POLY GREENHOUSE DRYING OF SELECTED HORTICULTURAL CROPS

Thesis submitted in part fulfillment of the requirements for the degree of ***Master of Engineering (Agriculture)*** *in Agricultural Process Engineering to the Tamil Nadu Agricultural University, Coimbatore.*

By

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CERTIFICATE

This is to certify that the thesis entitled **"POLY GREENHOUSE DRYING OF SELECTED HORTICULTURAL CROPS"** submitted in part fulfillment of the requirements for the degree of **MASTER OF ENGINEERING (Agriculture)** in **AGRICULTURAL PROCESS ENGINEERING** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Er.C.V.KAVITHA** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal of magazine.

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Abstract

ABSTRACT

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Degree	:	Master in Engineering (Agriculture) in Agricultural Process Engineering.
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A semi-circular type poly greenhouse of size (4 x 5 m) with 3m height was constructed with white PVC sheet (200 micron) as roof. The floor was covered with black polyethylene sheet (25 micron). An adjustable ventilation was provided at the top and at the bottom of the greenhouse. The ventilation area (6.52 m^2) was covered with nylon mesh to prevent the entry of insects.

The characteristic of greenhouse was evaluated from the recorded temperature and relative humidity prevailed inside the greenhouse and the atmosphere. The greenhouse temperature and relative humidity varied from 36 to 57°C and 61 to 37 per cent whereas the atmospheric temperature and relative humidity outside the greenhouse varied from 28 to 40°C and 71 to 45 per cent. The higher temperature and lower relative humidity prevailed inside the greenhouse could be an ideal condition for drying and it was utilized for drying of

crops. Drying experiments were conducted in the greenhouse with coconut kernel, chillies and grapes. The quality parameters and bio-chemical characteristics of both the greenhouse and the dried produces were evaluated.

Coconut kernels were dried to copra from the initial moisture content of 92.31 to 6.48 per cent d.b. in 30 and 52 h under greenhouse and sun drying, respectively. Microbial load was found to be less in greenhouse dried copra samples than the sun dried samples and also resulted in better quality of oil.

Chilli fruits were dried from 410.2 to 5.78 per cent d.b. moisture content in 24 and 42 h in the greenhouse and open sun respectively. The greenhouse dried chillies yielded higher colour value and oleoresin than the sun dried chillies.

The pre treatments viz., Australian Cold Dip (ACD), Australian Mix Dip (AMD) and sulphuring were given to the grapes and dried under both greenhouse and sun drying conditions. The greenhouse and sun dried ACD, AMD, sulphured and control raisins took 26, 26, 36 and 34h in greenhouse and 46, 44, 68 and 66 h in sun drying respectively for the moisture reduction of 426.32 to the range of 15.37 to 16.63 per cent d.b. The total sugar content of the raisins was not significant on the method of drying. The greenhouse dried raisins retained more ascorbic acid content than the sun dried samples.

The cost of the greenhouse constructed in this study was estimated as Rs.17,500/-. The cost of greenhouse per square metre worked out to be Rs.875/- The drying cost of copra, chillies and grapes in the greenhouse was found to be Re 0.24/kg, Re 0.47/kg and Re 0.59/kg respectively. Greenhouse drying of crops saved 40 per cent (on an average) of time over the sun drying method.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

%	:	per cent
≤	:	lesser than or equal to
≥	:	greater than or equal to
°C	:	degree celsius
ASTA	:	American Spice Trade Association
CFU	:	colony forming units
cm	:	centi metre
d.b.	:	dry basis
et al	:	and others
g	:	gram
GH	:	Greenhouse
h	:	hour(s)
ha	:	hactare
kg	:	kilo gram
m	:	metre
m^2	:	square metre
m^3	:	cubic metre
mg	:	milli gram
MHz	:	mega hertz
min	:	minute
mJ	:	mega Joules
ml	:	milli litre
mm	:	milli metre
MT	:	metric tonnes
PVC	:	Poly Vinyl Chloride
Re	:	Rupee
RH	:	relative humidity
Rs	:	Rupees
sec	:	second
w.b.	:	wet basis

Introduction

CHAPTER I

INTRODUCTION

Fruits and vegetables have gained commercial importance and their growth on a commercial scale has become an important sector of the agricultural industry. Recent developments in agricultural technology have substantially increased the world production of fruits and vegetables. Consequently a larger proportion of several important commodities is being handled, transported and marketed all over the world than before with concomitant losses calling for suitable post harvest techniques for processing and storage to ensure improved shell life.

The need to reduce post harvest losses of perishable horticultural commodities is of paramount importance for developing countries to increase their availability, especially in the present context when the constraints on food production (land, water and energy) are continuously increasing. It is being increasingly realized that the production of more and better food alone is not enough and that it should go hand in hand with suitable post harvest conservation techniques to minimize losses, thereby increasing supplies and availability of nutrients besides giving the economic incentive to produce more.

Among the post-harvest techniques, drying is an important unit operation and plays a vital role under the post harvest phase. Dried products can be stored to a longer period without any deterioration's, since the microorganisms which cause the spoilage and decay are unable to grow and multiply in the absence of water. Many of the enzymes, which promote undesired changes in the chemical composition of the produce, cannot function without water.

1.1 Importance of Drying

The importance of drying of farm products is increasing. Drying permits the farmer to secure a greater economic return for the following reasons:

(i) Early harvest (at high moisture content) minimizes field damage and shatter loss and facilitates tillage operations.

(ii) Long period storage without product deterioration is possible.

(iii) Viability of seeds is maintained over longer periods.

(iv) Storage of products after drying makes products available during off-seasons. Selling of grains in off-season would fetch additional income to growers, as price remains higher during these periods.

(v) Dried products occupy minimum space, hence handling and transport costs could be minimized.

1.2 Methods of Drying

Here different methods used for drying various agricultural and horticultural crops are discussed in brief.

1.2.1 Sun drying

Sun drying is the conventional method. It is the simplest one but unhygienic, weather dependent, time consuming and labour intensive. It is not suitable because it contaminates the produce due to the dust and dirt carried out by the wind, infestations by insects and pests and by other interruptions, quantitative loss of produce due to birds, rats and rodents are occurring.

1.2.2 Mechanical drying

An alternative method of mechanical drying could be adopted to obtain a better and good quality dried products. It is independent of weather but it involves a high initial investment, fuel cost and requires adequate maintenance.

1.2.3 Solar drying

Considering the limited fossil fuel resources and its ever-increasing demand, decentralized renewable energy resources can be used for drying of agricultural produce. It is an alternative that is being encouraged in hot, dry countries of Asia and Africa. Solar drying is a promising option and saves a considerable amount of fuel. A major problem however in the case of solar drier is their typical short period of use from a few days to a few weeks resulting in high initial investments and operating costs.

1.2.4 Greenhouse drying

Greenhouse technology has been in use for crop production for more than 50 years all over the world. In low technology poly greenhouses used in tropical countries, where there is no provision for mechanical cooling or ventilation, the temperature inside the greenhouse becomes very high, making it unsuitable for cultivation of crops. Therefore, any existing low cost poly greenhouse facility can be utilized for drying purpose by suitably making the provisions for natural ventilation. Thereby a greenhouse could be effectively put in use throughout the year, either for crop production or for crop drying.

Hence, in the present investigation, efforts have been taken to study the drying characteristics of selected horticultural crops namely coconut, chilli and grapes inside the greenhouse.

(i) Coconut

Coconut is a versatile tree and presently cultivated in 10.94 million hectares with an annual production of 50,055 million nuts equivalent to 9.42 million tonnes of copra. The world production of copra in 1993 was 4.63 million tonnes. Philippines converts over 85% of its coconuts into copra, while Indonesia uses only 45% followed by India (35%) and Malaysia (35%), (Kaul, 1995). Global copra production is presented in Table 1.1.

Table 1.1 Global copra production (in '000 tonnes)

Particulars	1989	1993
Indonesia	1020.48	1127.00
Philippines	1668.00	1900.00
India	431.29	550.00
Srilanka	129.43	46.69
Thailand	62.00	59.84
Others	1049.39	951.61
Total	4361.37	4629.19

Source: Coconut statistics (1993) APGI, Jakarta

Table 1.2 Statewise area and production of chilli in India,1994-95

STATES	Area,ha	Production,tonnes
Andhra Pradesh	186300	348000
Arunachal Pradesh	1100	1300
Assam	13100	8600
Bihar	6100	2900
Gujarat	17500	20500
Harayana	3700	3800
Himchal Pradesh	1000	300
Jammu & Kashmir	700	500
Karanataka	167900	101500
Kerala	500	400
Madhya Pradesh	41300	12000
Maharashtra	99100	56900
Manipur	6100	3600
Meghalaya	1700	1100
Mizoram	3100	3100
Nagaland	300	4500
Orissa	100000	76900
Pondicherry	0	100
Punjab	2600	3800
Rajasthan	36500	39400
Tamil Nadu	66100	47600
Tripura	1700	800
Uttar Pradesh	19200	12700
West Bengal	53600	44300
TOTAL	829200	794600

Source : Directorate of Economics & Statistics (1997), Ministry of Agriculture, New Delhi.

(ii) Chilli

Chillies belong to the family "Solanacea" and to the genus capsicum. The total area and production of chillies in India during 1994-95 was estimated as 829200 ha and 794600 tonnes respectively. Statewise area and production of chilli is presented in Table 1.2.

(iii) Grapes

Grape is a crop of mainly warm climates and subtropical regions in the world. The raisins are produced in India either by drying the grapes in sun or by mechanical dehydration with or without pre-treatments. In India, the grapes production was 450 thousand MT (FAO, 1992).

The present investigation has been taken up with the following specific objectives,

(1) To construct a low cost semi-circular type greenhouse with provisions for natural ventilation.

(2) To dry the coconut kernel, chilli and grapes to a safe storage level in the newly constructed greenhouse.

(3) To analyse the quality of the dried products.

(4) To compare the results of greenhouse drying of coconut kernels, chillies and grapes with that of open sun drying method in terms of drying time, physiological loss in weight and other quality parameters.

(5) To work out the cost economics for greenhouse drying.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Drying of agricultural produce is essential to preserve the seasonal abundance and to meet the demand during off-seasons. The quality of the dried products depends mainly on age of harvesting of the produce, the method of drying and proper handling of the produce. In this chapter, brief reviews of earlier works on different methods of drying are presented.

2.1. Methods of Drying

2.1.1. Sun drying

Purewal (1953) stated, uniform sun drying of chillies without mould attack, and discolouration could be obtained by giving frequent stirring of the produce during day time and at night the fruits should be heaped and covered with tarpaulins. This procedure took 5-15 days to obtain 25-35 kg of dried spice from 100 kg of fruit.

Laul *et al.*, (1970) studied that sun-dried chillies and capsicum were contaminated with dust, dirt, rainfall and damaged by insects and birds, lead to more losses and could be as high as 70 to 80 per cent of the total quantity. They have suggested the ways of improving sundrying methods for Indian chilles and capsicums. Drying in single and multi-tier tray systems, in full sun and in the shade, and also blanching and pricking pretreatment were observed. A 4 tier system of wire mesh trays and a single tray of perforated aluminum both took 14 days in full sun to dry the fruit from a moisture content of 72-74 per cent,w.b. to about 6 per cent, where as normal Indian commercial sundrying method takes about 3 weeks to achieve a moisture of 15-20 per cent w.b.

Pruthi (1980) found that sun drying of hand peeled and abrasive peeled ginger with or without liming treatment took 7 to 9 days to obtain a final moisture content of 7.8 to 8.8 per cent,d.b.

Chillies were dried on mud floor, concrete floor, jute cloth, white canvas, tarpaulin, black and white polyethylene sheets. The olive-green tarpaulin and black polyethylene gave best results and tarpaulin saved 21 per cent drying time compared to mud floor (Singh and Anwar, 1982).

Kachru and Srivastava (1990) pointed out that conventional method of sundrying ripe chilles needs 3-15 days or even more depending upon weather conditions to yield good quality dried produce.

Mathew (1991) investigated that better quality could be obtained, when coconut cups are dried in the sun for 6 to 7 days on cement or bamboo floors rather than on ground. During sunshine moisture content comes down from 40 to 45 per cent to 5 to 6 per cent.

Shaji James and Mary Regina (1992) observed that pepper could be dried under sun in 26 hours.

Germination was highest (92 per cent) in seeds from sun dried fully-ripe red-coloured fruits, followed by seeds obtained from fully-ripe red-coloured fruits dried at an air temperature of 40°C. There was an interaction between harvesting stage and drying method (Dhanelappagol *et al.*, 1994).

Kostaropoulos and Saravacos (1995) suggested that a combined treatment consisting of alkali dipping and microwave treatment is promising option for reducing sun drying time for raisin production. Microwave pretreatment of dipped grapes dried nearly twice as fast in sun as the controls. Microwave pretreatment of fresh grapes was not successful since the berries bulged and exploded due to low water permeability of the grape skin.

Shivhare *et al.*, (1995) conducted studies on chilli drying and reported that concrete floor with tar coating was the best surface for sundrying as it gave higher drying rates. It took 20 h to reduce moisture of chillies to 5 per cent (db) while elevated wire mesh platforms took 37 hours.

Markose (1995) discussed that the coconut kernal exposed to the sun and allowed to dry for 2-3 days. At this stage, the moisture content of the kernel gets reduced to 20-28 per cent and kernel could be easily detached from the shell.

2.1.2. Mechanical drying

Lantz (1946) observed that slicing or spitting of pods reduced the drying time by half, and there was no loss of initial colour on drying for 72 h at 60 to 75°C using a mechanical dryer.

CFTRI suggested that at a temperature of 60 to 70°C. chillies could be dried in a forced draught of 2500 cu ft (71 cubic metre /mt) (Anon.,1961).

Lease and Lease (1962) conducted studies on the effect of forced air drying of chillies. Chilli fruits were sliced and dried to 8 per cent moisture content in 6 hr while whole fruit took 12 h. The optimum drying temperature for a good quality product was found to be 65°C. Extended drying was considered permissible at 50 and 65°C but at 80°C a lowering of pungency and initial colour retention properties were encounted.

Rama Rao and Ojha (1972) stated that freshly harvested chillies should be dried on the same day in thin layer at lower temperature.

Dhanelappagol *et al.*, (1988) carried out studies on drying characteristics of chillies and the results showed that the drying rate as well as the drying time depended upon the initial moisture content of the seed, temperature and relative humidity of dry air.The effects of 2 industrial drying processes (slow drying by wood combustion and fast drying using hot air) on the carotenoid content of capsicum annum fruits for paprika production were studied.

The slow drying resulted in an increase in the concentration of some pigments and during fast drying only degradable losses were measurable (Minguez - Mosquera *et al.*, 1994).

Kanawade *et al.*, (1995) studied the drying behaviour of peas in fluidized bed. The drying rate increased with increase in drying air temperature.

Markose (1995) found, in kiln drying of copra, the hot smoke with a temperature of 40-45°C directly comes into contact with the kernel. The copra produced by this method is of inferior quality and brownish in colour with slight reduction of oil content when extracted.In a chest-type 2-direction - flow heated air drier for vegetables, a new phenomenon was discovered the degree of uniformity of temperature, and that of the extent of drying of material in the drying chamber were almost the same as that of the air flow under unloaded and unheated conditions. This phenomenon may be applied to measure indirectly the temperature profile and uniformity of drying in the drying chamber (Yin Yong and Bai Chongren, 1995).

Twenty-five commercial copra kilns in SriLanka were studied for variations of their dimensions and copra curing practices in relation to the "Standard Ceylon Copra Kiln" and the quality of copra produced. Changes in the height and width of the platform resulting in probable changes in drying conditions of copra were noted (Rodrigo *et al.,* 1996).

Fuenties and Celis (1997) designed a multipurpose drier for agricultural products.

Tulasidal *et al.* (1997) conducted experiments on drying of Thomson seedless grapes into raisins under combined convective and microwave drying in a single model cavity applicator at 2450 MHz with varying operator parameters. A model of microwave drying was developed and the "Method of Lines" solved it. The simulated results were tested with the experimental data and good agreement was found, proving the validity of the procedures.

Kaensap *et al.* (1998) found that significantly improved drying rates for white pepper seeds were achieved by utilizing a combined microwave / fluidized bed compared with a conventional fluidized bed.The effect of drying conditions on colour changes of apples, bananas, carrots and potatoes during conventional and vacuum drying was investigated. The Hunder colour scale parameters were used to estimate colour changes during vacuum and conventional drying was regulated at 50, 70 and 90°C. Air humidity during conventional drying was regulated at 15, 30 and 40 per cent. The rate of colour deterioration increased as temperature increased and air humidity decreased for both drying methods and all the examined materials (Krokida *et al.*, 1998).

2.1.3. Solar drying

Carbonell *et al.*, (1985) studied the effect of various operating parameters on carrot drying. Drying were reported to increase with increase in solar radiation flux and airflow rates. Maximum drying rates were achieved for air flow rates of 50-150 kg/ha.

Mandhyan *et al.*, (1988) reported that winter vegetables like spinach, peas, carrot and cabbage could be dried in solar cabinet drier with a reduction in drying time of 15-20 per cent compared to sun drying.

Patil (1988) reported that drying of pepper in a solar cabinet drier offered advantages like quick drying, good quality pepper free from dirt and dust contamination, higher capacity and very good natural black colour owing to the temperature build up in the cabinet drier.

Jarnail *et al.* (1990) had reported a prototype solar cabinet drier (1200 x 1000 mm) for the drying of vegetables with wind aspirator and polyethylene top cover. Performance of the polyethylene sheet was comparable to that of the conventional glass cover.

Sanjay *et al.*, (1990) compared two types of solar driers with thermodynamic principles and performance. The dryers had uniform dimensions of 220 x 212 cm. Trials on ginger took 14 and 18 hours in the drier with glass cover and UV stabilized plastic sheet cover to bring down 84 per cent initial moisture to 10 per cent. The qualities of the product obtained from both the dryers were uniform.

Solar dehydrated cabbage, cauliflower, tomato, radish, turnip, fenugreek and palak was found better than the mechanically dehydrated samples in terms of duration, cost and quality (Joshi *et al.*, 1991).

Somchart and Marop (1991) stated that banana could be dried in a solar cabinet drier where it took 6 hours/day for one batch of drying.

Walde *et al.*, (1992) showed that carrots could be dried to a final moisture content of 10 per cent w.b. in a solar cabinet drier.

Maiava (1992) observed that a 40 mm layer of coconut meal on the drying tray decreased the airflow rate through the dryer by 20 per cent. The air flow rate, temperature, humidity, driving pressure and heat loss of a dryer were varied to simulate solar drying. This produced good quality copra characterized by its off - white colour and final moisture content.

A rotary tray system was developed and tested for use in a solar tunnel drier used for dried fruit production. The system ensures even drying and easy loading and unloading compared with the conventional stacked trays system (Fuller *et al.*, (1994).

Tiris *et al.*, (1994) designed a new solar dryer and tested with sultana grapes, green beans, sweet peppers and chilli pepper and compared with traditional sun drying. The drying curves obtained indicated that use of the solar drier reduced the drying time by factor of 1.7, 2.2, 1.8 and 2.2 respectively for grapes, beans and sweet and chilli peppers. Mass losses were prevented and better product quality was acheived.

Atmawinata *et al* (1995) constructed a transparent house with walls and roof made from fibre glass reinforced plastic for drying coffee berries. The constructed one trapped the solar radiation to heat up the circulated air to 44°C with a relative humidity of 45 per cent. The house took only 72-80 hours to reduce the moisture content of coffee from 65 to 12 per cent compared with 120-140 h for sun drying.

Tiris *et al.*, (1995) conducted an experimental investigation on solar drying for the selected sultana grapes, green beans, sweet and chilli peppers as test samples. The drying periods of solar dried sultana grapes, green beans, sweet and chilli peppers were 1.8, 2.2, 1.9 and 2.0 times shorter, respectively, than for the natural sun dried products. The collector efficiency was satisfactory for heating the drying air.

Ahmad and Khan (1997) designed and constructed an 8 flat plate solar collectors, each has a gross area of 2.0 square meter, effective area of 1.86 m^2 and an average heat generation capacity of 18.6 mJ/day (at 50 per cent efficiency). An economic analysis showed that this drying system is very economical for drying and has promising potential for seed, fruit and vegetable growers.

A solar drier was designed to dry dates under controlled and protected condition. It took a drying time of 9.8 h to dry 100 kg of dates under average ambient conditions of 32°C air temperature and 65 per cent relative humidity and a minimum of 16m^2, solar collector area (Ampratwum, 1998).

2.1.4. Greenhouse Drying

Mathala Juliet and Pitam Chandra (1989) conducted studies on drying of pigeon peas in the greenhouse type solar dryer. The time taken for open sun drying was higher (17.23 per cent) than the greenhouse type solar dryer with natural ventilation.

Muller *et al.*, (1993) described a solar dryer based on a standard plastic film greenhouse with a batch dryer inside to dry medicinal plants. The use of a small supplementary heater in conjunction with solar drying reduced unit costs. These costs were below those of conventional drying when 2 species were dried in the dryer.

Sawada and Horibe (1994) developed a Drying model for ventilation drying of rice in a green house.

Thermal analysis of a simple greenhouse type solar timber kiln was undertaken by Sattar (1995) in Bangladesh for 4 mixed charges of 4 indigenous hardwood. The combined overall efficiency of the kiln was reported as 18 per cent and the areas of heat use and loss were determined.

Ucuncu (1997) designed and constructed a small solar greenhouse kiln, of capacity $2m^3$ and collector area 6 m^2. It is concluded that the kiln is well suited to timber drying for the 7 warmest months of the year.

2.2 Effect of Pretreatments

According to Vishansky *et al.*, (1983) grapes, cherries and plums were found to have a waxy layer each with a homogenous and characteristic ultra structure. Water blanching for 30 sec reduced the wax layer.

Peri and Riva (1984) observed, reduced drying time, improved sensory quality, colour and retention of the integrity of the skin in the grapes subjected to gaseous SO_2 and chemical treatments.

Grapes dipped in boiling 0.25 per cent sodium hydroxide solution or an aqueous emulsion containing 2 per cent oleic acid and 2.5 per cent potassium carbonate had accelerated drying rate (Silveira *et al.*, 1984).

Riva and Peri (1986) reported that a preliminary dip of grapes in alkaline ethyl oleate solution was able to stabilize the fruit and to modify the skin permeability. This reduced the drying times by a factor of 5 to 10.

Rime (1987) observed that banana treated with sulphur fumes retained better colour and quality.

Studies conducted by Shanthi (1991) indicated that the effect of pretreatment by sulphuring resulted in a better retention of ascorbic acid during drying and storage of the dried amla pulp.

Mulay *et al.*, (1994) found that among the dehydrated cabbage samples, retention of ascorbic acid was more in sulphited samples. The non-enzymatic browning in potassium metabisulphite treated sample (> 0.5) was lower compared to other samples.

The highest rehydration ratio (5.23) was obtained for samples from Oyster mushrooms dried after pretreatment had the best organoleptic quality (Nehru *et al*, 1995).

2.3 Qualities

2.3.1. Acidity

Vidhya and Maini (1991) observed a decreased acidity values in sun dried raw mango slices, after 9 months of storage.

Jesupriya (1994) found that in raisins, there was no significant difference of acidity level between the pre-treated samples and drying methods.

2.3.2. Ascorbic acid

Levi *et al.*, (1985) reported highest retention of ascorbic acid in directly dried papaya slices in cabinet drier compared to water blanched and dried samples.

Pawar *et al.*, (1988) observed that the ascorbic content of sun and solar dried onion flakes were 2.12 and 2.48 mg per 100g in control samples and 3.45 and 4.78 mg per 100g in sulphited samples just after drying.

Jesupriya (1994) found that the ascorbic acid depletion rate was higher in sun dried banana samples when compared to solar dried and among the various treatments given to grapes. Australian cold dip was the best method, in retaining the ascorbic acid followed by control, sulphured and Australian mix dipped.

2.3.3. Total Sugars

Jesupriya (1994) pointed out that among the four treatments, control raisins retained more total sugar followed by Australian cold dipped, Australian mix dipped and sulphured.

2.3.4. Colour

Sharma *et al.*, (1993) discussed the colour changes during drying of apricot. Effect of pre-treatments to prevent discolouration was investigated. Sulphur fumigation and lye peeling were the most effective pre-treatments.

Yamuna (1998) found that sun dried chillies (57.7 ASTA units) obtained less colour value compared to solar cabinet dried samples (64.3 ASTA units) and static bed dried samples (67.3 ASTA units) at 40°C.

2.3.5. Oleoresin

Distinct differences in quality and yield of both essential oils and oleoresins have been noticed in varieties of important spices such as cardamom, ginger, chillies, pepper and turmeric grown in India (Lewis, 1972).

Yamuna (1998) observed that chillies dried under static bed drier at 40°C has 8.15 per cent oleoresin content while sun dried samples got 6.43 per cent oleoresin content.

2.3.6 Microbial Count

Rehumath Niza and Chandrasekharan Nair (1992) investigated that the incidence of microorganisms on copra is directly proportional to the relative humidity of the atmosphere and moisture content of copra. The influence of copra by fungi and bacteria vary according to the season of drying and storage.

Sundaravadivelu and Palaniswami (1993) found that the iodine value of oil extracted from copra samples contaminated with different fungi was higher than that for control samples. Saponification value of oil extracted from contaminated copra was higher when compared to control samples.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials used and methods adopted for conducting the drying studies of selected horticultural crops namely coconut, chilli and grapes and quality analysis of the dried produce.

3.1 Raw Materials

3.1.1 Coconuts

The first lot of matured coconuts with husk were procured from the coconut research farm, TNAU, Coimbatore and used for the study.

3.1.2 Chillies

Local variety of ripened chilli fruits were procured from the local private farms and used for the study.

3.1.3 Grapes

Thomson seedless variety was purchased from the local fruit shop and used for the study on the same day.

3.2 Equipments

3.2.1 Dehusking unit

A manually operated portable dehusking unit was used to dehusk the coconut.

3.2.2 Electronic balance

An electronic balance of 5 kg capacity with 0.1 g least count was used to weigh the raw materials and the dried produce.

3.2.3 Hot air oven

A thermostatically controlled hot air oven was used to determine the moisture content of samples.

3.2.4 Humidity / Temperature meter

A digital humidity / temperature meter with measuring range of 10 to 95% and 0 to 60°C for humidity and temperature respectively with an accuracy of 70 ± 3%, when RH ≤ 70% and 70 ±1%, when RH is ≥ 70% and °C + 0.8°C for humidity and temperature repectively was used to record the relative humidity and temperature of the atmosphere both inside and outside the greenhouse throughout the drying period.

3.3 Preparation of samples for drying studies

3.3.1 Coconuts

The matured coconuts were dehusked with the manually operated dehusking unit and split into two equal halves. The coconut kernels (with shell) were weighed.

3.3.2 Chillies

The ripened red chilli fruits were selected and weighed.

3.3.3 Grapes

The berries were detached from the grape bunches, washed and weighed after draining surface water and divided equally for control and various treatments, viz., Australian cold dip method, Australian mix dip method and sulphuring.

3.3.3.1. Dewaxing treatments for grapes

3.3.3.1.1 Australian cold dip method

The cold dip treatment has important beneficial effects. It caused the grapes to dry quickly and produced an attractive golden brown colour. Also the skin of the grapes was not checked or cracked as with the caustic treatments. The procedure was adopted from More and Kanawade (1985). The emulsion was prepared with 5 g of potassium carbonate and 0.4 g of refined groundnut oil and 100ml of water using a homogenizer. The grapes were dipped in the emulsion at 55°C for 4 minutes.

3.3.3.1.2 Australian mix dip method

The procedure was adopted from More and Kanawade (1985). In this method an emulsion was prepared by mixing 0.3 g of sodium hydroxide, 0.5 g of potassium carbonate and 0.4 g of refined groundnut oil in 100 ml of water using a homogenizer. The emulsion was heated to a temperature of 82°C. The grapes were immersed in the hot emulsion for 10 seconds.

After the dewaxing treatments, the berries were immediately washed in cold water repeatedly to remove the alkali. The berries were immersed in 0.5 per cent citric acid solution for 5 min. to neutralize the residual alkali. The grapes were washed in running water, drained and were subjected to surface drying.

3.3.3.2. Sulphuring

The grapes were exposed to sulphur fumes in the sulphuring chamber for 30 min. at the rate of 3 g of sulphur per kg of the prepared materials. The sulphulring chamber used was an air-tight metallic container of size 50 x 30 x 60 cm.

3.4. Methods of Drying

3.4.1. Sun drying

Samples were spread uniformly on trays and exposed to sun. One of the two halves from each coconut kernel (with shell) were taken and the white kernel parts were exposed to sun until the moisture content was reduced to less than 6 to 7 per cent d.b. Scooping of coconut kernel was done at the moisture content of approximately 17 per cent d.b. on the 4th day. The coconut kernel was dried and the copra was obtained on the 7th day.

Chillies and Grapes samples (control and pre-treated) were spread on trays and exposed to sun till safe moisture content were reached. Temperature and relative humidity were recorded at intervals of 2 hours. The physiological loss in weight was also taken during these intervals.

3.4.2. Greenhouse drying

A greenhouse of 4 x 5 x 4 m dimension with semicircular roof glazed with a single layer of ultra violet stabilized polyethylene film (200 micron thickness) was constructed and used. The orientation of greenhouse was towards East-West direction. The floor of the greenhouse was covered with a black polyethylene film (25 micron thickness). The detailed structural drawings of poly greenhouse are given in figure 3.1. The greenhouse with and without ventilation opening are shown in Plates 3.1. and 3.2. Adjustable ventilation arrangement was provided at the crest of the greenhouse with the ventilation area of 1.5 2 m^2 and another shut and open type ventilation at the bottom to a depth of 100 cm with the ventilation area 5 m^2 . The dimensions of ventilation areas adopted were arbitrarily fixed. The ventilation areas were covered with nylon mesh to prevent the entry of insects. The ventilation area helps in efficient removal of moisture from the produce, by allowing the entry of fresh air from the bottom and removal of moist air through the top, by natural convection. The bottom ventilation area was left open for the first half an hour of the 1st day drying period and then closed. The air inside gets heated for the next 2 hours with the ventilation shut at both the bottom and top. The top ventilation was then kept open for half an hour for the escape of moist air. Then the top ventilation was closed and the bottom one was kept open for the entry of fresh air. This repeated opening and closing of bottom and top ventilation at every 2 hours intervals hastened the removal of moisture and this frequent ventilation was given during the initial stage (first 2 days) of drying period.

Another half of the each coconut kernel (with shell) was spread on the greenhouse floor with white kernel part exposed to the roof of the

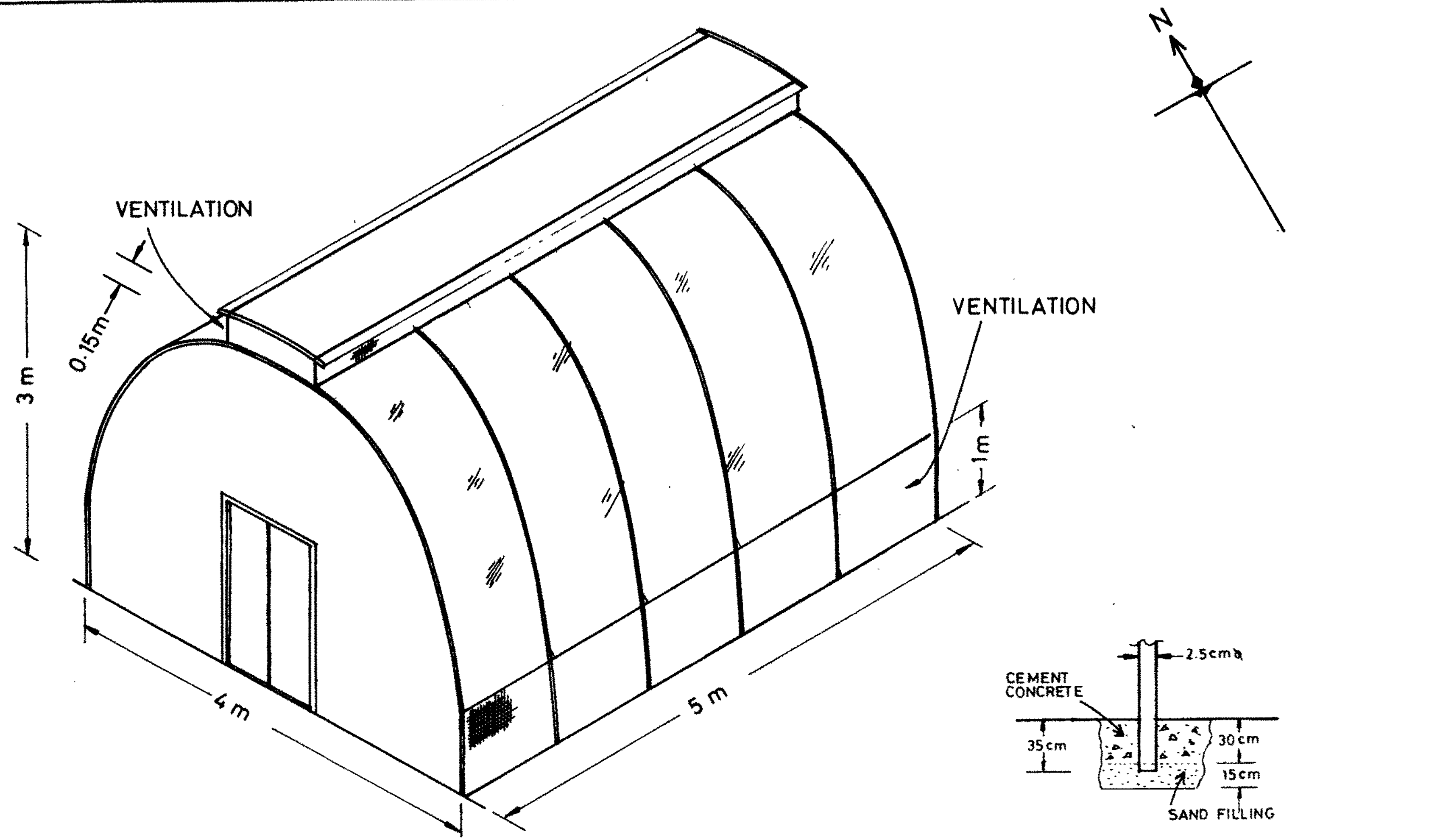


FIG. 3.1 POLY GREEN HOUSE

Plate 3.1 Greenhouse with ventilation opening

Plate 3.2 Greenhouse without ventilation opening

greenhouse. Scooping of coconut kernel from the shell was done on the 2nd day at the moisture content of 17 per cent d.b. Coconut kernel was dried for about 3 1/2 to 4 days to obtain the copra with the final moisture content of 6.48 per cent d.b. Chilli and grapes samples were spread on trays and dried inside the greenhouse till safe moisture contents were obtained.

Temperature and relative humidity were recorded at intervals of 2 hours. The physiological loss in weight was also noted during these intervals.

3.5 Quality analysis of the products

3.5.1 Determination of moisture content

The moisture content of the samples was determined as per the method described by Ranganna (1977). About 5 to 10 g of the chilli and grapes samples were weighed accurately and dried in an oven at 70°C to a constant weight. About 5 g of coconut samples were dried in an oven at 130°C for 1 hour.

3.5.2 Enumeration of bacteria and fungi in copra

1 gm of sample was serially diluted upto 10^{-6} solution. 1 ml of 10^{-6} dilution was taken and plated using Rose Bengal Agar medium and incubated for about 3 to 5 days at 30°C for enumeration of fungi. Similarly 1 ml of 10^{-6} dilution was taken and plated using Nutrient Agar medium and incubated for about 4 hours at 3°C for enumeration of bacteria (Jhonson and Curl, 1972).

3.5.3 Refractive index

The coconut oil was extracted using hydraulic press. The extracted oil was examined in an Abbe refractrometer and the value of refractive index at 25°C was noted (William Hortrwitz,1955).

3.5.4 Lipids

The free fatty acid or acid value, saponification value and iodine value of coconut oil were estimated following the procedure of Sadasivam and Manickam (1991).

3.5.5 Colour value

ASTA Analytical Methods-method 20.1(1997) was followed to determine the extractable colour in chillies.

3.5.6 Oleoresin

Oleoresin content of chillies was extracted using acetone as the solvent in a soxhlet apparatus. The ground samples of 2g passing through IS 20 sieve (20 µm aperture size) was used for the extraction.

$$\text{Oleoresin (\%)} = \frac{\text{Weight of residue (g)}}{\text{Weight of sample (g)}} \times 100$$

3.5.7 Ascorbic acid

The ascorbic acid content of raisins was determined by volumetric method following the procedure of Sadasivam and Manickam (1991).

3.5.8 Total sugar

The total sugar was estimated by Anthrone method following the procedure of Sadasivam and Manickam (1991).

3.6 Sensory evaluation

The sensory attributes viz., appearance, colour, taste and overall acceptability of the raisins were evaluated using a panel of ten persons from different field. The score cards used for the organoleptic evaluation of raisins are given in Appendix C.

Results and Discussion

CHAPTER - IV

RESULTS AND DISCUSSIONS

This chapter deals with the results obtained during the drying studies of copra, chillies and grapes under greenhouse and sun drying conditions. The quality analysis of the dried produces ware also presented.

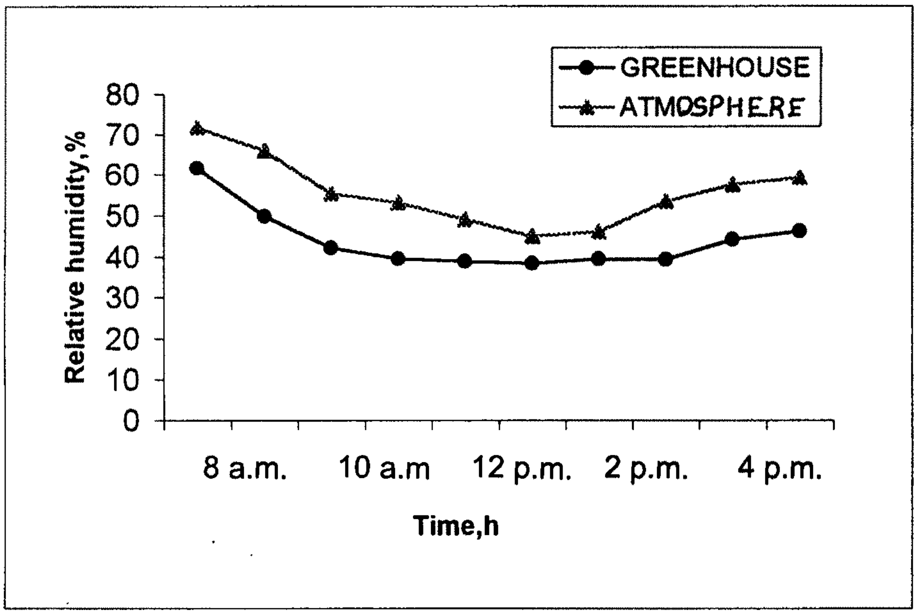
4.1 Characteristics of Greenhouse

4.1.1 Characteristics of greenhouse without ventilation

The temperature and relative humidity prevailed in the greenhouse without ventilation and atmosphere recorded at one hour interval for 2 days during are given in Fig.4.1 (Appendix-A). The lowest humidity and the peak temperature values were recorded in the noon time between 12 and 2 p.m. under both the conditions. The atmospheric temperature and relative humidity varied from 28 to 40°C and 71 to 45 per cent whereas the greenhouse temperature and relative humidity varied from 36 to 57°C and 61 to 37 per cent respectively. It is seen from the graph, that the temperature is inversely proportional to the relative humidity under both the conditions.

4.1.2. Characteristics of greenhouse with ventilation

The temperature and relative humidity in the greenhouse and atmosphere were recorded immediately after closing the ventilation provided at



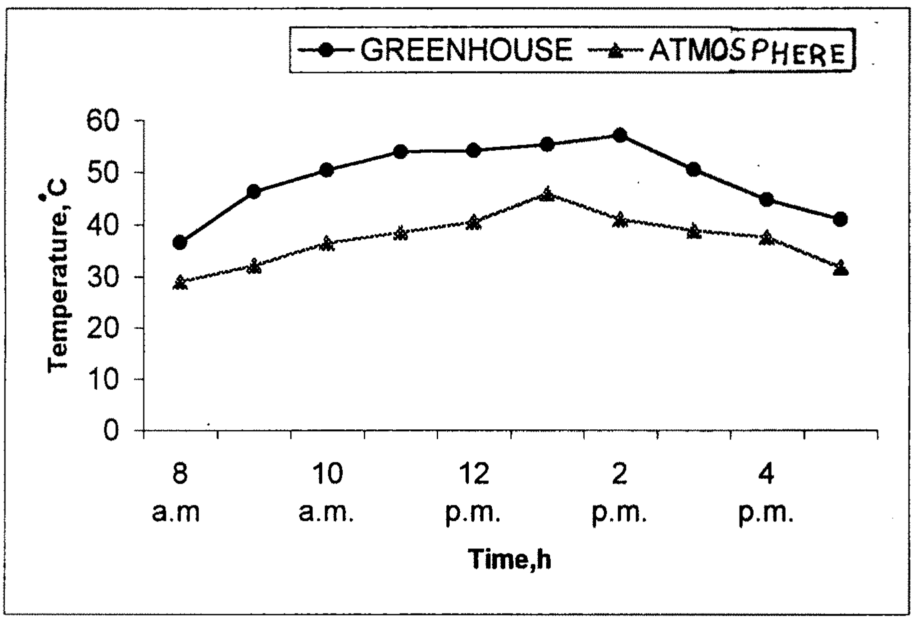


FIG.4.1 VARIATIONS OF TEMPERATURE AND RELATIVE HUMIDITY WITH TIME

the top. It was observed that the temperature and relative humidity were more inside the greenhouse than the atmosphere. The differences in temperature and relative humidity between the greenhouse and atmosphere were 5°C and 2 to 3 per cent respectively. The temperature and relative humidity were again recorded after 30 minutes of closing the ventilation at the top. It was found that the greenhouse attained its original temperature and relative humidity and maintained the difference in temperature and relative humidity as the same when the greenhouse ventilation arrangements had not been kept open

4.2. Drying Characteristics of Crops

The observations and calculations obtained during the drying studies of copra, chillies and grapes are presented in Appendix-B. The drying rate and drying characteristics curves were plotted between drying rate and time, and moisture content (%d.b.) and drying time.

4.2.1. Drying of copra

The drying characteristics of copra (Plate 4.1, Plate 4.2, Plate 4.3) under greenhouse and sun drying are shown in Fig.4.2 and Fig.4.3 It is observed from Fig.4.2 that the coconut kernels are dried from an initial moisture content of 92.31 per cent d.b. to a final moisture content 6.48 per cent d.b. in 30h (4 days), under greenhouse condition where the temperature and relative humidity prevailed are 43 to 60°C and 66 to 35 per cent respectively. The scooping of meat from the shell could be effected at the moisture content of

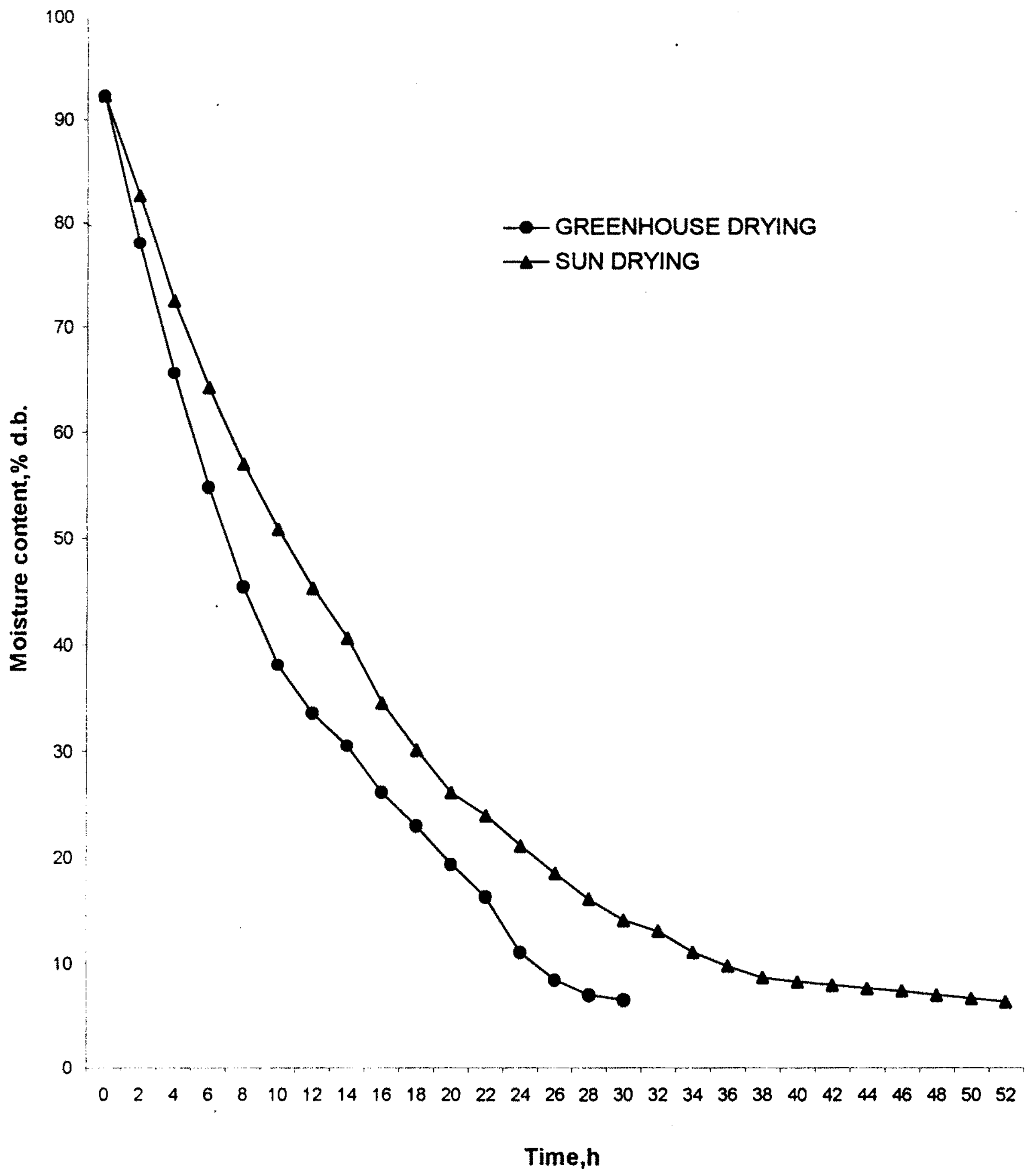


FIG. 4.2 DRYING CHARACTERISTICS OF COPRA UNDER GREENHOUSE AND SUN DRYING

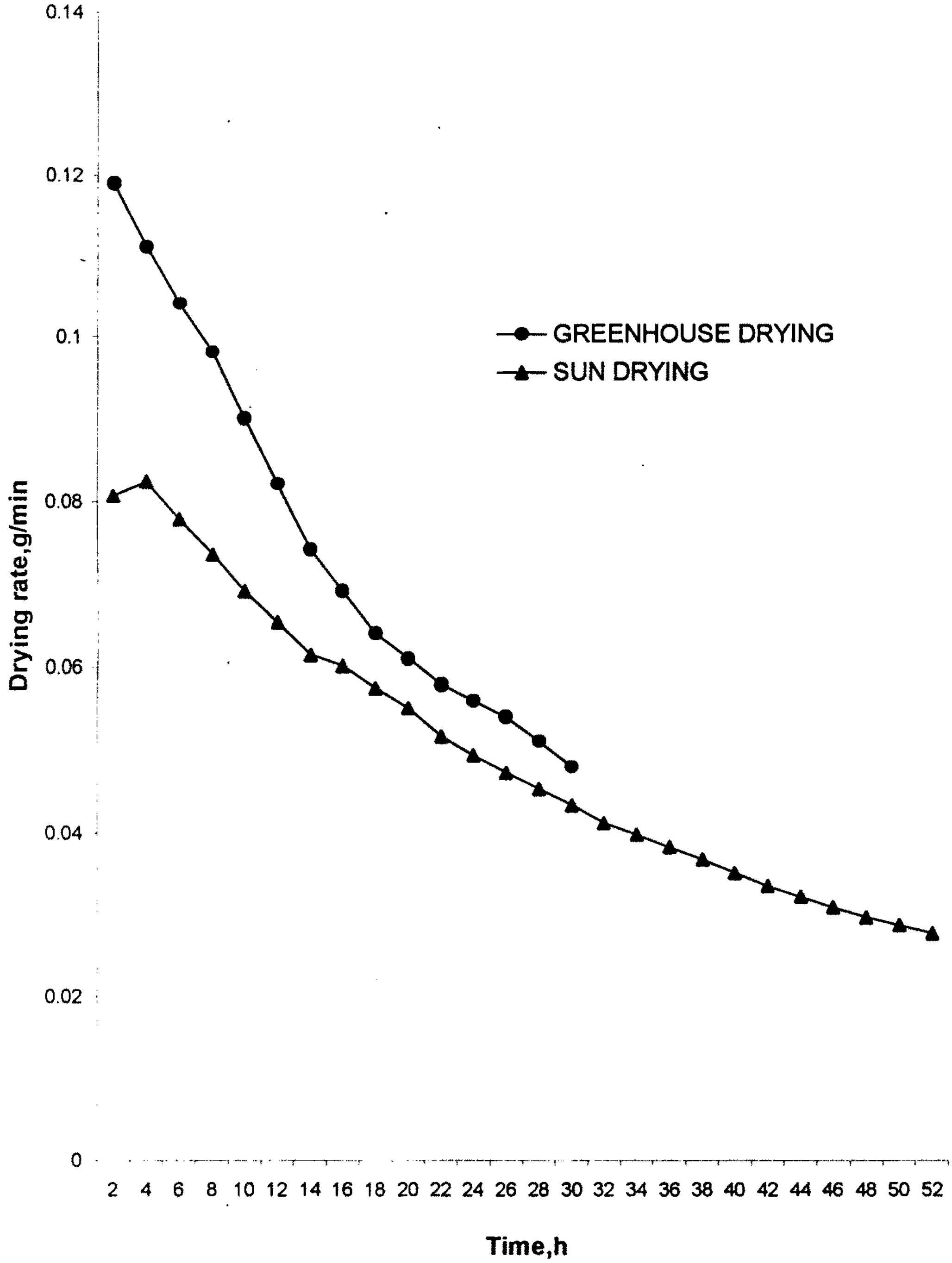


FIG.4.3 DRYING RATE OF COPRA UNDER GREENHOUSE AND SUN DRYING

Plate 4.1 Greenhouse dried copra

Plate 4.2 Sun dried copra

Plate 4.3   Greenhouse and sun dried copra

17.1 per cent d.b. on the 2nd day of drying in the greenhouse. For the same range of moisture reduction under sun drying, for an atmosphere range of temperature from 28 to 40°C and 82 to 50 per cent of relative humidity. it took 52h (7 days). The meat from the shell under sun drying was scooped on fourth day at the moisture content of 17.5 per cent d.b. It is seen from the Fig.4.3 that the drying rate of copra under greenhouse drying is more than the sun drying. The drying rate decreases as the drying time increases under both the drying conditions. From the experiments it is clear that drying of copra under greenhouse condition takes 50 per cent less time than sun drying.

Mathew(1991) reported that coconut kernels from the initial moisture content of 45 per cent w.b. were dried to a final moisture content 5 to 6 per cent w.b. in the sun for 6 to 7 days on a cement or bamboo floor rather than on ground.

4.2.2. Drying of chillies

The Fig.4.4. and Fig.4.5. represents the drying characteristics of chilles(Plate 4.4) under greenhouse and sun drying. From the Fig.4.4 it is found that the chilli fruits with the initial moisture content of 410.20 per cent d.b. (including stalk) are dried to a final moisture content of 5.78 per cent d.b. in 24 h, at the temperature and relative humidity of 36 to 59°C and 52 to 21 per cent respectively under greenhouse drying. The same final moisture content is obtained in 42 h, under sun drying where the temperature and relative humidity

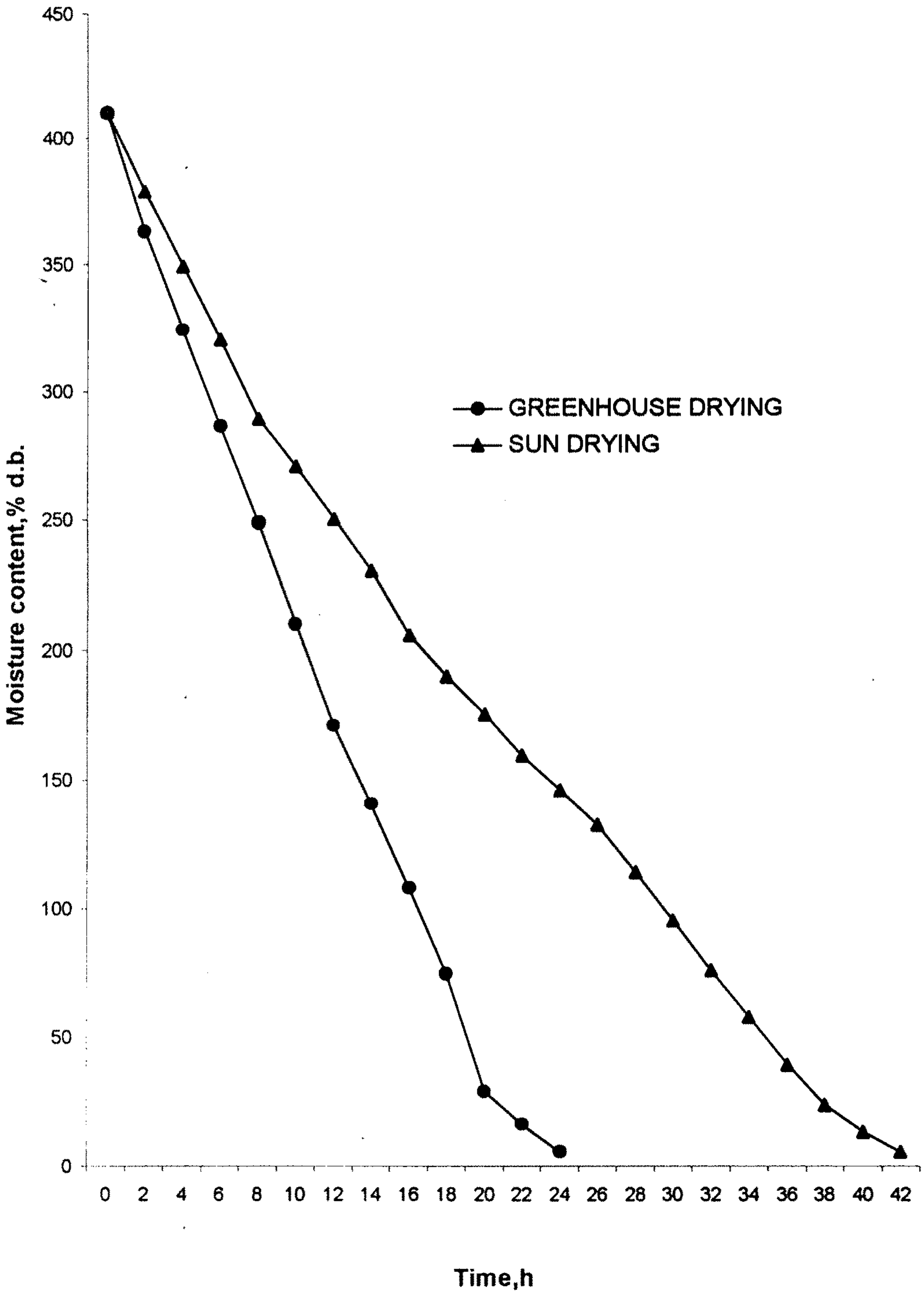


FIG.4.4 DRYING CHARACTERISTICS OF CHILLES UNDER GREENHOUSE AND SUN DRYING

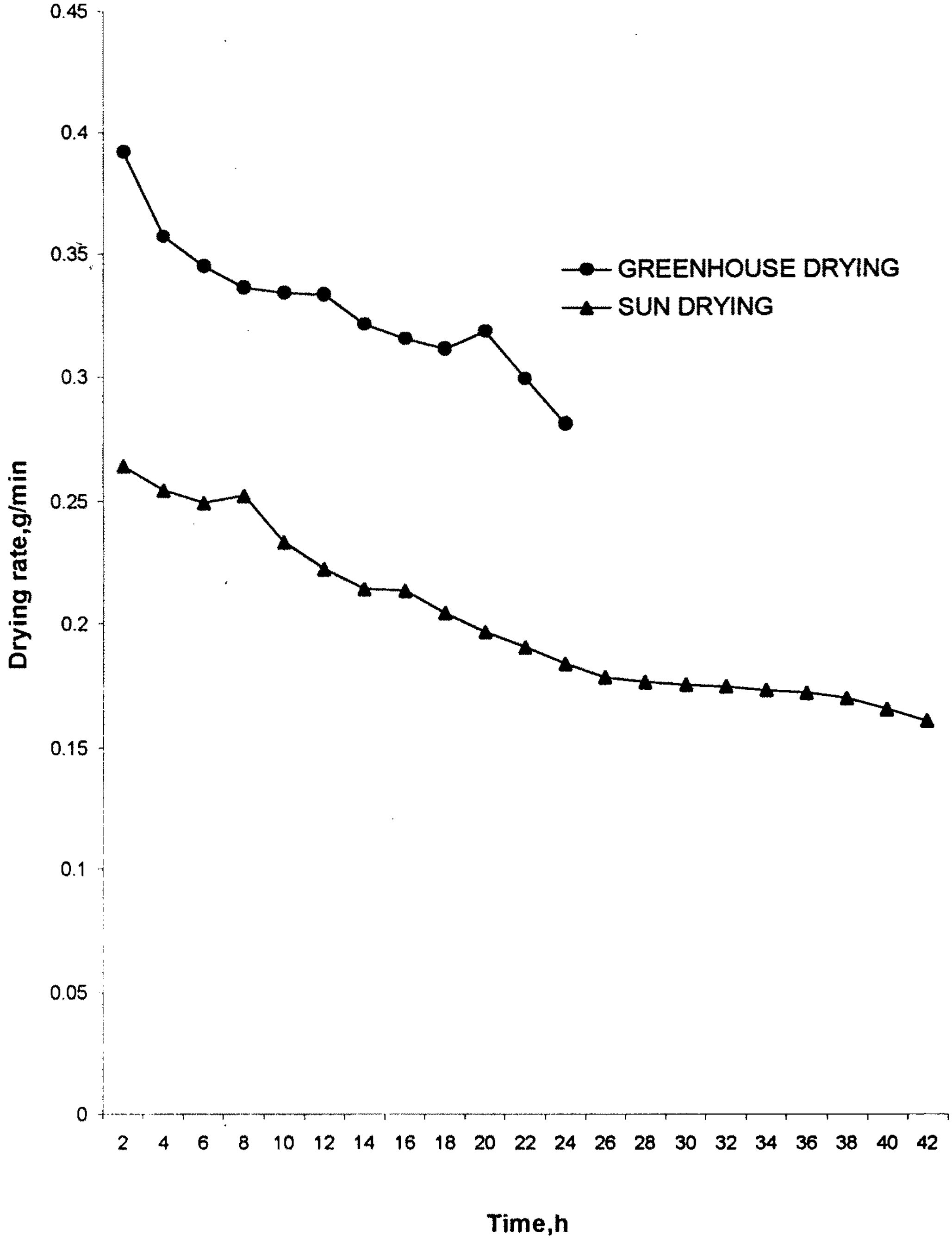


FIG.4.5 DRYING RATE OF CHILLES UNDER GREENHOUSE AND SUN DRYING

Plate 4.4 Greenhouse and sun dried chillies

recorded are 28 to 38°C and 80 to 41 per cent respectively. The Fig.4.5 shows that the drying rate is more in the greenhouse drying than the sun drying and it decreased as the drying time increased for both the drying conditions. From the experiments conducted, it is seen that the drying of chillies in the greenhouse saves 50 per cent of time than the sun drying.

Yamuna(1998) found that the chillies from an initial moisture content of 244.83 per cent d.b. are dried to a moisture content of 2.93 per cent d.b in 31 h, under sun drying.

4.2.3. Drying of pre-treated grapes.

The drying characteristics of pre-treated grapes under greenhouse and sun drying (PLATE 4.5 and 4.6) are shown in Fig.4.6 and Fig.4.7. It is seen from the Fig.4.6 that the pre-treated Australian Mix Dipped(AMD) grapes from an initial moisture content of 426.32 per cent d.b. are first effectively converted into raisins with the moisture content 15.82 per cent d.b. in 26 h, under greenhouse drying. For the same treatment and moisture reduction, it took 44 h to reach the final moisture content of 15.97 per cent d.b. under sun drying. The Australian Cold Dipped(ACD) grapes, Sulphured and Control grapes from an initial moisture content of 426.32 per cent d.b. are dried and converted into raisins to a final moisture content of 16.52, 16.57, and 15.37 per cent d.b. in 26, 36 and 34 h, respectively under greenhouse drying. For the same treatments under sun drying it took 46 , 68

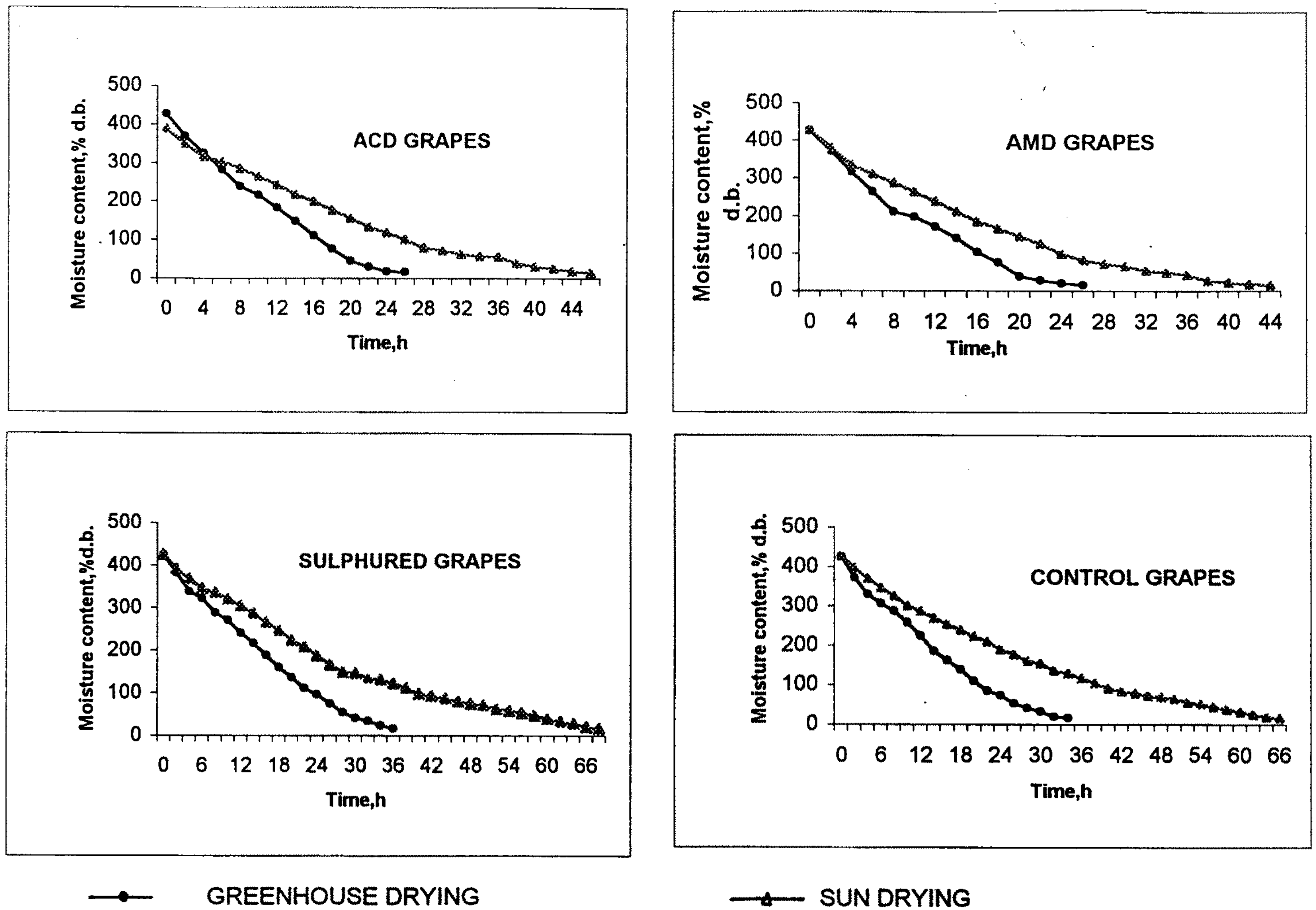


FIG 4.6 DRYING CHARACTERISTICS OF PRE-TREATED GRAPES UNDER GREENHOUSE AND SUN DRYING

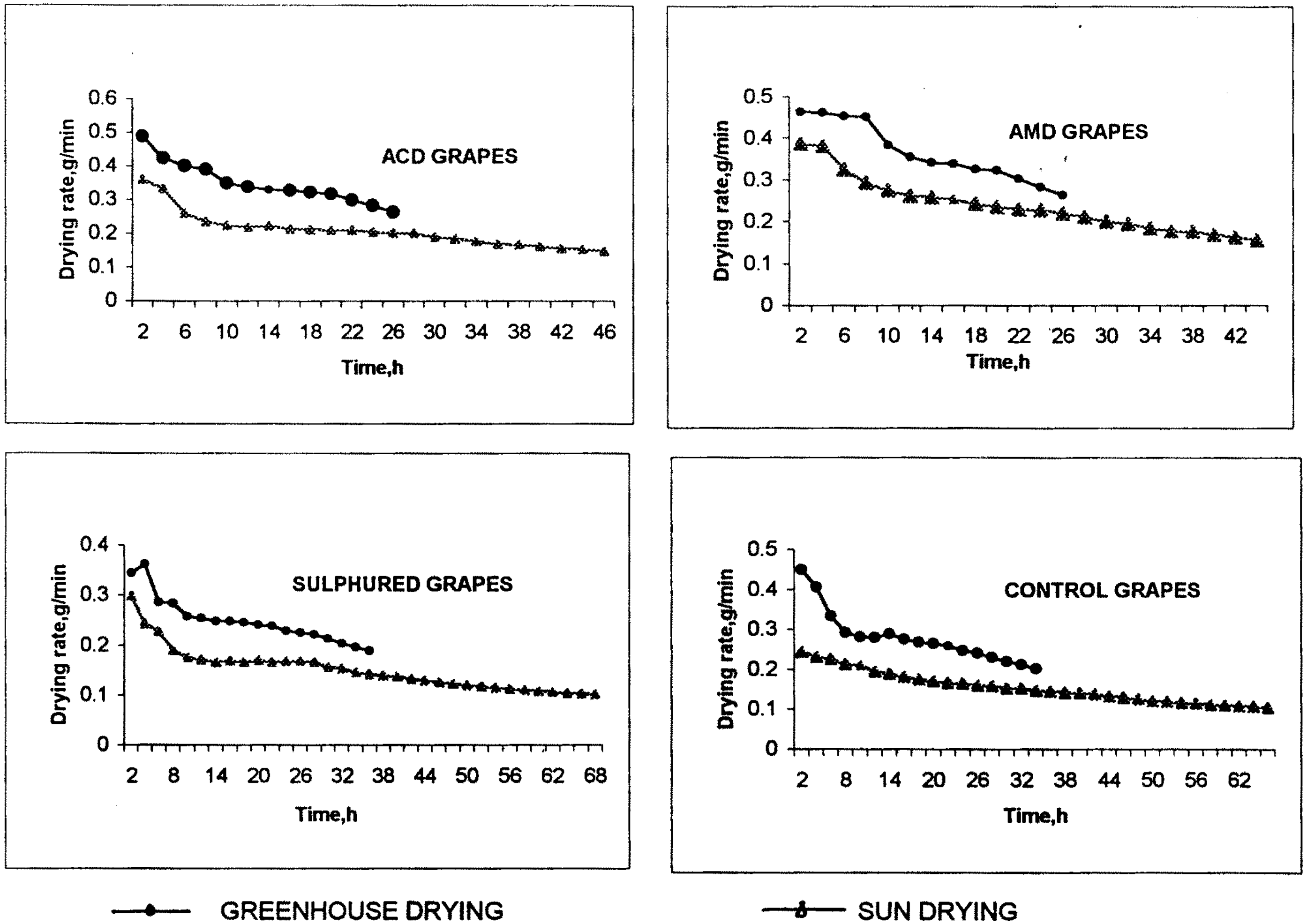


FIG 4.7 DRYING RATE OF PRETREATED GRAPES UNDER GREENHOUSE AND SUN DRYING

Plate 4.5 Greenhouse dried raisins

Plate 4.6 Sun dried raisins

and 66 h to reach the moisture content of 16.04, 15.58 and 16.63 per cent d.b., respectively. The temperature and relative humidity prevailed under greenhouse and atmospheric conditions are 37 to 59°C and 66 to 35 per cent, and 28 to 41°C and 82 to 48 per cent respectively.

It is observed from Fig.4.7.that the drying rate of pre treated grapes under greenhouse condition is rapid than the sun drying. The highest drying rate of 0.487g/min is found in the ACD grapes during the second hour of drying in greenhouse. The drying rate of AMD grapes under both the drying conditions are faster than the other pre-treated grapes. From the experiments it is noted that the pre-treatment given to the grapes enhanced the drying rate and reduced the drying period than the control. Also it is seen that the pre-treated grapes dried under greenhouse conditions took 50 per cent less time than sun drying.

Dhabhade and Khedkar (1980) observed that in cabinet as well as in sun drying, drying was rapid in blanched mango sliced samples compared to the unblanched ones.

Nilamani et al., (1992) found that maximum moisture loss was noticable during the first hour of drying of peas. After the fourth hour of drying, 73 to 80 per cent of the original moisture was removed.

4.3. Quality analysis of the dried produces

The different quality parameters of the dried produces under greenhouse and sun drying are presented in Table4.1.

Table.4.1 Effect of drying method on quality parameters of the dried produces

Produces and quality parameters	Greenhouse dried	Sun dried
COCONUT		
I Microbial load		
-Bacteria (CFU)	3.43×10^{-6}	5.81×10^{6}
-Fungi (CFU)	2.83×10^{6}	3.99×10^{6}
ii Refractive index	1.4481	1.4490
iii Lipids		
-Free fatty acid (%)	2.8	3.7
-Iodine number	8.1	9.53
-Saponification value	248.81	263.78
CHILLIES		
I Colour value (ASTA units)	58.6	51.5
Ii Oleoresin (%)	6.5	4.65
GRAPES		
I Total sugars (g/100g)		
-ACD	92.52	92.20
-AMD	92.68	92.36
-Sulphured	92.91	91.0
-Control	93.30	92.50
ii Ascorbic acid (mg/100g)		
-ACD	7.89	6.67
-AMD	8.31	7.01
-Sulphured	6.54	6.35
-Control	8.17	7.02

4.3.1. Copra

4.3.1.1. *Microbial load*: Moisture content is considered to be an important factor governing the quality deterioration of copra. From the table 4.1 it can be seen that the microbial population on greenhouse dried samples was less compared to sun dried samples, as it took lesser drying period to reach the desired moisture content. It can be also due to the lower relative humidity and higher temperature prevailed under greenhouse conditions.

Susamma Philip (1978) conducted path analysis studies to observe the influence of weather elements on quality deterioration of copra and found that relative humidity of the atmosphere and moisture content of copra are the important factor influencing microbial deterioration of copra.

Rehumath and Niza Chandrasekharan Nair (1992) investigated that the incidence of micro organisms on copra is directly proportional to the relative humidity of the atmosphere and moisture content of copra.

4.3.1.2. *Refractive index of coconut oil* : The refractive index of coconut oil extracted from greenhouse and sun dried samples are given in Table4.1. It is found that the effect of drying is not significant on the refractive index of the oil. Sundravadivelu et al.,.(1993) observed that there was no significant difference in refractive index of extracted from healthy as well as contaminated copra.

4.3.1.3. ***Lipids content of coconut oil:*** The per cent free fatty acid, iodine number and saponification value of coconut oil extracted from greenhouse and sun dried copra are given in Table.4.1. From the values it is seen that the free fatty acid, iodine and soponification values of greenhouse dried samples were less compared to sun dried samples and resulted in better quality of oil. This is due to the faster drying of copra in greenhouse at higher temperature and lower humidity. The data in general are in agreement with that of Sundaravadivelu *et al.*, (1993).

4.3.2. Chilles

4.3.2.1. ***Colour value:*** Table 4 . shows the colour value of greenhouse and sun dried chillies. It was found thart the colour value was more for the greenhouse dried chillies than the sun dried chillies. The drying of chillies under sun drying takes longer period (42 h) resulting in pale colour. Yamuna (1998) found that sun dried chillies resulted in lower colour value than the samples dried in solar cabinet dryer.

4.3.2.2. ***Oleoresin content of chillies:*** The per cent oleoresin content of greenhouse and sun dried chilles are presented in Table 4.1 and it could be inferred that the chillies obtained under greenhouse drying were better in quality. This may be due to fact that drying the chillies by sun drying for a longer duration resulted in loss of volatile matter. The greenhouse drying at temperature higher than sun drying with higher drying rate has yielded higher per cent oleoresin. Similar results were obtained by Yamuna (1998).

4.3.3. Grapes

4.3.3.1. *Total sugars in dried raisins*: From the values presented in Table 4.1, it was observed that the total sugar content of raisins with different pre-treatments under greenhouse and sun drying are on par. Jesupriya (1994) observed similar results on total sugar content of the raisins immediately after sun drying and solar drying conditions.

4.3.3.2. *Ascorbic acid content of dried raisins*: It is seen from table 4.1 that the average ascorbic content of greenhouse dried raisins are high compared to sun dried raisins. This may be due to the shorter drying period for raisins in greenhouse compared to the longer period under sun drying. Jesupriya (1994) noted that the loss of ascorbic acid was highly observed in sun dried samples than the samples dried in solar cabinet dryer

4.3.3.3. *Sensory evaluation of dried raisins*: The scores of sensory evaluation of dried raisins are shown in Table 4.2. The greenhouse dried AMD raisins had better colour, texture, flavour and taste and has been accepted well compared to others. On an average greenhouse dried raisins had obtained an overall acceptability than the sun dried raisins.

4.4 Cost of Greenhouse

The cost of the constructed greenhouse was estimated as Rs.17,500/- The cost of greenhouse per square metre worked out to be Rs.875/-

Table.4.2. Sensory evaluation scores of the raisins

Items	Greenhouse dried				Sun dried			
	ACD	AMD	Sulphured	Control	ACD	AMD	Sulphured	Control
Colour	4	4	4	4	3.9	4	4	4
Texture	3.9	4	3.9	3.8	3.8	4	3.8	3.9
Flavour and taste	4	4	4	4	3.8	3.8	3.8	3.9
Overall acceptability	4	4	3.9	3.9	3.9	4	3.9	4

4.5 Cost of Greenhouse Drying

The drying cost of copra, chillies and raisins in the greenhouse is calculated and presented in Appendix-D. The drying cost of copra, chillies and grapes in the greenhouse is found to be Re 0.24/kg, Re 0.47/kg, and Re 0.59/kg respectively.

4.6 Saving in drying time

The per cent of drying time saved in the greenhouse drying of copra, chillies and grapes over the sun drying method is calculated and presented in Appendix-E. The per cent of savings in drying time of Copra, chillies and grapes is found to be 42.31, 42.86 and 40.91 respectively in the greenhouse drying over sun drying method.

Summary and Conclusion

CHAPTER - V

SUMMARY AND CONCLUSION

Drying of crops under suitable conditions is important to obtain a superior quality dried produces. The low cost poly greenhouse technology used for protected cultivation can be utilized for drying of crops by suitably manipulating the natural ventilation.

A semi-circular roof greenhouse was constructed to cover an area of 4 X 5 m with 3m height using white polyethylene sheet (200 micron) with an adjustable ventilation upto 1.52 square meter provided at the crest and 5 square meter at the bottom of the greenhouse. The ventilation area helps in efficient removal of moisture from the produce, through the top. A black sheet (25 micron) was spread on the greenhouse floor to increase the prevailing temperature inside.

The pre treatments viz., ACD, AMD, Sulphuring were given to the grapes and the drying experiments of copra, chillies and pre treated grapes were conducted simultaneously under greenhouse and sun drying conditions. The prevailing temperature and relative humidity in the greenhouse and the atmosphere were recorded at 2 h intervals and the physiological loss in weight of the drying produces were also taken at 2 h interval, throughout the drying period. The drying characteristics of copra chillies and pre treated grapes were studied from the observations under both the greenhouse and sun drying conditions. The quality parameters of the dried produces were evaluated. From the results obtained during the experiments and analysis, the following conclusions were drawn.

(i) The temperature and relative humidity in the greenhouse varied from 36 to 57°C and 61 to 37 per cent, respectively and for the atmospheric temperature and relative humidity of 28 to 40°C and 71 to 45 per cent, respectively.

(ii) The coconut kernels were dried from an initial moisture content of 92.3 to 6.48 per cent d.b. in 30 h (4 days) and 52 h (7 days) under greenhouse and sun drying conditions respectively.

(iii) Chilli fruits were dried from the initial moisture content of 41.20 to 5.78 per cent d.b. in 24 and 42 h under greenhouse and sun drying, respectively. The observed temperature and relative humidity of greenhouse and the atmosphere were 36 to 59°C and 52 to 21 per cent, and 28 to 38°C and 80 to 41 per cent respectively.

(iv) Among the pre treated and control grapes, AMD grapes with the initial moisture content of 426.32 per cent d.b. was first effectively converted into raisins in 26 and 44 h with the final moisture content of 15.82 and 15.97 per cent d.b. under greenhouse and sun drying respectively.

(v) The drying rate of copra, chillies and pre treated grapes were rapid in the greenhouse drying than the sun drying conditions and saves 40 per cent (on an average) of drying time.

(vi) Microbial population on greenhouse dried copra samples was less (Bacteria – 3.43 x 10^6 CFU and Fungi – 2.83 x 10^6 CFU) compared to sun dried samples (Bacteria – 5.81 x 10^6 CFU and Fungi – 3.99 x 10^6 CFU) and resulted in better quality of oil than the sun dried samples.

(vii) Chillies dried in greenhouse resulted in a bright red colour (58.6 ASTA units) and higher per cent oleoresin content (6.5 per cent) than the colour (51.1 ASTA units) and oleoresin (4.65 per cent) of the sun dried chillies.

(viii) The total sugar content in pre treated grapes was not found significant on the method of drying. The average ascorbic acid content of greenhouse dried raisins was higher than the sun dried raisins. The greenhouse dried raisins yielded a better colour, flavour, taste, texture and overall acceptability than the sun dried samples.

(ix)The cost of the constructed greenhouse in this study was estimated as Rs.17,500/-. The cost of greenhouse per square meter worked out to be Rs.875/- .

(x) The drying cost of copra, chillies and grapes in the greenhouse is found to be Re 0.24/kg, Re 0.47/kg and Re 0.59/kg with 42.31, 42.86 and 40.91 per cent of savings of drying time respectively in the greenhouse drying than sun drying.

FUTURE WORK

1. Experiments may be conducted to optimize the ventilation areas of greenhouse (both inlet and outlet) in order to obtain maximum drying air temperature and minimum relative humidity.

2. Experiments to be conducted for utilizing the full volume of greenhouse for drying of crops.

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Appendices

APPENDIX-A

A.1 Observations of greenhouse and atmospheric temperature and relative humidity before drying period

Time	Temperature, °C		Relative humidity,%	
	Greenhouse	Atmosphere	Greenhouse	Atmosphere
8.00A.M.	36.5	29	61.6	71.7
9.00A.M.	46.3	32.1	49.8	65.8
10.00A.M.	50.4	36.4	42.2	55.4
11.00A.M.	54	38.5	39.4	53.2
12.00P.M.	54.2	40.5	38.8	49.1
1.00P.M.	55.3	45.9	38.4	44.9
2.00P.M.	57.1	41	39.4	46
3.00P.M.	50.6	38.8	39.3	53.5
4.00P.M.	44.8	37.6	44.1	57.5
5.00P.M.	41	31.8	46.2	59.3

A.2. Observations of greenhouse and atmospheric temperature and relative humidity during drying periods

Time	Temperature, °C		Relative humidity,%	
	Greenhouse	Atmosphere	Greenhouse	Atmosphere
11.30A.M.	52.4	36.3	38.9	55.2
1.30P.M.	57	38.7	33.5	45.5
3.30P.M.	52.3	35.1	38.3	61.2
5.30P.M.	36.1	31.9	55.2	60.3
8.00A.M.	39.4	28.8	53.1	67.6
10.00A.M.	53.7	31.7	48	68.5
12.00P.M.	55.4	34.6	36.6	54.7
2.00P.M.	58.9	37.1	34.1	51.5
4.00P.M.	46	31.7	43	66
8.00A.M.	37.2	28.2	55	63.2
10.00A.M.	53.7	37.8	38	53
12.00P.M.	57.4	40.8	36.7	50.4
2.00P.M.	53.8	29.9	38.4	47.9
4.00P.M.	43	32.1	47.5	62
8.00A.M.	43.4	30.3	48.3	70.6
10.00A.M.	55.3	33.3	37.6	60.5
12.00P.M.	55.8	35.8	35.3	51.6
2.00P.M.	56.9	38.2	35.7	50.2
4.00P.M.	33.4	43	47.4	63.5
8.00A.M.	40.4	27.4	49.6	79.4
10.00A.M.	55.3	39	48.8	59
12.00P.M.	55.9	38.3	41.6	58.8
2.00P.M.	56.9	37.4	40.5	55.6
4.00P.M.	41.4	29.6	53.8	66.8
8.00A.M.	41.7	30.3	51.7	71
10.00A.M.	53.2	38.9	39.2	53.2
12.00P.M.	53.1	36.7	39.1	58
2.00P.M.	56.2	37.1	36.2	54
4.00P.M.	48	35.6	43.3	58
8.00A.M.	39.3	28.3	62.1	82.2
10.00A.M.	50.2	33.7	45.3	68
12.00P.M.	48.6	31.8	47.3	69.5
2.00P.M.	56.9	37.8	38.6	60
4.00P.M.	43.8	36.4	47.4	57.4
8.00A.M.	-	32.1	-	71.4
10.00A.M.	-	34.5	-	78.5

Time	Temperature, °C		Relative humidity,%	
	Greenhouse	Atmosphere	Greenhouse	Atmosphere
12.00P.M.	-	40	-	57.3
2.00P.M.	-	41.1	-	55.1
4.00P.M.	-	36.3	-	50.6
8.00A.M.	-	32.1	-	71.4
10.00A.M.	-	36.3	-	70.1
12.00P.M.	-	33.9	-	67.4
2.00P.M.	-	34	-	64.1
4.00P.M.	-	31	-	57.6
8.00A.M.	-	28.7	-	75.6
10.00A:M.	-	31.5	-	63.2
12.00P.M.	-	36	-	50.3
2.00P.M.	-	35.6	-	50
4.00P.M.	-	33.4	-	64.8
8.00A.M.	-	-	-	-
10.00A.M.	46.5	30.6	35.3	62.9
12.00P.M.	44.1	32.4	42.8	52.7
2.00P.M.	41.2	33.5	40.3	52.7
4.00P.M.	40.1	33.8	44.2	56.5
8.00A.M.	41.8	30.4	41.6	71.8
10.00A.M.	52	32.8	51.9	58
12.00P.M.	56.9	38.9	23.3	46.3
2.00P.M.	54.7	34.1	25.6	48
4.00P.M.	45.1	35.1	33.4	45.6
8.00A.M.	36.1	28	45.6	79.1
10.00A.M.	53.8	33.7	26.8	54.1
12.00P.M.	58.2	37.5	24.3	44.9
2.00P.M.	59.1	36.5	21.5	44.6
4.00P.M.	46.9	33.4	30.4	50.7
8.00A.M.	-	29.5	-	72.5
10.00A.M.	-	33.6	-	48.6
12.00P.M.	-	35.3	-	42.4
2.00P.M.	-	36.2	-	41.3
4.00P.M.	-	34.5	-	48.3
8.00A.M.	-	29.2	-	68.2
10.00A.M.	-	33.1	-	54
12.00P.M.	-	35.6	-	33.8
2.00P.M.	-	36	-	48.1
4.00P.M.	-	33.2	-	50.7
8.00A.M.	-	29.8	-	71.6
10.00A.M.	-	31.5	-	57.5
12.00P.M.	-	34	-	48.5
2.00P.M.	-	35.3	-	46
4.00P.M.	-	33.4	-	50.7

APPENDIX-B

Observations and calculations of drying rate of crops under greenhouse and sun drying methods

B-1 Drying rate of copra

Time(h)	Moisture content		Drying rate (g/min)
	w.b.(%)	d.b.(%)	
Greenhouse drying			
0	48	92.31	
2	43.82	77.98	0.119
4	39.61	65.59	0.111
6	35.39	54.78	0.104
8	31.21	45.37	0.098
10	27.58	38.08	0.09
12	25.12	33.54	0.082
14	23.32	30.42	0.074
16	20.7	26.11	0.069
18	18.62	22.89	0.064
20	16.2	19.33	0.061
22	13.98	16.25	0.058
24	9.91	11.01	0.056
26	7.73	8.38	0.054
28	6.53	6.98	0.051
30	6.09	6.48	0.048
Sun drying			
0	47.99	92.29	
2	45.24	82.61	0.081
4	42.04	72.52	0.082
6	39.12	64.27	0.078
8	36.32	57.03	0.073
10	33.71	50.86	0.069
12	31.18	45.31	0.065
14	28.89	40.63	0.061
16	25.68	34.55	0.06
18	23.17	30.16	0.058
20	20.7	26.1	0.055
22	19.34	23.98	0.052
24	17.44	21.12	0.049
26	15.61	18.49	0.047
28	13.86	16.08	0.045
30	12.39	14.14	0.043
32	11.6	13.12	0.041
34	10.02	11.14	0.04
36	8.9	9.77	0.038
38	7.95	8.64	0.037
40	7.65	8.28	0.035
42	7.38	7.97	0.033
44	7.09	7.63	0.032
46	6.89	7.4	0.031
48	6.55	7.01	0.03
50	6.23	6.64	0.029
52	5.95	6.33	0.028

B2 Drying rate of chillies

Time(h)	Weight(g)	Moisture content w.b.(%)	Moisture content d.b.(%)	Drying rate (g/min)
Greenhouse drying				
0	1200	80.4	410.2	
2	1089.5	78.41	363.22	0.392
4	998.4	76.44	324.49	0.357
6	908.5	74.11	286.27	0.345
8	821.5	71.37	249.28	0.336
10	729.5	67.76	210.16	0.334
12	636.8	63.07	170.75	0.333
14	565.8	58.43	140.56	0.321
16	489.5	51.95	108.12	0.315
18	410.4	42.69	74.49	0.311
20	303.7	22.56	29.12	0.318
22	273.5	14	16.28	0.299
24	248.8	5.47	5.78	0.281
Sun drying				
0	1200	80.41	410.55	
2	1125.5	79.12	378.85	0.264
4	1056.5	77.75	349.49	0.254
6	989.2	76.24	320.85	0.249
8	915.5	74.33	289.49	0.252
10	871.6	73.03	270.81	0.233
12	824.2	71.48	250.64	0.222
14	777.4	69.76	230.72	0.214
16	718.5	67.28	205.66	0.213
18	681.6	65.51	189.96	0.204
20	646.6	63.64	175.06	0.196
22	610.3	61.48	159.62	0.19
24	578.2	59.34	145.96	0.184
26	547.6	57.07	132.94	0.178
28	503.8	53.34	114.3	0.176
30	459.2	48.8	95.32	0.175
32	413.6	43.15	75.91	0.174
34	371.1	36.64	57.83	0.173
36	327.4	28.18	39.23	0.172
38	291.6	19.35	24	0.17
40	267.4	12.05	13.7	0.165
42	248.8	5.47	5.79	0.161

B3 Drying rate of grapes

Time(h)	Weight(g)	Moisture content w.b.(%)	Moisture content d.b(%)	Drying rate (g/min)
Australian cold dipped grapes				
Greenhouse drying				
0	518.6	81	426.27	
2	460.8	78.61	367.6	0.487
4	418.1	76.43	324.27	0.423
6	376	73.79	281.54	0.4
8	333.6	70.46	238.51	0.389
10	311.6	68.37	216.18	0.348
12	278	64.55	182.08	0.338
14	245.1	59.79	148.69	0.329
16	208.1	52.64	111.13	0.327
18	174.3	43.45	76.83	0.322
20	143.4	31.26	45.47	0.316
22	127.8	22.86	29.64	0.299
24	116.4	15.3	18.07	0.282
26	114.4	13.82	16.04	0.262
Sun drying				
0	518.3	79.5	387.81	
2	476.1	77.68	348.09	0.359
4	440.3	75.87	314.4	0.332
6	427.1	75.12	301.98	0.259
8	408	73.96	284	0.234
10	386.7	72.52	263.95	0.224
12	364	70.81	242.59	0.219
14	336.2	68.4	216.42	0.221
16	318.5	66.64	199.76	0.212
18	294.6	63.93	177.27	0.211
20	271.6	60.88	155.62	0.21
22	248.4	57.23	133.79	0.209
24	232	54.2	118.35	0.203
26	212.9	50.09	100.38	0.2
28	190.1	44.11	78.92	0.199
30	183.1	41.97	72.33	0.19
32	173.3	38.69	63.11	0.183
34	166	35.99	56.24	0.176
36	164.7	35.49	55.01	0.167
38	147.6	28.01	38.92	0.166
40	138.7	23.4	30.54	0.161
42	132.5	19.81	24.71	0.156
44	124.7	14.8	17.36	0.152
46	121.7	12.7	14.54	0.147

Australian Mix Dipped grapes

Greenhouse drying

0	515.8	81	426.3	
2	461.4	78.8	370.8	0.463
4	407.3	75.9	315.6	0.461
6	356.1	72.5	263.4	0.453
8	303.8	67.7	210	0.451
10	290.2	66.2	196.1	0.384
12	265.3	63.1	170.7	0.355
14	234.2	58.2	139	0.342
16	198.1	50.5	102.1	0.338
18	171.5	42.9	75	0.325
20	135.9	27.9	38.7	0.323
22	125.6	22	28.2	0.302
24	118	16.9	20.4	0.282
26	113.5	13.7	15.8	0.263

Sun drying

0	516	81	426.32	
2	470.6	79.17	380.01	0.386
4	426.4	77.01	334.92	0.381
6	401.7	75.59	309.73	0.324
8	378.5	74.1	286.07	0.292
10	355.3	72.41	262.4	0.273
12	331.8	70.45	238.43	0.261
14	303.4	67.69	209.47	0.258
16	279.1	64.87	184.68	0.252
18	260.5	62.36	165.71	0.241
20	239.2	59.01	143.98	0.235
22	219.7	55.38	124.09	0.229
24	194.2	49.52	98.08	0.228
26	178.2	44.98	81.76	0.221
28	169.1	42.02	72.48	0.211
30	163.4	40	66.67	0.2
32	151	35.07	54.02	0.194
34	146.1	32.9	49.02	0.185
36	139.4	29.67	42.19	0.178
38	123.6	20.68	26.07	0.176
40	118.4	17.2	20.77	0.169
42	115.3	14.97	17.61	0.162
44	113.7	13.77	15.97	0.155

Sulphured grapes

Greenhouse drying

0	500	80.93	424.34	
2	459.1	79.3	383.03	0.344
4	414.3	77.16	337.78	0.361
6	397.9	76.26	321.21	0.286
8	365.4	74.25	288.38	0.283
10	347.3	72.98	270.1	0.257
12	318.7	70.69	241.21	0.254
14	293.7	68.35	215.96	0.248

16	265.5	65.21	187.47	0.247
18	238.4	61.55	160.1	0.245
20	215.1	57.73	136.57	0.24
22	189.3	52.5	110.51	0.238
24	174.5	48.86	95.56	0.228
26	153.2	42.54	74.04	0.225
28	133.1	34.95	53.74	0.221
30	120.5	29.08	41.01	0.213
32	113.6	25.4	34.04	0.203
34	103.2	19.05	23.54	0.196
36	96.3	14.21	16.57	0.189
Sun drying				
0	500	81	426.32	
2	466.1	79.62	390.63	0.297
4	444.8	78.64	368.21	0.242
6	422.4	77.51	344.63	0.227
8	413.5	77.03	335.26	0.19
10	399.8	76.24	320.84	0.176
12	383.6	75.23	303.79	0.17
14	367.5	74.15	286.84	0.166
16	346.3	72.57	264.53	0.169
18	330.5	71.26	247.89	0.165
20	306.9	69.05	223.05	0.169
22	292.7	67.54	208.11	0.165
24	271.6	65.02	185.89	0.167
26	251.4	62.21	164.63	0.168
28	236	59.75	148.42	0.165
30	233.8	59.37	146.11	0.156
32	221.8	57.17	133.47	0.153
34	219.2	56.66	130.74	0.145
36	210.3	54.83	121.37	0.141
38	201.4	52.83	112	0.138
40	187.7	49.39	97.58	0.137
42	182.4	47.92	92	0.133
44	177.3	46.42	86.63	0.129
46	170.9	44.41	79.89	0.126
48	165.8	42.7	74.53	0.122
50	161.3	41.1	69.79	0.119
52	154.4	38.47	62.53	0.117
54	150.4	36.84	58.32	0.114
56	145.2	34.57	52.84	0.111
58	140.1	32.19	47.47	0.109
60	132.3	28.19	39.26	0.108
62	126.4	24.84	33.05	0.106
64	121.4	21.75	27.79	0.104
66	114.2	16.81	20.21	0.103
68	110.8	14.26	16.63	0.1
Control grapes				
Greenhouse drying				
0	500	81	426.32	
2	448.8	78.83	372.42	0.449

4	407.4	76.68	328.84	0.406
6	386.2	75.4	306.53	0.333
8	367.4	74.14	286.74	0.291
10	340	72.06	257.89	0.281
12	308.8	69.24	225.05	0.28
14	270.4	64.87	184.63	0.288
16	249.3	61.89	162.42	0.275
18	226.3	58.02	138.21	0.267
20	198.8	52.21	109.26	0.264
22	175.5	45.87	84.74	0.259
24	164	42.07	72.63	0.246
26	144.7	34.35	52.32	0.24
28	133.5	28.84	40.53	0.23
30	125.6	24.36	32.21	0.219
32	113.4	16.23	19.37	0.212
34	109.6	13.32	15.37	0.201
Sun drying				
0	500	81	426.32	
2	472.2	79.88	397.05	0.244
4	447.2	78.76	370.74	0.232
6	423.1	77.55	345.37	0.225
8	403.3	76.44	324.53	0.212
10	380.4	75.03	300.42	0.21
12	367.2	74.13	286.53	0.194
14	350.4	72.89	268.84	0.187
16	336.3	71.75	254	0.179
18	321.4	70.44	238.32	0.174
20	306.5	69	222.63	0.17
22	292.4	67.51	207.79	0.166
24	275.6	65.53	190.11	0.164
26	263.2	63.91	177.05	0.16
28	247.9	61.68	160.95	0.158
30	240.2	60.45	152.84	0.152
32	223.6	57.51	135.37	0.152
34	217.4	56.3	128.84	0.146
36	205.4	53.75	116.21	0.144
38	193.8	50.98	104	0.141
40	180.6	47.4	90.11	0.14
42	174.4	45.53	83.58	0.136
44	169.1	43.82	78	0.132
46	163.3	41.82	71.89	0.128
48	159.6	40.48	68	0.124
50	155.7	38.99	63.89	0.121
52	148.1	35.85	55.89	0.119
54	143.8	33.94	51.37	0.116
56	136.3	30.3	43.47	0.114
58	131	27.48	37.89	0.112
60	125.2	24.12	31.79	0.11
62	118.7	19.97	24.95	0.108
64	113.4	16.23	19.37	0.106
66	110.8	14.26	16.63	0.103

APPENDIX-C

Score card for the sensory evaluations of the dried raisins.

S.NO.	Quality attributes	Scores
1	**Colour**	
	Orange	4
	Reddish orange	3
	Brown	2
	Dark brown	1
2	**Texture**	
	Very soft	4
	Soft	3
	Firm	2
	Hard	1
3	**Flavour and taste**	
	Very good	4
	Good	3
	Fair	2
	Poor	1
4	**Overall acceptability**	
	Highly acceptable	4
	Moderately acceptable	3
	Acceptable	2
	Not acceptable	1

APPENDIX D

Cost of Greenhouse Drying

Total cost of the constructed greenhouse, C = Rs.17500.00

Total area of greenhouse = 20 m^2

Assumptions made are,

Useful life of the greenhouse = 10 years

Salvage value, S = 10 %

Depreciation = 10 %

Interest, r =12 %

No. of working hours per year = 3650 h

Fixed cost

(i) Depreciation = (17500 - 17500 x (10/100)) x (10/100) = Rs. 1575 / yr.

(ii) Salvage value = (17500 x (10/100)) = Rs. 1750 / yr.

(iii) Interest of average investment = ((C + S)/2) x r

= ((17500+1750)/2) x(12/100)

= Rs. 1155 / yr.

Total fixed cost = Rs. 1575 + Rs.1750 + Rs.1155

= Rs. 4480 / yr.

Variable cost

Repair and maintanence = 5% = 17500 x (5/100) = Rs. 875 / yr

Labour cost,

4 h of labour required in every 4 days.

Total labour hour = 365 h / yr.

Labour cost for 8 h = Rs. 40.00

Therefore, total cost of labour = Rs. 1825 / yr.

Total variable cost = Rs.875 + Rs. 1825 = Rs2700 / yr.

Therefore, total cost = Total Fixed Cost + Total Variable Cost

= 4480+2700

= Rs 7180 / yr = Rs. 7180 /3650 = Rs 1.97 / h.

D.1 Drying cost of copra:

Approximately 250 kg (equal to 1000 coconut no.) of coconut kernels could be dried in the available 20 m^2 greenhouse area in 30 h.

Capacity of the greenhousse = 250 /30 = 8.33 kg / h.

Total cost of operation / kg of coconut = 1.97 / 8.33

= Re 0.24 / kg.

D.2 Drying cost of chillies

Approximateky 100 kg of chillies could be dried in 24 h in the available 20 m^2 greenhouse area

Capacity of the greenhouse = 100/24 = 4.17 kg / h

Total cost of operation / kg of chillies = 1.97 / 4.17

= Re. 0.47 / kg.

D.3 Drying cost of grapes

Approximately 120 kg of grapes could be dried in the available 20 m^2 greenhouse area in 36 h

Capacity of the greenhouse = 120 / 36 = 3.33 kg / h

Total cost of operation for 1 kg of grapes = 1.97 /3.33

= Re. 0.59 / kg

APPENDIX E

Saving in drying time in greenhouse drying

E.1 Copra

Total time required for drying 100 no. of coconut kernels in greenhouse= 30h

Total time required for drying 100 no. of coconut kernels in open sun = 52h

Percentage of saving in time by greenhouse drying of copra

over sun drying = 44.31%

E.2 Chillies

Total time required for drying 2 kg of chillies in greenhouse = 24 h

Total time required for drying 2 kg of chillies in open sun = 42 h

Percentage saving in time of chillies by greenhouse drying

over sun drying = 42.86 %

E.3 Grapes

Total time required for drying 10 kg of grapes in greenhouse = 26 h

Total time required for drying 10 kg of grapes in open sun drying= 44 h

Percentage saving in time by greenhouse drying of grapes

over sun drying =40.91 %