DRYING STUDIES OF GARCINIA CAMBOGIA

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled "**DRYING STUDIES OF GARCINIA CAMBOGIA** " is a bonafide record of project work done by us during the course of study 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 another University or Society.

Place: Tavanur
Date: 5/5/2012

PREENU, N.P

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CERTIFICATE

Certified that this project report, entitled, "***DRYING STUDIES OF GARCINIA CAMBOGIA*** " is a record of project work done jointly by Preenu ,N.P and Rahul Kumar Singh under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of another University or Society.

Place: Tavanur
Date: 5/5/2012

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RAHUL KUMAR SINGH

Dedicated to

Our loving family &

friends

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SYMBOLS AND ABBREVIATIONS

ºC	degree celsius
m	meter
g	gram
%	percentage
mg/gm	milligram per gram
°Brix	degree brix
EMC	equilibrium moisture content
db	dry basis
HCA	hydroxycitric acid
W	watt
Kg	kilogram
H	hour
Mw/cm^2	mega watt per square centimeter
wb	wet basis
mm	millimeter
mm/sec	millimeter per second
N	Newton
Kg/cm^3	kilogram per cubic centimeter
et al.	and other people
etc.	etcetera
i.e	that is
min.	minutes
%	percentage
/	per
fig:	figure

INTRODUCTION

CHAPTER 1

INTRODUCTION

Spices are defined as "a strongly flavored or aromatic substance of vegetable origin, obtained from tropical plants, commonly used as a condiment". A spice is a dried seed, fruit, root, bark or vegetative substance used in nutritionally insignificant quantities as a food additive for the purpose of flavoring (Raju and Reni, 2001). In ancient times, spices were as precious as gold; and as significant as medicines, preservatives and perfumes. India - the land of spices plays a significant role in the global spices market. No country in the world produces as many kinds of spices as India with quality spices come from Kerala, an Indian state. At present, India produces around 2.75 million tones of different spices valued at approximately 4.2 billion US $ (Anon, 2011), and holds the premier position in the world spices market. Because of the varying climates in India from tropical to sub-tropical, and to temperate (45 to 0 ºC) almost all spices are grown in this country. In almost all of the 28 states and seven union territories of India, at least one spice is grown in abundance.

Garcinia cambogia in Kerala is locally known as 'kodampuli'. The tree belongs to flowering plant family *Guttiferae*. The species is quite common in homesteads and moist deciduous forest areas of Kerala and it is naturally occurring in peninsular India, Sri Lanka and Thailand. It is a light demanding tree when fully grown and is suited to the climate and soil of moist deciduous, semi evergreen and evergreen forests. The trees attain an average height of about 25 m with dense rounded or pyramidal, evergreen crown.

The bark contains a yellow gum and the branches are usually horizontal or drooping with thick, glossy, dark green leaves. Male and female trees are separate and male trees bear flowers in auxiliary umbellate clusters, whereas female flowers are in groups of 1-4. The fruit is a berry, light yellow in colour. Each fruit contains 6-8 ovoid, pale brown seeds which are covered with white, sweet or sourish, slimry aril. The logs are straight, attaining 10-15 m length and 0.5 m width. The tree is grown in Kerala, mainly for its fruits, even though its timber is suitable for making match boxes and splints. Other than condiment, the raw and processed rinds of the fruits are extensively used as a coagulant and for polishing gold and silver. The bark yield the gum called gummi-gutta or camboge is used as pigment, medicine and varnish. The seed is a source of edible fat.

As the name suggests (*Puli* = sour in Malayalam), the dried fruit is used as a souring agent in Kerala's famous fish curries and other seafood preparations. Once fully ripe, fruits are collected, cut in half, deseeded and are sun-dried for a day. The sun-dried fruit halves are smoked till black, and are rubbed with a mixture of salt and oil before transferring to earthenware pots and tightly sealed. Regular availability of kodampuli is assured by preservation techniques. The most accepted technique for kodampuli preservation and making it as a condiment is sun drying followed by smoking (H:\intro\about_kodampuli.html).

Drying is a preservation technique that reduces the moisture content of agricultural products in order to prevent spoilage and to maintain their quality. In practice, the agricultural products are dried either on paved grounds in the sun or with a drying system using an energy source. The natural sun drying has been used all over the world for thousands of years. This method has several disadvantages like damage to products by rodents, birds, animals, degradation through rain, snow, wind, and contamination by dust, dirt, environment pollution, splitting of grain, insect infestation. Open air drying changes the surface characteristics of material and alters its reflectivity and colour. Chemical changes to carotenoid and chlorophyll pigments are caused by heat and oxidation in drying. Longer drying time and higher drying temperatures result in pigment losses (Verma and Joshi, 2000). In the drying process it is essential to consider two important criteria like product characteristics and drying conditions. Product quality is of great importance in food drying. In fact, the first objective is to remove moisture from the product and to stabilize it. But in food drying many other changes may occur like physio-chemical modifications that modify the overall quality of the final product. Thus, drying of products must also preserve various quality criteria, like nutritional factors (vitamin, minerals), colour, shape and texture.

The sun drying method followed by smoking process in case of *garcinia cambogia* (kodampuli) is time consuming and weather labour skill dependent process. This process leads into an ample amount of time, money and work loss.

With this point of view, a project was undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur to study the effects of different methods of drying and pretreatments on quality retention of garcinia cambogia with the following objectives-

1) To study the effect of different methods of drying on the *garcinia cambogia* (kodampuli)

2) To study the effect of different temperatures on kodampuli rinds

3) To analyze the quality of dried kodampuli

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

This chapter gives general information on *garcinia cambogia* (kodampuli), its chemical composition, various methods of drying and its effects on the quality of end products in terms of texture, colour and acid content. Research done on these aspects and related field are also reviewed and discussed in detail.

2.1 Garcinia cambogia

Cambodge (*Garcinia cambogia Desr*.) is a tropical fruit commonly known as Malabar tamarind and belongs to the family *Clusiaceae* earlier known as *Guttiferae*. It is a medium-sized evergreen deciduous tree with rounded crown and horizontal or drooping branches generally attaining a height of 18 m. The fruit is a berry having the size of a small apple, yellow or red, 6–8 grooves forming blunt lobes with tough rind, 6–8 seeds and succulent aril. The fruits may vary in size weighing 50–180 g. It is a native of Western Ghats of Kerala (India) and Malaysia. It grows in the evergreen forests of the Western Ghats in South India and its habitat extends from Konkan southward to Travancore and into the Shola forest of Nilgiris where the altitude is up to 2000 m above mean sea level. In Kerala, it is very popular in the Central Travancore areas and Kerala seems to be one of the centers of origin of cambodges where maximum diversity is seen. It is fairly common and abundant in the forests of western Sri Lanka from sea level to 600m and in Malaysia. It is widely distributed in the evergreen forests of Western Ghats from South Kanara and Mysore to South Kerala up to the low lying reclaimed lands bordering the backwaters. The plant flowers in the hot season and the fruits ripen in the rains. Cambodge fruit has excellent therapeutic value and the dried rind is a popular fruit spice used in cookery as an important ingredient in many dishes for flavouring curries in place of tamarind or lime (Peter, K.V., 2001).

Table 2.1 Chemical composition of *Garcinia cambogia*

Moisture content of the ripened fruit	80-85%
Hydroxy-citric acid in dried rind	10-30%
Tartaric acid	10.6%
Reducing sugars	15%
Phosphoric acid	1.52%
TSS	8º brix
Ascorbic acid	7.2mg/100gm

The rinds of *Garcinia cambogia* are the richest sources of (hydroxycitric acid (HCA), which has an excellent therapeutic value against obesity. Earlier the acid present in the rind was misidentified as citric acid. Later Lewis and Neelakantan isolated the acid and identified it as hydroxycitric acid, which is present in the isomeric form.

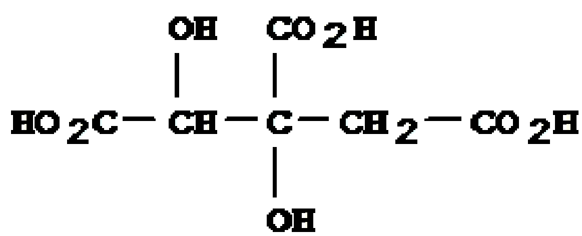

Fig 1: Structure of hydroxycitric acid (HCA) (Sidney J. Stohs, 2010)

The seeds of cambodge yield 31% of edible fat, resembling kokam butter, and are rich in oleic and stearic acid. The fat has a granular structure and the following properties:

Table 2.2 Properties of cambodge fat

Melting point	29.5º C
Acid value	5.0
Sap value	203.5
Acet value	Nil
Iodine value	52.5
R.M value	0.2
Unsap matter	1.0
Titre	51.2º

The details of different type drying processes involved in this study are described below:

1) **Sun drying**- Sun drying of fruits, vegetables and grains are still practiced largely unchanged from ancient times. Traditional sun drying takes place by storing the product under direct sunlight. Sun drying is only possible in areas where, in an average year, the weather allows foods to be dried immediately after harvest. The main advantages of sun drying are low capital and operating costs and the fact that little expertise is required. The main disadvantages of this method are as follows: contamination, theft or damage by birds, rats or insects; slow or intermittent drying and no protection from rain or dew that wets the product, encourages mould growth and may result in a relatively high final moisture content; low and variable quality of products due to over - or under-drying. Moreover, since sun drying depends on uncontrolled factors, production of uniform and standard products is not expected. The quality of sun dried foods can be improved by reducing the size of pieces to achieve faster drying and by drying on raised platforms, covered with cloth or netting to protect against insects and animals (Chakravarthy, 2000).

2) **Solar drying-** Solar dryers have some advantages over sun drying when correctly designed. They give faster drying rates by heating the air to 10-30ºC above ambient, which causes the air to move faster through the dryer, reduces its humidity and deters insects. The faster drying reduces the risk of spoilage, improves quality of the product and gives a higher throughput, so reducing the drying area that is needed. However care is needed when drying fruits, to prevent too rapid drying and prevent complete drying which would result in case hardening and subsequent mould growth. Solar dryers also protect foods form dust, insects, birds and animals. They can be constructed from locally available materials at a relatively low capital cost and there are no fuel costs. Solar food drying can be used in most areas but how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity (Chakravarthy, 2000).

3) **Oven drying-** Oven can be defined as a closed or thermally insulated chamber for drying an object by heating at relatively low or high temperatures. Oven drying is the simplest way to dry food because you need almost no special equipment. It is also faster than sun drying or using a food dryer. But oven drying can be used only on a small scale. There are a number of different types of ovens according to mode of heat transfer and capacities. Mainly in this study convection type oven is used. Convection ovens have a built-in fan that circulates warm air; they may be effectively used as a dehydrator, especially if the moist air can be vented. Convection ovens that have a controllable temperature starting at 120°F and a continuous operation feature rather than a timer-controlled one, work best. The air circulation, or convection, tends to eliminate "hot spots" and thus food may bake more evenly (Peter, K.V., 2001).

4) **RRLT-NC drier-** Dr. Thomas, who is a Scientist in Process Engineering Section in Regional Research Laboratory, Trivandrum has invented Natural Convection Drier for the drying of agricultural products. The improved natural convection driers named RRLT-NC drier, the hot air is generated separately outside the drier chamber and is conveyed upwards through a separate duct by natural convection.

At the top of the duct an opening is provided for the entry of the hot air to the drying chamber. Performed trays are arranged one above the other in the drying chamber. All the sides of drier chamber, except the bottom side are covered with heat insulating materials. The hot air after entering into the drying chamber tends to occupy the topmost layer just below the top-covering sheet. As the hot air comes into contact with the wet material on the top tray, the temperature of air drops, consequently the density increase & has a tendency to flow down by percolating through the trays and the wet material placed on the trays. The cooled air by the process of heat transfer finally leaves at the bottom of the drier to the drier to the atmosphere. Thus the hot air is made to flow in a downward direction after overcoming the frictional resistance offered by the perforated trays and the wet material contained in the trays without the help of any blower or fan. Thus the wet material gets dried. Three models are in market now under the name of model no. 101, 151, and 201.

2.2 DRYING THEORY

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

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

A number of physical mechanism have been proposed to describe transfer of moisture within the material, liquid movement due to the surface forces(capillary forces) moisture concentration differences(liquid diffusion) and water or vapor movement due to the total pressure differences. After completion of the surface moisture phenomenon further drying depends on the rate at which 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 unit operations in the primary process of agricultural produce. It permits long term 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.

2.2.1 Drying process

Drying process involves the removal of water from the material requiring an amount of heat equal to the latent heat of vaporization of water plus a current of air moving over the surface to carry away the water vapour. The process is characterized 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 water surface. The magnitude depends on the area exposed, the difference in the 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 due to the migration of liquid boundary in to material with the vapor 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 after drying condition. The moisture content of the product when it is in equilibrium with the surrounding atmosphere is called equilibrium moisture content. It will vary with relative humidity and temperature and may be expressed in either wet or dry basis.

2.2.2 Equations of drying

Lewis (1964) suggested that the rate of removal of moisture from the material was proportional to the difference between the average moisture content and EMC of the material.

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

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

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

Me = 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

$$\frac{M - Me}{M_o - M_e} = e^{-KQ}$$

Where M = moisture content of the corn at time zero hours (%DB)

Me = EMC of corn (%DB)

Mo = initial moisture content of the corn (%DB)

K = drying rate constant

U= empirical constant

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

The equation is

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

(Chakravarthy, 2000)

Where M-Md of the material at a hours (%DB)

K = drying rate constant h-1

Mo and Md are the initial and dynamic EMC (%DB)

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

$$1 - RH = \exp(-CTMe^{\dagger}n\ )$$

Where RH = equilibrium relative humidity in decimals

Me = EMC (%DB)

T = Temperature K

c & n = product constants

2.3 Quality analysis

Quality analysis of the dried product is determined based on the observation of different parameters like texture, colour, and its acid value content (volatile matter content). Brief description about each parameter is given below:

Texture – It can be defined as the characteristic of feel or touch. group of attributes that describes the mouthfeel of a food product. Texture can be described as slimy, thick, gritty, sandy, rubbery, spongy, soft, hard, grainy, dry, tacky, slippery, creamy, or fatty just to name a few. Sensory attributes of texture are typically detected and transmitted by both trigeminal nerves and touch sensors in the mouth (Inteaz Alli, 2004).

Colour - The colour of a food is the first contact point of the consumer with it. Thus, we first judge it from its appearance (colour, texture, shape) and then from other sensory attributes such as aroma or taste. The prominent role of food colours in their acceptability is therefore unquestionable. The colour can be assessed visually during the tasting of the product or by comparison with colour atlases or dictionaries; although in both cases a subjective description rather than an objective definition is achieved. In contrast to this, it is possible to define objectively any colour by using appropriate instruments (mainly, spectrophotometers, colorimeters and) and following the recommendations laid down by the CIE (International Commission on Illumination). (http://www.scitopics.com/Food_Colour.html: 02/05/012)

Acid content - Acid value (or "neutralization number" or "acid number" or "acidity") is the mass of potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of chemical substance. The acid number is a measure of the amount of carboxylic acid groups in a chemical compound such as a fatty acid. In a typical procedure, a known amount of sample dissolved in organic solvent is titrated with a solution of potassium hydroxide with known concentration and with phenolphthalein as a color indicator. (http://www.thesmarttime.com/testing/testing-procedures-31.html : 02/05/12)

2.4 Related studies

Oxley *et al.* (1960) conducted a study about determination of moisture content of cereals and evaluating the errors of known changes in moisture content. "Water added to a soft wheat, whether as vapour (humid atmosphere) or liquid, was accurately assessed by the oven method (heating 4 h. at 113), but water added to a hard wheat by either method was over-assessed proportionately to the amount added. The over-assessment amounted to 1% when the moisture content was increased from 9% to 25%, on the dry weight basis. The amount of water removed from both varieties of wheat by drying in a warm air current was over-assessed. That from the hard wheat was over-assessed proportionately to the amount removed (but only to the extent of about 0.25% on drying from 25% to 9% on the dry weight basis), whilst the over-assessment was inversely proportional in the case of the soft wheat. It is concluded generally that the ability of an oven-drying method to measure known quantities of water in wheat is related to the type of wheat.

Anthony *et al.* (2002) at Dept. of Chemistry, Mar Athanasius College, Kothamangalam conducted an experiment about spectrophotometric determination of hydroxy citric acid present in *Garcinia Cambogia*. This method is based upon, the colour complex formation (lambdamax: 467nm) between hydroxy citric acid and sodium meta vanadate.

Malik *et al.* (2002) did a research study by collecting the germoplasms of Garcinia Cambogia in the areas of its diversity in Kerala and Karnataka. A total of 56 accessions of Malabar tamarind were collected. Two collections of Malabar tamarind were found to be very specific because of the uncommon fruit colour, which is pinkish red. All the collected accessions are grown at National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Thrissur for characterization and conservation. Extensive range of variability was found in fruit colour, shape, size and nature of branching and canopy of trees. Characterization of 13 fruit and five seed characters was done for 51 accessions. The variability was found to be maximum for nipple length (74.8%) and minimum for fruit girth (12.8%). Two promising accessions were identified based on mean fruit weight (161 g) in IC 354028 and mean rind thickness (15 mm) and mean rind weight (125 g) in IC 354019.

Bala *et al.* (2003) conducted an experiment on drying of pineapple using solar tunnel dryer. In this study field level experiments on solar drying of pineapple using solar tunnel drier were conducted at Bangladesh Agricultural University, Mymensingh, Bangladesh. The drier consists of a transparent plastic covered flat plate collector and a drying tunnel connected in a series to supply hot air directly into the drying tunnel using two dc fans operated by a solar module. This drier has a loading capacity of 120–150 kg of pineapple and a total of eight drying runs were conducted. In all the cases the use of the solar tunnel drier leads to considerable reduction of drying time in comparison to sun drying.

Jayashree *et al.* (2005) conducted a study about thin layer drying kinetics of mace (*Myristica fragrans)* using reverse air flow drier (Model: 60 RRLT-NC Drier Model 101). In this study Fresh and blanched mace of 'Viswasree' variety was dried at 50, 55 and 60 ^{o}C in a reverse air flow, natural convection mechanical drier. Blanching was done by dipping in boiling water for 1 min. The experimental data for moisture loss was converted to moisture ratios and fitted to five thin layer drying models to describe the drying process mathematically. The results were compared for their goodness of fit in terms of coefficient of determination (R^2), root mean square error (RMSE), mean bias error (MBE) and mean square of deviation (χ^2). Page model was found most suitable to describe the drying process of mace. The unblanched mace took 330, 240 and 210 min and blanched took 300, 210 and 180 min to dry from moisture content of 186.5 to 5.2 % (db) at air temperatures of 50, 55 and 60^{o}C respectively. The effective moisture diffusivity varied from 1.59 x 10^{-08} to 2.82 x 10^{-08} $m^{2//}s^{-1}$. The activation energy was higher for unblanched than for blanched mace and was found to vary from 47.56 to 52.77 23 kJ/mol.

Jayashree *et al.* (2006) conducted an experiment about Thin layer modeling for drying of black pepper in agricultural waste fired reverse flow drier named RRLT-NC drier model no. 201 (Thomas and Paulose 2003). In this study Fresh and blanched black pepper (*Piper unigram*) of Seeker variety was dried in a reverse air flow, natural convection, and agricultural waste operated mechanical drier. Blanching was done by dipping in boiling water for 1 min. The experimental data for moisture loss was converted to moisture ratios and fitted to nine thin layer drying models to describe the drying process mathematically. The results were compared for their goodness of fit in terms of coefficient of determination (R^2), root mean square error (RMSE), mean bias error (MBE) and mean square of deviation ($\chi 2$). Diffusion approximation model was found most suitable to describe the drying process of black pepper. The unblanched Sreekara took 30 h and blanched took 28 h to dry from moisture content of 178.55 % to 9.56 % and 9.29 % d.b respectively. The effective moisture diffusivity varied from 4.67 x 10^{-07} to 5.20 x 10^{-07} m^2s^{-1} for unblanched and blanched pepper.

Yamada *et al.* (2007) found from experiment about chemistry, physiological properties and microbial production of hydroxy citric acid present in *Garcinia Cambogia* and *Hibiscus subdariffa.* The tropical plants *Garcinia cambogia* and *Hibiscus subdariffa* produce hydroxycitric acid (HCA), of which the absolute configurations are (2*S*, 3S) and (2*S*, 3R), respectively. (2*S*, 3S)-HCA is an inhibitor of ATP-citrate lyase, which is involved in fatty acid synthesis. (2*S*, 3R)-HCA inhibits pancreatic α-amylase and intestinal α-glucosidase, leading to a reduction in carbohydrate metabolism. In this study, they review current knowledge on the structure, biological occurrence, and physiological properties of HCA.

Sudha *et al. (*2008*)* did a study about kokum *(Garcinia Indica)* in India. Garcinia indica, commonly known as 'kokum', is an underutilized fruit tree, native of the Western Ghats in India and Malaysia. In India it mainly grows in the western parts of Maharashtra, Karnataka, Kerala and Goa. The fruit is used as a medicinal plant against obesity; the rind as souring and food colouring agent and fat of the seed is extracted for cosmetic and confectionery preparations. This paper presents the findings of a study conducted in Uttar Kannada district in Karnataka and Sindhudurg district in Maharashtra.

Jose (2009) conducted a study about solar tunnel drying of turmeric (curcuma longa linn. Syn. C. domesticaval) for quality improvement. Turmeric is one of the most ancient medicinal spices of the world. As its homeland, India acts as the largest producer, exporter and consumer of turmeric. The value of turmeric is due to its color and flavor, which is being given by curcumin, volatile oil and oleoresin. The end quality of turmeric is very much dependent on its post-harvest methods. Traditionally, open sun drying is the chief method adopted for processing. In the present investigation, freshly harvested turmeric rhizomes were collected from 30 stations and drying experiments were conducted by adopting three methods: (1) solar tunnel drying; (2) conventional drying; and (3) commercial drying. Various pre-drying and post-drying treatments were conducted. The results proved that conventional processing could maintain the intrinsic quality up to a certain level, but extrinsic quality could not be achieved.

Masullo e*t al.* (2010) conducted a study on the Polyisoprenylated Benzophenone Derivatives from the Fruits of Garcinia Cambogia and their Absolute Configuration by Quantum Chemical Circular Dichroism calculations. Three new tetra cyclic Polyisoprenylated xanthones, named oxy-guttiferones M, K_2, and I, along with oxy-guttiferone K and guttiferone M, have been isolated from the fruits of *Garcinia cambogia*.

Ozcan *et al.* (2010) researched about Effect of Sun, Oven and Microwave Drying on Quality of Onion Slices. In this study Sun, oven (50 and 70 °C) and microwave oven (210 and 700 W) drying of onion slices were carried out to monitor the drying kinetics and quality degradation of the product. Page, "Modified Page" and "Midilli and Küçük" models exhibited high coefficient of determination (R^2) values, ranging between 0.994 and 0.999. The calculated effective diffusivity (D_{eff}) values (m^2/s) of onion slices for the sun, oven 50 °C and oven 70 °C, microwave 210 W and microwave 700 W drying process were 8.339×10^{-10}, 7.468×10^{-10}, 1.554×10^{-9}, 4.009×10^{-8} and 4.869×10^{-8}, respectively. Fresh and dried onion slices had high amounts of K (696.82-16357.55 mg/kg), Ca (69.64-340.03 mg/kg), Na (37.72-1895.43 mg/kg), Mg (3.31-964.77 mg/kg) and P (46.47-3384.07 mg/kg) minerals. The highest mineral values were determined in oven dried samples. Sun (L^* 58.00 ± 4.83, a^* 0.27 ± 0.10, b^* 14.36 ± 2.40) and microwave oven drying (210 W) (L^* 54.78 ± 7.54, a^* −0.71 ± 0.09, b^* 13.17 ± 1.05) revealed better colour values in the dried products. The phenolic contents of microwave oven dried samples (1664.39 ± 134.12 and 1623.59 ± 140.02 for 210 W and 700 W, respectively) were higher than those of the other dried onion slices.

Kulanthaisami *et al.* (2010) conducted a study about drying of chilies in solar tunnel dryer. Solar Tunnel Dryer (STD) MPUAT design was installed at the Farmers Association of Singarayarpuram village of Ramnad District. The results showed that, temperature inside the solar tunnel dryer gets boosted up by 15-20 ^{0}C more than the ambient. The results also revealed that the chilies dried in the solar tunnel dryer was completely protected from rain, insects and dust and the dried chilies were high quality compared to open sun dried product. Solar tunnel dryer dried chilies are in good colour and it also reduces the cost of drying and drying time to 40 percent.

Tunde *et al.* (2011) experimentally did mathematical modeling of sun and solar drying of chilli peppers. In this study the drying characteristics for chilli pepper using sun and solar drying were investigated. Chilli pepper was pretreated by water and steam blanching and by soaking in osmotic solutions of 60 and 70° brix. Untreated chilli pepper was taken as a control. The pretreated chilli pepper dried faster than untreated chilli pepper while the drying of both samples occurred in falling rate period. Four thin-layer drying models (Newton, Henderson and Pabis, Logarithmic and Page) were fitted to the experimental data to select a suitable drying equation. The Page model was found to best describe the drying behavior of chilli pepper for sun and solar drying.

Arslan *et al.* (2011) conducted an experiment on dehydration of Red bell-pepper (Capsicum Annuum L.) and Change in Drying Behavior, Colour and Antioxidant Content. In this experiment the sun, oven (50 and 70 °C) and microwave oven (210 and 700 W) drying behaviors of red bell-pepper slices were investigated.

Guine (2011) did an experiment about the influence of drying methods on some Physical and Chemical Properties of Pears. The objectives of this study were to evaluate how drying influences some properties of pears: moisture, dimensions, water activity, pH, °Brix, acidity, and color. In particular, color is a very important quality attribute of these dried pears. Thus, the different systems should produce products with the same color as the traditional method. The results indicated that the alternative drying methods, if they include sun exposure, allowed us to obtain products similar to the traditional ones.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter mainly deals with the various drying methods used for drying *Garcinia cambogia* and also methodology for determining the quality of dried samples.

3.1 TEST SAMPLE

Fully ripened kodampuli fruits were taken for the trials. The drying trials with kodampuli procured from the farm areas like Kuttanadu in Kottayam and Kalpatta in Wayanad districts of Kerala. The fruits of Kodampuli from Kuttanadu area were big in size and over matured. Some fruits weigh more than 500 grams.

3.2 DRYING

To study the drying characteristics of kodampuli a series of preliminary experiments were conducted in a convective dryer, modified solar cooker and traditional sun drying. For drying, a sample weighing approximately 1000g is taken for each process. The samples for traditional sun drying were kept open on a mat under sun. The ambient temperature was measured with a thermometer and intensity was measured using a suryamapi. The temperature was recorded at 35 to 40 ^{0}C and intensity was 56 Mw/cm^2. The weights were noted at an interval of 30 minutes, one hour and later at two hour intervals for the purpose of drying curve. It took two full day drying for the samples to reach the desired moisture content.

The samples weighing approximately 1000g were also placed in an ANERT model box type solar cooker (plate 3.1) providing ample ventilation for making it worked like solar dryer. The maximum and minimum temperature inside the cooker was measured using a thermometer without putting any samples inside and they were noted. The minimum temperature observed was 29 ^{0}C at 10.00 hrs and maximum temperature obtained was 86 ^{0}C at 13.00 hrs. The weights were noted at a regular interval of 30 minutes, one hour and later at two hour intervals.

Plate 3.1: Box type solar cooker (ANERT model)

As a part of mechanical drying convective dryers were selected at various temperature values for different samples.

The kodampuli sample weighing approximately 1000g was dried in a convective drier I (Regional Research Laboratory Trivandrum-RRLT Natural convection dryer) as shown in plate3.2. Drying was accomplished by vaporizing the water that is contained in the food. In the improved natural convection driers named RRLT-NC drier, the hot air is in the food. In the improved convection driers named RRLT-NC drier, the hot air is generated separately outside the chamber and is conveyed upwards through a separate duct by natural convection. At the top of the duct an opening is provide for the entry of hot air to drying chamber. Perforated trays are arranged one above the other in the drying chamber. All the side of the drying chamber, except the bottom sides is covered with the heat insulating materials. The hot air after entering into the drying chamber tends to occupy the top most layers just below the top covering sheet. As the hot air comes into contact with the wet material on the top tray, the temperature of air drops, consequently the density increase and has a tendency to flow down by percolating through the trays and the wet material placed on the trays. The cooled air by the process of heat transfer finally leaves at the bottom of the drier to the atmosphere. Thus the hot air is made to flow in the downward direction after overcoming the frictional resistance offered by the perforated trays and the wet material contained in the trays without the help of any blower or fan. Thus the wet material gets dried. The driers are simple in design, easy to operate and energy utilization is maximum.

The kodampuli samples were kept in convective drier I at different temperatures at 60 and 80 ^{0}C till the moisture content of the dried sample was in the range of about below 25% (wb). The time taken for each sample to reach this range of moisture content was noted. After the drier reached steady state conditions for the set points (at least 30 minutes), the samples were distributed uniformly in thin layer. Each sample utilized in the experiment weighted 1000 ± 10 g. The weight loss was recorded at every 30 minutes and later at one hour and two hour intervals. Drying process was stopped when the moisture content of the sample was about below 25 %(wb).

Plate 3.2: RRLT dryer

The samples weighing approximately 1000g were also kept in an electric cabinet drier (convective dryer II) plate 3.3. This dryer can be utilized for drying many different food products. The construction of the cabinet dryer is suitable for drying at different ranges of temperature using heated forced- air. The product to be dried is placed in thin layers on trays stacked in a column within the dryer chamber. Heated air is circulated vertically through the column with a circulating fan. Fresh air is brought into the cabinet and moist air is exhausted by using dehumidistat to control an exhaust fan and air intake shutters. A perforated tray floor is used to uniformly distribute the air within the dryer. The dryer trays are tight-fitting in the cabinet to prevent air from bypassing the material to be dried. The samples were kept at different temperatures at 70, 90 and 100 ^{0}C till the desired moisture content below 25% (wb) is achieved. The weight loss was recorded at every 30 minutes and later at one hour and 2 hour intervals.

Plate 3.3: Cabinet dryer

3.3 ANALYSIS OF DRIED KODAMPULI

3.3.1 MOISTURE CONTENT

Moisture was determined by using electric oven method (Ranganna, 1991). The dried sample was kept in the oven at 100 ^{0}C for 24 hours.

Moisture (%wb) = Ww/w *100

Where, Ww = weight of water, g

W= Initial weight of the sample, g

Moisture content was expressed in wet basis.

3.3.2 ESTIMATION OF ACIDITY

The acidity of the sample of dried kodampuli was determined by conducting the following test.

Reagents

0.1N NaOH, phenolphthalein

Procedure

The dried samples obtained from various methods were soaked in water for sometimes before being heated mildly for the extraction. The heated dried rind and water is crushed in mortar and pestle for pulp extraction. Five ml of extract was taken from 6 g of sample. It can dilute to 100 ml with distilled water and 10 ml of the sample was pipette out .It was titrated against the standard NaOH solution using phenolphthalein as the indicator. The acidity was expressed in percentage.

Calculation

Percentage of total acid=

$$\frac{(\text{titre value} \times \text{normality of NaOH} \times \text{vol made up} \times \text{equivalent mass of acid}) \times 100}{(\text{Volume of sample taken for estimation} \times \text{volume of sample taken})}$$

3.3.3 OBJECTIVE ANALYSIS:

3.3.3.1 COLOUR

The colour was measured using a Hunter lab colorimeter (plate 3.4). It was set up to operate in reflectance mode, with an observer angle of 10^0 to record L*, a* and b* values. The L* value represents relative colour brightness ranging from total black (L*=0) to total white (L*=100). The* value represents the colour hue ranging from red (+) to green (-). The b* value represents the colour hue ranging from blue (-) to yellow (+). The instrument was standardized each time with a white and black ceramic plate. The final dried kodampuli samples were taken were inserted in a 10 cm^3 transparent cell and L*, a* and b* values were measured.

Plate 3.4: Hunter lab colorimeter

3.3.3.2TEXTURE PROFILE ANALYSIS

Textural properties of the product were carried out on dried kodampuli samples using a food texture analyzer (stable micro systems, UK) plate 3.5. The dried samples were compressed using a cylindrical probe (dia 5mm) under measure force in compression mode with a test speed of 0.5 mm/sec. From the force deformation curves, the peak force is designated as hardness and area under the curve as toughness.

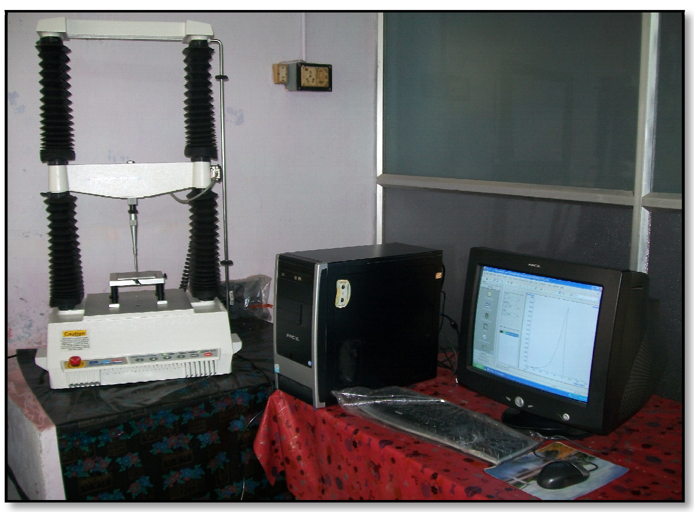

Plate 3.5: Texture analyzer

3.3.4 SENSORY ANALYSIS

Sensory Evaluation of Kodampuli Added Fish Curry

For better acceptability and sustained marketing of the dried kodampuli, various sensory parameters like taste, texture & over-all acceptability was considered. Organoleptic evaluation was performed as per procedure outlined by Ranganna (1979) by a panel of 5 untrained judges in a 9 point hedonic scale varying from 'like extremely' (rated as 9) to 'dislike extremely' (rated as 1). (refer appendix no:

Sample A: fish curry prepared by adding smoke dried rinds

Sample B: fish curry prepared by adding sun dried garcinia rinds

Sample C: fish curry prepared by adding solar dried rinds

Sample D: fish curry prepared by adding garcinia rinds convectively dried at 60^0C

Sample E: fish curry prepared by adding garcinia rinds convectively dried at 70^0C

Sample F: fish curry prepared by adding garcinia rinds convectively dried at 80^0C

Sample G: fish curry prepared by adding garcinia rinds convectively dried at 90 ^{0}C

Sample H: fish curry prepared by adding garcinia rinds convectively dried at 100^0c

In the experiment, 8 samples of fish curry was prepared by adding 8 different samples of dried kodampuli in equal proportions, keeping all other constituents same in each sample. The sensory analysis was carried out by a team of 5 panelists, who estimate the:

(1) Flavour
(2) Over-all liking

Arithmetic average values of independent estimations, presented in table 3.1 as dependent variables, were used for further analysis.

RESULTS AND DISCUSSIONS

CHAPTER 4
RESULTS AND DISCUSSION

This chapter enunciates the various experiments conducted to analyze the drying processes of mature kodampuli fruit and the parameters involved. The chapter also discusses in detail the post drying analysis of dried kodampuli rinds in terms of texture, colour and acidity value.

4.1 TEST SAMPLES

Mature and ripe *garcinia cambogia* (kodampuli) fruits procured from the farm of Kottayam and Wayanad districts were the samples used for studies. Physical properties like firmness and color could be used as a fruit maturity index since these properties change with time. Moreover, the appropriate properties for harvesting and processing can be determined by its specific gravity (thus density will be known). Fruit density where the fruit was in an appropriate handling period, not too hard or soft in texture, was found to be 1,035 kg/cm^3. Firmness was observed to be very high at 85.14 N. We suggest that this is due to highly non-soluble pectin compounds, which is mostly responsible for general fruit texture. The color in the Hunter lab colorimeter was as follows: L value (lightness) was 66.30, a value (light green attribute) is –1.42 and b value (yellow attribute) was 27.57.

Table 4.1 Physical and chemical properties of garcinia fruit

Composition	**X+SD**
Moisture content (% wet basis)	86.47±1.35
Total acidity as citric acid (%w/w)	5.54±0.13
Total soluble solid (%)	6.34±0.25
Firmness (N)	85.14±1.89
Density (kg/m^3)	1,035.00±0.03
Color value: **L (lightness)** **a (light green attribute)** **b (yellow attribute)**	66.30±0.33 –1.42±0.69 27.57±1.08

The samples weighing approximately 10g from each were kept in oven for finding the dry matter and obtaining the moisture content for each sample based on the dry matter content. The initial moisture content for each sample selected for various drying methods were found out and described in table

Table 4.2 Initial moisture content of sample 1

Drying sample	**Sun drying**	**Solar drying**	**Convective dryer I**	**Convective dryer II**
Moisture content (%)	88.39	88.15	89.12	88.21

Temperatures involved in different drying methods were: Sun drying -35-40 ^{0}C

Solar drying - 29-86 ^{0}C

Convective dryer I - 80 ^{0}C

Convective dryer II - 90 ^{0}C

For the comparative study 100 g sample of traditionally smoke dried rinds (named T5) of kodampuli were obtained from market and its moisture content was found 18% (wb) based on dry matter content.

Table 4.3 Initial moisture content of sample 2

Drying sample	**Convective dryer II**	**Convective dryer II**	**Convective dryer I**
Moisture content (%)	88.01	88.05	88.06

Temperatures involved in different drying methods were: Convective dryer II - 70 ^{0}C

Convective dryer I - 100 ^{0}C

Convective dryer II - 80 ^{0}C

4.2 DRYING KINETICS

4.2.1 Sun and solar drying

In the comparative study involving various methods of drying for mature kodampuli fruit, first of all the fruit samples were dried through traditional sun drying method and using an ANERT model box type solar cooker. The samples were dried in open air under an ambient temperature of 35 to 40°C and the intensity of sunlight was 56 MW/cm². The solar cooker was ventilated from the sides lifting the mirror so as to make it work like a solar dryer. The data on moisture content present versus drying time were plotted for both the drying samples were plotted. Sun drying is a slow process and it is too difficult to dry the kodampuli rinds below 25% moisture level. In comparison to sun drying the ANERT model box type solar cooker was fast and effective. It took approximately 9 hrs to reach a moisture content of 19% (wb). From the fig4.1 it was observed that during the initial period of drying in both solar and sun drying there a sudden decline in moisture content. This is due to evaporation of moisture from the surface. After that there was a decrease in drying rate. This is due to time taken for diffusion of moisture from the interior to the surface. The solar drying curve is steeper than the sun drying curve which represents fast removal of moisture from the product and reaching of falling rate period.

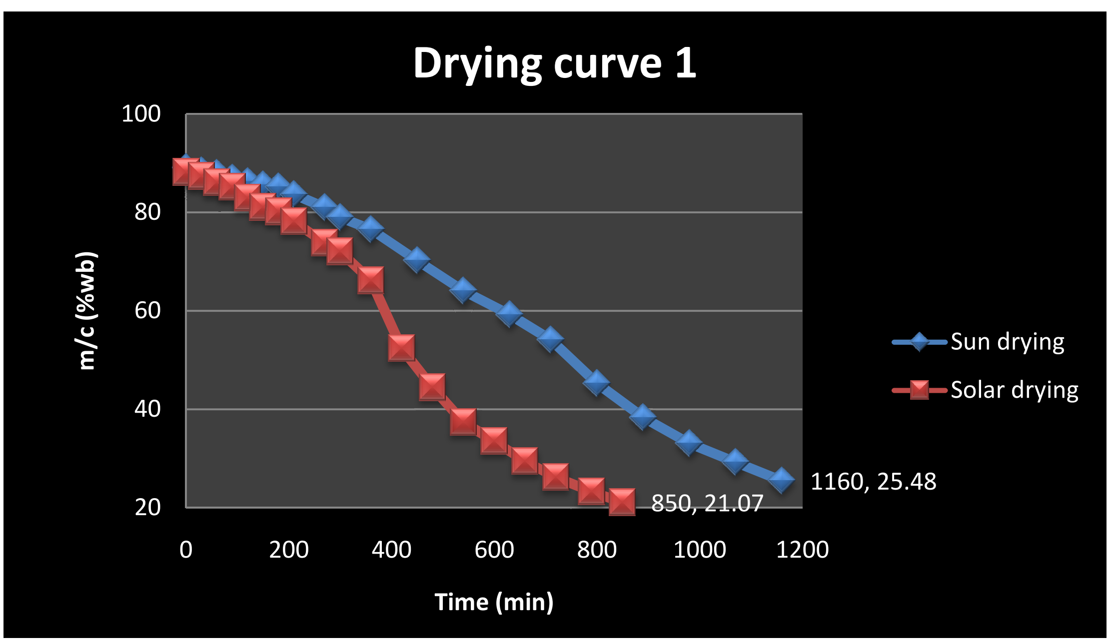

Fig4.1: Drying curve of kodampuli (solar and sun drying)

4.2.2 Convective Drying

The drying was carried out mechanically by mainly two types of dryers, first one is **cabinet** dryer and another one is **RRLT-NC** dryer. These both types of drying were kept in the category of **convective** drying and drying curve were plotted for different temperatures. Even the availability of fan not ensures the uniform drying of kodampuli rinds. Various temperatures involved during drying were 60^0C, 70^0C, 80^0C, 90^0C, and 100^0C.

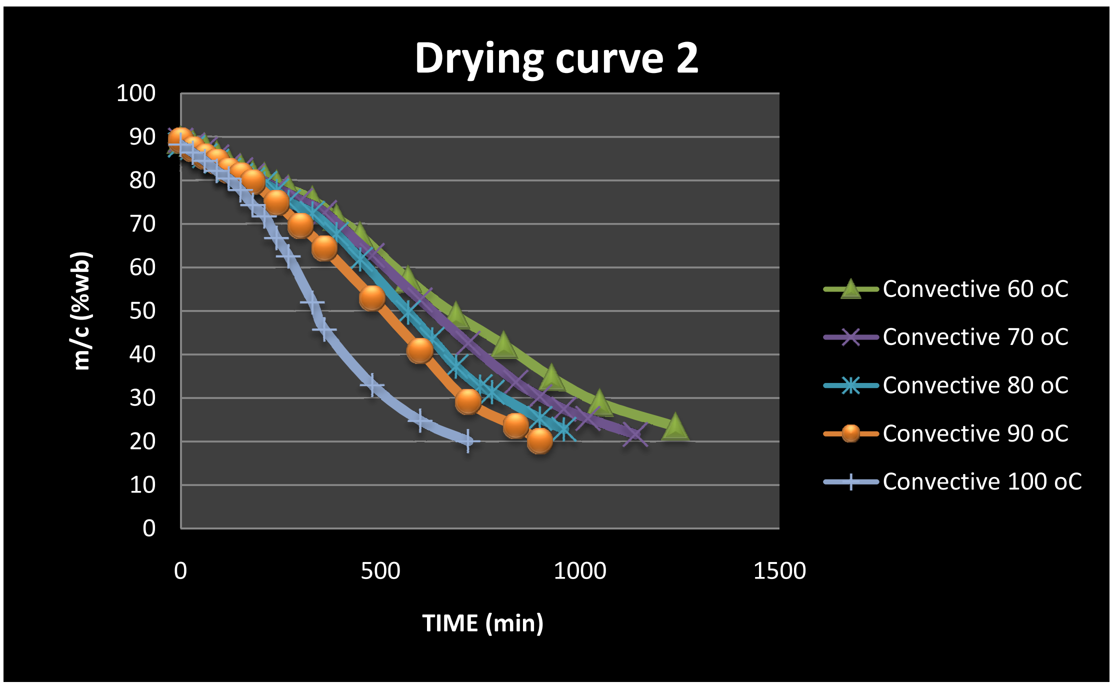

Fig4.2: Drying curve (convective drying)

From the above figure (4.2) it is clear that for 720 minute drying, the moisture content values for each drying temperatures were different and such behavior was the same through about the drying process. This was because higher the air temperature, greater the drying rate (Travatravaglini *et al*. 1993) i.e.; at 100ºC air temperature the moisture content reduced from 90% to 20% where the time taken for drying is 720 minutes and for 60 ºC air temperature the moisture content reduced from 90% to 23% the time taken 1240minutes. The differences in the moisture contents among treatments were not very high at the beginning. However it increased with the drying process and in the whole form, a significant part of the moisture is free on kodampuli surface and easily removed. As the drying advanced, the difference increased due to the internal resistance to moisture transport. In this period, the water interacts with polar groups of the molecules of the constituents and, therefore, the higher the temperature the more easily the water is removed.

The above stated fact was followed by the other temperatures also i.e. lower the temperature, longer the time taken for drying and vice versa. The times taken for drying for other three different temperature values are given below:

At 70 ºC, the observed drying time for reduction of moisture content from 89.12% to 21.58% was 1140min where as time taken at 80 ºC was 960 min for similar reduction(89.15% to 22.81%).At 90 ºC , the drying time was 900 min for a reduction from 89.12% to 20.12%.However a lowest drying time was observed at 100 ºC.

Since the use of low drying temperatures leads to long processing time, high drying temperatures could be used because neither color or texture were altered in the product and consumer requirements are met.

Dried garcinia rinds should have 25% moisture content (Raju and Reni, 2001). Thus the suitable drying time based on moisture content can be determined from the drying curves.

4.2.3 Appearance of dried products

Visual observation was carried out in terms of colour, texture and hardness. Each sample was compared with the smoke dried sample (T5) bought from market. Sun dried rinds were not dark black in colour but were soft and of non uniform texture. In comparison solar dried rinds (T2) were comparatively dark in colour with bit hardness. Comparing all the convective dried products the samples dried in convective dryer I (RRLT-NC) was not black in colour as compared to cabinet dryers but was a bit hard in textural appearance. Similar study was conducted in carrots by Talburt and Smith (1975) and found that, the colour of the sliced carrot dried at 50 ^{0}C had good appearance, but it consumes more time and slow dehydration at low temperature giving it a hard dense texture. The pretreated samples dried at 70^{0}C became darker.

Plate 4.1: convectively dried rinds @ 60^0C

Plate4.2: convectively dried rinds @ 70^0C

Plate4.3: convectively dried rinds @ 80^0C

Plate4.4: smoke dried rinds

Plate 4.5: sun dried rinds

Plate 4.6 convectively dried rinds @ 90 ^{0}C

Plate4.7: convectively dried rinds @ 100 ^{0}C

Plate4.8: solar dried rinds

4.3 OBJECTIVE ANALYSIS

4.3.1 Texture

The texture characteristics of dried kodampuli rinds in terms of hardness were measured using a Stable Micro System TA-XT2 texture analyzer fitted with a 5mm cylindrical probe. Compression tests have been more widely reported than tensile tests for these types of products. The presence of air cells within many fruits and vegetables has a significant effect upon the results of such tests. Hardness value was considered as mean peak compression force and expressed in Newton. The studies were conducted at a pre test speed of 1.0 mm/s, test speed of 0.5 mm/s, distance of 10 mm and load cell of 5 kg.

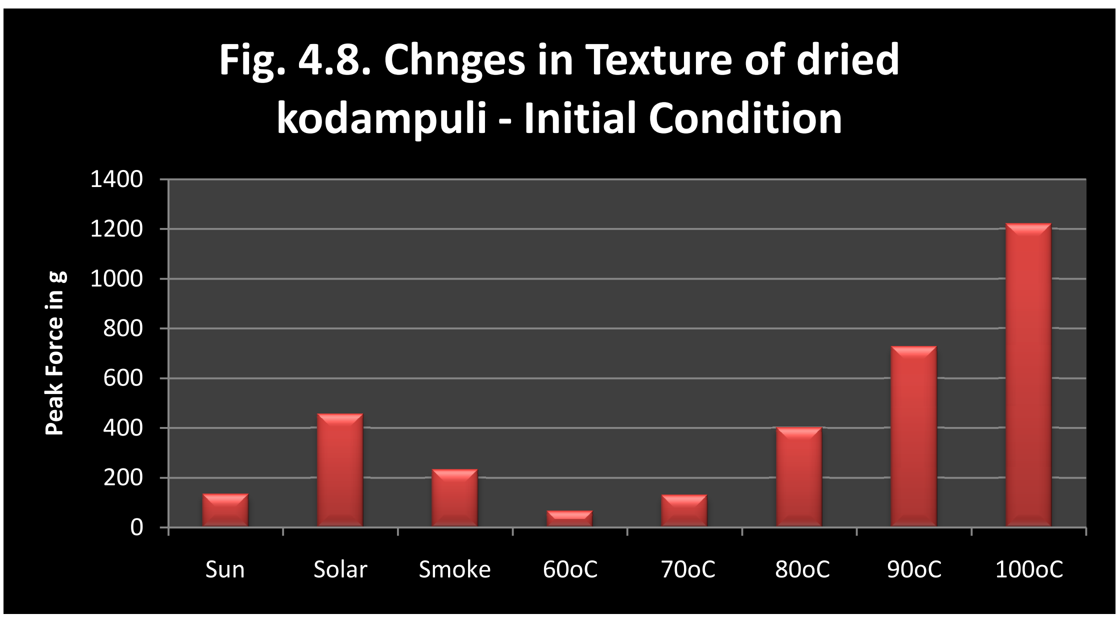

Fig 4.3 change in texture of dried kodampuli- initial condition

The effect of various drying treatments on the texture is shown in above fig 4.3. The figure 4.3 shows that the texture or peak force increased with increase in temperature from 60 ^{o}C to 100^{o}C. Maximum peak force was observed for kodampuli dried at 100 ^{o}C (1221.6 g), followed by 90 ^{o}C (728.25), solar (456.96), 80 ^{o}C (401.66), smoke drying (233.16), 70 ^{o}C (129.45), sun drying (133.67) and 60 ^{o}C (65.87).

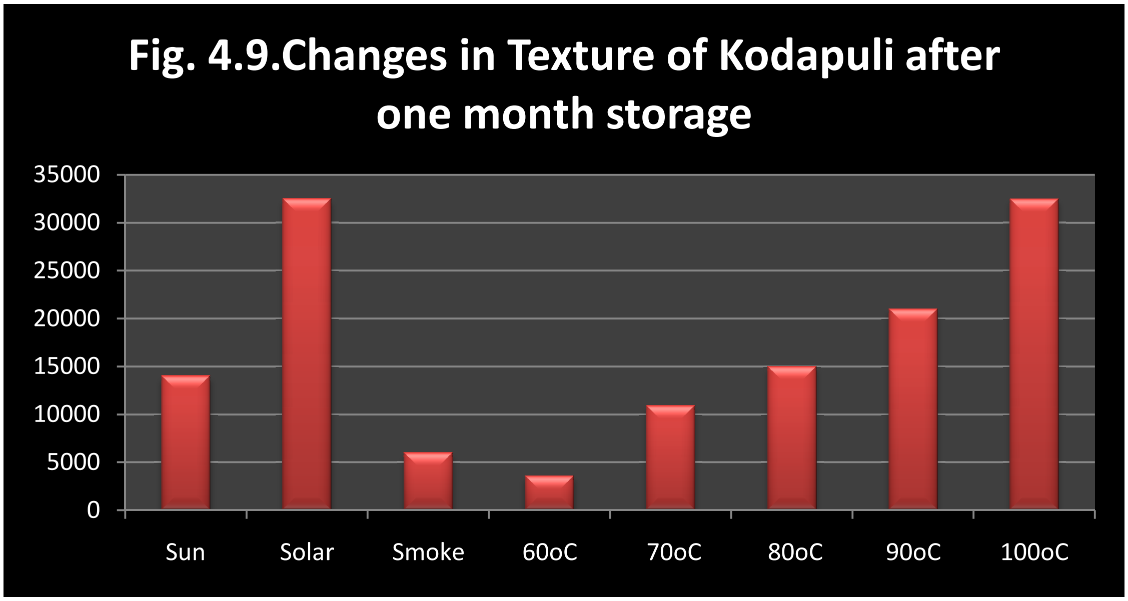

Fig 4.4 change in texture of dried kodampuli - after one month storage

The effect of various drying treatments on the texture after one month of storage is shown in above fig 4.4. The figure 4.4 shows that the texture or peak force increased with increase in temperature storage period of all samples. This could be attributed to the possible loss of moisture content from the samples hence increase in the hardness of surface. Maximum peak force was observed for solar dried kodampuli (32511.89 g), followed by 100 ^{o}C (32492.73), 90^{o}C (21016.92), 80 ^{o}C (14997.15), sun drying (14021.18), 70 ^{o}C (10925.68), smoke drying (3586.27) and 60 ^{o}C (3586.27).

4.3.2 Colour

The first judgment of a product quality is dependent on its various appearances, characteristics such as its colour, surface structure and shape. Colour, in particular, is an important sensory attribute (Brimelow and Groesbeck, 1993). The L*, a*, b* uniform colour space is based on the CIE system reference. L* defines lightness, a* denotes the red/green value and b* the yellow/blue value. A dark product is usually unappealing to the consumer as it indicates over processing. The CIE system of colour measurement transforms the reflection or transmission spectrum of the object into three dimensional spaces using the spectral power distribution of the illuminant and colour matching functions of the standard observer (MacDougall, 1993).

Reading taken with the help of hunter colorimeter after drying of samples were given in fig below:

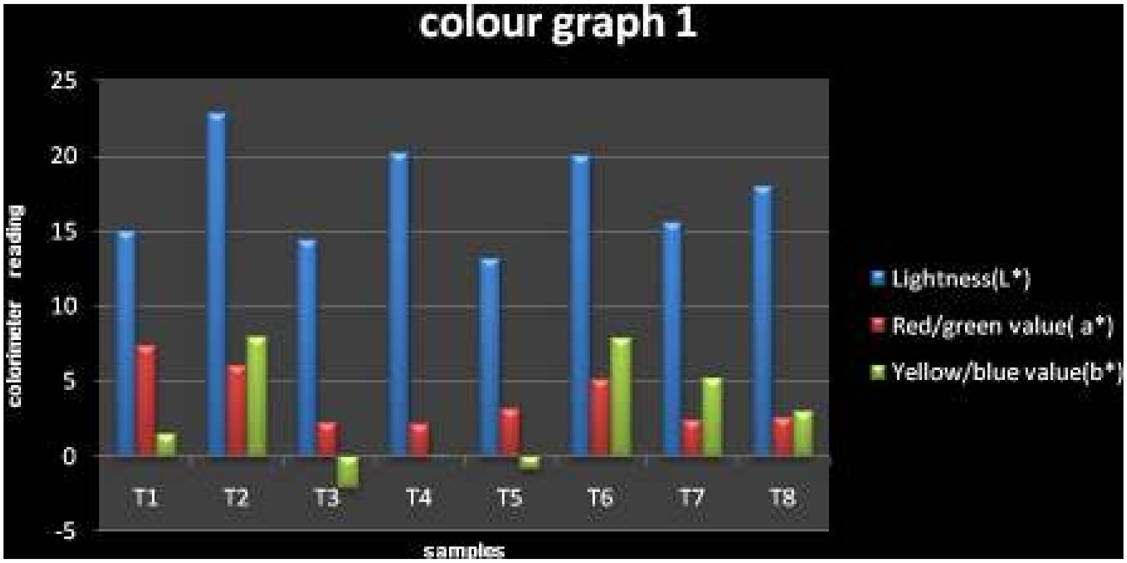

Fig 4.5: changes in color (hue values L*, a*, b*) of dried kodampuli

Reading taken with the help of hunter lab colorimeter after one month duration are shown in fig below:

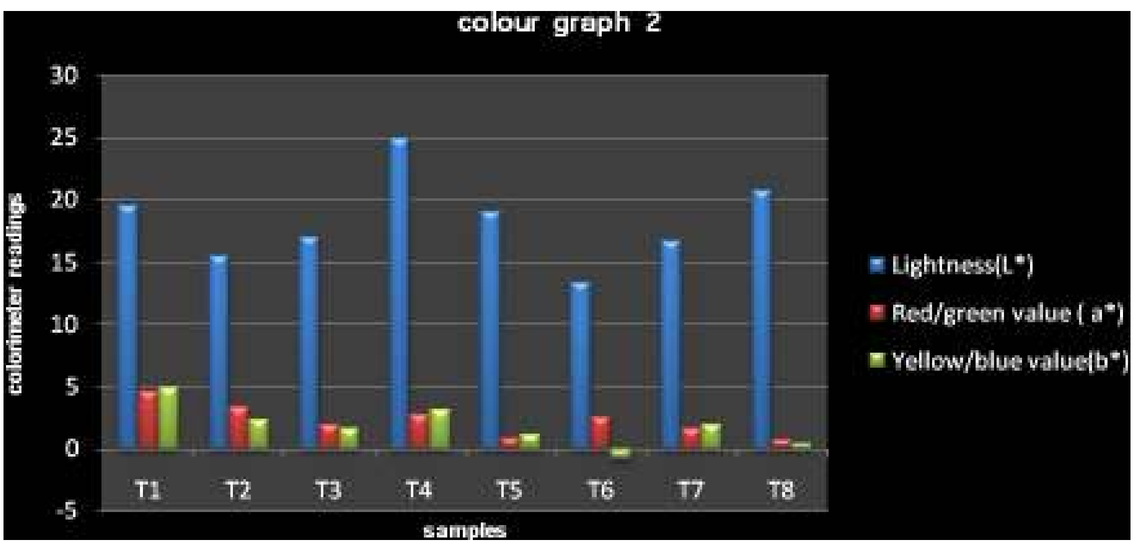

Fig 4.6: changes in colour (hue values L*, a*, b*) after one month

a. **Lightness (L*)**

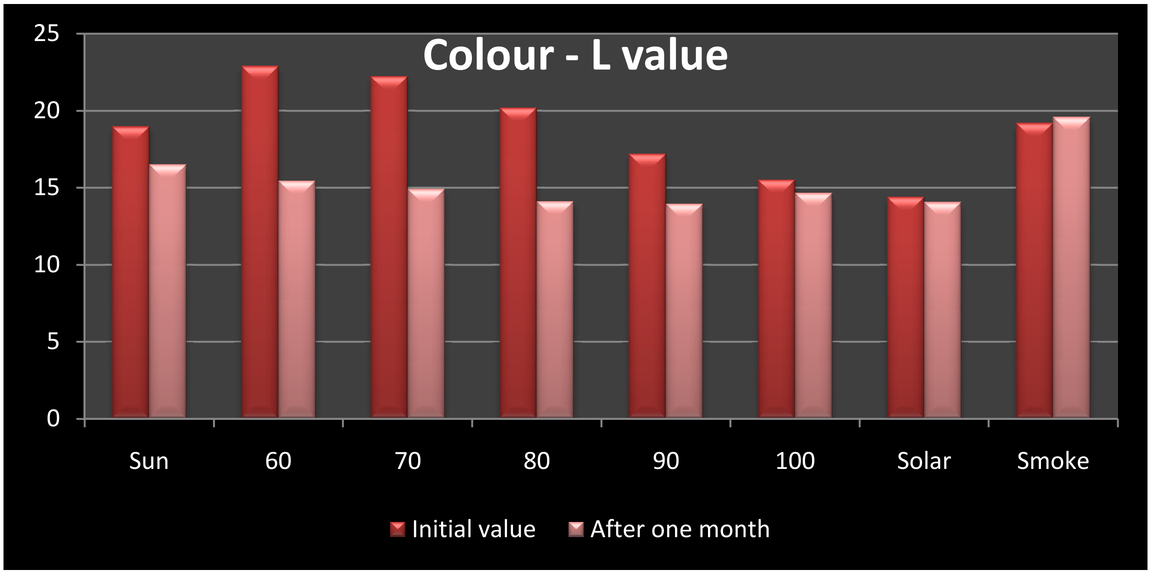

Fig 4.7: changes in hue (L* value) of dried kodampuli

In general, the hue colour (L* value) decreased as the temperature increased from 60 ^{0}C to 100 ^{0}C. 'L*'value of convectively dried kodampuli at 60 ^{0}C was highest (22.86) followed by 70^{0}C (22.21), 80 ^{0}C (20.17), 90 ^{0}C (17.18), 100 ^{0}C (15.15). 'L*' value for sun, solar and smoke dried samples were 18.93, 14.37 and 19.16. During the storage period there was a reduction in 'L*' value irrespective of the treatments except for the smoke dried rinds. The 'L*' value of the smoke dried rinds showed a minor increase in the 'L*' value. This could be attributed to the possible increase in the enzymatic activities during storage for the smoke dried rinds.

b. Red/green value (a*)

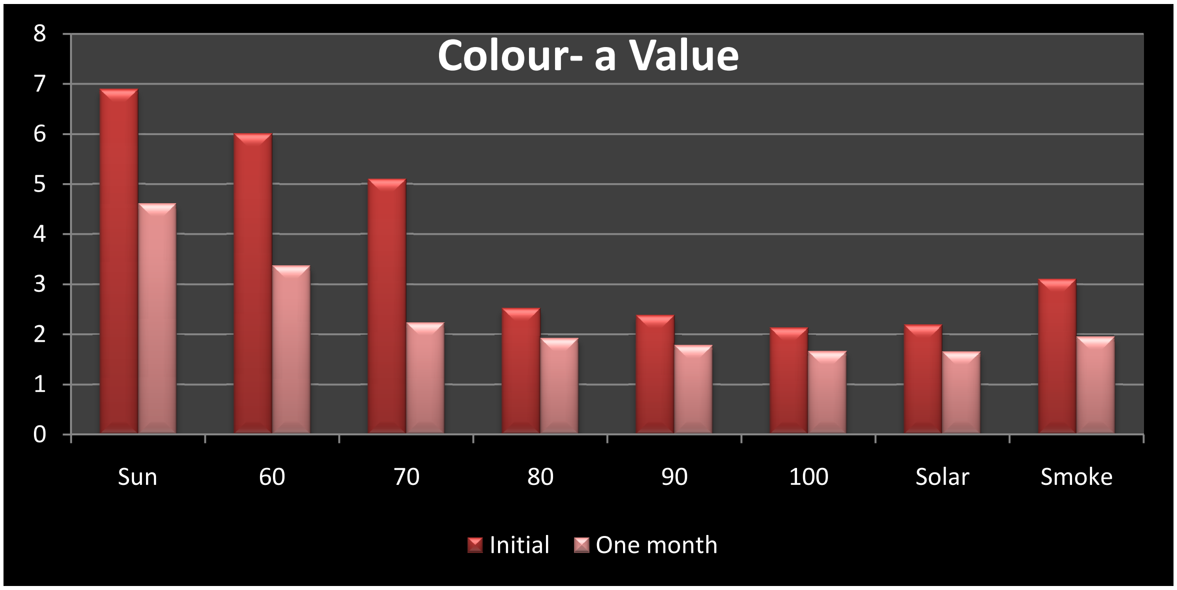

Fig 4.8: changes in hue (a* value) of dried kodampuli

In general, the hue colour (a* value) decreased as the temperature increased from 60 ^{0}C to 100 ^{0}C. ‘a*’ value of sun dried kodampuli was highest (6.89) followed by 60^{0}C (6.01), 70 ^{0}C (5.1), 80 ^{0}C (2.52), 90 ^{0}C (2.38), 100 ^{0}C (2.13). ‘a*’ value for solar and smoke dried samples were 2.19 and 3.1respectively. During the storage period there was a reduction in ‘a*’ value irrespective of the treatments. However, this change was not significant at 80 ^{0}C, 90 ^{0}C, 100 ^{0}C and solar drying. This could be attributed to the possible increase in the enzymatic activities during storage for the smoke dried rinds.

c. **Yellow/blue value (b*)**

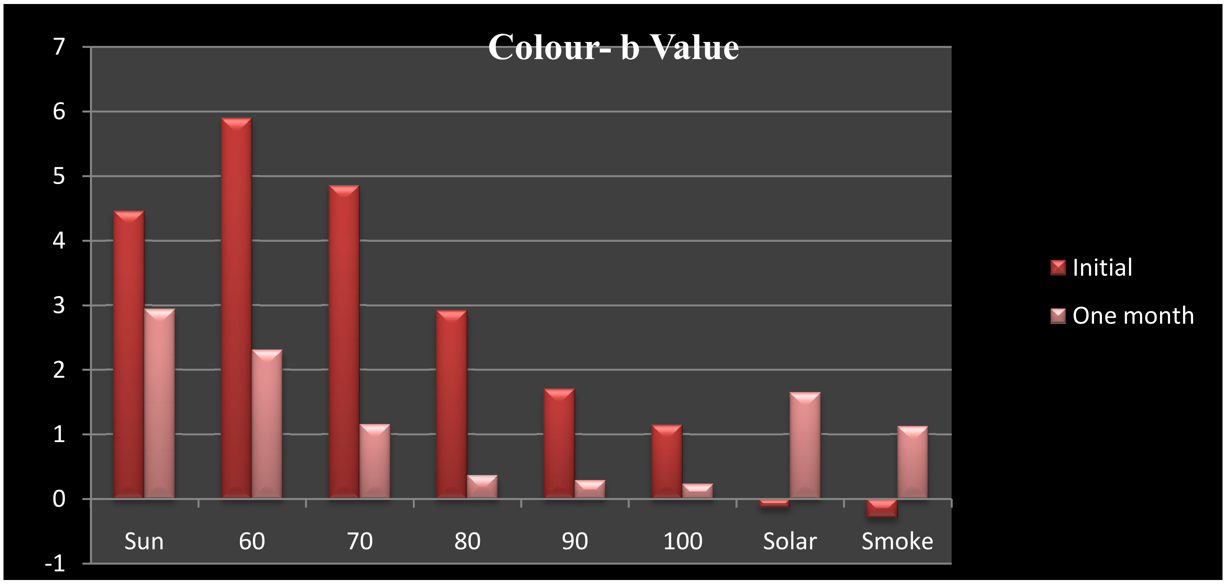

Fig 4.9: changes in hue (b* value) of dried kodampuli

In general, the hue colour (b* value) decreased as the temperature increased from 60 ^{0}C to 100 ^{0}C. ‘b*’ value of convectively dried kodampuli at 60^{0}C was highest (5.9) followed by 70 ^{0}C (4.86), 80 ^{0}C (2.92), 90 ^{0}C (1.71), 90 ^{0}C (1.71), 100 ^{0}C (1.15). ‘b*’ value for sun, solar and smoke dried samples were 4.46, -0.13 and -0.29 respectively. Here for solar and smoke dried sample the values were found negative which represents the colour of the sample on the bluish side. During the storage period there was a reduction in ‘b*’ values for sun and convectively dried samples but for solar and smoke dried samples values increased from negative to positive values. The positive values of the samples show the transformation of sample from bluish to more yellowish side.

4.3.3 ACIDITY

The acid content (hydroxy-citric acid) of the dried samples was analyzed at an interval of one month duration and results were shown in graph below.

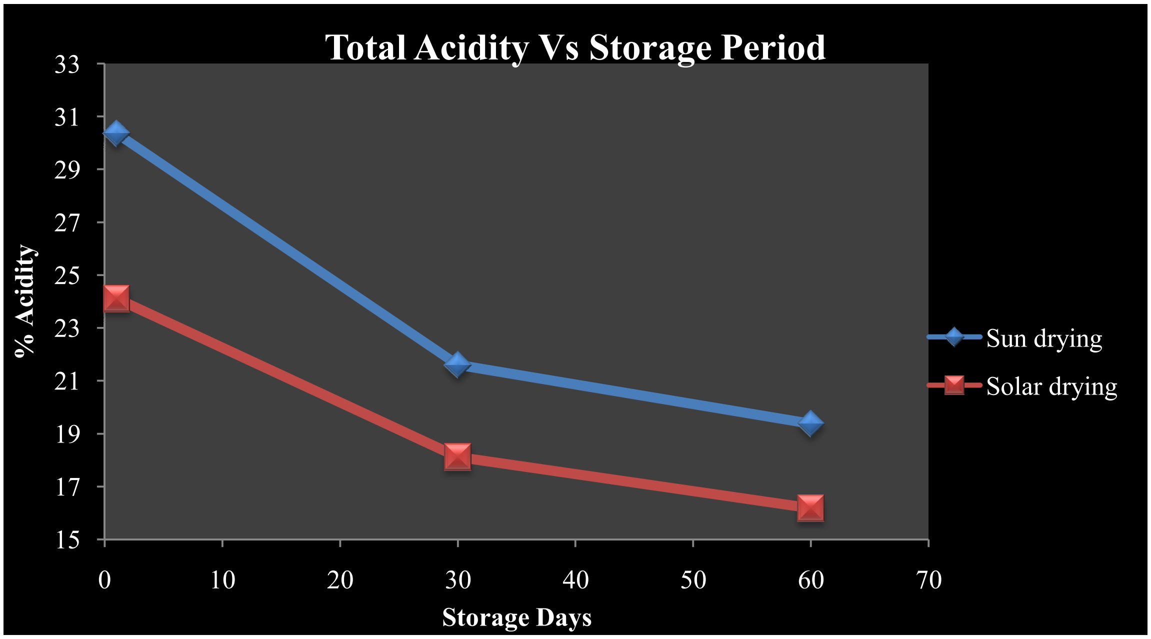

Fig 4.91 change in acidity of sun and solar dried kodampuli

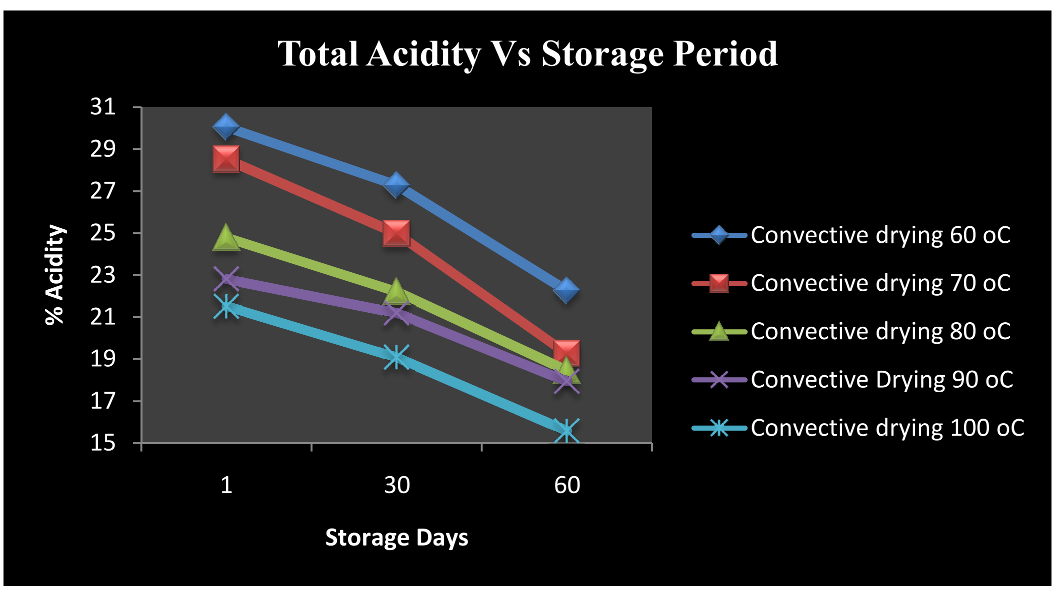

Fig 4.92 change in acidity of convectively dried kodampuli

From the above two graphs obtained after plotting the % acidity values and storage days shows that the acid content of all the samples decreased with time. Convectively dried samples have a much slow decrease in acid values as compared to sun and solar dried samples with respect to time interval (days). For sun, solar and convectively dried samples the acid content showed a lesser values for the increase in drying temperature. This can be explained by the fact that there will be more decrease in the volatile acid content of the rinds as the drying temperature increases.

4.4 Sensory evaluation of kodampuli added fish curry

All the 8 samples of fish curry (with equal amount of different 8 samples of kodampuli) was undergone a sensory evaluation in a 9 point hedonic scale with a group of 5 panelists.

The average score attained by each sample is shown in table 4.4:

SAMPLE	**SCORE**
SMOKE DRIED	**5.2**
SUN DRIED	**1.8**
SOLAR DRIED	**8**
CONVECTIVELY DRIED AT 60^0C	**5.4**
CONVECTIVELY DRIED AT 70^0C	**8.8**
CONVECTIVELY DRIED AT 80^0C	**7.2**
CONVECTIVELY DRIED AT 90^0C	**2.2**
CONVECTIVELY DRIED AT 100^0C	**2.0**

According to the sensory evaluation fish curry prepared by adding garcinia rinds convectively dried at 70^0C was best liked by 4 out of 5 panelists.

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

Kodampuli (*Garcinia cambogia* Desr.) is a small fruit that resembles a miniature pumpkin. As the name suggests (Puli = sour in Malayalam), the dried fruit is used as a souring agent in Kerala's famous fish curries and other seafood preparations. The extract is hydroxycitric acid **(HCA)**, It claimed to suppress appetite and enhance fat-burning. Conventionally the seeds and rinds from under-ripe fruits are detached and cut into half or sectioned into thicknesses varying inversely with the humidity of the weather. These are then spread in thin layers and dried in the sun for three to seven days to a moisture level of 15 to 20% and smoked. Rinds are dried until they attain a coal black colour and characteristic acid taste.

As the current practice of drying in laboratory and time consuming this study was designed to evaluate the three drying methods viz., sun drying, solar drying and convective drying. The quality of the dried kodampuli rinds were was expressed in terms of texture, colour, acid content, and cooking quality result.

The results obtained in present study are summarized below:

- Kodampuli rinds were dried by different methods below moisture content of 25%. Drying curve for each of the methods was drawn. It was noted that conventionally and solar drying rinds were faster and more efficient drying than conventional sun drying method.
- The effects of different methods of drying on the quality of kodampuli rinds were studied and it was expressed in terms of texture, colour and acid content values for each.
- From the texture profile curve it was noted that peak force value increased with the increase in temperature. The peak force value in texture profile curve represents the hardness of the respective sample.
- The L*, a* and b* values obtained from hunter colorimeter showed that samples dried at low temperatures were not black but dark brown in colour. Whereas, samples dried at high temperature were more on black in appearance.

- The acid content (hydroxy citric acid) for each samples were calculated thrice at an interval of one month. The results obtained showed that the acid content for all the samples decreased with time. Samples dried at higher temperature showed a less value of acid content.
- Sensory evaluation result obtained after cooking fish curry from each samples were done. Sensory panel suggested that dried rinds at 70 ^{0}C were the best among all.

ABSTRACT

ABSTRACT

Kodampuli *(Garcinia cambogia*) is a tropical fruit commonly known as Malabar tamarind and belongs to the family *Clusiaceae* earlier known as *Guttiferae*. It is an essential ingredient in all the seafood loving kitchens of Kerala, the coastal South Indian state. Fresh and mature kodampuli fruits procured from farms were subjected to three different drying methods namely; sun drying, solar drying and convective drying. The study involves understanding drying kinetics of kodampuli and post harvest behavior of dried kodampuli rinds. The first major step involved drying of procured fruit samples by above stated methods at different temperatures and then obtaining a drying curve for each method. The time taken to reach moisture content below 25% was compared by drying curve analysis. Convectively dried kodampuli rinds at high temperature reached the desired moisture content faster as expected. The second step involved the quality analysis of dried rinds in terms of acid content (hydroxy-citric acid), texture and colour parameters. Acid content for each of the samples deceased with respect to time and samples dried at higher temperature had low acid content. The analysis of force-deformation curve shows that values of samples dried at high temperature have a rough texture as compared to low temperature dried rinds. Colours of the samples were mainly dark brown except convectively dried samples which were a bit blacker. Sensory analysis done by a panel ranked convectively dried rind at 70 ^{0}C the best.

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CHAPTER 6

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APPENDICES

APPENDIX I

1. **Preparation of Sodium Hydroxide solution (40%)**

0.4 g of sodium hydroxide crystals were dissolved in 100 ml of distilled water.

2. **Extraction of juice from dried sample for acid content determination**

Dried samples were first soaked in water for 10 minutes before heating. After that it was being heated mildly for one minute in order to make the rinds soft. Then the rinds were crushed using a mortar and pestle. The juice was extracted using a muslin cloth. The amount of juice extracted was made 100 ml for titration. 10 ml of sample was taken and titrated using prepared sodium hydroxide solution. Two drops of phenolphthalein was added to each sample prior to titration. This method was standardized and followed each time for every sample.

APPENDIX II

Variation of moisture content of kodampuli fruits during sun drying:

TIME INT (MIN)	WIEGHT (gm)	M/C (%wb)
0	1000	89.12
30	979.6	88.52
60	964.5	87.96
90	871.1	87.01
120	805	86.31
150	790	85.62
180	775	85.22
210	711	83.67
270	612	81.03
300	548.4	79.02
360	474.7	76.55
450	399.5	70.26
540	346.7	64.09
630	314.5	59.23
710	206	54.14
800	198.5	45.27
890	157.5	38.31
980	145.2	33.08
1070	137.4	29.27
1160	130.4	25.48

Variation of moisture content of kodampuli fruits during solar drying:

TIME INT (MIN)	WIEGHT (gm)	M/C (%wb)
0	1000	88.15
30	940	87.41
60	853.1	86.12
90	800	85.19
120	695	82.96
150	602	81.08
180	595	80.16
210	562.5	78.18
270	452	73.81
300	352	72.08
360	255.7	66.15
420	202.7	52.35
480	161.12	44.42
540	146.2	37.38
600	137.8	33.51
660	129.9	29.46
720	124.15	26.22
790	119.4	23.29
850	116.05	21.07

Variation of moisture content of kodampuli fruits during convective drying (RRLT-NC dryer @ 60^0C):

TIME INT (MIN)	WIEGHT (gm)	M/C (%wb)
0	1000	89.12
30	940	88.48
60	900.5	87.72
90	800	85.89
120	695	83.95
150	602	82.99
180	595	81.36
210	562.5	80.91
240	452	79.16
270	352	78.06
330	255.7	75.49
390	202.7	71.43
450	161.2	67.28
570	146.2	57.18
690	122.6	48.94
810	108.3	42.18
930	95.9	34.71
1050	87.9	28.85
1240	81.7	23.41

Variation of moisture content of kodampuli fruits during convective drying (RRLT-NC dryer @ 80^0C):

TIME INT (MIN)	WIEGHT (gm)	M/C (%wb)
0	1000	88.15
30	951.8	87.49
60	855.4	85.62
90	851.4	84.34
120	812.1	82.27
150	773.9	81.09
180	744.1	80.11
210	652.1	79.23
240	640.6	77.51
270	562.1	75.06
330	497.5	72.42
390	424.19	67.61
450	360.9	61.82
570	249.1	49.59
630	195.7	43.44
690	171.9	37.19
750	160	32.52
780	157.2	31.31
900	144.5	25.29
960	139.9	22.81

Variation of moisture content of kodampuli fruits during convective drying (cabinet dryer @ 70^0C)

TIME INT (MIN)	WIEGHT (gm)	M/C (%wb)
0	1000.5	89.12
30	959.7	88.03
60	834.3	87.13
90	815.31	85.33
120	788	83.28
150	751.3	82.41
180	706.2	81.06
240	647	78.22
300	626.4	75.36
360	585.7	72.53
480	494.7	62.71
600	430.1	52.46
720	335.7	42.52
840	247	33.61
900	215.4	30.29
960	194.4	27.37
1020	181.5	25.26
1140	178.5	21.58

Variation of moisture content of kodampuli fruits during convective drying (cabinet dryer @ 90^{0}C)

TIME INT (MIN)	WIEGHT (gm)	M/C (%wb)
0	1000.5	89.12
30	970.5	87.12
60	857.5	85.42
90	775	84.26
120	698	82.19
150	568.4	81.11
180	514	79.54
240	385	74.78
300	315	69.59
360	205.2	64.28
480	176.1	52.91
600	153.1	40.83
720	145.34	29.11
840	134.7	23.52
900	128.98	20.12

Variation of moisture content of kodampuli fruits during convective drying (cabinet dryer @ 100^0C)

TIME INT (MIN)	WIEGHT (gm)	M/C (%wb)
0	1000.1	88.15
30	941.2	86.29
60	834.7	84.41
90	738.7	82.11
120	638	80.27
150	538.5	77.71
180	506	74.27
210	438	71.66
240	389.3	66.71
270	331.6	62.48
330	224	51.91
360	145.4	45.68
480	117.7	32.91
600	104.9	24.73
720	98.8	20.03

APPENDIX IV

L*, a* and b* values obtained from hunter lab colorimeter are given in table form below:

			Colour		L value		a value			b value
SAMPLES		**TEMP(°C)**	**1**	**30**	**TEMP(°C)**	**1**	**30**	**TEMP(°C)**	**1**	**30**
SUN DRYING (T1)		Sun	18.93	16.48	Sun	6.89	4.61	Sun	4.46	2.94
Convective DRYER(T8)		60	22.86	15.42	60	6.01	3.37	60	5.9	2.31
Convective DRYING(T6)		70	22.21	14.89	70	5.1	2.23	70	4.86	1.16
Convective DRYER(T2)		80	20.17	14.09	80	2.52	1.92	80	2.92	0.37
Convective DRYING(T4)		90	17.18	13.94	90	2.38	1.78	90	1.71	0.29
Convective DRYING(T7)		100	15.5	14.63	100	2.13	1.66	100	1.15	0.23
SOLAR COOKER(T3)		Solar	14.37	14.03	Solar	2.19	1.65	Solar	-0.13	1.65
Smoked sample		Smoke	19.16	19.56	Smoke	3.1	1.95	Smoke	-0.29	1.13

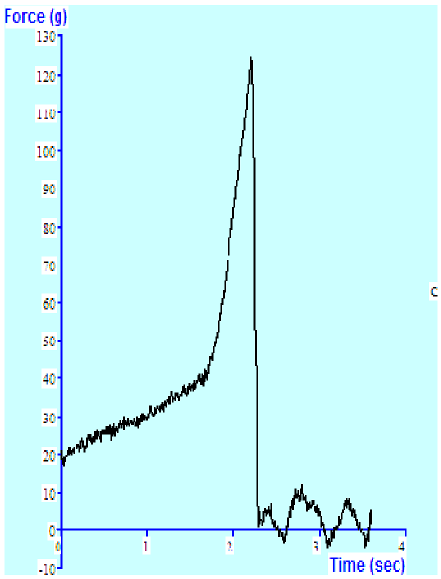
APPENDIX V

Peak force values obtained from texture analyzer is given in table below:

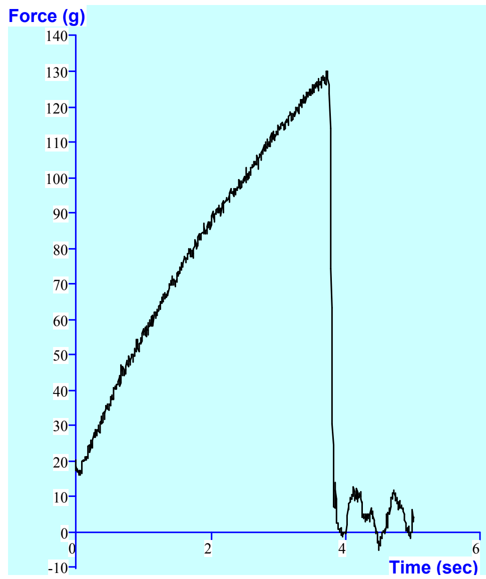
Sl no	Treatments	Initial Peak force	Peak force after one month
1	Sun drying	133.67	14021.18
2	Solar drying	456.96	32511.89
3	Smoke drying	233.16	5996.82
4	Convective drying 60^{o}C	65.87	3586.27
5	Convective drying 70^{o}C	129.45	10925.68
6	Convective drying 80^{o}C	401.66	14997.15
7	Convective drying 90^{o}C	728.25	21016.92
8	Convective drying 100^{o}C	1221.6	32492.73

APPENDIX VI

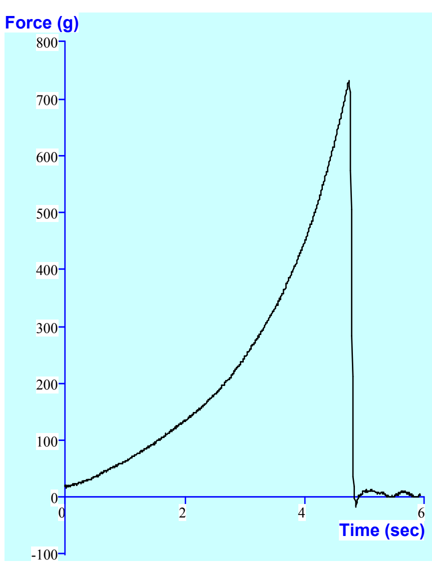
Texture profile curve obtained from TA-XT2 texture analyzer for different samples are given below:



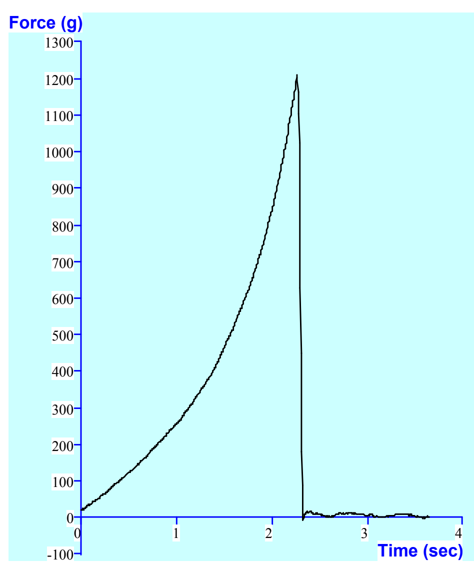
Sun dried sample



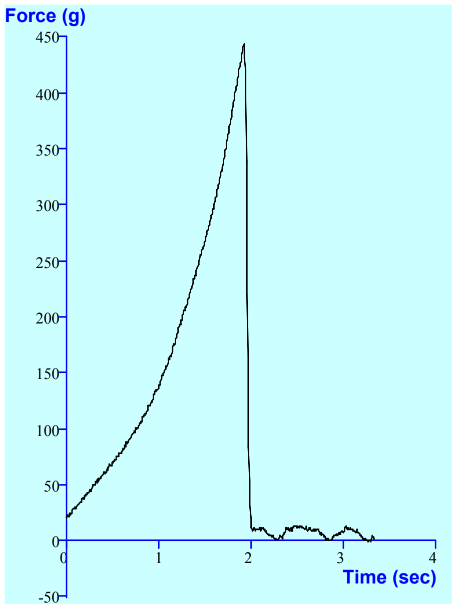
Convective drying 70^{o}C



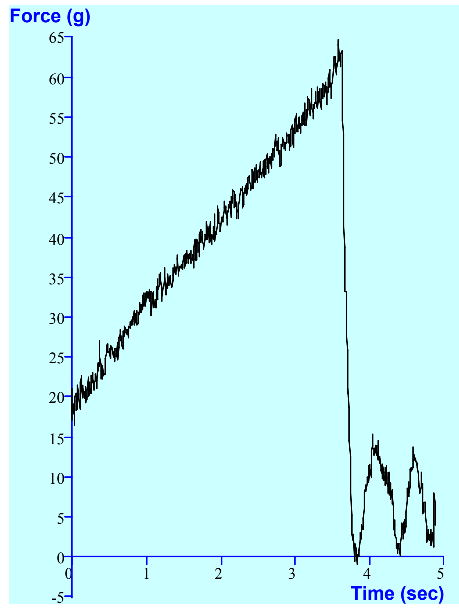
Convective 90 ^{o}C



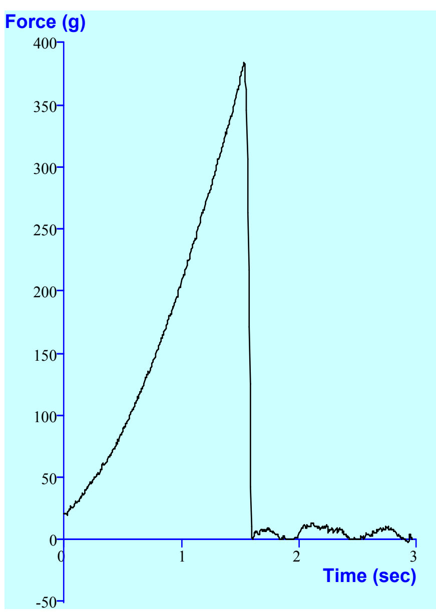
Convective drying 100 ^{o}C



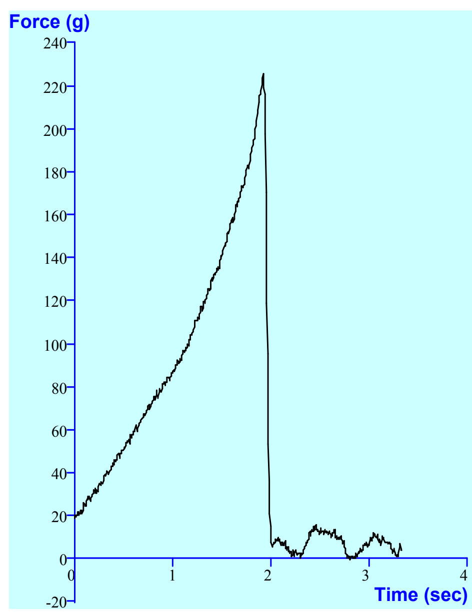
Solar dried sample



Convective drying 60^{o}C

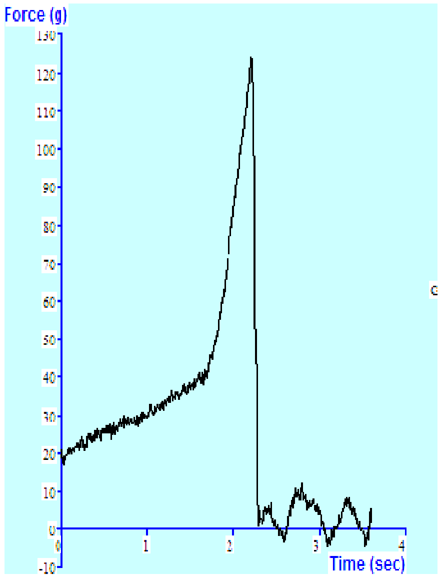


Convective drying 80^{o}C

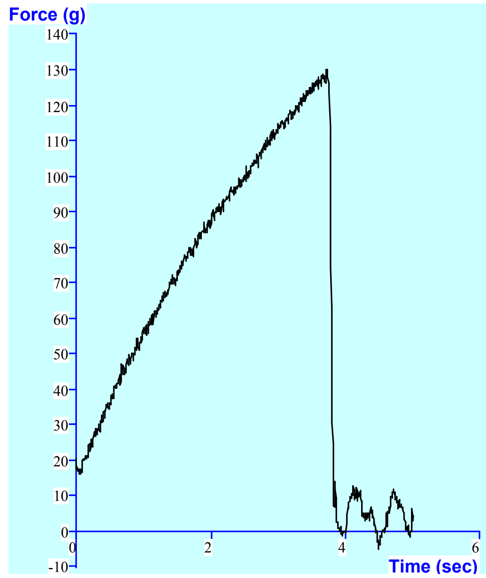


Smoke dried sample

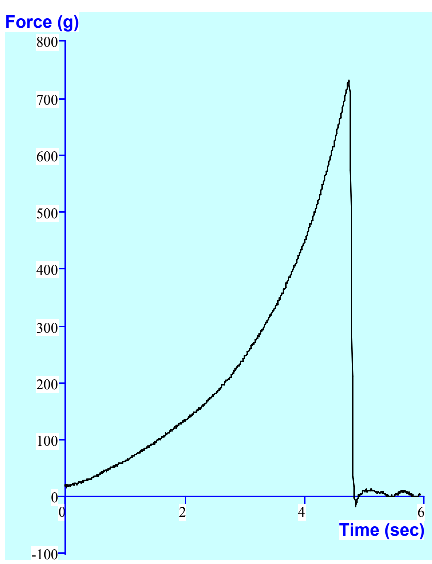
Texture profile curve obtained from TA-XT2 texture analyzer for different samples are given below:



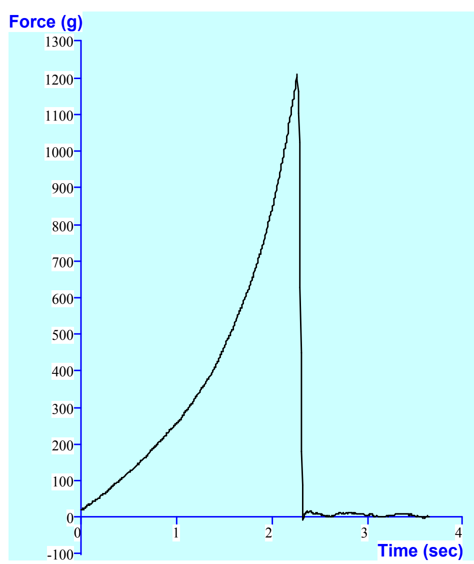
Sun dried sample



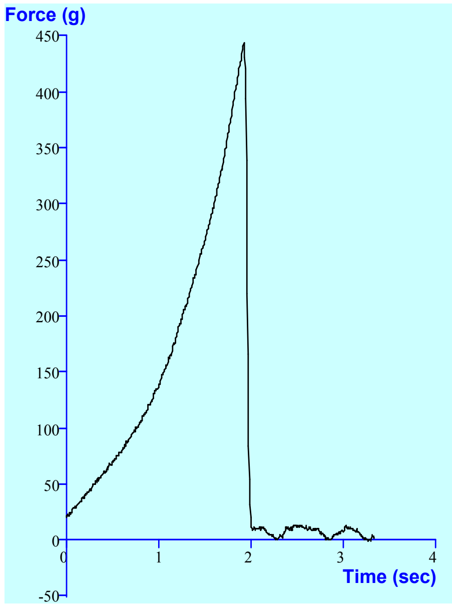
Convective drying 70^{o}C



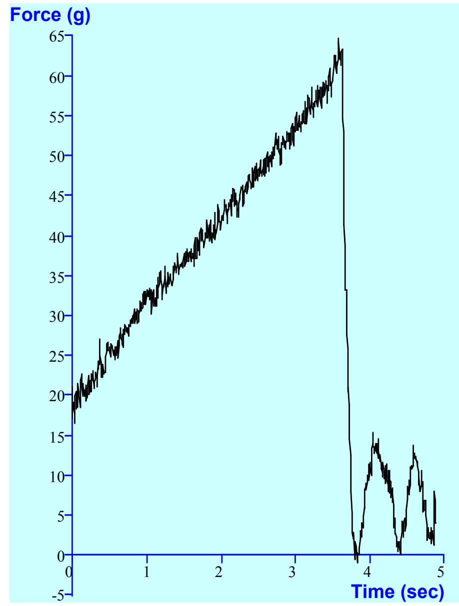
Convective 90 ^{o}C



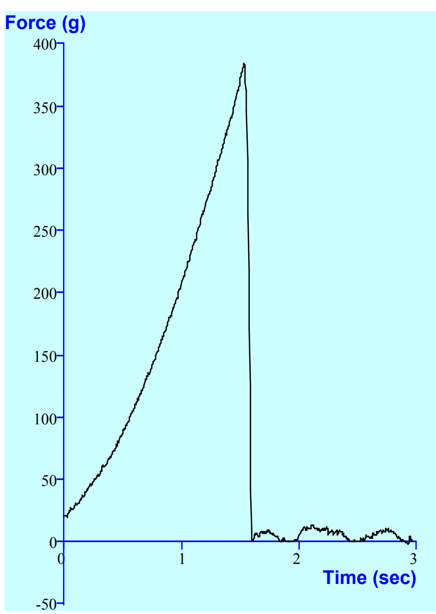
Convective drying 100 ^{o}C



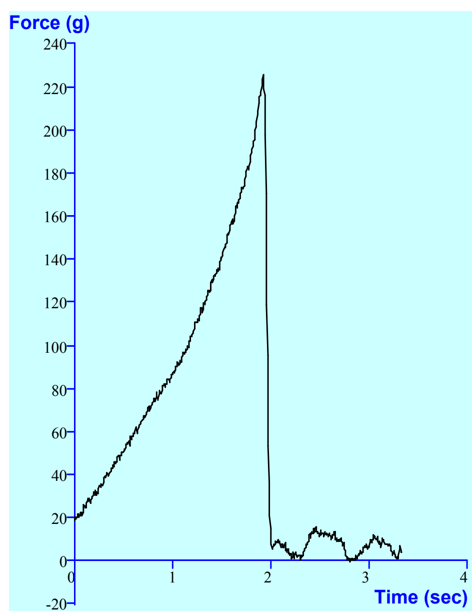
Solar dried sample



Convective drying 60°C



Convective drying 80°C



Smoke dried sample

APPENDIX VII

Acceptability Test

Score card: **Hedonic scale: 9**

Judge Name: **Date:**

Product Name: Garcinia cambogia

Attribute:

Degree Of Preference	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G	Sample H
Like very much								
Like much								
Like moderately								
Slightly like								
Neither like nor dislike								
Slightly dislike								
Dislike moderately								
Dislike much								
Dislike very much								

Comments: