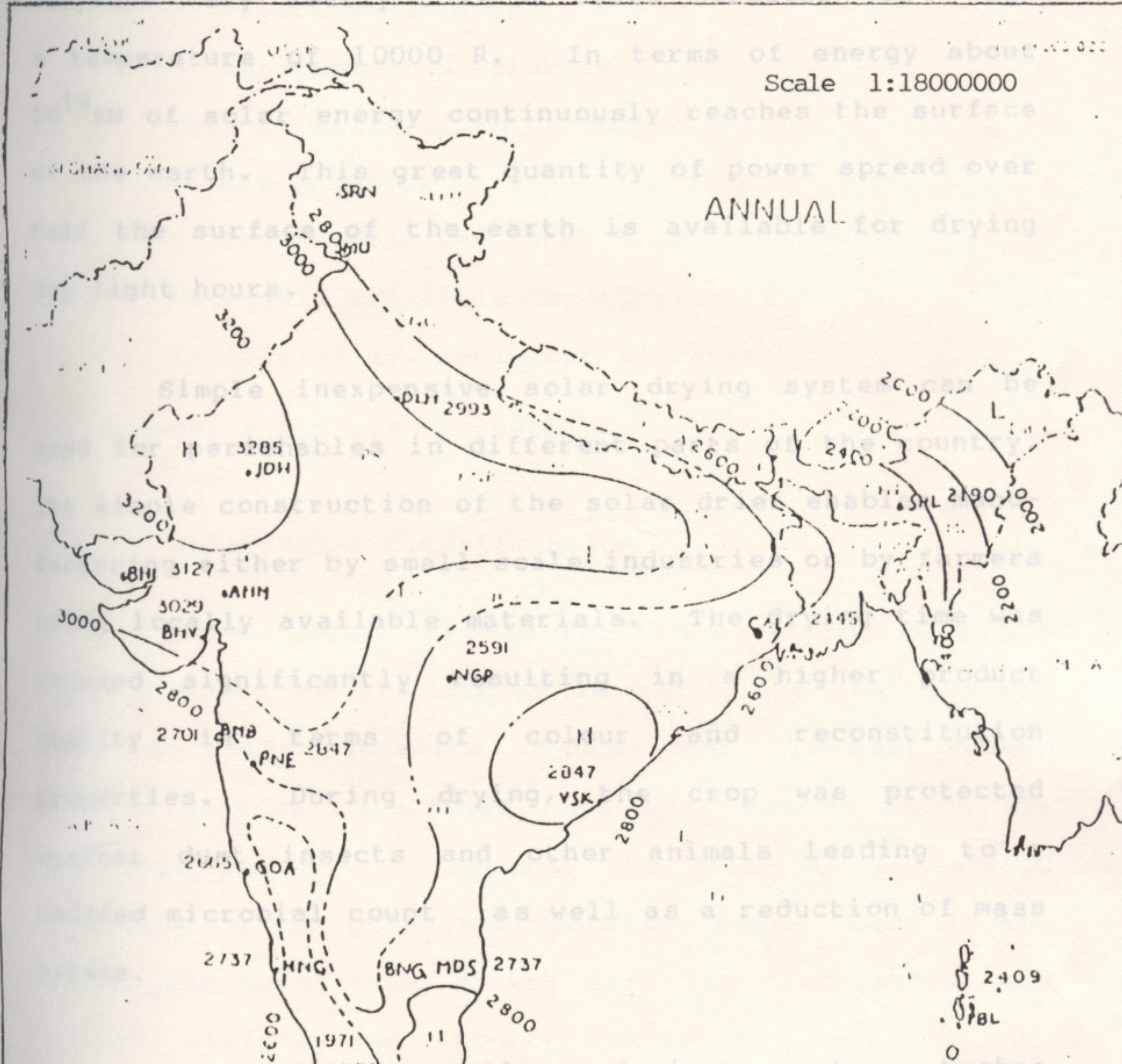


Fig. 2 Distribution of hours of sunshine (Annual)

pressing problems in developing countries. Sun radiates very nearly like a black circular disc with a temperature of 10000 R. In terms of energy about 10^{14} KW of solar energy continuously reaches the surface of the earth. This great quantity of power spread over half the surface of the earth is available for drying day light hours.

Simple inexpensive solar drying system can be used for perishables in different parts of the country. The simple construction of the solar drier enables manufacturing either by small scale industries or by farmers using locally available materials. The drying time was reduced significantly resulting in a higher product quality in terms of colour and reconstitution properties. During drying, the crop was protected against dust insects and other animals leading to a reduced microbial count as well as a reduction of mass losses.

To make a solar drying system techno economically feasible following design considerations should be taken into account.

1. Geographical location
2. Local climatic condition
   - availability of solar insolation

- variation of ambient temperature
- Relative humidity
- existing wind velocity

3. Type of material to be dried
   - Its property
   - Its initial and final M.C.
4. Materials available for construction
5. facilities available for operation

ie. natural and forced convection.

2.7 Solar Drier Classification

Solar driers are classified according to their heating modes or the manner in which the heat derived from the solar radiation is utilized. In this regard several general categories have been set up which are described below. In general the drier is classified according to its principal operating mode. Some of the direct and mixed mode driers also use circulating fans and are strictly not totally passive systems.

Passive Systems : Driers using only solar or wind energy for their operation.

Sun or natural driers : These driers make use of the action of solar radiation ambient air temperature and relative humidity and wind speed to achieve the drying process.

Solar driers - Direct : In these units, the material to be dried is placed in an enclosure, with a transparent cover or side pannels. Heat is generated by absorption of solar radiation on the product itself as well as on the internal surfaces of the drying chamber. This heat evaporates the moisture from the drying product. In addition, it serves to heat and expand the air in the enclosure, causing the removal of this by the circulation of air.

Solar driers - Indirect : In these driers solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then conducted to the drying chamber for dehydration.

Solar lumber drierss : In these forced ventilation is used. The proper circulation of air helps control the drying rate and to avoid case hardening.

Chamber drier : One in which the material to be dried in an enclosure..

Hybrid systems : Driers in which another form of energy such as fuel or electricity is used to supplement solar energy for heating and ventilation.

2.8 Different Systems of Drying

2.8.1 Radiator-Absorber type or hot box/cabinet drier

A hot drier or cabinet drier is an example of a passive solar drier. It consists of a transparent glass$ sheet or of plastic film which covers an insulated box made from cheap materials. The material to be dried is placed on a wire net or sheet netting located on a few centimetres above the floor of the box Ventilation holes are provided at the top and bottom of the box. Solar radiation is transmitted through the roof and absorbed by blackened surfaces. As the temperature rises warm air passes out at the ventilation holes by natural convection.

2.8.2 Shelf type driers

This type consists of a conventional type of solar air heater collector connected to drying chamber. The solar radiation falling on the collector plates heats up the air inside it. The warm air rises and discharges into the drying chamber. Ambient air enters through the open bottom end of the collector. Air is thus circulated by natural convection.

2.8.3 Tunnel Drier

This is active type of solar drier. It essentially consists of a solar collector for continuous generation of hot air. The other parts include an air circulating system and a drying tunnel for keeping materials. One end of the tunnel is attached to the discharge end of the air blower and the exit is provided with an insect proof screen. There is an arrangement for supporting the trays inside the tunnel in the form of shelfs.

2.9 Foldable Solar Drier

The foldable solar drier is an radiator absorber type cabinet drier. The black metallic mat finish is essential to obtain an increase in the inside temperature at faster rate. It is very simple easy to handle, requires no fan or blower, can be folded light in weight and thus is portable.

2.10 Test Samples

2.10.1 Grape

Grape is a crop of mainly warm climates and subtropical regions. The scientific name of grape is vitis vinifera. The science of grape cultivation is referred to as viticulture. India produces grapes on commercial scale in the southern states Tamil Nadu, Karnataka, Andrapradesh, Maharashtra and in the north-west regions of the country.

Some of the important varieties of grapes are Bangalore blue, Bhokri, Thmpson, and the world's largest seedless black grape variety "Black Opal Seedless". Average yield of grapes in India is about 22 tonnes/hectare and the yield of about 99 tonnes per hectare have been reported.

The pulp and juice referred as Must constitute 80 to 90% of grape while the stem skin and seeds constitute 10 to 20%. The skin contains pigment, tannins and flavour compounds. The nutritional constituent of the fruit is given in Appendix - 1.

The moisture content of ripened grape is about 85%. The raisins are produced in India either by drying the grapes in sun or by mechanical dehydration. They generally contains 10-15% moisture and are stored at room temperature 33 ± 3°C.

2.10.2 Chilly

There is Considerable International trade in chilly which is extensively used as a spice for flavouring food. Of the five recognised species of capsicum the major commercial variety is capsicum Annum and is widely used in food flavouring. This species comes under the family solanaceae. Capasaicin is the active hot principle which has several pharmaceutical uses. Composition of chilly is given in Appendix - 2.

Red ripe fruits of chilly contain higher percentage of its constituent than matural green fruits. Initial M.C. of red ripe fruit is 80 - 85% and safe storage M.C. according to ANERT is 15%. Capasium Oleoresin in concentration of 2 - 20% capsaein are now available in India.

2.11 Work done on Different types of Crop Driers

A study of application of solar heated air to the final stages of belt drying of potato from 20 - 30% moisture to 7% moisture at 100 - 150°F is described by Smith et al with reference to design and performance of solar collector and drying unit. Under favourable conditions solar power provided 58% of the energy required to dry the potatoes.

Two small scale solar driers one using natural convection and the other forced air circulation have also been described by Coleman et al. and compared for drying mangoes and muscadine grapes. The drying rate was increased when forced air circulation was used.

The construction & performance of a natural convection solar fruit drier for drying fruits and onions is described by Moyls *et*. *al*. in which a $342m^2$ plastic collector directed hot air into a drying shed when 500Kg of fruit was dehydrated in 3 - 5 days with a peak air temperature of 63°C and an air flow rate of $79m^3$/min. Presence of a 65 tonnes rock bed under the collector gave some heat storage but was detrimental to the collector efficiency and overall drying performance of the system.

Designing and construction of a solar osmotic drier is reported for use in two step osmovae dehydration of papaye by Moy *et*. *al*. Results showed that solar osmotic drying has higher drying rates and sucrose up take the samples than in non solar runs. Drying rates for solar vacuum drying was found to be twice that of non solar vacuum drying and reached the ends of the constant rate period for both in about 3 hours. Mandhyan *et*. *al*. experiments on the drying rate and constant for several winter vegetables (peas, spinach, carrot, cabbage) in sun and solar cabinet drying indicated moisture depletion with time to be a straight line function and reduction in drying time was 15 - 20%. When solar cabinet was used instead of direct sun drying.

In 1929, a rice drier was built at St. Charles Ark, operated for a short time and then abandoned. Drier was designed to recirculate all or part of the air and to limited extent control the relative humidity of the drying air. Electricity was used as a source of heat. The drier was equipped with a set of sealed whereby the weight of grain may be determined at regular intervals to determine drying progress.

Buelon and Davis (1961) worked on indirect solar drying of grains and other field crops. They showed that the essential requirement in the drying of corn and other grains by means of circulating atmospheric air through the grain bin was humidity low enough to permit vapourisation of the moisture from the grains.

Buelon (1962) found that the drying rate in glass covered air heating unit was heigher than the one without glass. It was also investigated and found out that the most desirable surfaces for solar air heating were corrugated surfaces with corrugations at right angles to the air flow.

Lewand et. al. (1966) developed and field tested the preliminary cabinet model type solar drier for drying gram and fruits.

Ghosh et. al. (1973) employed the cabinet drier principles for drying cocoa on a large scale in a glass roof drier. Thedrier was a small shed with sloping roofs oriented lengthwise along the north-south direction.

Alvero et. al. (1974) introduced a cabinet type coffee drier in colombia. He reported that in general a cabinet type drier reduced the drying period by one half in comparison to open air driers. Improved product quality in some cases was an additional benefit.

Biswas et. al. (1974) reported that the south facing collector, oriented at an angle of the lattitude of the placed, received the maximum heat and hence gave better heat performance. He further observed that the main advantage of solar drying was in the economic benefits through saving of fuels. Also it was easy to operate and required only unskilled persons.

Mathew et. al (1975) had reported that the loss of volatile oil is as high as 20 percent during sun drying. The oil obtained from sun dried samples was rated flat devoid of the lemong note.

Niles, P.W. et.al (1976) designed and studied the performance of an air collector for industrial crop dehydration. Experiments were conducted for the glazed and unglazed solar collectors used to heat air to 200°F ranges. The collectors were made of standard black painted metal decking and they were tested in various conditions. So that pressure drops and constant heat transfer rates could be varied inddependent of collector operation temperature.

Osborn et.al. (1976) developed a solar collector modelling technique for grain drying application. A computer routine to calculate the performance of low temperature solar collectors was discussed. The programme utilised red or simulated solar flux data, collector geometry, air flow rate and environmental data. They computed temperature and expected energy as a function of time of day.

Seblag et.al. (1976) has a detailed study of solar collectors. They have compared four different types of solar collectors which were used for crop drying, green house heating & heating animal shelter.

Peterson (1977) reported that by coating the stool walls of grain storage bins with black paint the glazing it with a semi-rigid or an inflated plaste sheets the temperature increased in the range of 40°C to 90°C with an efficiency range of about 63.9% to 57.5%.

Fobr J.P. et.al (1979) developed a grape drier in which a fan and a few square meters of plastic film can constitute an efficient solar collector which can increase air temperature by about 20°C. The drier composed of a few trays stacked in a wooden shed. In order to obtain a regular flow through the trays the shed is placed in front of the fan.

Two models of a new low cost easy to fabricate small scale solar drier using the principle of parabolic reflector to increase radiation on the product to shorten the drying time were developed and used by Wagne et.al (1979) for dehydration of grapes, mangoes, peaches, and mushroom to give products comparable with other solar dried or conventional hot air dried ones.

Excel *et.al.* (1980) developed a batch type solar drier of capacity ½ to 1 ton. In this drier heated air rose by natural convection through the grains and affected drying. The major design importance was that only locally available materials were used for its construction and it was found effective even during the wet season in tropical climates. Besides drying rice it was also found suitable for other agricultural products as banana, maize, beans, coconut, chilly, cassava, pepper, corns, coffee, cocoa, shrimps, fish etc.

The performance studies on an improved solar cabinet drier was conducted by Pande, P.C. (1980). This was conducted with an improved solar cabinet drier having a chimney and a regulating valves. 17.5kg of grain could be dried in 5 days from 80 to 6.8 moisture content percentage (W.B.)

Ezekev, C.I. (1981) designed a solar air heater in tropical Nigeria for crop drying. Three important crops, cocoas, beans, rice and cassava, are dried in direct insolation and forced convection driers. A mathematical model based on the heat and mass transfer balances coupled with a tin layer drying equation was used to predict the moisture content of the products. The experimental results and theoritical results were found quite coinciding.

A low cost solar rice drier suitable in wet seasons in Asian Countries was designed by Keshri,J.R. et.al. (1981). The experimental solar drier was one tonne capacity with in $0.5m^2$ rice bed area and $34.5m^2$ collector area. The drier used the combined heat of solar radiation incident directly on the material and air passing by natural convection from the solar heater. The presence of a chimney 2.0 meter fall having equitriangular cross sectional area of $0.5m^2$ was found to double the air flow.

Clark,S. (1982) designed a solar food drier for Bangladesh the design was based on rural fruit and vegetable drying inclustries of Bangladesh.

Tiny and Shove (1982) developed a simpler means of direct calculation of a collector's daily efficiency based on its design parameters. Functional relationships were developed for calculating daily efficiency directly from the design parameters of single cover, flat plate, ambient air heating solar collectors. The materials of cover and absorber plates considered in the study were tedlar coated fibreglass and black painted plywood respectively.

Carbanell, J.V. (1983) made a prototype of solar drier and evaluated the performance of the flat plate collectors. A prototype of solar drier which incorporate the desicant bed for energy storage was described.

Walpita et.al. (1984) proposed solar energy as an alternative source for drying sheet rubber in order to reduce the cost of drying and also to improve its quality.

Arora and Sebyhal (1985) sundried freshly harvested paddy on different types of floors namely concrete, kacha, black polythene, white polythene and canvas. Results of drying studies, milling tests and cost analysis for different floors revealed that black polythene was the best surface for sundrying of row paddy.

Njai et.al. (1986) investigated the use of solar tents for crop drying using low cost locally available materials to prevent infestation & reduce losses. Problem with driers eg : difficulty of obtaining polythene, durability of the materials used & research methods are discussed. The results obtained were encouraging temperature inside the driers were high enough to kill micro organisms, the quality of the dried product was good.

Malaviya and Gupta (1987) developed a cabinet drier natural convection solar drier with chimney for drying chillies. They kept 2.5kg of chillies with 80% initial moisture content in each case ie. cabinet type natural convection solar drier with chimney and solar cabinet drier without chimney. Temperature in the drying box was kept within the safe limit (50°C ± 5°C) by partially covering the glass of drier with white plastic sheet Chillies from 80% moisture content to 6% moisture content reduced in four days in convection drier with chimney & it tool 6 days in cabinet drier without chimney during the month of March. Quality of drying and stress concentration at the surface of chilly was better in natural convection drier.

Thanvi et.al. (1989) described the design details and performance of an inclined solar drier for maximum energy capture which can be used for dehydrating 30kg of fruit & vegetables. In a field tests, the moisture content of chillies was reduced from 82% to 7.2% within 5 - 6 days. The efficiency of the drier is about 13%.

Devi Ajayambica,S.J. <u>et.al</u>. (1990) developed a mechanical ginger drier in Tavanur using agricultural waste as fuel. Their results show that sliced ginger of 0.5cm thickness dried at 60°C with an air velocity of 1m/min for 4 hours with an oleoresin yield of 7.85% gives high quality ginger.

Kamilov <u>et.al</u>. (1990) developed a radiation convection solar energy unit which consists of an air heater and accumulator & a drying chamber. The drying chamber is a wooden cabinet with trays inside, arranged in 4 tiers. The temperature in the drying chamber is 55 - 60°C and air velocity of 0.6 - 1.3m/s. Results of the tests showed that the drying time in comparison with natural drying is 1.2 to 2 times shorter & drying quality is higher. The unit can be used in field conditions.

Rossello C et.al (1990) of university of Illes Balears developed two twin forced convection driers of $1.5m^2$. They are of mixed kind with solar air collectors and a green house type chamber. A wooden frame supports polycarbonate walls. After two years operation they have been proved weather resistant six solar air collectors 2.12x1.05m were used in each drier.

Shrivastava et.al. (1990) designed a low cost solar cabinet type drier with overall dimensions of 1450 x 1460 x 805mm to dry 25kg of chillies. The total solar collector area is $1.17m^2$ and the drying cost is Rs. 23.32/d comparative studies on the effect of bed thickness showed that drying time increases with increase in bed thickness which the moisture content reduction pattern for any bed thickness is similar. Drying time was found to be half that of sun drying.

Hashim Abdulla, P.A. et.al. (1991) designed & tested a solar cabinet drier for spices. They found that the oleoresin content of 5cm length and 2.5cm length of ginger at 12% moisture content were 7% and 6.7% respectively. From the test results it can be concluded that the sliced samples of 5cm length dried at 61°C for four days. The traditional methods of drying takes normally 8 - 10 days to attain this safe storage moisture level.

MATERIALS AND METHODS

This chapter deals with the design location, materials of construction, fabrication and testing of the foldable solar drier. The determination of moisture content, oleroresin (content of chilly and quality test for grape) are also described here.

3.1 Solar Dehydration

The unit consists of a main body, foldable sides, product loading tray and top inclined frame with polythene sheet. The drier box was provided with four rows of holes, two rows on each longer side.

3.2 Design of the Drier

3.2.1 Calculation of Heat Requirement for Drying

Assumptions :

The temperature of the grape after drying	=	Exhaust air temperature T_e
The temperature of the grape at the drier inlet	=	Ambient temperature, T_i
Amount of grape to be dried	=	10 kg
Initial moisture content of grape	=	85%
Final moisture content after drying	=	15%

Ambient temperature	=	30°C
Temperature of the grape during drying	=	50°C

Heat load of the grape was calculated from the following formulae,

$$Q = W\, C_{pf}(T_e - T_i) + W_{mi}\, C_{pw}\, (T_e - T_i) +$$

$$W(m_i - m_e)\ T_{av}$$

where Q = heat load of grape, k cal

C_{pf} = specific heat of wet grape = 0.93 kcal/kg (Assumed)

W = weight of the grape = 1.5 kg

W_{mi} = weight of the moisture = 8,5 kg

C_{pw} = specific heat of water = 1 Kcal/kg

m_e = weight of moisture finally retained

= 0.2647 kg

$$T_{av} = \frac{T_e + T_i}{2} = \frac{50 + 30}{2} = 40°C$$

T_{av} = Latent heat of evaporation of water

= 600 kcal/kg

$$Q = 1.5 \times 0.93\ (50 - 30) + 8.5 \times 1\ (50 - 30)$$

$$+ 1.5(8.5 - 0.2647)600$$

= 7609.67 kcal

= 31.96 MJ

q = Rate of extraction of energy to load

$$q = \frac{31.96 \text{ M.J} \times 1000}{35 \times 3600} = 0.2536 \text{ kJ/sec}$$

(Effective drying time is taken as 35 hours).

M = Mass flow rate kg/sec

$$M = \frac{q}{C_p (T_e - T_i)}$$

C_p = 1.01 kJ/kg°C

T_e = 50°C

T_i = 30°C

q = 0.2536 kJ/sec

$$\therefore M = \frac{0.2536}{1.01 \, (50 - 30)} = 0.01256 \text{ kg/sec}$$

The volume of air needed for drying can be calculated using the formulae,

$$PV = MRT$$

P = atmospheric pressure = 101.3 kPa

V = volume of air needed for drying m^3/sec

R = specific air constant

= 0.291 kPa m^3/kg K

T = atmospheric temperature = 303 K

$$\therefore V = \frac{M R T}{P}$$

$$= \frac{0.01256 \times 0.291 \times 303}{101.3} = 0.11 \text{ m}^3\text{/sec}$$

Assuming velocity as 1.2 m/sec

$$\text{Area} = \frac{V}{\text{Velocity}} = \frac{0.011}{1.2} = 9.11 \times 10^{-3} \text{ m}^2$$

Providing 240 holes,

Area of one hole $= 3.78 \times 10^{-5}$

Diameter of one hole $= \sqrt{\underline{3.78 \times 10^{-5} \times 4}}$

$= 6.95 \times 10^{-3}$ m

7 mm

=====

3.2.2 The Required Air flow

As per assumptions the designed drier will dry 10kg of grape from an initial moisture content of 85% (W.B.) to a final moisture content of 15% with ambient air temperature at 30°C. Also the air is heated to 50°C in the solar drier. Calculations show that the air flow rate required is about $0.011 m^3/sec$.

We also expect the drying to be complete within five days of 8 effective sun shine hours each.

3.2.3 Area of the Solar Drier

In order to determine the area of the drier required to collect sufficient solar energy to dry the grape we must know the heat load of grape = 31.96 MJ the rate of extraction of energy to load = 0.2536KJ/sec.

Taking daily average global radiation as $80 mw/cm^2 = 800\ J/sec\ m^2$ and assuming the efficiency of the drier as 20%. The amount of heat provided by the drier per unit area is therefore estimated to be $800 \times 0.2 = 160$ J/sec m^2

$$\therefore \text{Drier area} = \frac{253.6}{160} = 1.585 m^2$$

with practical consideration the solar drier was given an area of $1.5m^2$

Five trays are provided to accomodate 10Kg of grape.

3.3 Location

The project was done in Kelappaji College of Agricultural Engineering & Technology Tavanur, Malappuram in Kerala. The place is situated at 10°53'30" North latitude & 76° East longitude.

3.4 Detils of the system

3.4.1 Main body

The main body was made from 1.2mm thick aluminium sheet and the size is 1500 x 1000 x 300mm. Its bottom is insulated with 10mm thick thermocole sheet.

The foldable sides are made of aluminium angle with measurement of 25mm x 25mm x 2mm. The outside of the frame was covered with 1.2mm thick aluminium sheet. The foldable sides are fixed on the main body in such a way that one side should be fixed above 38mm above the base and another one 76mm. The angle fixed on the folding side supports the product loading tray during drying.

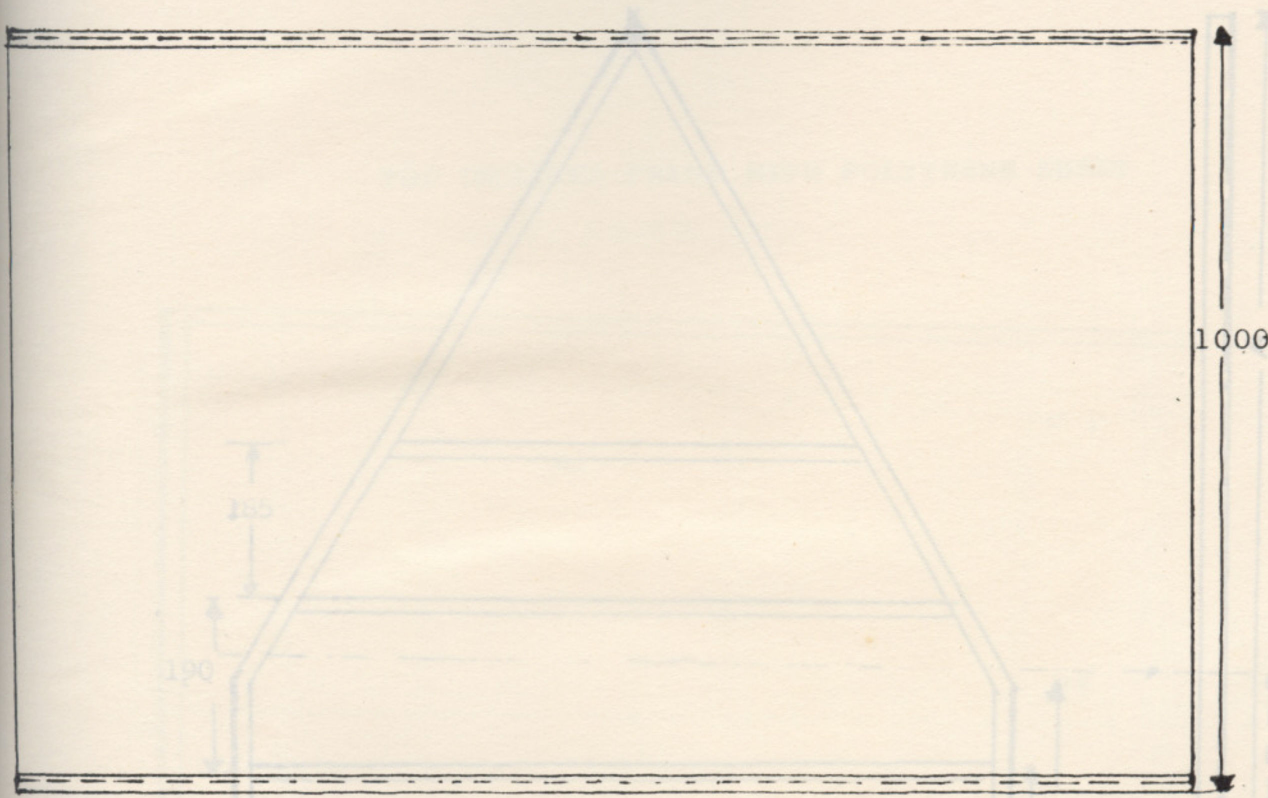
3.4.3 Top inclined frame with polythene sheet

It is a 25mm x 25mm x 2mm aluminium angle frame 1495mm x 990mm in size. This frame is divided into two sections with wooden reaper fixed at a height of 300mm. Thhis was covered with 1495mm x 300mm, 1.2mm thick aluminium sheet Remaining Portion is covered with 400 gauge polythene sheet. The frame is inclined at 60° from the horizontal.

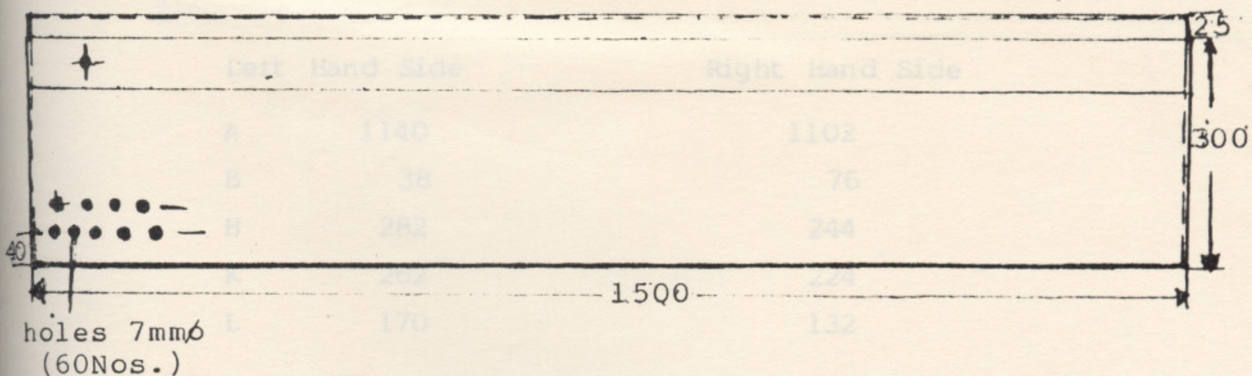
3.4.4 Product Loading Tray

Five trays were made from aluminium angle and nylon wire mesh. Main frame of those trays were made out of 25mm x 25mm x 2mm aluminium angle with three supports. These trays were placed in three levels, two at bottom, two at middle and one at top. The size of bottom trays were 148 x 440mm middle trays - 1480x4001480x400mm and that of top tray is 1480x550mm.

MAIN BODY



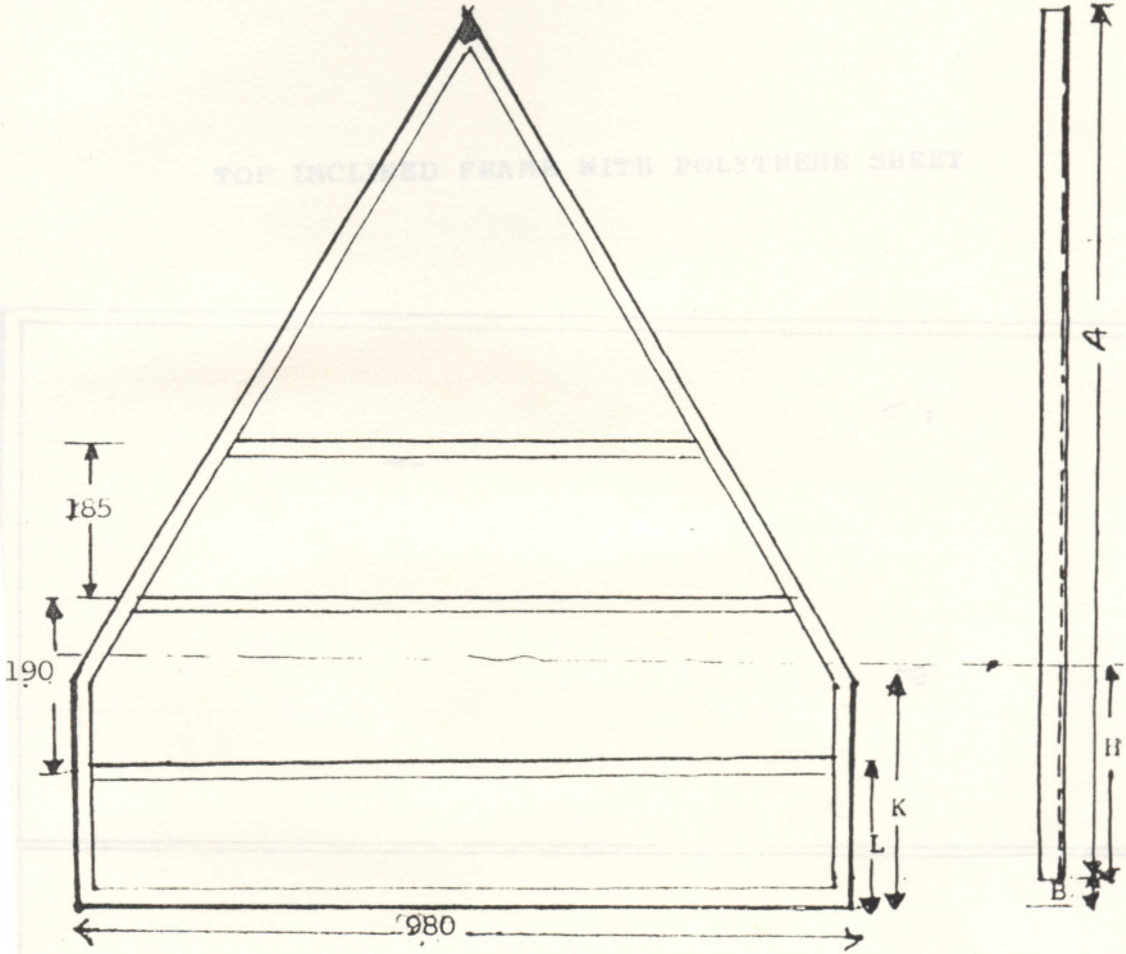
PLAN



ELEVATION

Fig. 3(a)

FOLDABLE SIDE



Left Hand Side		Right Hand Side
A	1140	1102
B	38	76
H	282	244
K	262	224
L	170	132

Fig. 3(b)

TOP INCLINED FRAME WITH POLYTHENE SHEET

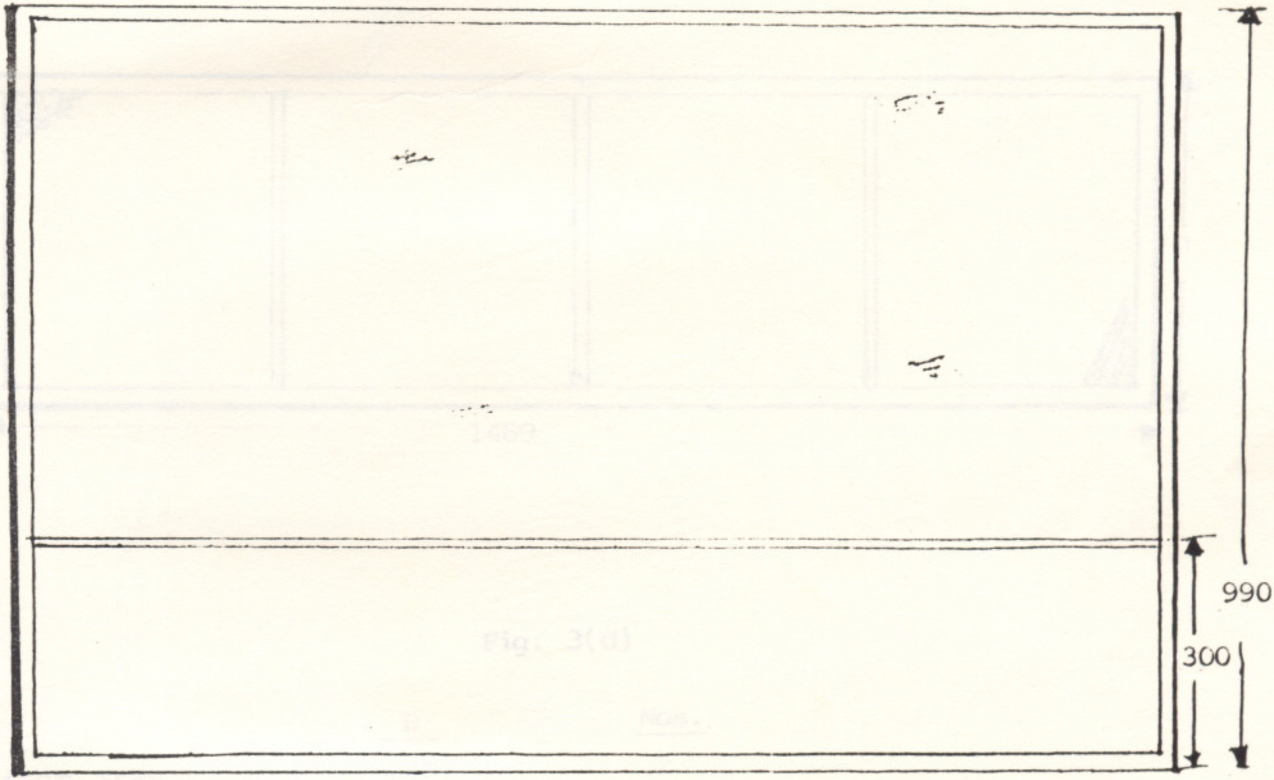


Fig. 3(c)

PRODUCT LOADING TRAY

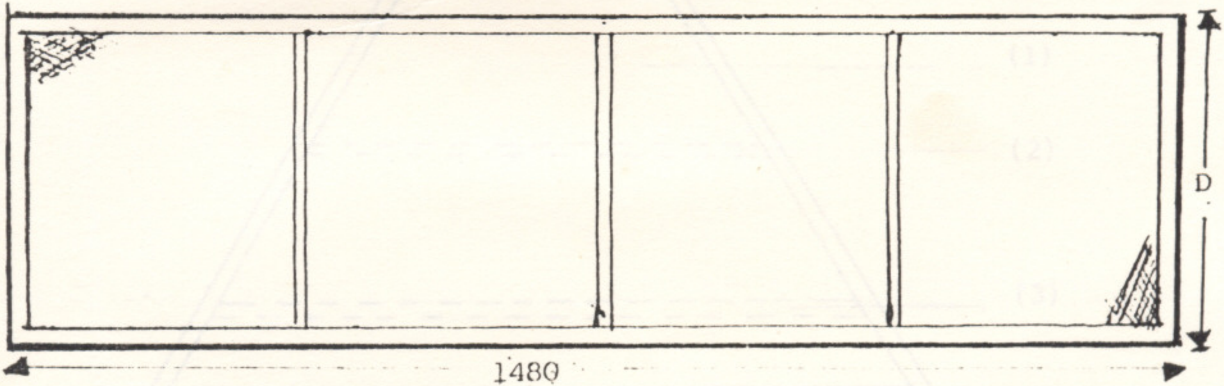
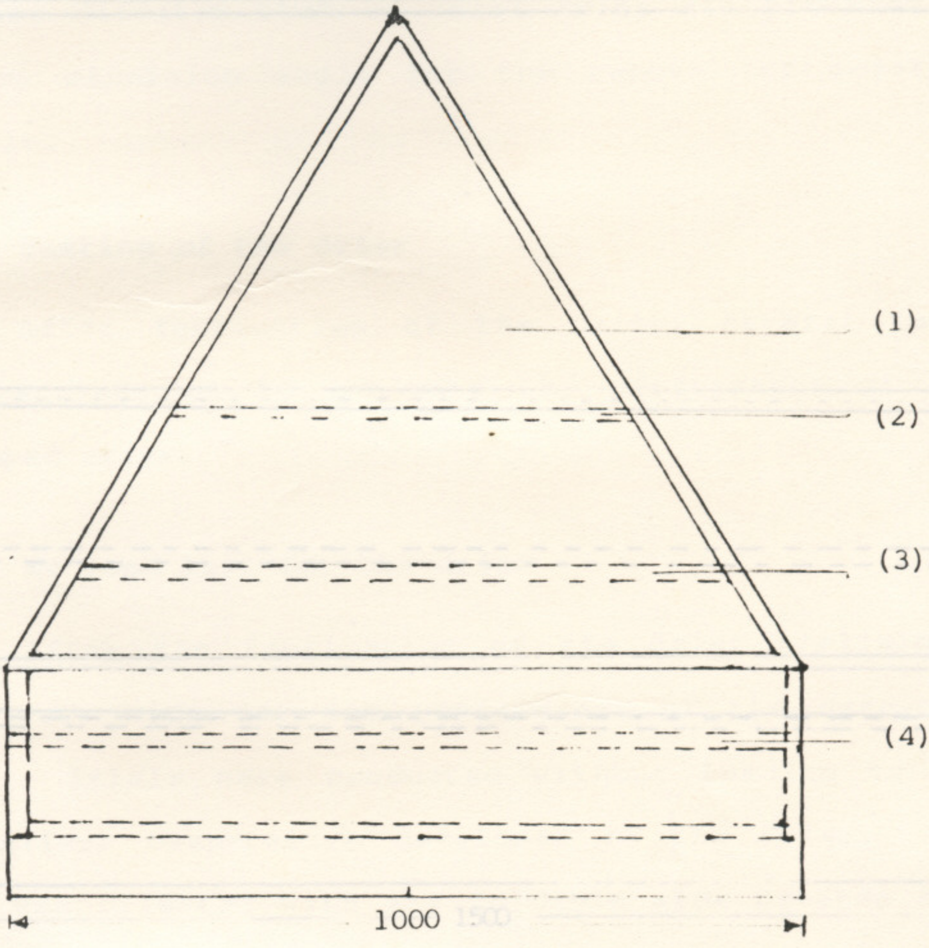


Fig. 3(d)

	D	Nos.
Bottom Tray	440	2
Midddle Tray	400	2
Top Tray	550	1

FOLDABLE SOLAR DRIER ASSEMBLY

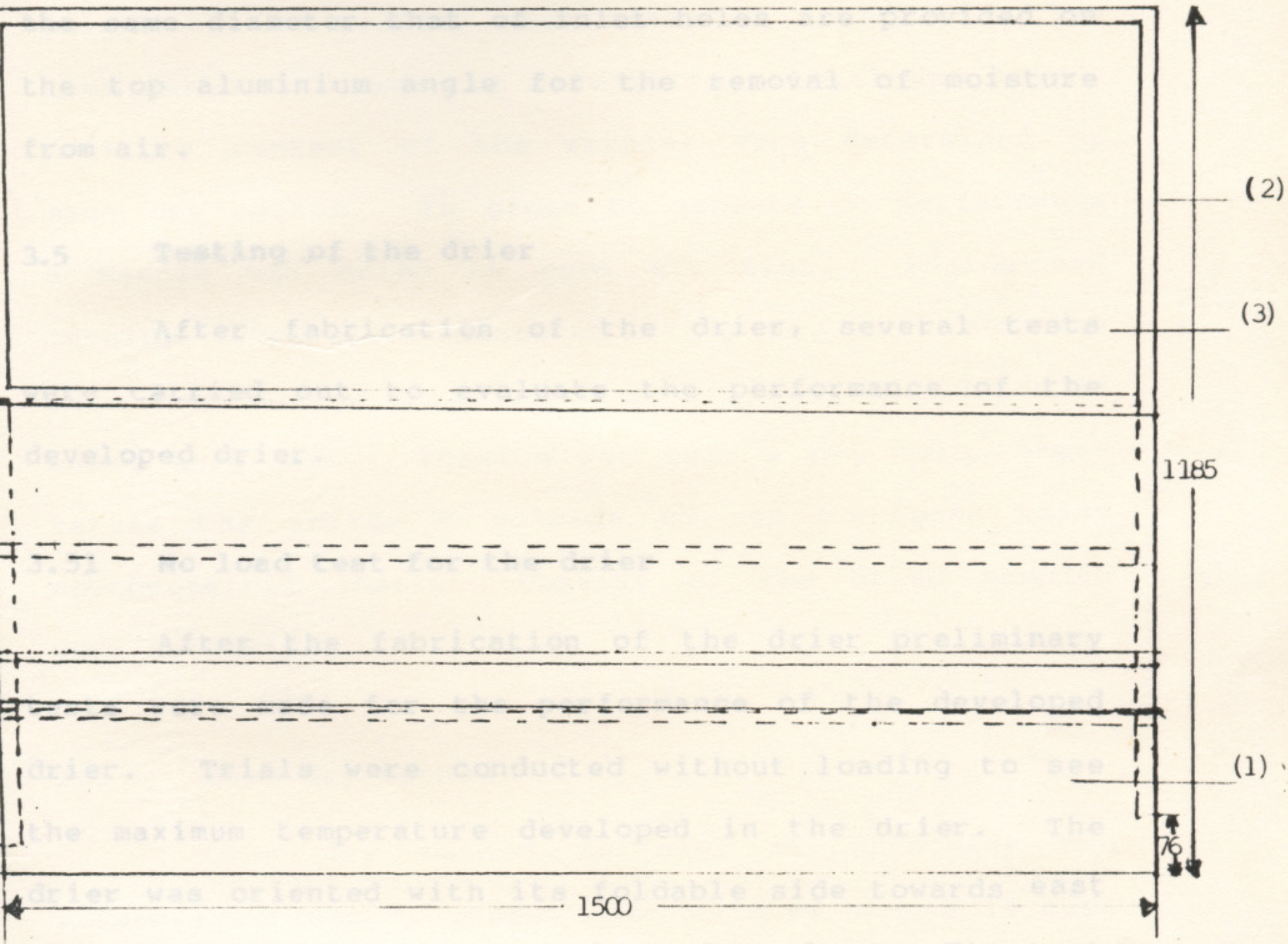


SIDE VIEW

Fig.3(f)

1. Foldable side - Right hand
2. Product loading tray - Top
3. Product loading tray - Middle
4. Product loading tray - Bottom

FOLDABLE SOLAR DRIER ASSEMBLY



Front View

Fig. 3(e)

1. Main body
2. Foldable side - Right hand
3. Top inclined Frame with Polythene sheet

3.4.5 Inlet and outlet holes

The inlet holes were made 40mm high from the bottom level measuring 7mm diameter and 120 numbers on each longer side. Outlet holes of 30 nos. having the same diameter that of inlet holes are provided on the top aluminium angle for the removal of moisture from air.

3.5 Testing of the drier

After fabrication of the drier, several tests were carried out to evaluate the performance of the developed drier.

3.51 No load test for the drier

After the fabrication of the drier preliminary tests were made for the performance of the developed drier. Trials were conducted without loading to see the maximum temperature developed in the drier. The drier was oriented with its foldable side towards east and the polythene sheet was kept dust free. The test was performed from 9 a.m. to 5 p.m. on clear sunny day. The inside and outside temperature were measured by using thermometers and solar flux incident on the drier was measured using suryamapi by keeping the one centimeter sensor of the meter in such a way that the sunlight falls directly on the sensor.

3.5.2 Sample Test

Grape & Chilly procured from the local market were used for the testing of the fabricated drier. The tray was loaded with the weighed samples and weight of the samples were taken at intervals. The time taken to reach the safe storage level was noted. Moisture content of the samples were determined by even dry method. In order to compare to performance a sample was dried in open air also. Inside and outside temperature measured using dry bulb and wet bulb termometers & solar flux incident on the drier using suryamapi. Knowing wet bulb & dry bulb temperature the inside & outside RH can be found using psychrometric chart. Quality of the dried samples were determined.

3.6 Oven dry Method

Oven dry method is used to determine the moisture content of grape. The weighed sample is kept in an oven at 110°C for 12hrs.

The moisture content on dry basis = $\frac{W_1 - W_2}{W_2} \times 100$

Moisture content on wet basis $\frac{W_1 - W_2}{W_1} \times 100$

Where W_1 and W_2 are the initial and final weight of the sample.

3.7 Toulene Distillation Method

Toulene distillation method is used to determine the moisture content of chilly. The toulene distillation method using Dean Stark apparatus as per AOAC method was used.

100ml toulene was added to a round bottomed flask which contain 25gm of sample and attached it to the Dean Stark apparatus with Feflux Condensor. The flask is heated with heating mantle. On boiling the water vapour distilled from the flask came out and condensed and it was collected in the apparatus. Distillation was continued till the volume of water collected in the apparatus was constant. The apparatus was cooled and the volume collected was noted. The moisture content of the sample was calculated by moisture content % (W.B.) = $\frac{V}{W} \times 100$

Where V = Volume of water collected in ml.

W = Weight of the sample taken gm.

The apparatus is shown in fig. 4.

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The apparatus is shown in fig. 4.

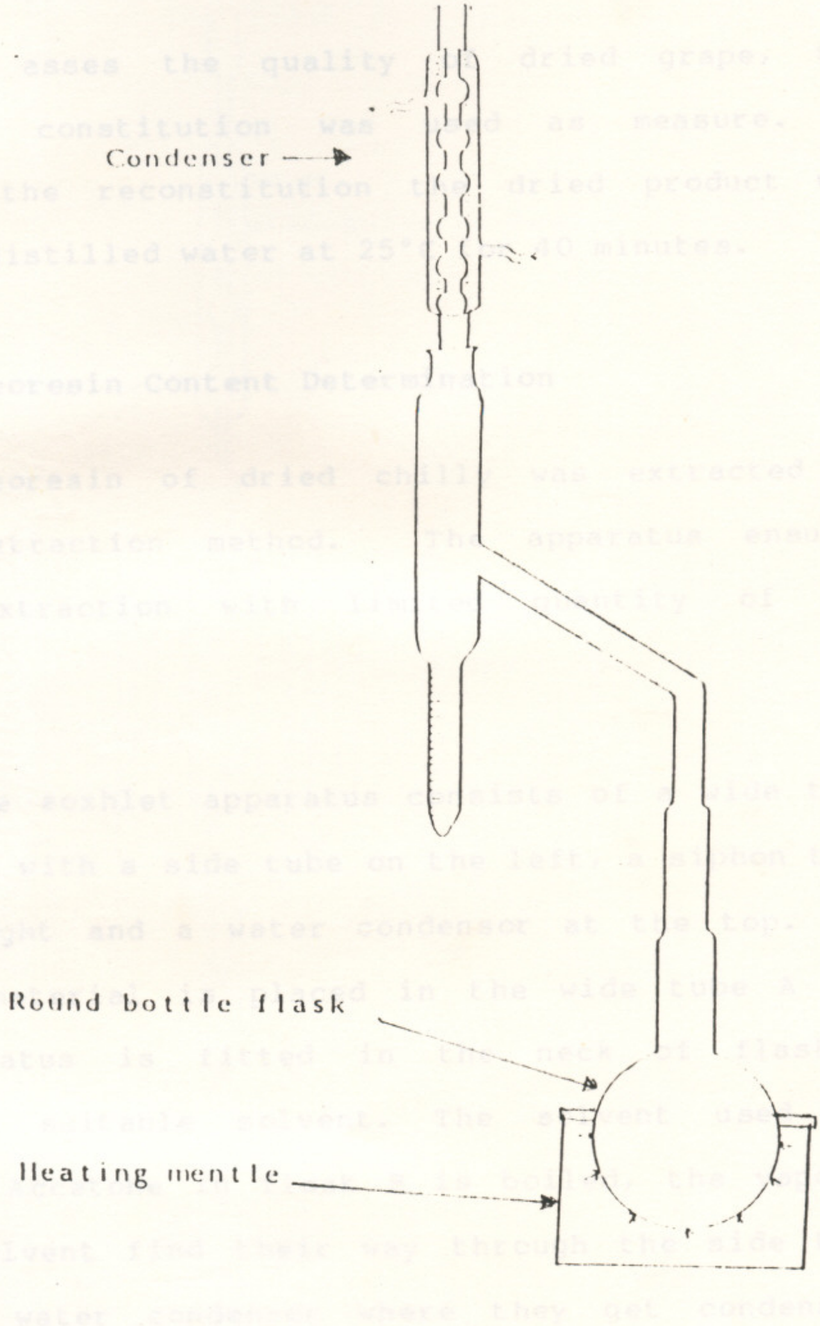


FIG. 4 DEAN STARK APPARATUS

3.8 Quality Test for Grape

To asses the quality of dried grape, the extent of constitution was used as measure. To determine the reconstitution the dried product was soaked in distilled water at 25°C for 40 minutes.

3.9 Oleoresin Content Determination

Oleoresin of dried chilly was extracted by soxhlet extraction method. The apparatus ensures maximum extraction with limited quantity of the solvent.

The soxhlet apparatus consists of a wide tube A provided with a side tube on the left, a siphon tube on the right and a water condensor at the top. The powdered material is placed in the wide tube A and the apparatus is fitted in the neck of flask B containing suitable solvent. The solvent used was accetone. Accetone in flask B is boiled, the vapours of the solvent find their way through the side tube into the water condensor where they get condensed. The droplets of the condensed not accetone fall on the powdered Chilly placed in the wide tube & dissolve out the soluble constituent from it. The level of the solution goes on rising till the siphon begins

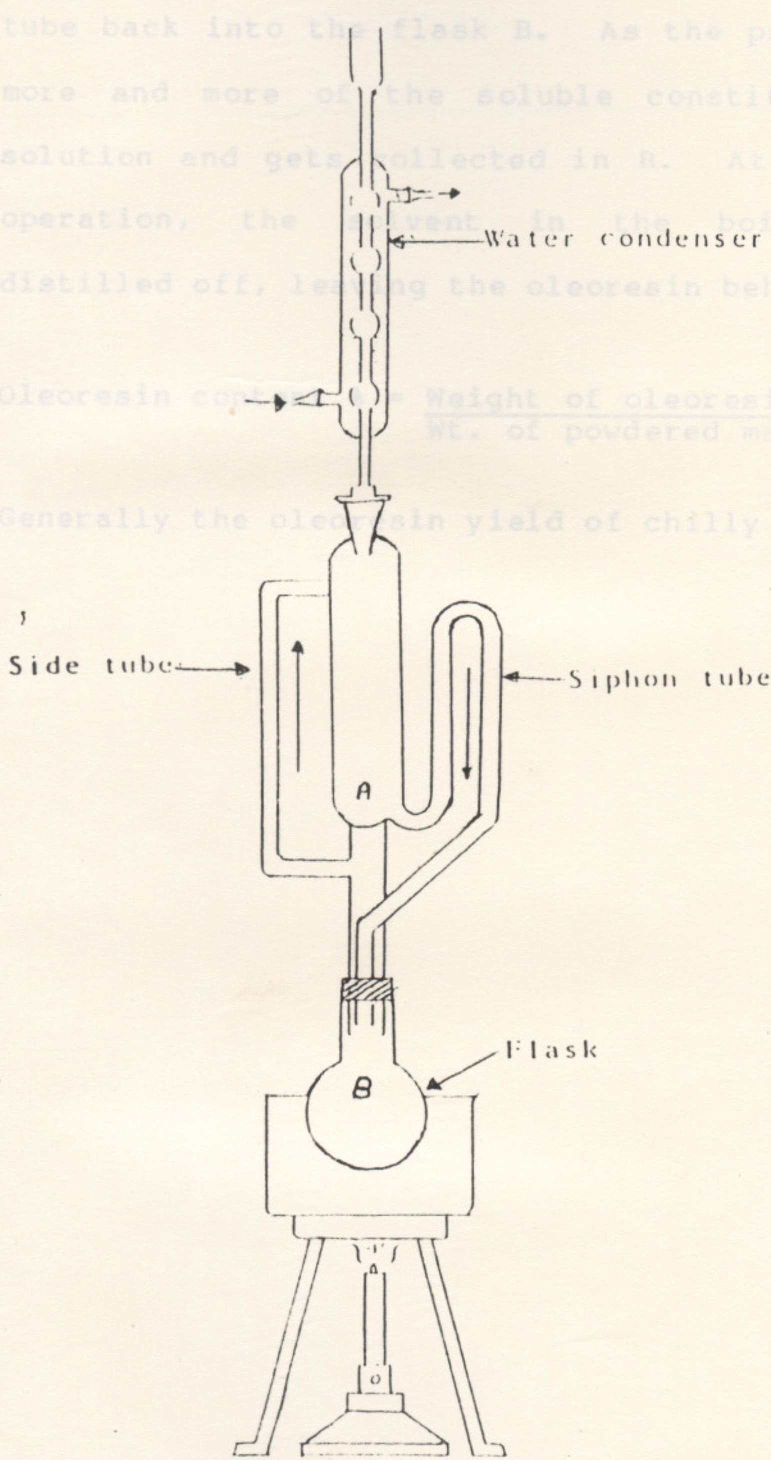


FIG. 5 SOXHLET APPARATUS

to work and the solution passes through the siphon tube back into the flask B. As the process continues more and more of the soluble constituent passes in solution and gets collected in B. At the end of the operation, the solvent in the boiling flask is distilled off, leaving the oleoresin behind.

$$\text{Oleoresin content \%} = \frac{\text{Weight of oleoresin}}{\text{Wt. of powdered material}} \times 100$$

Generally the oleoresin yield of chilly was 10 - 14%.

Plate No.3 Holding Tray

Plate No.2 Sideview of Foldable Solar Drier with Side Cover Open

Plate No.1 Foldable Solar Drier

Plate No.4 Suryamapi

RESULTS AND DISCUSSION

This section highlights the results of the performance, evaluation of the drier and the test for the quality of the dried product obtained from the drier.

4.1 Sample Analysis

4.1.1 Grape

The moisture content of the grape was determined by oven dry method as explained in the previous chapers. The moisture content (85%) was obtained.

4.1.2 Chilly

The moisture content of chilly was determined by toulene distillation method as explained previously. The moisture content (80%) was obtained.

4.2 Drier Test

4.2.1 No Load Test

The designed drier was fabricated. The drier was tested initially without loading to get maximum temperature. Suryamapi readings, inside and outside temperatures were ploted in Figures 6. Since the maximum radiation in a day was obtained between 10 A.M. to 1 P.M. the inside temperature was maximum at this time interval itself. After 2 P.M. the intensity of total radiation decreased rapidly causing a corresponding decrease in a drier temperature. For a maximum value of solar radiation 102MW/cm^2 between 12 A.M. and 1 P.M. On 20.11.92 the temperature inside the drier was 62°C. It was the maximum temperature recorded. From these observations, the drying time was taken between 10A.M. and 5 P.M.

4.2.2 Load Test

Grape: 3.75kg of seedless variety of grape were kept in the drier. The samples were spread on the trays at three levels uniformly. The drying time was 10 A.M. to 5 P.M. Giving tempering overnight the experiment was carried out for five days. The moisture content was found in every day morning by weighing the sample. Similar readings were taken for the sample kept outside for open drying. The reduction of moisture content was from 85 to 15% W.B. Figures 7 show the recorded values of solar insolation, inlet and outlet temperatures with the load for five days. The maximum temperature obtained was 58°C. This may be because the temperature will decrease with the increasing of moisture content. In Fig. 7(b), since rain occured from 2 P.M. to 4 P.M. reading were not taken.

The drying curve for grape was given in fig. 8. During the initial stages removal of moisture is low and is due to bound moisture.

Fig. 9 shows the graph of RH verses moisture content. Due to the removal of moisture from the sample RH increases which will reduce the rate of drying.

For the reconstitution test 15gms of drier sample 15% moisture content and same weight of open dried 15% moisture content sample were soaked in water for 40 minutes. The drier sample attained a moisture of 30% (W.B.) and open dried sample attained a moisture content of 25% (W.B.).

Fig. 10 shows the graphical representation of test results. Degree of reconstitution was taken as a measure of quality.

Chilly :- Local variety of chilly weighing 3kg was dried in the similar way as that of grape. The reduction of moisture from 80 to 2.5% (W.B.) took 2.5 day.

Figs. 11 show the observed values of solar insolations inlet & outlet temperatures with the chilly. The maximum temperature obtained with the load was 60°C because temperature decrease with increase in moisture content.

The drying curve of chilly was given in fig.12. During the initial stages removal of moisture is show. This is due to bound moisture.

Fig. 13 shows the graph of RH verses moisture content. Due to the moisture removal from the sample R.H. increases causing a reduction in the moisture content.

Oleoresin content of dried chilly was estimated by soxhlet apparatus. 2gms of the powdered sample which is dried inside the drier and same weight of open dried sample were packed seperately in filter papers and inserted into two seperate apparatus. Acetone of boiling point 57°C was taken in the round bottomed flask. On heating by stem the vapours of the solvent were produced. After condensing the vapours were allowed to fall on the sample. The soluble constituents from chilly were dissolved out. The solvent in the boiling flask were removed by distillation Oleoresin yield was calculated using the formulae

$$\text{Oleoresin Content \%} = \frac{\text{Weight of Oleoresin}}{\text{Weight of powdered material}} \times 100$$

Oleoresin of the drier sample was found to be 10% and that of open dried smaple was 8%.

From the test results it can be concluded that drying time of grape in comparison with natural drying was 2 times shorter with a superior quality product. Drying of chilly inside the drier takes only ½ the time that of open drying and the sample obtained is better in quality than open dried one. Hence the unit can be recommended for the production of high quality dried products in summer season.

4.3 Suggestions

1) Suitable Solar Collector with thermostat valve fitted at the bottom of the drier helps to maintain an optimum constant temperature throughout the drier.

2) If drier can be made electric cum solar, it can be used in night and winter season.

3) Aluminium sheet of 12mm thickness was used for the fabrication of the drier. Aluminium sheet of more thickness can be used to get more rigidity to the drier.

4) Drier can be used for drying some other crops like Bitterguard, Banana, Pepper, Ginger, Tapioca etc.

Date of Experiment : 20.10.92

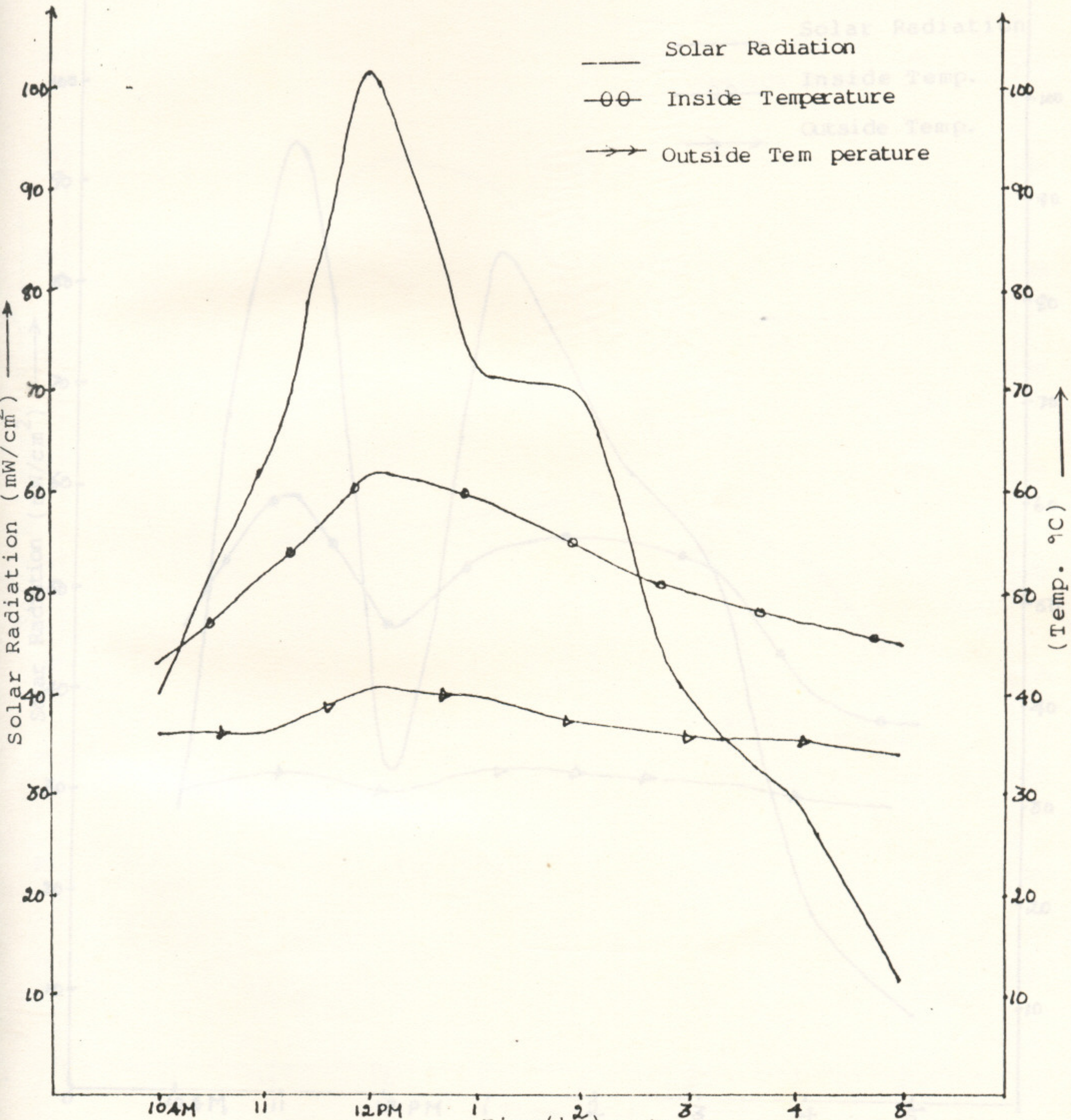


Fig.6 Diurnal curves for solar foldable drier with 'No-load

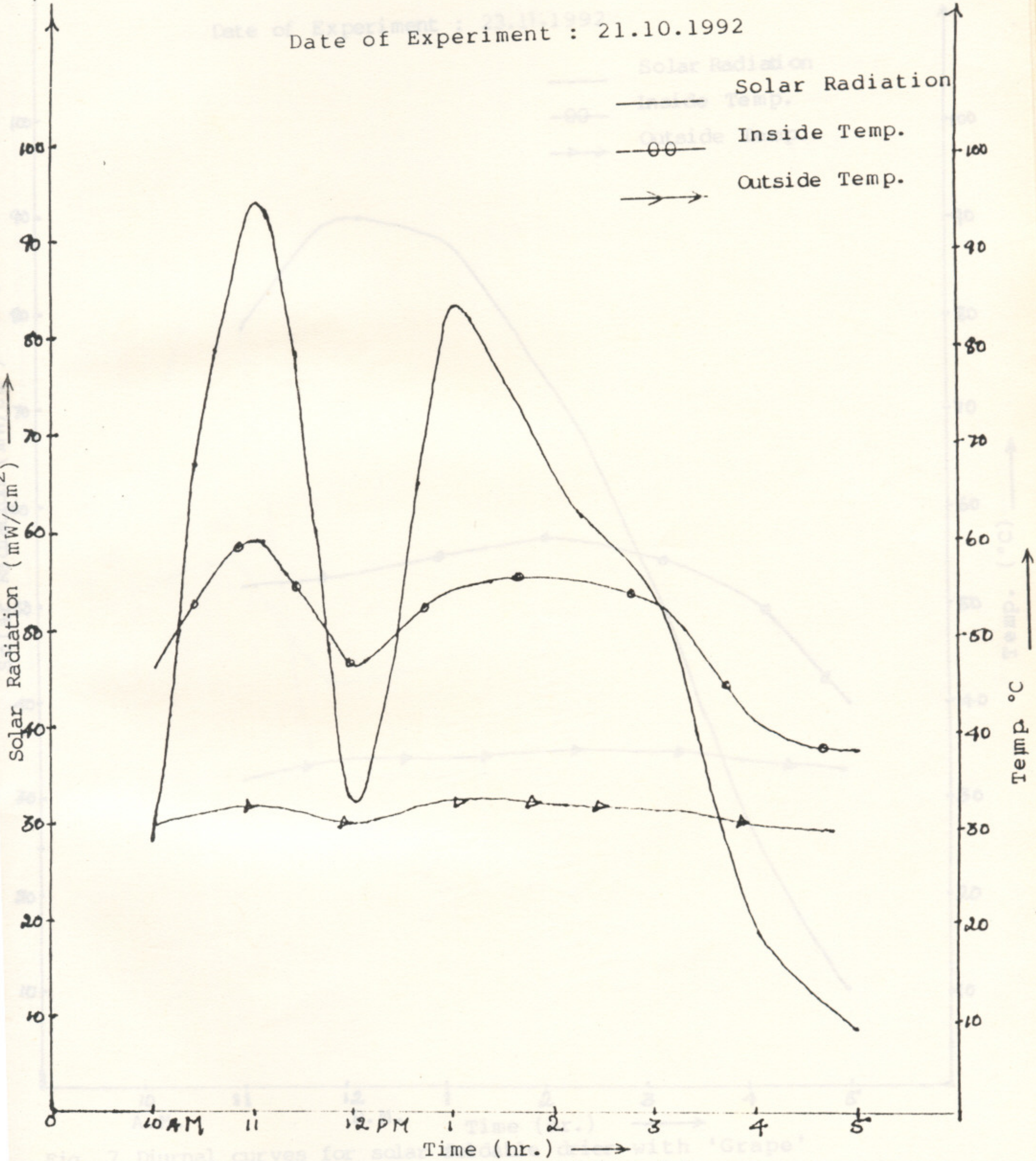

Date of Experiment : 21.10.1992
Solar Radiation
Inside Temp.
Outside Temp.
Solar Radiation (mW/cm²)
Temp. °C
100
90
80
70
60
50
40
30
20
10
0
10AM
11
12PM
1
2
3
4
5
Time (hr.)

Fig. 6 Contd......(b)

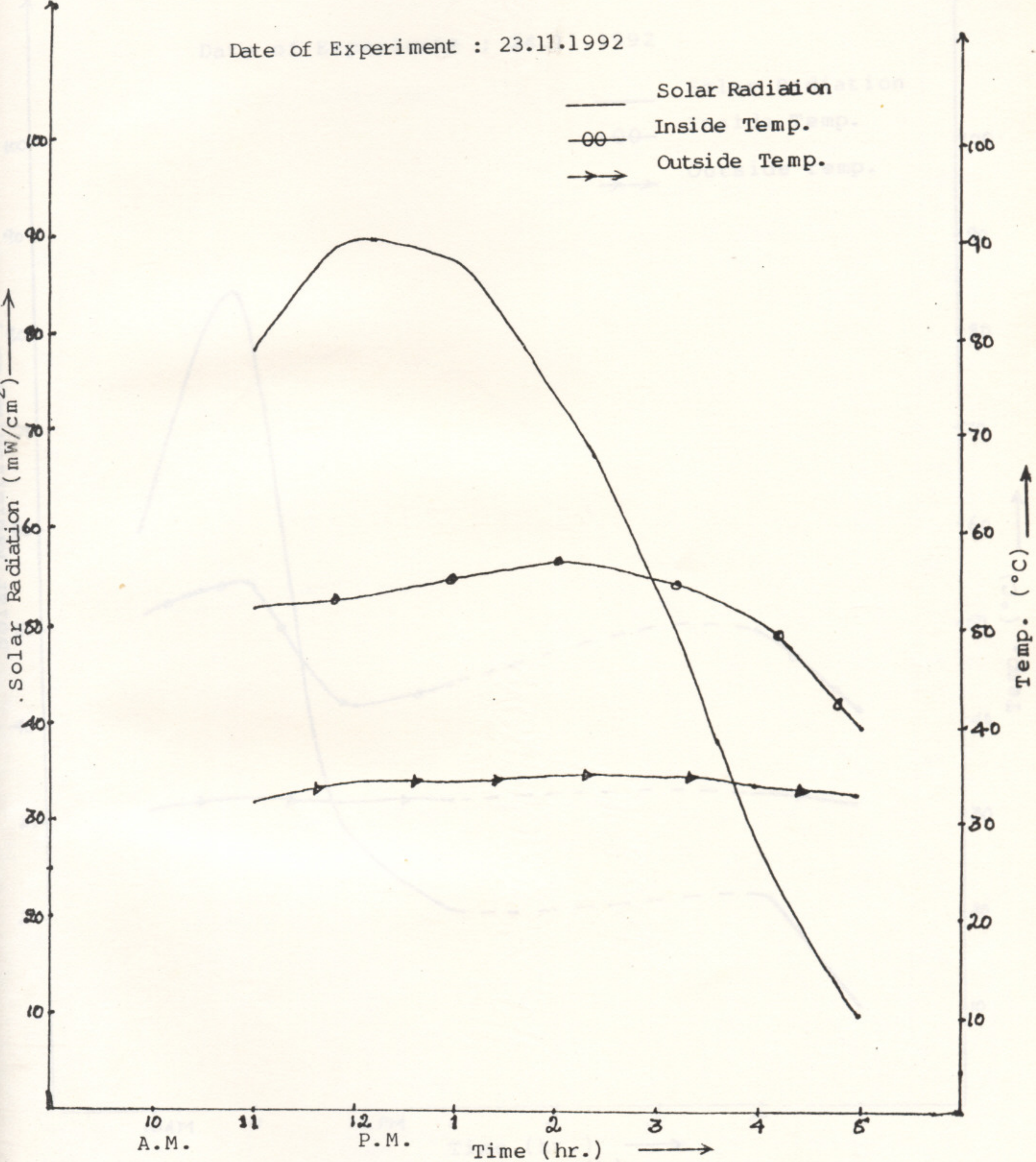
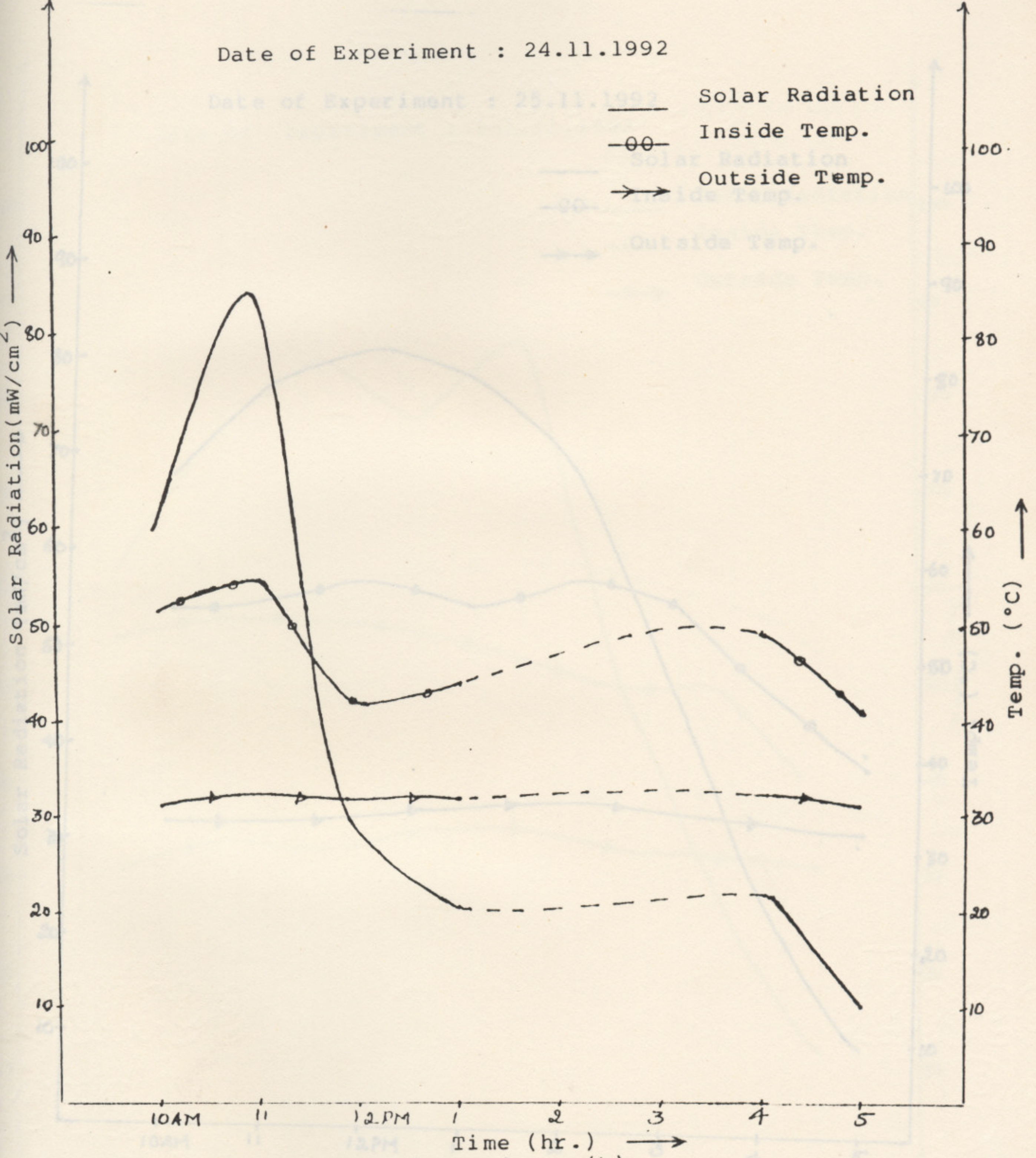


Fig. 7 Diurnal curves for solar foldable drier with 'Grape'



Date of Experiment : 24.11.1992
Solar Radiation
Inside Temp.
Outside Temp.
Solar Radiation(mW/cm^2)
Temp. (°C)
100
90
80
70
60
50
40
30
20
10
10AM
11
12PM
1
2
3
4
5
Time (hr.)

Fig. 7 Contd.....(b)

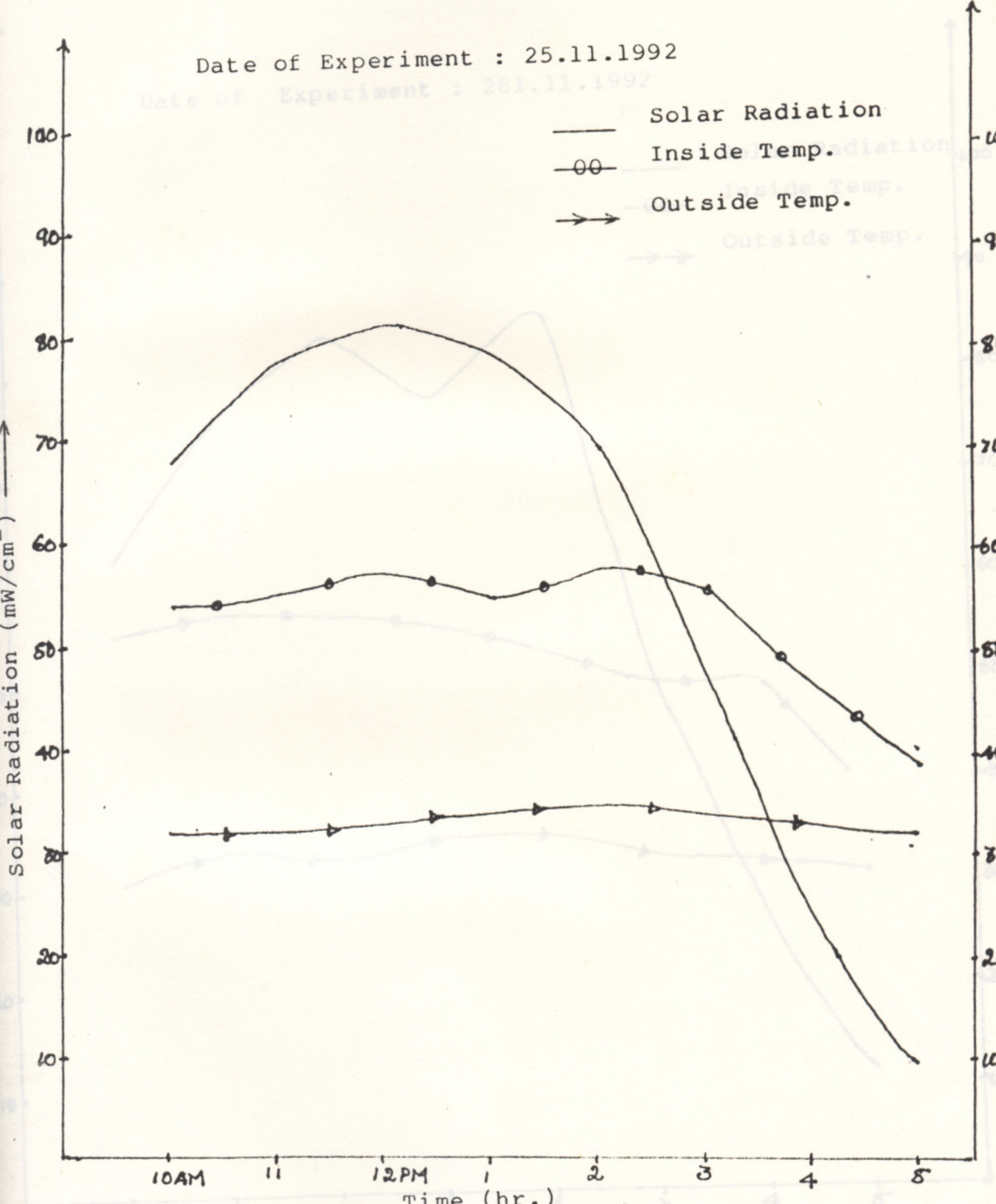
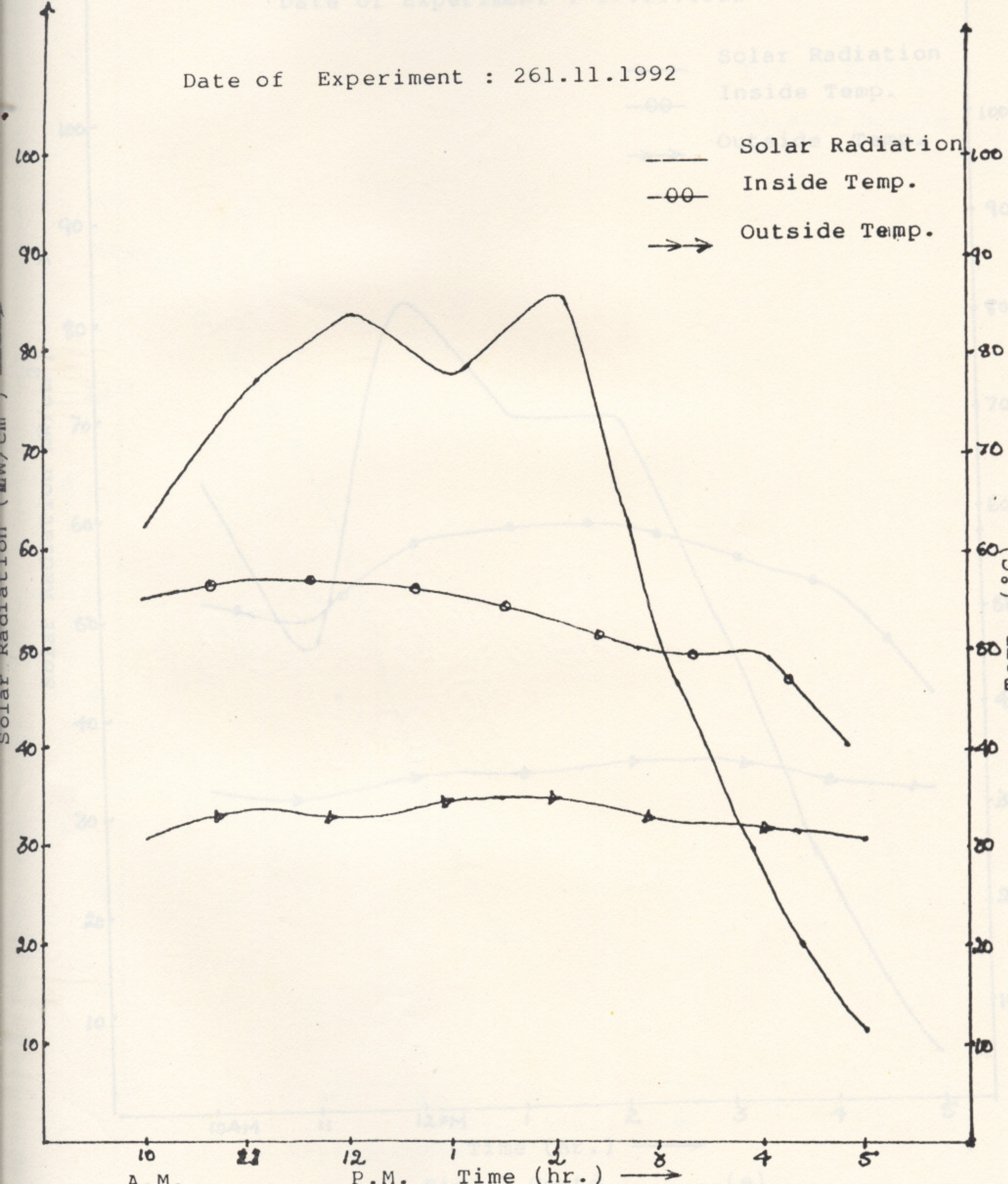
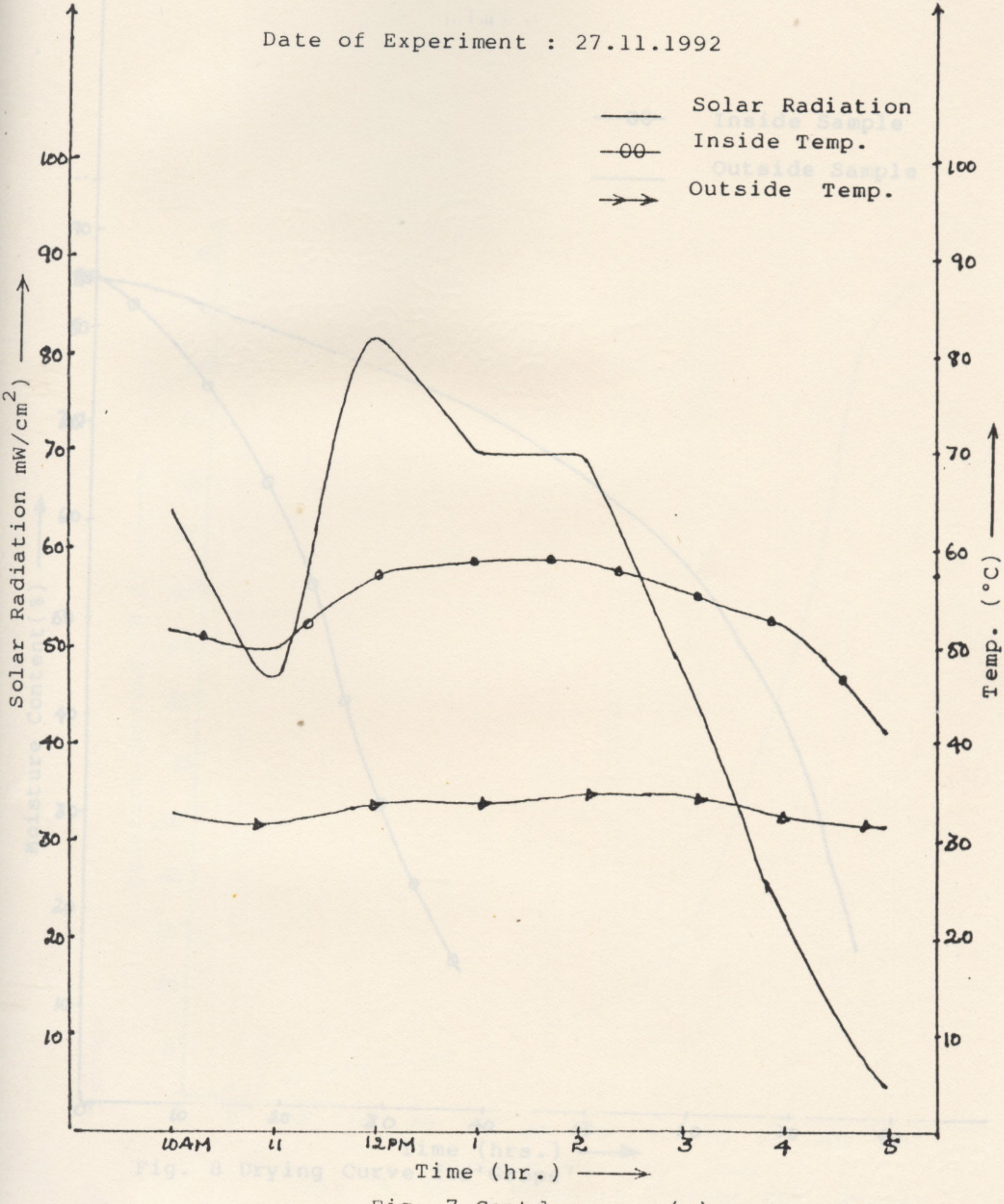

Date of Experiment : 25.11.1992
Solar Radiation
Inside Temp.
Outside Temp.
Solar Radiation (mW/cm2)
Temp. (°C)
100
90
80
70
60
50
40
30
20
10
10AM
11
12PM
1
2
3
4
5
Time (hr.)

Fig. 7 Contd..............(c)



Date of Experiment : 261.11.1992
Solar Radiation
Inside Temp.
Outside Temp.
Temp. (°C)
10
A.M.
11
12
P.M.
1
2
3
4
5
Time (hr.)

Fig. 7 Contd......(d)



Date of Experiment : 27.11.1992
Solar Radiation
Inside Temp.
Outside Temp.
Solar Radiation mW/cm^2)
Temp. (°C)
100
90
80
70
60
50
40
30
20
10
10AM
11
12PM
1
2
3
4
5
Time (hr.)

Fig. 7 Contd........(e)

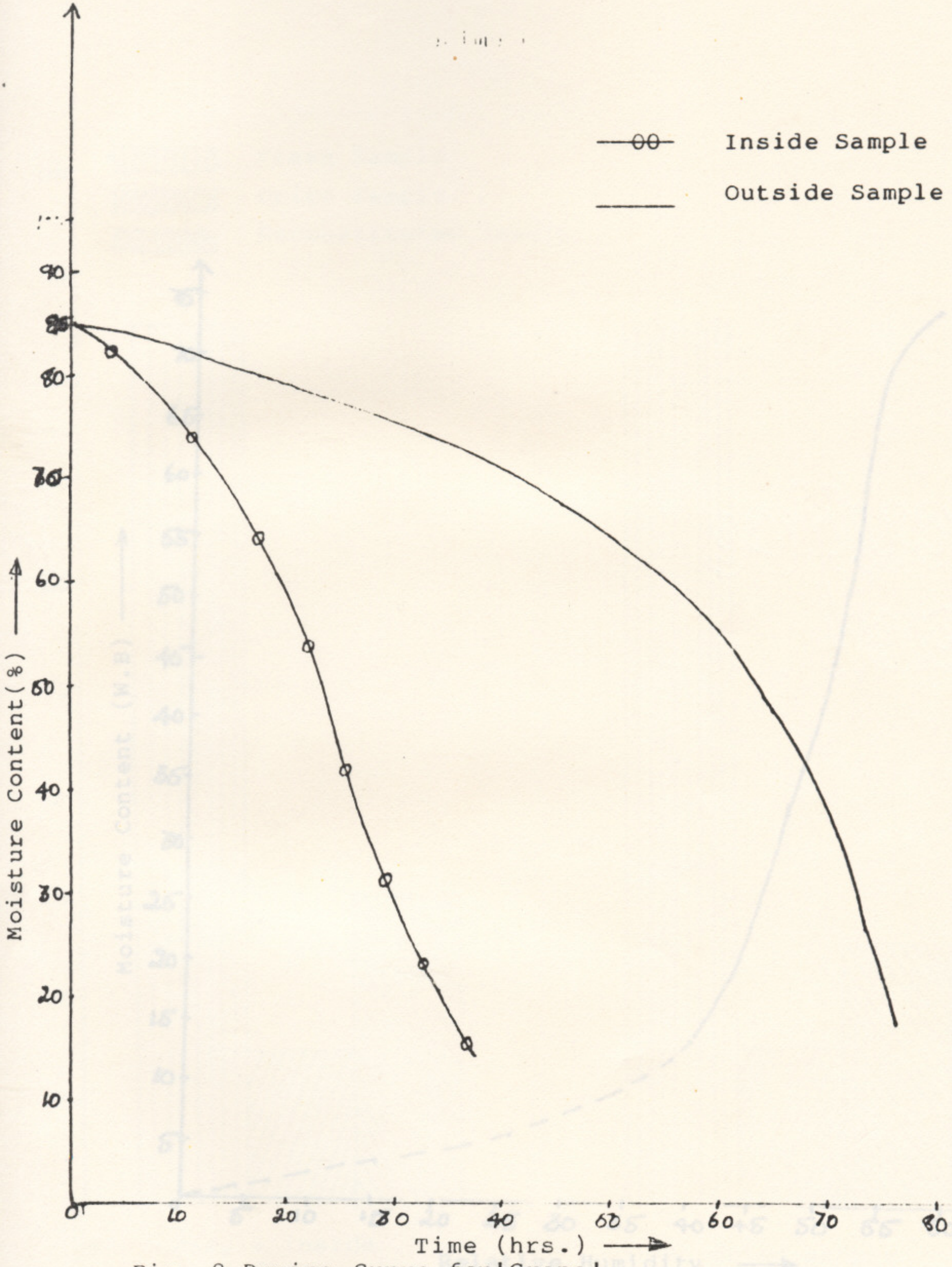


Fig. 8 Drying Curve for'Grape'

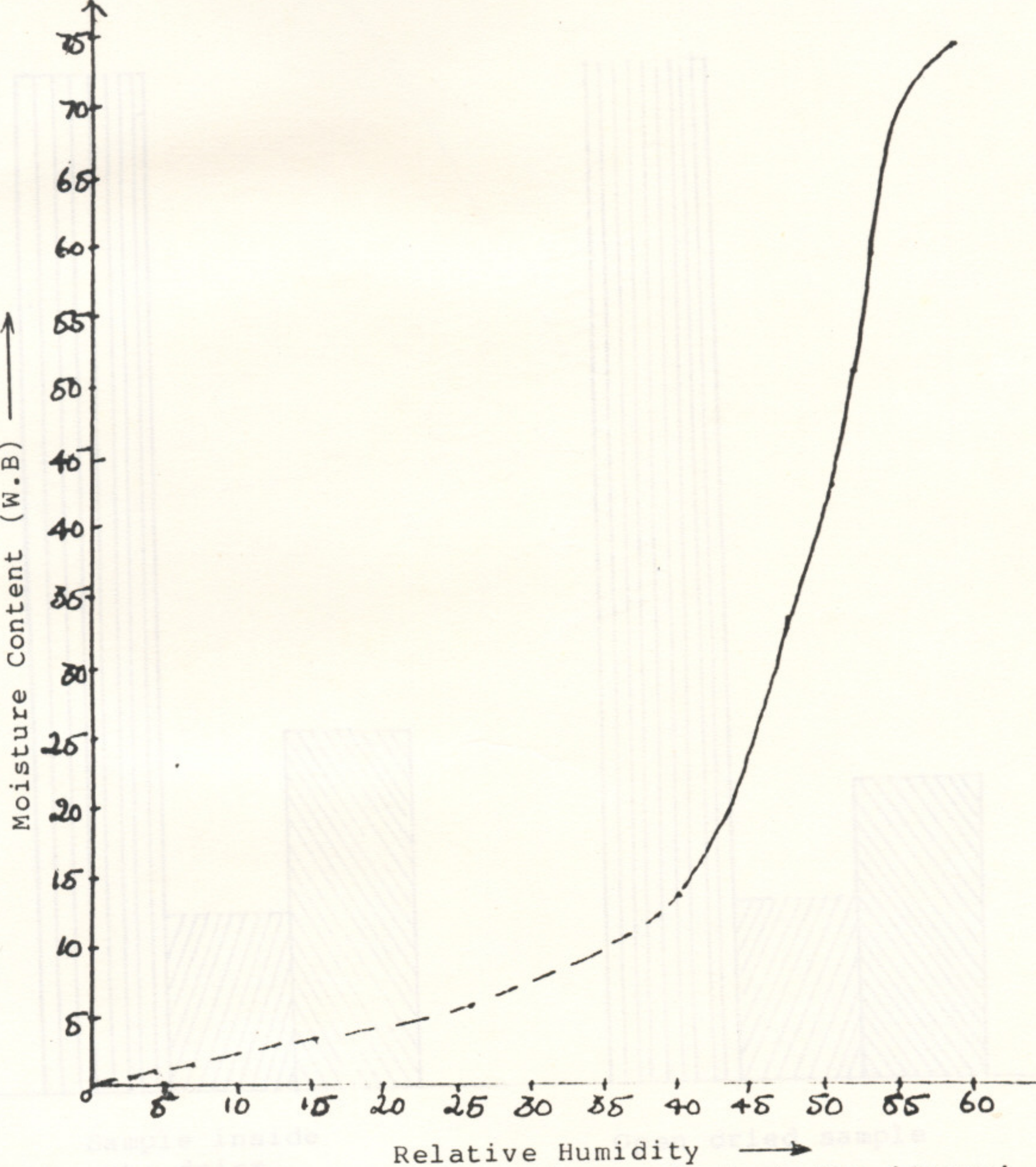


Fig. 9 RH V_s Moisture Content for 'Grape'

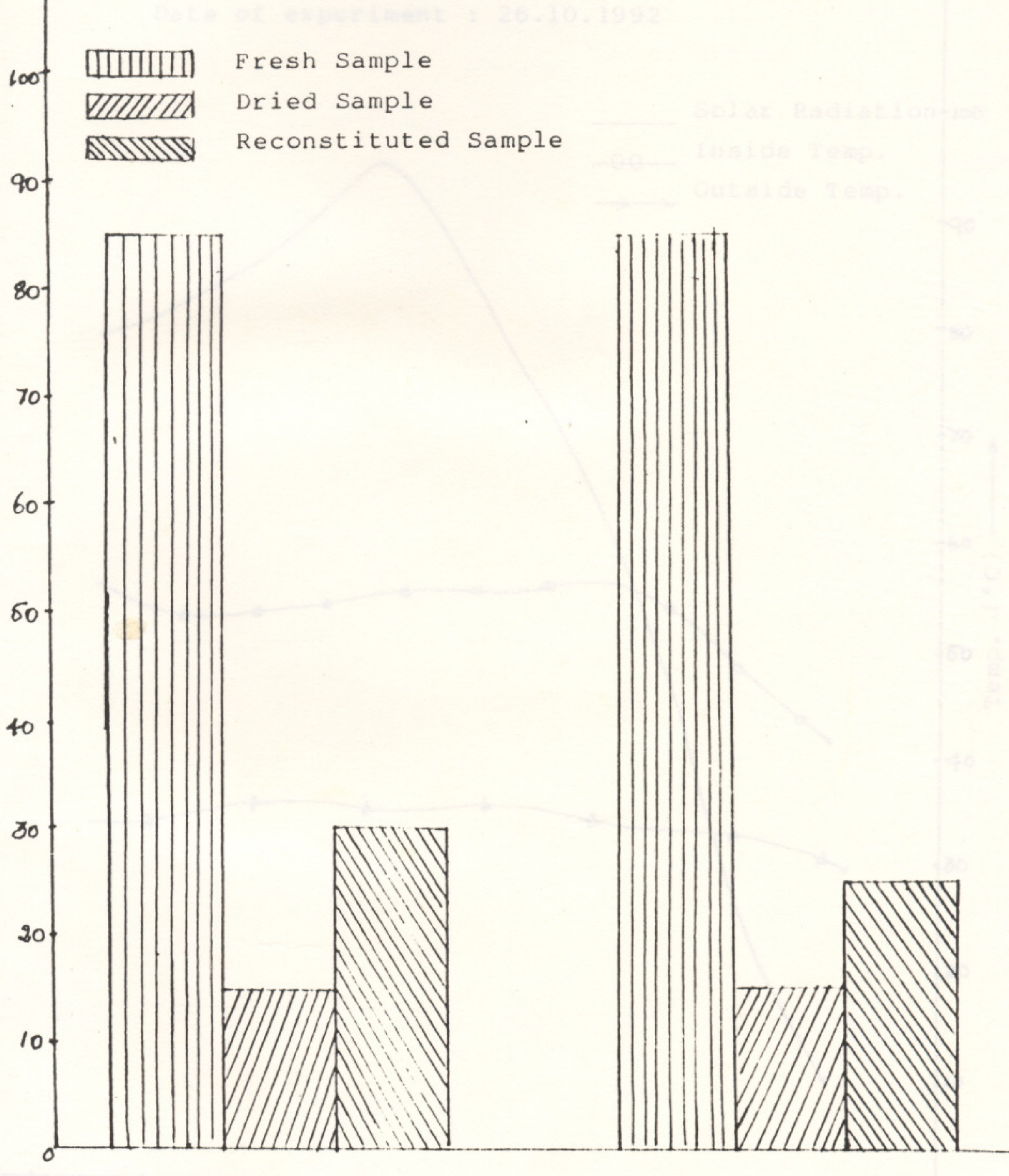


Fig. 10 Graphical representation of Reconstitution test for Grape

Date of experiment : 26.10.1992

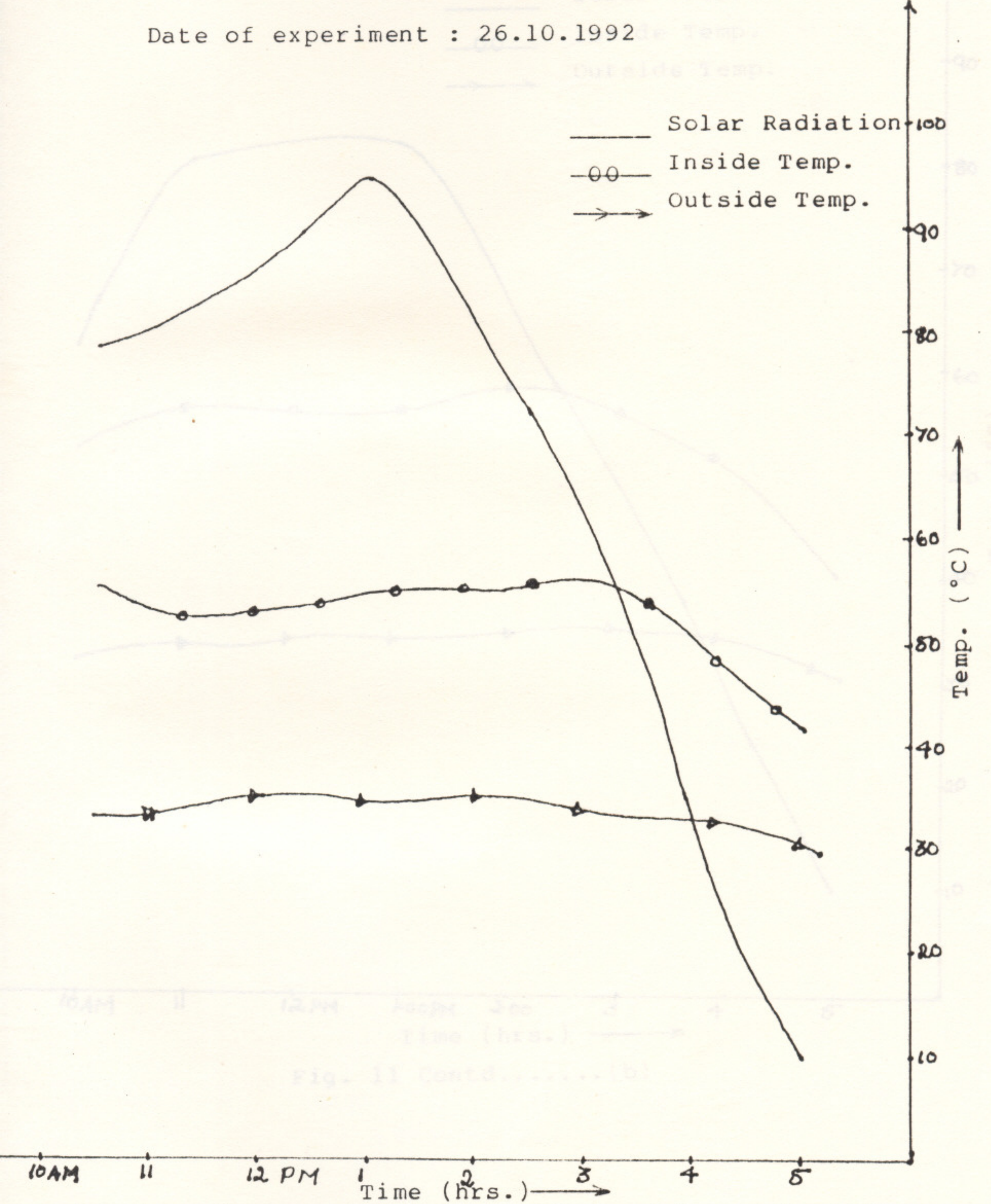


Fig. 11 Diurnal curve for solar foldable drier with chilly

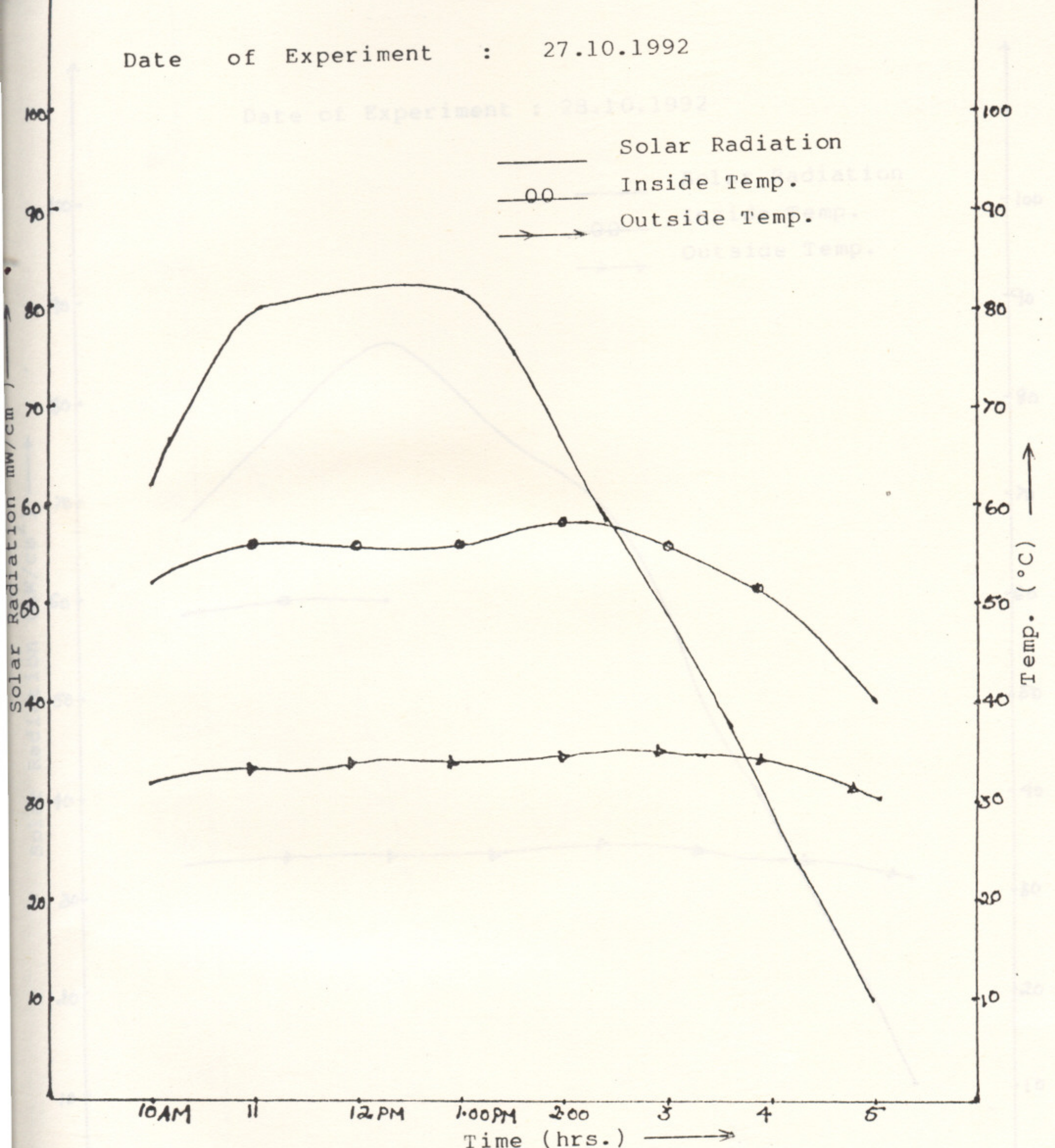


Fig. 11 Contd.......(b)

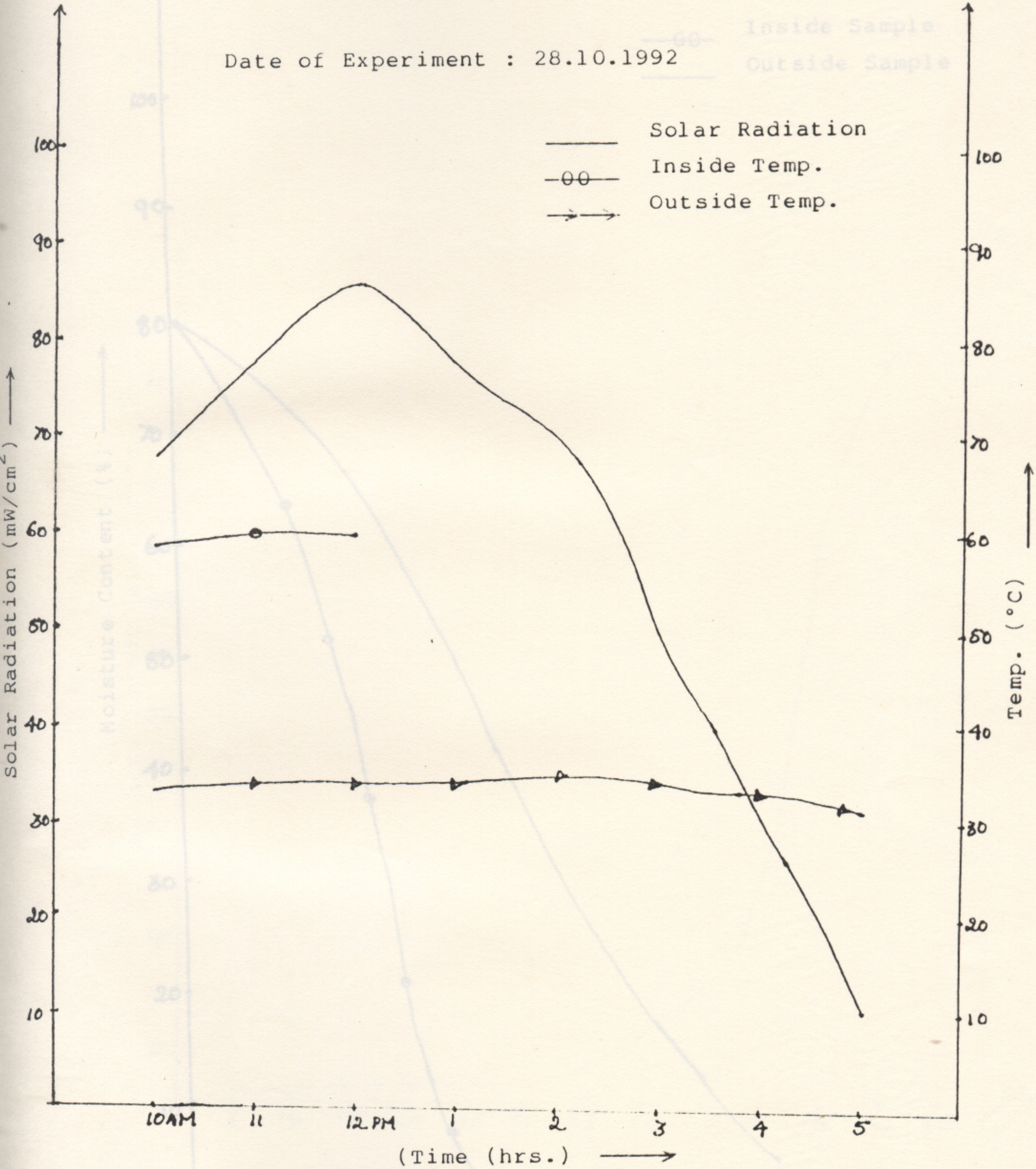


Fig. 11 Contd . ...(c)

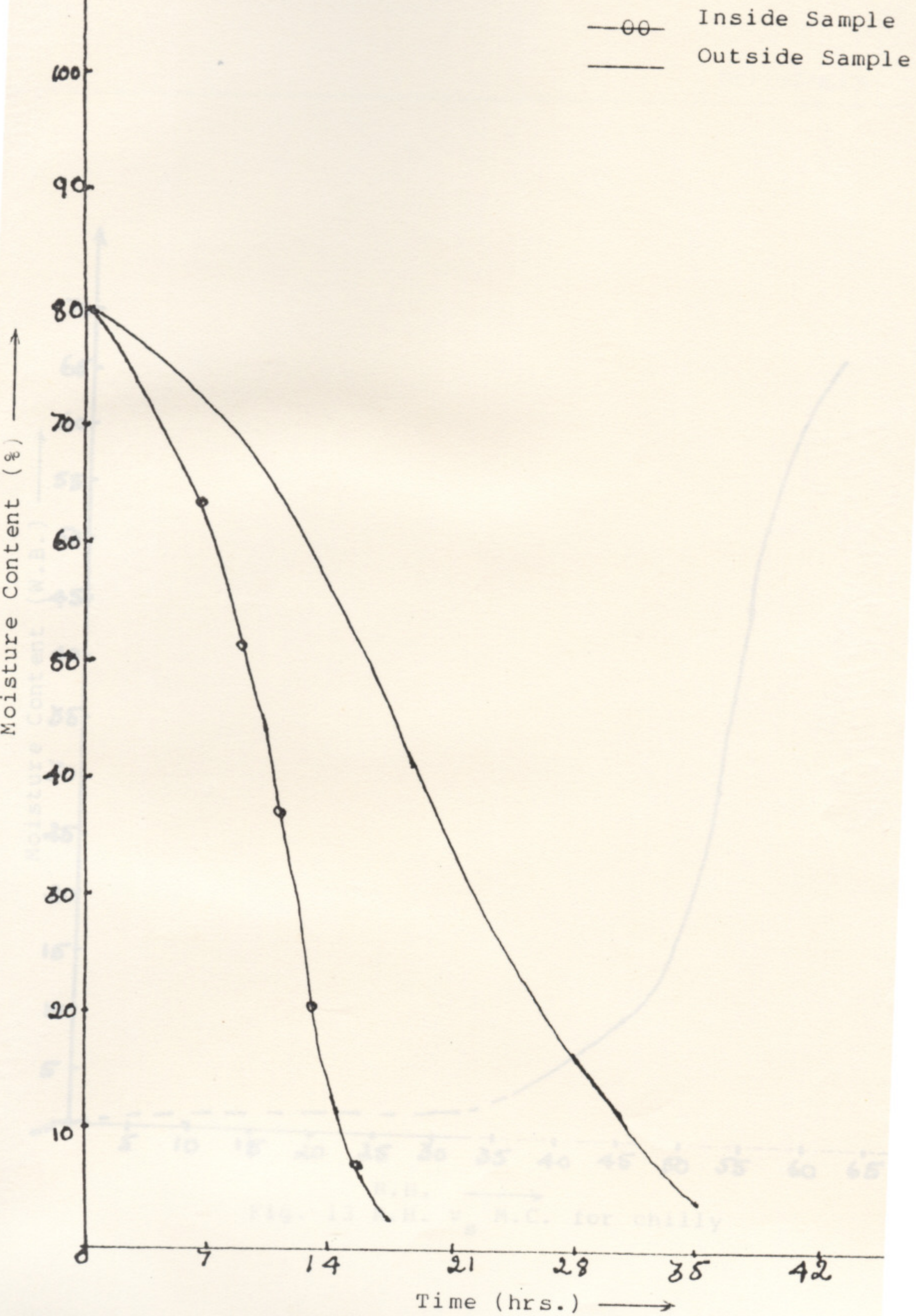


Fig. 12 Drying curve for chilly

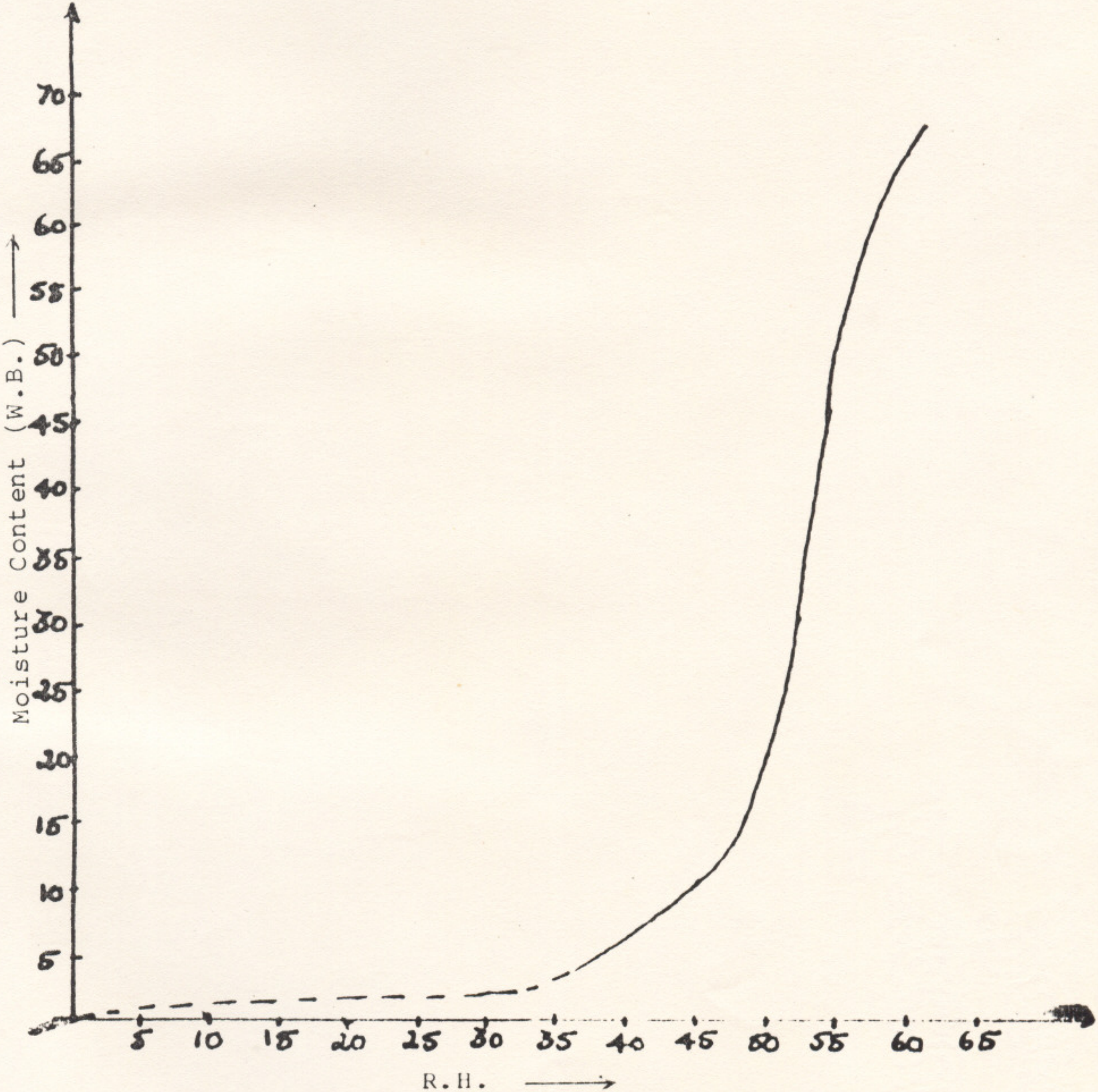


Fig. 13 R.H. V_s M.C. for chilly

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Appendix 1

Nutritional Constituent of Grape

Carbohydrate %	13 - 16.5
Protein %	0.6
Fat (%)	0.4
Vitamin A (I.U)	3 Ug
Vitamin C (Mg %)	1
Thiamine (Mg)	0.04
Riboflavin (Mg)	0.03
Iron (Mg)	0.5
Calcium (Mg)	20

Appendix 2

Composition of Chilly

Proteins	12.8
Fibre	31.8
Non-voatile ether extractive	21.7
Total Ash	6.3
Acid insolube Ash	1.05
Carbohydrate	27.0

Appendix 3

Physico-Chemical Characteristics of three varieties of chilly

Physico Chemical characteristics	Indian green chilly	Indian red chilly(dry)	American pepper chilly
Moisture %	82.6	10.0	6.5
Protein %	2.9	15.9	14.0
Fat %	0.6	6.2	14.1
Fibre %	6.8	30.2	15.6
Carbohydrates %	6.1	31.6	42.6
Total Ash %	1.0	6.1	7.2
Calcium	0.03	0.16	0.1
Phosphorous	0.08	0.37	0.32
Iron	1.20	2.3	0.01
Sodium %	-	-	.01
Potassium %	-	-	2.1
Thiamine Mg/100g	-	-	0.59
Ribotlavin	1.18	-	1.66
Niacin	0.5	-	14.2
Ascorbic acid	111	50	58.8
Vitamin A $\left(\frac{I.U}{100g}\right)$	54	576	6165
Caloritic value	41	246	415

Table No.1(a) No Load Test Observations

Date of Experiment : 20.10.1992

Time (hrs.)	Solar Radiation (MW/cm^2)	Inside Temperature(°C)	Outside Temperature(°C)
10 AM	28	46	30
11	94	60	32
12 PM	32	46	30
1	84	55	33
2	68	56	32
3	60	54	32
4	19	40	30
5	18	38	29

Table No. 1(b) No Load Test Observations

Date of Experiment : 21.10.1992

Time (hrs)	Solar Radiation (MW/cm^2)	Inside Temperature(°C)	Outside Temperature(°C)
10 AM	40	43	34
11	65	52	33
12 PM	102	62	35
1	72	60	34.5
2	70	54	33
3	40	50	32
4	30	48	32
5	12	45	31

Table No. 2(a). Load Test Observations (Grape)

Date of Experiment : 23.11.92

Time (hrs)	Solar Radiation (MW/cm^2)	Inside Temperature (°C)		Outside Temperature(°C)		Relative Humidity (%	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
11 A.M.	78	52	43	32	27	60	69
12 P.M.	90	53	44	34	29	60	70
1	88	55	44	34	29.5	54	73
2	74	57	45	35	30	52	70
3	54	55	44.5	35	3	55	70
4	28	51	42	34	30	60	76
5	8	40	35	33	29	72	75

(b) Date of Experiment : 24.11.1992

Time (hrs.)	Solar Radiation (MW/cm^2)	Inside Temperature(°C)		Outside Temperature(°C)		Relative Humidity (%)	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
10 A.M.	60	52	43	32	27	60	69
11	85	55	39	33	28	39	70
12 P.M.	28	42	36	32	28	69	75
1	20	44	37	32	28	64	75
4	22	49	35	32	28	40	75
5	8	40	32	31	27	58	75

(c) Date of Experiment : 25.11.1992

Time (hrs.)	Solar Radiation (MW/cm^2)	Inside temperature (°C)		Outside Temperature (°C))		Relative Humidity (%)	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
10 A.M.	68	54	41	32	27	47	69
11	78	55	41	32	28	45	75
12	82	57.5	41	33	29	34	75
1	79	55	41	34	29	45	70
2	70	58	43	35	30	42	70
3	48	56	42	34	29	45	70
4	25	47	37	33	28.5	53	74
5	10	39	34	32	29	72	80

(d) Date of Experiment : 26.11.1992

Time (hrs.)	Solar Radiation (MW/cm^2)	Inside Temperature (°C)		Outside Temperature (°C)		Relative Humidity (%)	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
10 A.M.	64	55	41	31	27	45	75
11	70	57	40	34	28	37	65
12 P.M.	84	57	41	33	28	40	70
1	78	56	42	35	29	45	65
2	86	53	40	35	29	46	65
3	52	50	38	33	29	48	75
4	28	50	40	32	29	55	80
5	12	38	34	31	28	77	80

(e) Date of Experiment : 27.11.1992

Time (hrs.)	Solar Radiation (MW/cm^2)	Inside Temperature (°C)		Outside Temperature (°C)		Relative Humidity(%)	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
10 A.M.	64	52	37	33	26	40	59
11	47	50	37	32	26	45	62
12 P.M.	82	58	38	34	29	30	70
1	70	59	40	34	30	33	76
2	70	59	40	35	30	33	70
3	48	56	40	35	30	39	70
4	22	52	39	33	30	42	81
5	5	42	33	33	28	55	70

Table No. 3(a) Load Test Observations (Chilly)

Date of Experiment : 26.10.1992

Time (hrs.)	Solar Radiation (MW/cm^2)	Inside Temperatures (°C)		Outside Temperatures (°C)		Relative Humidity (%)	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
10 A.M.	78	55	45	33	28	55	69
11	80	53	45	33	28	64	69
12 P.M.	86	53	43	35	31	55	76
1	94	54	44	34	32	55	88
2	80	55	44	35	32	50	90
3	62	56	46	34	32	57	88
4	32	50	40	33	28	55	69
5	10	42	36	32	27	68	70

(b) Date of Experiment : 27.10.1992

Time (hrs.)	Solar Radiations (MW/cm^2)	Inside Temperatures(°C)		Outside Temperatures (°C)		Relative Humidity(%)	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
10 A.M.	62	52	41	32	28	53	75
11	80	56	43	33	28	48	70
12 P.M.	82	56	43	34	29	48	70
1	82	56	43	34	29	48	70
2	66	58	42	35	31	40	75
3	49	56	41	35	29	42	75
4	30	51	37	34	29	40	70
5	10	40	32	31	28	55	85

(c) Date of Experiment : 28.10.1992

Time (hrs.)	Solar Radiation (MW/cm^2)	Inside Temperatures (°C)		Outside Temperatures (°C)		Relative Humidity(%)	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Inside	Outside
10 AM	68	58	41.5	33	32	38	92
11	78	60	40	34	33	31	99
12 P.M.	86	60	39	34	34	30	100
1	77			34	32		96
2	70			35	34		95
3	50			34	31		80
4	30			33	29		75
5	10			31	27		75

Table No. 4 Inside and Outside weight and M.C. for grape

Date	Inside Sample		Outside Sample	
	Weight (gm)	Moisture content(%)	Weight (gm)	Moisture content(%)
23.11.92	3750	85	250	85
24.11.92	2864	80.5	223	83
25.11.92	2035	72.35	201.89	81
26.11.92	1345	58.2	185.6	79.8
27.11.92	910	38.2	166.65	77.5
28.11.92	657	14.4	146.99	74.5
29.11.92			120	68.8
30.11.92			103.52	63.78
01.12.92			86.65	56.67
02.12.92			65.37	42.6
03.12.92			46.13	18.7

Table No. 5 Inside and Outside weight and M.C. for chilly

Date	Inside Sample		Outside Sample	
	Weight (gm)	Moisture content(%)	Weight (gm)	Moisture content(%)
26.10.92	3000	80	500	80
27.10.92	1578	62	354.95	71.8
28.10.92	690	15	233.5	57
29.10.92	615	2.5	152.5	34.4
30.10.92			120.4	16.9
31.10.92			104	3.9

DESIGN FABRICATION AND TESTING OF A FOLDABLE SOLAR DRIER

BY

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ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology in Agriculture Engineering

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1992

ABSTRACT

The project was undertaken with the objectives of design, fabrication and testing of a foldable solar drier.

Based on the design the drier was fabricated. The no-load test of the developed drier was conducted and the maximum temperature obtained was 62°C. Grape was used for load test. Moisture content of the sample was determined by oven dry method. The maximum temperature obtained was 58°C. Reduction of M.C. from 85% to 15% (wb) took place within 5 days and the quality of raisins was evaluated by reconstitution test.

The drier was also tested for chilly. The moisture content of 80% wb was determined by touline distillation method. The maximum temperature inside the drier with load was 60°C. Sample was dried for 2½ days to get moisture content of 5%. Quality was tested by oleoresin content and was found 10%. The drier can be used efficiently in summer season.