DEVELOPMENT OF PROCESS PROTOCOL FOR G*arcinia cambogia* POWDER

By

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(2010 -18 - 105)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Technology

in

Agricultural Engineering

(Agricultural Processing and Food Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University
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TAVANUR-679 573
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2012

DECLARATION

I hereby declare that this thesis entitled **"Development of Process Protocol for *Garcinia cambogia* Powder"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or associateship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

*I bow to the lotus feet of '**God the Almighty'** whose grace had endowed me the inner strength and confidence and blessed me with a helping hand at each step during this work*

*I am awestricken to express my scrupulous gratitude to **Dr. Santhi Mary Mathew**, Professor and Head, Dept. of PHT & AP, KCAET, Tavanur, my guide, for her avuncular guidance, unremitting support, bolstering encouragement, indefatigable concern, constructive comment and Professional criticisms.*

*I am ever grateful to **Dr. Sivaswami**, **M,** the Dean, Agri. Engg. KCAET, Tavanur for his invaluable help, guidance and constant encouragement during the course of the project work.*

*I am at loss of words to express my sense of gratitude to **Dr.Sudheer Babu**, **P,** Associate Professor, College of Dairy Science and Technology, KVASU, Mannuthy, member of Advisory Committee, for his invaluable help, guidance, enthusiasm, relevant suggestions and whole hearted co-operation throughout the period of project.*

*I am immensely thankful to **Er. George Mathew**, Associate Professor, Dept. of PHT and AP, KCAET and **Dr.Sudheer, K.P**, Associate Professor, Dept. of PHT & AP, KCAET, Tavanur, members of Advisory Committee for their constant backing of constructive suggestions and kind support.*

*I am genuinely indebted to **Dr. Prince, M.V**, Associate Professor, Dept. of PHT & AP, KCAET, for the constant encouragement and timely advice rendered during the work.*

*I acknowledge my gratitude to **Shi. Krishnan, S**., Associate Professor and Head, Department of Statistics, College of Horticulture, Vellanikkara and **Dr. Musthafa Kunnathadi,** Assistant Professor, Dept. of SAC, KCAET, Tavanur, for their timely help.*

*I am in dearth of words to express my indebtedness to **Dr. Rajakumar, S.N**, Associate Professor, College of Dairy Sci. and Technology, KVASU, Mannuthy for the advice and help rendered at different phases of my work.*

*I am highly courteous to **Er. Anu Varugheese**, Assistant Professor, Dept. of IDE, KCAET, Tavanur, for her timely help.*

*On my personal note I express my extreme grateful to **Er. Priya, G, Nair,** Assistant Professor, Dept. of IDE, KCAET, Tavanur, for her timely advice inspiration, forbearance, constant encouragement and moral support shown throughout my study.*

*Words would not suffice to express my gratitude to all staffmembers of PHT and AP, especially **Mrs. Sasmila Bai**, Guest Lecturer and **Mrs. Divyasree, C.S,** Biochemist for their sincere help and co-operation during the entire project work.*

*My heartfelt gratitude to **Mr. Rajesh** and all other staff members of Dairy plant, Mannuthy cannot be captured in words for their co-operation and assistance during the processing.*

*Words seem to be inadequate to express my loving thanks to my **beloved classmate**s for sparing their precious time at various stages of this study. Their timely help and earnest assistance during the conduct of project work is immemorable.*

*I express my special thanks to my friends **Drisya, J and Sabitha, K.**T for their timely help.*

I express my thanks to all the faculty members of Library, KCAET, Tavanur for their ever willing help and co operation.

The award of Junior Research Fellowship by Kerala Agricultural University is greatly acknowledged.

Above all I am greatly indebted to my parents and my friends for the moral support, constant encouragement, affectionate concern and prayers without which I could not have completed this work. I am thankful to all those, who helped me though their prayers.

Sunitha,C.P.

Dedicated to My Parents

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SYMBOLS AND ABBREVIATIONS

α	alpha
°C	degree celsius
^{0}brix	Degree brix
β	beta
µm	micrometer
µl	microlitre
Art	Article
cm	centimetre
d.b	dry basis
Eqn.	Equation
et al.	and others
Fig.	figure
g	gram
g / cm^3	gram per cubic centimeter
GC	Gas Chromatography
G.cambogia	*Garcinia cambogia*
HCA	Hydroxy Citric Acid
hp	horse power
HPLC	High Performance Liquid Chromatography
h	hour
IDE	Irrigation and Drainage Engineering
i.e	That is
KAU	Kerala Agricultural University
kg	kilogram
KPa	Kilo Pascal
l/h	litre per hour
m	metre
m^3	cubic metre

M.C	Moisture content
mg	milligram
min	minute
ml	millilitre
mm	millimetre
MS	Mild Steel
NaCl	sodium chloride
p	probability
PHT & AP	Post Harvest Technology and Agricultural Processing
rpm	Revolutions per minute
RSM	Response Surface Methodology
s	second
SAC	Supportive and Allied Courses
SEM	Scanning Electron Microscopy
Tg	glass transition temperature
Ts	sticky point temperature
TSS	Total soluble solids
viz.	namely
UV	Ultra violet
w.b	wet basis
WSI	water solubility index
w/w	weight by weight
w/v	weight by volume

Introduction

CHAPTER I

INTRODUCTION

In ancient times, spices were as precious as gold; and as significant as medicines, preservatives and perfumes. The Geneva-based International Standards Organization (ISO) defines spices and condiments as: vegetable products or mixtures thereof, free from extraneous matter, used for flavouring, seasoning and imparting aroma in foods. Spices appeal to the five senses and influence cultures and societies through trade and daily use.

Through centuries it had played a major role in our lives and in the economic development of many countries. Valued for more than just taste and appearance, spices have nutritional and medicinal merits as well; better known as home remedies than proven treatments in medicine. Spices are considered very important in the ayurvedic tradition because of the therapeutic value they bring to food. Including variety of spices in our daily meal is highly recommended by ayurvedic practitioners.

India is the abode of many spices. Acclaimed as the 'virtual spice bowl', India is the largest producer and consumer of spices in the world. Indian spices are considered best in the world and occupy a prominent role in the International trade. The importance of spices can be traced from Vasco-De-Gamma's voyage for Indian spices. India commands a formidable position in world spice trade with a share of 48% in volume and 44% in value. The total spices export for the year 2011-12 stood at 5,75,270 tonnes, valued at Rs 9,783.42 crore (Sajeev, 2012). Because of the varying climates in India - from tropical to sub-tropical almost all spices are grown in this country. By judging recent trends in the local consumption as well as export demand of spices there has been allocation of export quantum of spices at a growth rate of 10% in production and 6% in export earnings. Facing stiff global competition from other producing countries it is imperative to increase the production and export and improve post harvest technology by the quality upgradation of spices.

The production, processing, packaging and marketing of spices have a prominent role in the economy of our country. It provides employment to millions of people and brings substantial foreign exchange.

ISO have recognized 109 spices all over the world, out of which 52 are grown in India. Apart from the, important spices such as pepper, ginger and cardamom, *Garcinia cambogia,* also an important spice, which is small, sweet, exotic fruit grown in Southern part of India, mainly in Kerala. Garcinia the 'cambodge tree' is a good-sized glabrous and evergreen tree belonging to the family Clusiaceae (Majeed *et al.*, 1998) earlier known as Guttiferae (Trimen, 1893) and presently known under the scientific name, *Garcinia cambogia* (L.). Other common names of *Garcinia cambogia*: kodampuli, brindle berry, brindall berry, garcinia, malabar tamarind, citrin, gambooge, gorikapuli, uppagi, garcinia kola, mangosteen oil tree (Wealth of India, 1956).

The fruits are characterized by a sharp pleasant acidity. Though it is not eaten raw, it is included in curries as an appetizer in South India and Srilanka (Watt, 1972). For centuries, the fruit was recommended by folk healers and ayruvedic medicine practitioners for suppressing appetite and for aiding weight loss. *Garcinia cambogia* extract has been used traditionally in Indian medicine to treat tumors, ulcers, hemorrhoids, diarrhea, dysentery, fever, open sores, and parasites. It has been reported to be indicated for constipation, rheumatism, dyspepsia, obesity, and high levels of triglycerides and cholesterol (Duke and Bogenschutz, 2002; Mahendran *et al.*, 2002). It is also employed in veterinary medicine as a rinse for diseases of mouth in cattle. The dried slice of this fruit, when used in place of tamarind in the preparation of fish and non-vegetarian curries is supposed to impart a special flavour and taste. The dried rind with its rich acidity possessed marked antiseptic properties and it also counteracts the tang of salt (Benny, 2003).

The major problem faced by the farmer is in drying of the rind due to the coincidence of south west monsoon rains with the period of fruit ripening. However, if the fruits are not processed quickly fungal infection takes place.

Mainly three types of drying procedures are practiced, sun drying, smoke drying and both combined. Even if there is sufficient sunlight it takes six to seven days for drying of the product. Lengthy procedure of drying cause mould growth and affects the quality of the product. Moreover the storage requires a large space and the handling is difficult. Also the squeezing of juice from the dried rind takes time. Development of a process Technology for Garcinia powder from the fresh fruit itself will reduce its drying, handling and storage problems and make its use convenient to households. The *Garcinia cambogia* powder is an interesting product because of its characteristics. The powder can be used as an ingredient for cooking. Its advantages consist of a long shelf life at ambient temperature, low logistic expenditures due to little weight and volume, and ease of use. Development of such technology will enhance its utilization and fetch good returns to the farmer.

Considering the above cited facts, a study was undertaken to develop a process protocol for *Garcinia cambogia* powder from the fresh fruit itself with the following objectives**:**

1) Biochemical analysis of fresh *Garcinia cambogia* fruit
2) Selection and standardisation of drying agents for proper drying
3) Standardisation of drying parameters to get powder from extract
4) Quality analysis of the Garcinia powder
5) Storage and packaging studies of Garcinia powder

Review of literature

CHAPTER II

REVIEW OF LITERATURE

A comprehensive review is mandatory in any research endeavor. This helps the investigator to select relevant subject matter to organize and to report systematically. This chapter deals with the brief account of literature which provides the background information which directly or indirectly influences the present study. Literature pertaining to the study of production and analysis of *Garcinia cambogia* powder are reviewed.

2.0 *Garcinia cambogia*

Garcinia cambogia is an evergreen, small or medium-sized dioecious, understory tree, 5 to 20 m tall with a rounded crown and horizontal or drooping branches. The bark is dark and smooth. Leaves are opposite, petiolate, dark green and shining.

Neither male nor female flowers produce nectar. Fruit a green, ovoid berry, 5 cm in diameter, yellow or red when ripe, with 6-8 grooves. Seed 6-8, smooth, large, about 5 cm long and 2 cm wide surrounded by a succulent aril. The fruits may vary in size weighing 50–180 g. (Around 30 species occur in India (Benny, 2003).

2.1 Origin

Watt (1972) reported that *Garcinia cambogia* species thrive prolifically on the Indian subcontinent and in western Sri Lanka. *Garcinia cambogia* trees are found in tropical countries. It is a native of Western Ghats of 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 it can reach an altitude 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 centres of origin of cambodges. The plant flowers in the hot season and the fruits ripen in the rains. The fruits are edible, but too acid to be eaten raw.

They are valued for their dried rind which is used in Travancore-Cochin and Malabar as a condiment for flavouring curries in place of tamarind or lime. In Ceylon, the fruits are pickled under ripe, the thick pericarp cut into sections, dried in the sun and preserved for future. The tree is very much adapted to both hilltops and plain lands, but its performance is best in riverbanks and valleys. It also grows well in dry or occasionally water logged or flooded soils.

2.2 Varieties

Even though Garcinia is one of the oldest tree spices of the state, only recently that it has attained International importance. Hence research work in the field of crop improvement and crop husbandry is very meager. Most of the trees in the field are of seedling origin and they exhibit wide variability.

2.3 Harvesting

Seedlings start bearing generally at the age of 10-12 years. Grafts start bearing at the age of third year onwards and will attain full bearing at the age of 12-15 years (KAU, 2001). Flowering occurs in January-March and fruits mature in May. There are reports of off season bears, which bear two times a year i.e., during January-July and September-February. The flower buds rise in the mid night and the central bud rise first after that the both side buds arise. It will take three weeks after flowering to bear the fruits and take a 4 ½ month to fully mature the fruits. Mature fruits, which are orange yellow in colour, drop off from the tree. Harvest mature fruits manually before they fall. Harvesting time coincide with the monsoon. Green fruit become an orange yellow when fully matured. The fruits are harvested at ripening stage for getting good quality rind. Ripening takes five months from flowering. Immediately after harvest, wash the fruits in running water and separate the fruit rind for processing.

Harvesting of *Garcinia cambogia* depends on many factors such as the size of the fruit, colour, acidity (%) and storability. The record of harvesting date from previous years is a good index of the harvesting date of apples. The variation

of temperature within one month after full bloom was used to predict the harvesting date.

2.4 Chemical composition of *Garcinia cambogia*

Table 2.1Chemical composition of *Garcinia cambogia*

Moisture content of ripen 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	7.2 mg/100 gm

Sabinsa (2009) reported that fruit from *Garcinia cambogia* is included in the United States Department of Agriculture's inventory of perennial edible fruits of the tropics.

The aqueous extracts of the fruit showed two predominant acid spots on paper chomatograms run on different solvents, which were very near to tartaric and citric acids. Analysis of the fruit juice by use of an ion exchange column as described by Palmer (*1959)* showed the largest peak to be the citric acid region, but the acids failed the cream of tartar test for tartaric acid and the pentabromoacetone test for citric acid (Lewis and Neelakantan, 1965).

Peter (2004) mentioned in his studies the principal acid in the fruit rinds of *G.cambogia* and identified it as HCA on the basis of chemical and spectroscopic studies. It was thus clear that the two spots on the chomatograms are those of hydroxy acid and its lactone and not those of tartaric acid and citric acids.

2.5 Mechanism of action of *Garcinia cambogia*

Sulivan and Triscari (1977) reported that *Garcinia cambogia* is a revolutionary component in neutraceutical/dietary supplement, which is known as a weight reducing agent.

Garcinia cambogia has been the subject of extensive photochemical and physiological studies because of its derivatives used in human body metabolism. Hydroxycitric acid (HCA) is found to be the first natural weight loss compound without adversely affecting the central nervous system. This shows that Garcinia is not a stimulant, that it will not interfere with sleep and it will not cause changes in heart rate or blood pressure. Hence HCA is known as a safe fat fighting agent. HCA is available as herbal supplement and decreases adipose tissue weight after ingestion for few weeks (Chee *et al*., 1977; Greenwood *et al.*, 1981). The major part of research activities and publications concentrate on weight reduction and fat metabolism (Jena *et al*., 2002).

Kirtikar and Basu (1984) reported that *Garcinia cambogia* is a traditional home remedy useful for treating flatulence**,** heat strokes and infections.

Weight gain occurs when the limited capacity for storing glycogen in the liver and muscles is attained, and beyond this point excess glucose is converted into fat and stored in fat cells throughout the body (Clouatre and Rosenbaum, 2001).

HCA exerts its anti-obesity effect by inhibiting ATP: citrate lyase, consequently inhibiting the cleavage of citrate to oxaloacetate and acetyl-CoA, a key molecule, which plays a critical role in energy storage as fat. Now, instead of wasting energy to synthesize fat, the energy is diverted to the production of glycogen in the liver and muscles. This slows the production of fatty acids, cholesterol, and triglycerides with the net effect of reduced fat production and storage (Clouatre and Rosenbaum, 1994).

Hydroxycitric acid is present in the pericarp of the fruit of *Garcinia cambogia* up to 30% by weight. Commercially available *Garcinia cambogia*

extracts are prepared from the fruit rind and contain 50% hydroxycitric acid (Jena *et al*., 2002; Mattes and Bormann, 2000).

Hayamizu *et al*. (2003) suggested that *Garcinia cambogia* extract efficiently improved glucose metabolism and leptin like activity. Apart from this the anti-ulcer activity of *Garcinia cambogia* extract, its ability to decrease acidity and mucosal defense is well studied by Mahendran *et al*.2002. The same was repeated in gastrointestinal mucosa and increase in the mucosal defence in the gastric areas was obtained (Mahendran *et al*., 2002).

Chronic administration of HCA promotes lipid oxidation and spares carbohydrate utilization in mice at rest and during running (Ishihara *et al*., 2000).

Soni *et al*. (2004) studied about the Safety assessment of hydroxycitric acid and super citrimax, a novel calcium/potassium salt. Extensive experimental studies show that HCA inhibits fat synthesis and reduces food intake. Super citrimax, a novel calcium/potassium HCA extract, is considerably more soluble and bioavailable than calcium-based HCA ingredients.

Downs *et al*. (2005) suggested that *Garcinia cambogia* increases serotonin availability, reduces appetite, increase fat oxidation, improves blood lipid levels, reduces body weight, and modulates a number of obesity regulatory genes without affecting the mitochondrial and proteins required for normal biochemical and physiological functions.

2.6 Existing processing of *Garcinia cambogia*

On abscission, the fruits are collected, and then seeds and rinds are separated. A good percentage of fruits are wasted due to lack of proper processing and preservation technologies in the humid areas (Saju, 1998).

The rind is detached from the kernel of under-ripe fruits, 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. In Kerala mainly three types of drying

procedures are practiced (Joy and Jose, 1998). They are sun drying, smoke drying and alternately under sun and smoke:

• *Sun drying*: In this method under-ripe fruits are harvested and the rind is detached. After removing the succulent aril and seeds, the fruit is cut into two equal halves. The rind is spread on a specially prepared floor or mat. If there is sufficient sunlight it takes six to seven days for complete removal of moisture and the rind attains a coal black colour. In some places the rind is hanged in the midrib of coconut leaves, the ends of which are tied to poles or trees. As the rind hangs on the midrib all parts get uniform heat. Cambodge dried by this method is considered to be the best by the locals. This method is followed in Thodupuzha and Vazhakulam areas of Kerala.

• *Smoke drying*: Since the harvest coincides with the monsoon, enough sunlight is not available for drying. In these conditions, after removal of seeds, the rinds are smoked on lofts above the fireplace. The rind gets dried by the heat and smoke from the hearth. It takes one week or more for complete drying. When large quantities are to be dried, lofts are prepared in such a way that heat is distributed uniformly on the platform. Coconut husk, shell and other wooden logs are used for burning. Along with this, fresh eupatorium and loranthus are used and by the slow burning of these, the rind is dried. This practice is followed in Parur, Kodungallur, Thiruvalla and Vazhakulam areas of Kerala.

• *Sun and smoke*: When there is no rain the rinds are dried under the sun and during the night smoke drying is practiced. The dried rinds are preserved by rubbing with 50 ml of coconut oil and 150 g of common salt (sodium chloride) per kilogram of rind for storing for long periods. In some areas turmeric powder is also used (Joy and Jose, 1998).

Usually the ripe fruit is halved or sectioned and spread in thin layers dried in the sun for three to seven days to moisture level of about 15 to 20 % and smoked. Commercially available rind is loaded with considerable amount of common salt, which is added during drying. In Srilanka, the thick rind was cut into sections, dried in the sun and preserved for future use. The dried material along

with salt is used for curing (Chandraratna, 1947).

2.7 Different products from *Garcinia cambogia*

Majeed *et al*.(1998) in his study reported that the dried fruit rind of *Garcinia cambogia*, HCA was present at a level of 10-30% by weight and HCA can be isolated in the free form, as a mineral salt (i.e. potassium HCA, calcium HCA, Calcium/potassium-HCA, etc) or as the lactone by several different methods. The free acid is unstable and was converted to its more stable form and for consumer products the free acid was often stabilized by forming salts of HCA.

Ibnusaud *et al*. (2000) have reported the isolation of *Garcinia* acid from the fresh or dried rinds of the fruits of *G. cambogia*, *G. indica*, and *G. atroviridis*. It involves four to five extractions of *Garcinia* fruits with boiling water for 20 h. The combined extract was concentrated and treated with methanol to remove the pectin and filtered. The filtrate was treated with aqueous sodium hydroxide at 80 °C to obtain sodium hydroxycitrate.

Wenniger and Micheal (2001) invented an agent that suppresses appetite and provides quick energy. According to at least one aspect of the present invention, a lollipop is provided that suppresses appetite and provides quick energy. The herbal premixed formula includes the following active ingredients: Guarana PE 22%; citrimax.RTM and L-Tyrosine. The herbal premix formula can also include vitamin B6, and vitamin B12 Cyanacobalamin. The premixed formula is added to a candy base that may include corn syrup, Maltodextrin, sugar, natural colour and natural flavourings.

Dallas and James (2002) described a method for making the potassium and sodium salts of hydroxycitric acid and mixtures thereof workable, non-hygroscopic and non-reactive in acidic media by encasement in hydrophobic and acidophobic polymers. The resulting products are suitable for tableting, encapsulation and use in other dry media for weight loss, appetite suppression, improvements in fat metabolism and postprandial lipemia and other pharmaceutical purposes.

Another limited study reported that super citrimax, an extract of *Garcinia cambogia* with a content of calcium/potassium salt of 60% hydroxycitric acid, increased serum serotonin levels and HDL cholesterol and lowered serum leptin levels, LDL cholesterol, and triglycerides in human subjects in an 8-week clinical trial (Anonymous, 2002).

Benny (2003) studied the physical and chemical analysis of *Garcinia cambogia* and the isolation and comparative study of HCA. Physical and chemical properties of Calcium, potassium, and magnesium hydroxyl citrate of Garcinia were studied and found that calcium hydroxyl citrate is water insoluble and so used in dietary supplements like tablets, capsules etc. And the other water soluble hydroxyl citrates are useful for soft drinks and beverages.

Ganga *et al*. (2010) in his invention relates to new double salts of hydroxy citric acid with group II metals. Preferred double salts are calcium and magnesium and double salts of hydroxyl citric acid of the formula II. These double salts are tasteless and are soluble in water. They are useful as dietary supplements and in beverages.

2.8 Drying Studies

Drying of agricultural products is the most widely used method of preservation. It refers to the removal of water from products containing 70 to 95 % water that provides enough moisture to permit action by their own enzymes and those of micro organisms. The removal of water content below a certain level at which enzyme activity and growth of micro organisms is affected adversely ensures preservation for a long time. The desired products save energy, money and space in shipping, packaging, storing and transportation. It protects the products from attack of insects, moulds and other micro organisms during storage.

Drying is a process in which water is removed to halt or slow down the growth of spoilage microorganisms, as well as the occurrence of chemical reactions (Vega-Mercado *et al.*, 2001). Drying is usually defined as the removal of moisture until equilibrium with the environment, while the removal of moisture

to a very low moisture content, nearly bone-dry condition is called dehydration (Stuchly *et al.*, 1983). The drying process can be further divided into two periods, which are the constant drying rate period and the falling drying rate period.

.After the constant drying rate period, dry spots appear on the surface and the drying rate decreases. This is called the falling rate period, in which two processes involved: the movement or migration of moisture within the material (mass transfer) to the surface and the removal of moisture from the surface. When the surface is completely dry, the moisture is transported from the inner parts of the material to the external surface as the result of concentration gradients between the interior of the material and the surface (Mujumdar, 1995).

Drying is the unique method for producing powder forms of fruits and vegetables. The main benefits of powder forms, as compared with fresh fruits and vegetables, are the potential for long storage at ambient temperature, and a significant reduction in the costs for transportation and storage. This is particularly important for seasonal fresh fruits such as Garcinia fruit. Furthermore, the most important factor is that powder forms are very convenient food ingredients for use as flavours and colourings in food products, including juices and dairy products (Fellows, 2000; Tang and Yang, 2004).

Drying of food has been widely used for preservation of food in the last few years. There are as many reasons as there are materials that can be dried. Dried food, especially fruits and vegetables can be stored and transported at a relatively low cost. The handling of product marketing will be easier and faster. However, water removal during drying leads to a serious decrease in the nutritive and sensorial values of the product (Lenart, 1996). Several factors should be considered in order to apply drying for food preservation to achieve the best possible quality of the product.

Akanbi *et al.* (2005) studied on drying characteristics of tomato slices, including moisture content at different drying temperature. A research has to be undertaken in order to obtain the most optimum drying method and processes for

higher product quality of nutrient, enzymatic reaction and sensory acceptability retention.

Drying Technology has evolved from the simple use of solar energy to current Technology that includes, among others, kiln drying, tray drying, tunnel drying, spray drying, freeze dehydration, osmotic dehydration, extrusion, fluidization, and the use of microwaves, radio frequency and hurdle Technology.

At present, there are many drying techniques used for producing powder forms in the food industry; therefore, a suitable drying method for a particular food should be carefully selected. Many factors, such as the characteristics of the food material to be dried, the quality of the desired final product, and processing costs, i.e., energy and space requirements, must be considered (Tang and Yang, 2004; Sablani *et al.*, 2007).

In addition, it is necessary to understand the mechanisms, the drawbacks and the advantages of the different drying methods that can be applied to dehydrating a specific food product.

Thus, in a study of *Garcinia cambogia* fruit drying, it is necessary to investigate the effects of various drying methods on the final quality of *Garcinia cambogia* powder products in relation to retention of colour and nutrient composition. As a result of such investigations, depending on the desired final product quality and other considerations, a suitable drying technique can be chosen. Here we have selected three drying methods such as tray drying, vacuum tray drying and spray drying.

In this section, the processes and apparatus of several drying methods, specifically tray drying, vacuum drying and spray drying will be presented. Moreover, the fundamentals of drying procedures methodology are also reviewed.

Powder from semi fluid can be produced by many methods, such as tray, vacuum, freeze, drum, air and spray drying. The techniques to dry fruit juice are very specific for each drying method. Unfortunately, the sugar and acid content of fruit juice makes the drying process very complicated. The drying complication is

related to physico-chemical changes during drying of the juice. A drying aid is a necessary part of the fruit juice drying.

Al-Kahtani and Hassan (1990) found out from his study that the main difficulties in fruit juice spray drying were sticking of the powder in the drying and collecting zones, and scorching of the product.

(Bhandari *et al.,* 1997; Bhandari *et al.,* 1999; Adhikari *et al.,* 2003) stated that during the spray drying process, fruit juice may remain either as syrup or stick on the drying chamber wall. Also found out that fruit juice containing acids are more difficult to dry than the same materials with lower. Hence it is more difficult to dry orange juice or acid lactoserum than when those materials had lower acidity.

(Bhandari *et al.,* 1997; Boonyai *et al.,* 2004) found out from the study that the recovery of product from a spray drier is strongly affected by powder stickiness.

Laxminarayan *et al*. (1997) described the method of preparation of milk shake powder from cow milk blended with "musa cavendishii" variety of banana (5:1). Banana pieces were heated with water and carboxy methyl cellulose was added. The mix was spray dried and ground sugar was blended with dried mix to obtain final sugar content of 42.5 % in banana milk shake powder.

(Adhikari *et al.*, 2000; 2001; Bhandari *et al.,* 1993) reported that among food-stuffs, fruit juice is the most difficult substance to be spray dried so as to retain as many as possible of the natural properties and qualities in the final powder such as colour, flavour, taste and texture.

(Dolinsky *et al.,* 2000; Goula *et al*., 2004) in their studies reported that owing to the thermoplastic and hygroscopic nature characteristics of the fruit and vegetable powders special attention needs to be paid to the chamber design, the inlet and outlet temperature, total solid content of the fruit juice to be spray dried, a suitable drying aid, the handling of the dried particles and the packaging of the product after drying.

Adhikari *et al.* (2003) stated that the continuous airflow in a spray drier can prevent the collisions of the highly viscous particles in the drier chamber, but

they might contact each other at the bottom of the drier, or in the cyclones and collection ducts to form unwanted agglomerates.

The dissolved solid content of most natural fruit juices lies between 6 - 15% by weight (Azoubel *et al.*, 2005; Ramos and Ibarz; 1998; Gunko *et al.*, 2006; Vaillant *et al.*, 2001; Cassano *et al.*, 2003; Camerlingo *et al.*, 2007). The maturity of fruit affects the amount of total soluble solids in fruit juice differently.

To date, there have been a number of studies about the drying of fruit juices. Some researchers claimed that drying of fruit juice could produce the fruit powder that reconstituted rapidly to a fine product resembling the original juice (Gabas *et al.*, 2007)

Chegini and Ghobadian (2008) studied about the basic parameters of laboratory spray dryer for drying of orange juice with 65% concentration. The investigated parameters include: drying agent material, feed flow rate, inlet and outlet air temperature and sticky point temperature. Tests were performed without and with agent materials. With the addition of liquid glucose, the optimum conditions have been obtained with feed flow rate of 15 ml/min, inlet air temperature of 130°C and outlet air temperature of 85°C. For the orange powder containing 2% moisture, the sticky point temperature was 44°C.

Cheuyglintase (2009) developed a spray dried mango milk-shake powder. Concentrated skim milk (30% total solids), cream and sugar were well mixed and preheated to 50°C. The heated mix was filtered and homogenized at a temperature of 65-70°C followed by pasteurization at 65.5°C for 30 minutes and cooled to 10°C. The fruit pulp (20 per cent TSS) was mixed with cooled concentrated milk. The mix was filtered and spray dried at an inlet and outlet air temperature of 170-175°C and 98-160°C respectively to give a product with final moisture content of 2.5 per cent. He also found out that cooling of fruit juice powders after drying can help to prevent sticking or caking but juice powders with less than 2% moisture were non-caking.

Mahendran (2010) conducted a research study to determine the effect of different drying methods (using freeze drying, spray drying and tunnel drying) and the addition of drying aids on the physico-chemical properties and sensory characteristics of dehydrated guava concentrate. Guava juice at 10.5°Brix was used to prepare the fruit powders. A significant reduction (p<0.05) in titratable acidity of 0.22% as citric acid and an increase in pH of 0.44 after drying of guava juice indicated that some acids were lost during the drying process. Spray dried powders were obtained from the guava juice with different maltodextrin concentrations as drying aids. When 30% maltodextrin was added to guava juice, the solubility of powder was 95% whereas; adding 60% maltodextrin decreased the solubility to 86%. The freeze dried product had superior nutritional and sensory qualities, however spray dried product was stable and more economical to produce free-flowing guava powder with good stability.

Weerachet *et al*. (2011) produced tamarind powder by drum dryer using maltodextrin and Arabic gum as adjuncts. Two popular drying aids namely maltodextrin and Arabic gum were applied at the ratios of juice (20°Brix) and drying aids of 1:0.4, 1:0.8 and 1:1.4. A double drum dryer was employed in this work at the drying temperatures of 120 and 140°C, drum speed of 0.35 rpm, and the gap between drums of 0.4 mm. The results indicated that in order to obtain the tamarind powders, the ratio of tamarind juice and maltodextrin should be 1:0.8 if drying at 140°C or 1:1.4 if drying at 120-140°C. In case of using Arabic gum as a drying carrier the proportion should be 1:0.4 or 1:0.8 for drying temperatures between 120 and 140°C. Sensory evaluation indicated that the tamarind powders with maltodextrin were preferred in facet of appearance, colour, and overall liking, while those with arabic gums were favored in their aroma and taste.

2.9 Additives in drying

Other than the operational techniques, such as cooling the drier wall and blowing with cold air, an additive or drying aid can be used to reduce stickiness during fruit juice spray drying (Carol *et al*., 1967; Kudra, 2003; Gupta, 1978; Breene and Coulter, 2010). A drying aid is added for many purposes such as

improving the drying rate, stickiness prevention, reducing hygroscopicity, maintaining flow ability of the dry powder and maintaining quality of the powder in storage (Cheuyglintase and Morison (2009); Cheuyglintase (2009);Langrish *et al.*, 2007). The additives protect core material from factors that may cause its deterioration, prevent a premature interaction between the core material and other ingredients, limit volatile losses, and also allow controlled or sustained release under desired conditions (Shahidi and Han, 1993). They need to meet some of the required criteria such as mechanical strength, compatibility with the food product, thermal or dissolution release, particle size (Brazel, 1999). There are many materials used as carriers.

Currently maltodextrin is the most widely used additive to obtain fruit juice powders, since it satisfies the demands and is reasonably cheap (Bhandari *et al.*, 1993). Stickiness is a major reason which has limited the use of spray drying for sugar-rich and acid rich foods. On the other hand, the stickiness was not encountered when less hydrolyzed starch derivatives such as maltodextrin were spray dried; instead, they facilitated the spray drying process of the sugar-rich foods. Hence, they are frequently used as drying aids.

Maltodextrins are digestible carbohydrates made from several different cereal sources, including corn, potato, rice and tapioca. The processes to produce maltodextrins involve cooking of starch followed by acid and/or enzymatic hydrolysis to break the starch into smaller chains. These chains are composed of several oligosaccharides molecules along with polysaccharides of larger molecular weight (Avaltroni *et al.*, 2004).

Maltodextrins consist of b-D-glucose units linked mainly by glycosidic bonds (1- 4) and are usually classified according to their dextrose equivalency (DE). The DE of a maltodextrin determines its reducing capacity and is inversely related to its average molecular weight (Be Miller and Whistler, 1996).

Bhandari *et al*. (1993) tested two spray dryers to obtain powders from concentrated juices of black currant, apricot, raspberry, with different maltodextrins as drying-aid agents. Composition of fruit juices and dextrose

equivalent for maltodextrin are considered. Best results were obtained for a ratio juice to maltodextrin DE6 of 65/35 for blackcurrant, of 60/40 for apricot and 55/45 for raspberry, and low air temperatures (160 – 190°C). A compromise must be found between the ratio fruit juice to additives, the drying yield and the cost of raw materials.

Bhandari *et al.* (1997) reported that a 1:1 ratio was good for spray drying of honey + maltodextrin and pineapple + maltodextrin.

Dolinsky *et al.* (2000) suggested that 30-55% maltodextrin should be added to the fruit and vegetable juice in order to obtain the powder.

Wang and Wang (2000) stated that maltodextrins exhibited higher viscosities than syrups and were thus preferred to be used with respect to cohesive and foam stabilizing properties for specific applications.

Kudra, 2003 stated that stickiness is a problem of the dried juices. Even with little remaining moisture in the powder at high temperatures (greater than 70ºC), the product will be in a glassy syrupy state and will stick to machinery, vastly complicating materials handling. Maltodextrins or other low dextrose equivalent (DE) corn syrups can reduce the stickiness of the powder, but then the reconstituted juice is not pure.

Adhikari *et al.* (2003) reported that the addition of maltodextrins significantly reduced the stickiness of fructose solutions, showing its use as an effective drying aid.

Maltodextrins or other low dextrose equivalent (DE) corn syrups can reduce the stickiness of the powder, but then the reconstituted juice is not pure (Bates *et al.*, 2001; Kudra, 2003).

Walstra (2003) reported that in various confection industries, glucose syrup which is physically similar to maltodextrin was widely used to prevent crystallization of sugars.

Adhikari *et al.* (2004) predicted surface stickiness of mixture of sucrose + glucose + fructose drops during spray drying at 63 °C and 95 °C and found that

the 50% maltodextrin in the solid failed to overcome the stickiness. It was also found that lower outlet temperatures in spray drying reduced the stickiness of sugar rich foods. The interaction of maltodextrin mixtures in the drying process might affect the dried product properties. They also studied the effect of addition of maltodextrin on drying kinetics of drops containing fructose, glucose, sucrose and citric acid individually and in mixtures experimentally using single drop drying experiments and numerically by solving appropriate mass and heat transfer equations. The numerical predictions agreed with the experimental moisture and temperature histories within 5-6% average relative (absolute) errors and average differences of 1°C, respectively.

(Rodriguez *et al.*, 2005 used maltodextrins (10 and 20 DE) at concentrations of 180 to 230 g/l were used in spray drying of cactus pear juice.

Goula and Adamopoulos (2005) stated that as far as the addition of maltodextrin is concerned, the hygroscopicity and the degree of caking of mango powder were found to decrease with an increase in the amount of used maltodextrin.

At low moisture levels the products are very hygroscopic, readily picking up moisture from the air to become sticky and difficult to handle (Kudra, 2003).

Truong (2005) found out a good spray dried powder from 45% maltodextrin (solid content) in tamarind juice.

Maltodextrins at different dextrose equivalence values (DE) are the most common carriers in spray drying of fruit juice. They are mainly used in materials that are difficult to dry such as fruit juices, flavourings, and sweeteners, are sticky and also to reduce agglomeration problems during storage, thereby improving product stability (Gupta, 1978; Bhandari *et al.*, 1997; Rodriguez *et al.*, 2005; Langrish *et al.*, 2007).

According to Cano-Chauca *et al*. (2005) and Langrish *et al*. (2007), MD is the most popular in spray drying due to its physical properties such as high water solubility.

Even though very high amounts of maltodextrins were needed in spray drying of most fruit and vegetable juice, Quek *et al.* (2007) produced a good watermelon spray dried powder with 3-5% maltodextrin (DE 8-12).

Shrestha *et al.* (2007) found that adding more than 10% maltodextrin into watermelon juice produce powders with less of their attractive red-orange colour and decreased the lightness, redness and yellowness parameters of orange juice powder. He also found that under certain spray drying conditions 60% maltodextrin was the maximum amount to get a good yield from orange juice. It was found that increasing maltodextrin from 50 to 60% resulted in a significant increase in orange juice yield up to 78%. Further increases in maltodextrin in the juice were found to slightly increase the yield.

Athanasia *et al*. (2008) in his work investigated the effect of maltodextrin addition on the main powder properties during spray drying of tomato pulp in dehumidified air. 21 DE, 12 DE, and 6 DE maltodextrins were used as drying agents. Tomato pulp was spray dried at inlet air temperatures of 130, 140, and 150°C and (tomato pulp solids)/ (maltodextrin solids) ratios of 4.00, 1.00, and 0.25. It was found that maltodextrin addition improved powder hygroscopicity, caking, and solubility, whereas it deteriorated slightly its moisture content and density.

Cheuyglintase (2009) studied about the degrees of polymerization of the maltodextrins and the interaction between inlet air temperature and atomizing air pressure had a great effect on the moisture content of powder and on the retention of vitamin C in the reconstituted product. The maltodextrin concentration affected the colour of the final products but there was no significant effect of the type of maltodextrin on the hygroscopicity of the powder of cactus pear juice.

Jaya and Das (2009) studied about the glass transition and sticky point temperature and stability/mobility diagram of fruit powders. The principal components present in the fruits are low molecular weight sugars and organic acids. They have low glass transition (Tg) and are very hygroscopic in their amorphous state, so the dry product become sticky. Water acts as a plasticizer and

decreases the glass transition temperature of the product with the increase in moisture content and water activity. To overcome this problem, ingredients having high Tg value, such as maltodextrin, and food grade anti-caking agents were added to prepare vacuum dried food powders.

The particles stick to one another, to the dryer and to cyclone walls and remain there forming thick walls and remain there, forming thick wall deposits, while very little product comes out at the dryer's exit. This might leads to low product yields and operating problems. The presence of organic acids (citric, malic, etc.) increases the problem (Bhandari *et al*., 1997).

Osman and Endut (2009) study was conducted a study using Lab plant SD-06 mini-spray dryer of laboratorial scale to produce spray-dried roselle-pineapple powder. Three different maltodextrin DE 10 concentrations (3%, 5% and 10%) were added (w/w) as the encapsulating agent prior to spray drying. Inlet temperatures were varied at 140°C, 160°C, 180°C and 200°C respectively and the outlet temperature was fixed at 80°C. At 180°C, juice with 10% of maltodextrin produced the finest powder. When inlet temperature and the percentage of maltodextrin increased, the moisture content and water activity decreased; its hygroscopicity and dissolution time increased.

Ruiz *et al*. (2009) studied about the spray drying of passion fruit juice using lactose-maltodextrin blends as the support material. The objective of this study was to assess the effectiveness of the blends with different levels of maltodextrin (8:5, 10:5, 12.5% w/v) during the spray drying of the passion fruit. The drying was carried out in a laboratory spray dryer at two inlet air temperature (180 and 190°C), the moisture content, hygroscopisity and vitamin C retention were evaluated in the powder obtained. Response surface plots ($p<0.05$) showed that the lowest values of the moisture content and hygroscopicity were reached in the temperature range of 188-190 °C and at 12.5% (w/v) concentration of lactose-maltodextrin; the best vitamin C retention level occurred at 180°C .

Weerachet *et al*.2010 in his studies fresh pineapple juices were added with maltodextrin at 15, 20 and 25% before exposing to the drying temperatures at

130, 150 and 170°C with the feed rate 0.020, 0.022 and 0.035 litre per minute respectively. The results indicated that the pineapple juice should be added with maltodextrin at 15% and dried at 150°C. Furthermore, the moisture content and solubility of the pineapple powder produced under this condition were 5.1% and 6.2 minutes respectively while its solution had the lightness 58.8, redness 5.2, yellowness 25.1 and pH 3.5.

Mahendran (2010) prepared guava juice powder using maltodextrin as an additive by using freeze drying, spray drying and tunnel drying. He increased the concentration of maltodextrin from 30, 40, 50 and 60% and found that increasing the maltodextrin concentration during spray drying resulted in de-crease in moisture content of dried guava powder, probably due to an increase in solids in the feed and reduced amount of free water. When 30% maltodextrin was added to guava juice, the solubility of powder was 95%. Whereas, adding 60% maltodextrin decreased the solubility to 86%.

Hassan and Mehmet (2011) used the response surface, 3-level factorial design to evaluate the influence of spray-drying conditions on the physicochemical properties of a powdered product obtained by drying pomegranate juice concentrate. He found that adding maltodextrin significantly reduced the hygroscopicity and stickiness of the pomegranate juice powder, and thus yielded higher recovery. The results indicated that increasing inlet air temperature increases solubility time and loss of anthocyanins and decreases bulk density and moisture content of the powder.

Randy (2011) studied about instant pineapple drink powder and found that maltodextrin could also give protection of the enzyme but excessive maltodextrin addition can hinder the enzyme activity. He also found that spray drying process with the addition of maltodextrin 15% (w/w) was preferred for the production of pineapple instant drink powder.

Carolena *et al*. (2012) studied about the influence of carrier agents on the physiochemical properties of blackberry powder produced by spray drying. The use of maltodextrin resulted in less hygroscopic powders with lower moisture content and better reconstitution properties. He found out that particles produced with gum Arabic were smaller and showed more dented surfaces, which probably contributed to the increase in wettability values and lower pigment retention.

Fazaeli *et al*. (2012) studied about the effect of processing conditions and carrier concentration for improving drying yield and other quality attributes of spray dried mulberry (Morus nigra) juice. Independent variables were: inlet air temperature (110, 130 and 150°C), compressed air flow rate (400, 600 and 800 l/h), and maltodextrin concentration (8%, 12% and 16%). The optimal conditions for drying yield and total anthocyanin content correspond to: temperature =130°C, maltodextrin concentration 8%, and compressed air flow rate=800 l/h.

2.10 Tray drying

Tray drying is the simplest form of air drying equipment. The dryer comprises of perforated or shallow mesh trays fitted in an insulated cabinet. The material, from slurries to piece-form solids, is placed onto the trays. Air can be directly heated by a gas burner or an electric heater and is then circulated between the trays (cross-flow). Less commonly, the heated air can be direct to flow though the material on perforated trays (though-flow).

Tray drying is one of the least expensive methods of drying food materials. However, no literature is available on tray drying of *Garcinia cambogia* juice using any modified food starch or maltodextrin products.

Li and Morey (1984) studied thin-layer drying of yellow dent corn and found that it is affected by drying air temperatures, air flow rate, initial moisture content and relative humidity. He also found that drying air temperatures and initial moisture content affect drying rates, but air flow and relative humidity have negligible effects.

Mustafa *et al*. (1995) studied about the drying of apple slices in a conventional tray drier (initial slice thickness of 0.3–1.0 cm, drier temperature of 60–100 °C) and the Colour change and weight loss of apple slices during the drying.

The main advantage of the tray dryer is its flexibility in operation for use with different types of foods, and that it has low capital and maintenance costs. However, the quality of the final dried products is variable and usually low as compared to material produced by other drying methods such as vacuum drying and spray drying. The tray dryer is commonly used for small scale production and in pilot plants for experimentation (Fellows, 2000; Doymaz, 2007; Doymaz, 2008).

Jin *et al*. (2003) determined the drying curves of the pear Bartlett (*Pyrus* sp.) at temperatures of 50, 60 and 70°C and air velocities of 0.5, 1.0 and 1.5 m/s, resulting in nine drying curves in a convective vertical tray dryer.

Nindo *et al*. (2003) evaluated the drying parameters for retention of physical quality andantioxid ants in asparagus. The objective of this research is to evaluate drying methods that have the potential of adding value to green asparagus especially for use as ingredient in instant foods or as a nutraceutical product. Five drying methods were used: namely, tray drying (TD), spouted bed (SB) drying, combined microwave and spouted bed drying (MWSB), Refractance Window (RW) drying and freeze drying. Tray drying (TD) is commonly used for drying of vegetables, and it was chosen because of its simplicity and low cost. TD at air temperatures of 50°C , 60°C, and70°C temperature were selected for the study.

Ibrahim and Mehmet (2003) investigated the effect of ethyl oleate on the drying rates for corn in a pilot plant air-dryer. The Hunter colour scale parameters (lightness, redness and yellowness) were measured to quantify the colour changes. The shorter drying times and best quality dried product were obtained with corn kernels dipped in the solution of ethyl oleate. Aspragus tips that were tray dried at 60°C had the largest deviation (DE value of 26) from that of the fresh material.

Sablani *et al.* (2003) conducted a study on the effect of convective drying on apparent density, porosity and moisture diffusivity of potato and apple. During air drying apparent density of apple and potato varied from 676.2 to 839.6 kg/m³ and 1214 to 1050 kg/m³ respectively. In both cases porosity increased with decrease in moisture content. Drying temperature in the range of 60 to 80ºC did not have any effect on the degree of pore formation.

Abraham *et al*. (2004) obtained jackfruit drying curves using a convective tray drier at three different drying temperatures. The drying curve enables to predict the moment at which the process should be stopped when the required moisture content has been reached and thus obtaining a good quality product.

Joe *et al*. (2004) conducted a study to test the application of the glass transition approach to describe kinetics of ascorbic acid degradation during drying of a natural product, which is subjected to a high degree of heterogeneity due to environmental conditions, place of growth or degree of maturity. Whole persimmons were dried in an automatically controlled tray dryer with product temperatures and air velocities varying according a second order central composite design. Temperature ranged from 40 to 55°C and velocities from 0.8 and 2.0 m/s.

Marilia *et al*. (2004) studied the coffee berry drying by using a vibrated tray operating significant parameters. Variables studied were: the mass of coffee fruits (11.5, 12.5, and 13.5 kg) the air mass flow rate (7, 8, and 9 kg air/min) and temperature of coffee fruits (40, 45, and 50ºC). The only variable responsible for a significant effect in the drying time was the coffee temperature, which decreased 25.94 h on average. The size of coffee fruit is the most relevant difference in the drying, since moisture diffusion dominates the process of coffee drying. For a lower consumption of energy the dryer can be operated at 7 kg/min air mass flow rate and coffee fruits mass of 13.5 kg.

Nurul *et al*. (2005) studied the effect of various drying parameters *i.e.* temperature, air velocity and geometry cut on the quality of papaya based on moisture content. Slices (0.5 x 1.5 x 1.5 cm) and cubes (1.0 cm) of papaya were

treated in tray drier at different levels of temperature (40, 50 and 60ºC) and air velocity (0.5, 1.0 and 1.5 m/s). Temperature was found to be significantly influencing the drying performance for both slices and cubes**.**

Behera *et al*. (2006) conducted study on the effect of drying conditions on the quality of dehydrated selected leafy vegetables such as amaranth, curry leaves, drumsticks and spinach in cabinet dryer, solar dryer and low temperature dryer to evaluate the best drying condition for maximum retention of nutrients. Cabinet dryer was good for dehydration of leafy vegetables in respect of higher β-carotene, ascorbic acid, chlorophyll content, better rehydration ratio and less time required for drying with low non-enzymatic browning and less moisture in the product dried in bulk at a time compared to other dryers.

Nachiket *et al*.(2007) monitored the textural (hardness, cohesiveness, springiness, and chewiness) and optical (spectral surface reflectance) properties of paddy straw mushroom (Pleuratus spp.) during hot air drying of mushrooms in a cabinet tray drier at different air temperatures 50, 55, 60, and 70ºC. During drying, hardness and chewiness of mushrooms were increased, while cohesiveness and springiness increased initially and decreased at the final stage of drying. Hardness of mushroom dried at higher temperature was higher. Cohesiveness decreased with increased drying temperature. Whiteness index of mushrooms decreased while yellowness index increased during drying. Drying temperature had an inverse effect on whiteness of mushrooms.

Rittirut and Siripatana (2006) studied the drying characteristics of *Garcinia atroviridis* using a tray dryer. In this study the most suitable drying condition for Garcinia material in a tray dryer based on the final moisture content were determined by extensive testing. It was found that for the material thickness of 2, 4 and 6 mm, a temperature of 55 ºC and air velocity of 1.2 m/s are suitable for drying. The most suitable time where the final moisture content met the commercial standard was found to be 199, 256 and 427 min, respectively. The higher the temperature, the drying time will be shorter. It was observed that the suitable drying time for 2-mm thick material and air velocity of 1.2 m/s was 199,

159 and 99 min for drying temperature of 55, 65 and 75, respectively. Drying characteristics are also reported.

Pamidighantam *et al*. (2007) dried the Garlic cloves in the form of bits in a cabinet tray dryer and a microwave dryer, and pulverized to obtain free flowing powder. The studies were mainly restricted to comparing the effect of drying methods on the volatile oil composition of the powders. Although the drying time was reduced considerably from 8 h in a cabinet dryer to 0.25 h in a microwave dryer, essential oil yield and colour values were lower, and flavour quality varied considerably. The relative concentrations of major peaks such as diallyl disulfide, diallyl tetrasulfide increased in both the drying methods, and it was more so in microwave-dried samples. Hunter values of *L* and *b* were lower for samples obtained by microwave drying as compared to those of cabinet-dried samples.

Kavak and Bicer (2008) conducted an experimental study to determine the thin layer drying characteristics in a solar dryer with forced convection and under open sun with natural convection of long green pepper. An indirect forced convection solar dryer consisting of a solar air collector and drying cabinet was used in the experiments. Natural sun drying experiments were conducted for comparison at the same time. The constant rate periodwas absent from the drying curves. The drying process took place in the falling rate period.

For the hot air drying, temperatures at 60 and 70ºC were generally used for drying of herbs (Therdthai and Zhou, 2009).

Neha *et al*. (2008) carried out a study to evaluate the dehydration characteristics of garlic treated by using different methods. The effect of pretreatments viz. control (without any treatment), sample blanched in hot water at a temperature of 80-85ºC for a duration of 5 min. and sample treated with 0.5% sodium metabisul/hite for a duration of 20 minutes and dehydration methods viz. open sun drying, solar cabinet drying, electric tray drying, microwave oven drying were studied. The results of the study showed that the product quality of blanched sample for 55ºC and sodium metabi-sul/hite treated sample for 65ºC in electric tray dryer were best, as compared to rest of the samples.

Agnieszka and Krzyszt (2010) investigated the drying behaviour of apple particles in a laboratory type dryer. The effect of drying air temperature on the dehydration characteristics of apples was investigated. Increase in drying air temperature caused a decrease in the drying time and an increase in drying rate.

Jayashree *et al.* (2010) conducted a study about thin layer drying kinetics of mace (*Myristica fragrans)* using reverse air flow drier. In this study Fresh mace of 'Viswasree' variety was dried at 50, 55 and 60ºC in a reverse air flow, natural convection mechanical drier. The mace took 330, 240 and 210 min and to dry from moisture content of 186.5 to 5.2% (db) at air temperatures of 50, 55 and 60ºC respectively. she alsodeveloped a thin layer modeling for drying of black pepper in agricultural waste fired reverse flow drier named RRLT-NC drier model no. 201. In this study fresh and blanched black pepper (*Piper nigrum*) of Sreekara 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. Diffusion approximation model was found most suitable to describe the drying process of black pepper.

Juliana *et al*. (2011) studied about the fluidized bed and tray drying of thinly sliced mango (*Mangifera indica*) pretreated with ascorbic and citric acid. The purpose of this work was to determine the influence of air temperature, sample diameter and antioxidants on water activity, moisture content and colour difference of thinly sliced mango in a fluidized bed and tray dryer. Mango samples were treated with antioxidants solutions (ascorbic and citric acid) before the drying process. Fluidized bed and tray drying of control and treated samples were carried out at two temperatures: 50 and 60ºC. The temperature increment increases the drying constant and decreases the equilibrium moisture content and water activity of the dehydrated samples. Colour closest to the original colour of fresh mango was obtained when 2 cm diameter mango pretreated with citric acid (1%) was dehydrated by fluidized bed at 60ºC. In addition, it was observed that

the drying time at equilibrium by using fluidized bed was lower (60 min) than the tray dryer (120 min).

Ho Minh Thao and Athapol Noomhorm (2011) studied the drying behavior of sweet potato starches under tray drying at 45, 55 and 65°C. The results indicated that to reach final moisture content of 10% at 45, 55 and 65°C, the drying time for tray drying was 15, 8.5 and 5.5. The drying conditions only slightly affect the colour, gel texture, swelling power, solubility and pasting properties of starches.

Weerachet *et al*. (2011) studied the kinetics and temperature dependent moisture diffusivities of pumpkin Seeds during tray and fluidized bed drying. Pumpkin seeds were soaked in 25% w/w NaCl solution for 1 h before hot-air drying with a tray dryer or a fluidized bed dryer at drying temperatures of 60, 70 and 80°C. It was found that among the various model, both the Page model and two-compartment model were the best-fit models for the three drying conditions.

2.11 Vacuum tray drying:

Vacuum tray drying provides an alternative to conventional atmospheric drying. Using this method, it is possible to reduce the boiling point of water by decreasing the external pressure and, consequently, to obtain results similar to high temperature but with relatively moderate drying conditions (Tsotsas and Mujumdar 2007). It allows for the removal of moisture under low pressure. Vacuum expands air and water vapor present in the food and creates a frothy or puffed structure, providing a large area-to-volume ratio for enhanced heat and mass transfer (Jaya and Das 2003).

Most vacuum applications use levels of absolute pressure of 50 mm Hg (7 kPa), which lowers the boiling point of water to 39 °C (Barbosa-Canovas and Vega-Mercado 1996). Consequently, with vacuum drying, it is possible to have a higher drying rate, lower drying temperature and an oxygen-deficient processing environment (Wu *et al*. 2007). This method is useful for products that would be damaged by high temperature levels (Tsotsas and Mujumdar 2007) and is also

suitable when solvent recovery is required or if there are risks of fire and/or explosion (Devahastin 2000). In addition to this, high-value food products and easily oxidized products could be dried by vacuum drying (Baker and Masters 1997; Saravacos *et al*., 2002).

Vacuum dryers can be used for any type of feed such as moist solids, thin pastes, slurries, solutions, sludge-like materials and shaped pieces and diverse range of food products such as chocolate crumb, meat and vegetable extracts and fruit juices.

However, drying under vacuum is more expensive because of the necessity of constructing the dryer to pressure vessel standards and the need for additional equipment such as air locks, vacuum pumps and condensers (Baker and Masters, 1997; Devahastin 2000).

The quality of vacuum dried fruits and vegetables is usually better than that of air-dried products and nutrition and aroma are close to that of raw material (Brennan 2007; Wang *et al.* 2007).

More flavour retention has been reported in vacuum drying than air drying due to less loss of volatiles responsible for flavours. The loss of vitamin C is primarily due to oxidation which would be expected to be minimal in vacuum drying because the operation requires low temperature (Hui and Lee. 2008). In carrot drying, vacuum drying led to less degradation of β-carotene in the case of hot-air drying (Suvarnakuta *et al.* 2005). Porosity of dried products increases as vacuum pressure decreases, which means that shinkage, can be prevented by controlling pressure, hence, obtaining high porosity value in the final dried product (Hui and Lee, 2008).

The improvement of quality, functional properties and nutritive value of these products justifies the added cost, compared with the conventional (convective) drying methods (Hui *et a*l., 2008; Saravacos *et al*., 2002). Vacuum drying applications could be applied in batch or continuous operations and different-sized dryers are in operation (Barbosa-Canovas and Vega-Mercado 1996).

Vacuum tray drying is one of the least expensive methods of drying food materials. Vacuum drying provides an alternative to conventional atmospheric drying. It allows for the removal of moisture under low pressure (Jaya and Das, 2003).

Vacuum drying is performed in the absence of oxygen, so this method of drying protects sensitive components of foods from oxidation. As such, it is evident that the vacuum drying has an advantage over hot air drying. Furthermore, since some materials are sensitive to heat damage, vacuum drying is the better choice compared to hot air drying; this is because the vacuum can reduce the necessary drying temperature (Fellows, 2000; Tang and Yang, 2004).

The vacuum drying process can be used for some fruit, vegetables, herbs, spices and fruit juice concentrates. Generally, vacuum drying has similarities to freeze drying; however, the material is not frozen and the vacuum pressure is not high (Ramaswamy and Marcotte, 2006; Drouzas *et al*., 2005).

However, no literature is available on vacuum tray drying Garcinia juice using any maltodextrin as drying agent.

Suresh Kumar *et al*. (2005) conducted a study to find out the optimum tray load and drier type for the drying of osmosed mango, guava slices and aonla segments. The osmosed slices were dehydrated in a cabinet drier, low temperature drier and vacuum drier with the tray loads of 0.30, 0.35, 0.40 and 0.45 g/cm ^{2}. On the basis of correlation and regression analyses performed by using dehydration time (h), drier and tray load as independent variables and moisture content as dependent variables, vacuum drier was found to be the better in faster drying followed by cabinet drier.

Jena and Das (2007) studied about the Modelling for vacuum drying characteristics of coconut press cake. In the present work, coconut press cake was dried in a laboratory scale vacuum dryer to moisture content less than 0.02 kg water kg dry solid^{-1}. Drying characteristics of the presscake was investigated under varying conditions of press cake thickness (2, 3 and 4 mm) and vacuum

chamber plate temperature (65, 70 and 75°C) at 65 mm Hg absolute pressure. The relative deviation per cent between the actual and predicted moisture ratios at different drying time for this model was in the range of 3–15%.

Yu and Shi-ying (2007) prepared Garlic Powder with High Allicin Content by vacuum drier.

Jun Ho Lee and Hui Jeong Kim (2009) in this study, radish slices were dried as single layers with thickness of 4 and 6 mm in the ranges of 40–60 °C of drying air temperature in a laboratory scale vacuum dryer. The effect of drying air temperature and slice thickness on the drying characteristics was determined.

Vacuum drying assumes low processing temperatures and faster water evaporation, offering shorter drying times and higher quality of dried product compared with drying method without vacuum (Giri and Prasad (2007); Sunjka *et al*., 2008).

Ali *et al*. (2011) evaluated the energy consumption required in different drying methods. This study was conducted to evaluate energy consumption in various drying systems including hot-air convection, use of microwave pretreatment with convection dryer, microwave drying, vacuum drying and infrared drying. Tests were conducted using pomegranate arils under various experimental conditions as follows. In convection dryer six temperature levels (45, 50, 55, 60, 65 and 70 °C) were used. Experiments in the microwave dryer were done at three power levels of 100, 200 and 300 W and in vacuum dryer at five temperature levels (50, 60, 70, 80, and 90°C) under 250 KPa pressure. Experimental results showed that minimum and maximum energy consumption in pomegranate drying were associated with microwave and vacuum dryers, respectively. The use of microwave pretreatment in drying pomegranate arils in hot air dryer decreased drying time and energy consumption in comparison with pure convection drying. In infrared drying, it was found that drying time increased with air velocity which resulted in increased energy consumption.

Dimitrios *et al*. (2011) proposed the combined drying of hot air and microwave-vacuum as an alternative method to improve the quality of dried mushooms, especially the structural and textural properties. In the present study, the effect of different drying methods namely, convective hot-air drying, hot air combined with microwave-vacuum drying and freeze-drying on qualitative attributes of pretreated mushooms was investigated. Combined drying of hot air and microwave-vacuum resulted in a dried product of superior quality when compared to the slices dried completely by conventional hot air, exhibiting lower overall colour variation, higher porosity, greater rehydration ratio and softer texture.

Nantawan and Hasaya (2011) studied about hot air drying and microwave vacuum drying of Fingerroot (Bosenbergia pandurata). Based on Lewis model, drying rate constants were 0.0002, 0.0004, 0.0061 and 0.0072 s) 1 for the hot air drying at 60 and 70°C and the microwave vacuum drying at 2880 and 360Watt respectively. Compared with the hot air drying, the microwave vacuum drying decreased drying time by 90%. Rehydration ability of the microwave vacuum dried samples was also significantly improved, because of porous structure. In addition, the rehydrating water of the microwave vacuum dried samples contained higher b*-value (yellowness) than that of the hot-air-dried samples.

Serap and Can (2011) Studied about the Vacuum Drying Kinetics of Barbunya Bean. In this study vacuum drying characteristics of *barbunya* bean (*P. vulgaris* L. *elipticus* Mart) were investigated in a laboratory scale vacuum dryer for a temperature range of 50–80°C at constant vacuum pressure of 50 KPa.

2. 12 Spray drying

Drying of fruit juices is a difficult operation, mainly because of the undesirable changes in the quality of the dried product. The high temperatures and long drying times required to remove the water from the sugar containing fruit material in conventional air-drying may cause serious damage to the flavour, colour, and nutrients of the product. Spray drying reduces these undesirable changes (Saravacos *et a*l.2002).

Spray drying can be used to preserve food or simply as a quick drying method. The range of product applications continues to expand, so that today spray drying has connections with many things we use daily (Nath and Sathpathy (1998).

Spray drying belongs to the family of suspended particles systems as drying is accomplished while the particles are suspended in air. Spray drying is by definition the transformation of a feed from a fluid state into dry particulate form by spraying the feed into a hot drying medium (Barbosa-Canovas *et al.*, 2005; Masters, 1991). It is a one-step, continuous particle processing involving drying. The drying of liquid food is often accomplished in a spray dryer. Moisture removal from a liquid food occurs after the liquid is atomized or sprayed into heated air within a drying chamber various configuration of the chamber are used.

In the spray drying process, due to the large surface area of the small droplets, drying takes place rapidly (1-10 seconds). As a result, it is highly recommended for heat sensitive foods (Fellows, 2000; Tang and Yang, 2004; Ramaswamy and Marcotte, 2006). Furthermore, several other advantages of spray drying can be found in that the drying process is continuous, easy and entirely automatically controlled. Importantly, the quality of final powders will not be variable from one batch to another when spray drying conditions remain unchanged (Masters, 1991). However, installation costs, thermal efficiency, waste heat and exhaust-air handling are the key drawbacks of the spray drying process (Barbosa-Cánovas and Vega-Mercado, 1996).

Among various methods of preparing dehydrated products, spray drying is the most important one. Spraying is the method of choice due to its continuous design and flexibility. Spray drying delivers a powder of specific particle size and moisture content in relation to the drier capacity or product's heat sensitivity. In a continuous operation it delivers a highly controlled powder quality with relatively easy manipulation. Accordingly the objective of spray drying is to produce a spray of high surface to mass ratio droplets (ideally of equal size) and then to uniformly and quickly evaporate the water. Evaporation keeps the products

temperature to a minimum, which in turn reduces the chance of high temperature deterioration of the products. Further, spray drying minimises loss of volatile flavours as against other dehydration techniques. Spray drying consists of four process stages

1. Atomization of feed into a spray
2. Spray-air contact (mixing and flow)
3. Drying of spray (moisture/volatiles evaporation)
4. Separation of dried product from the air

Spray drying is used to produce a wide range of products including heat sensitive materials (Mahendran, 2010).

The flexibility of drier designs provides opportunities to produce the powders that consistently meet industrial specifications (Huntington, 2004; Sharma *et al.*, 2000). The production capacity can be expanded to over 25 tonnes of product per hour (Masters, 2004). The process is continuous and easily automated which can reduce labour costs (William, 1971; Sharma *et al.*, 2000). There are less sticking and corrosion problems in spray drying if the material does notcome in contact with the equipment walls until it is dry (Gupta, 1978).

Masters (2004) in his study reported that the products produced by spray drying include: pharmaceutical, such as antibiotics, analgesics, vaccines, vitamins and catalysts; chemicals, such as, carbides, ferrite, nitrides, tannins, fine organic/inorganic chemicals detergent and dyestuffs; ceramic, including advanced ceramic formulations; and foods such as, milk and milk products, food colour, food supplement, soup mixes, spice and herb extracts, coffee, tea and sweetener. Spray dried food products are appealing, retain nutritional qualities and are convenient to Consumer.

Masters (1997) Stated that spray drying is a powerful tool for delivering cost effective, high quality products.

Masters (2004) stated that spray drying is a technique widely used in many industries, as an effective method to obtain various dried products.

Spray-drying has been considered as a solution for conventional drying problems because the process has usually proved not only efficient but also economic (Masters, 2004). The main factors in spray-drying that must be optimized are feed temperature, inlet air temperature, and outlet air temperature (Liu *et al.*, 2006).

Chandrasekha *et al*. (1966) developed an infant food powder based on soyabean. Powdered barley malt was added to debittered soya dhal, centrifuged and the liquor from the centrifuge was warmed to 60°C. Weighed quantities of ground nut oil, skim milk powder, acid hydrolysed starch and buffer salts were added, homogenised and spray dried at 250°C inlet and 100°C outlet temperatures.

Spray drying is used for drying of solutions and paste especially for heat sensitive products (Mastres, 2004).

Hassan *et al*. (2006) studied about the spray drying of roselle extract. *Hibiscus sabdariffa* (Roselle) powder was produced by pilot scale spray drying using single strength and vacuum concentrated water extract of its calyces. The lowest inlet air temperature (198.5°C) resulted in the product with best protein content (12.43%), retention of vitamin C (82.76 mg/ 100 g), and solubility (dissolving in 97 sec); as well as the highest moisture content (3.78%) in the product. The powder showed a noticeable tendency to stick to internal surfaces of the drying chamber particularly with concentrated solutions at higher temperatures.

Brennan *et al*. (2007) studied about spray drying of concentrated orange juice, on a laboratory scale and some of the factors affecting the process. In his study concentrated orange juice (a) without additives and containing (b) sodium carboxymethyl cellulose, (c) Gum Acacia, and (d) liquid glucose as additives were spray dried in a laboratory drier. Liquid glucose was found to be the most satisfactory additive, producing a powder with good %, free-flowing characteristics and a minimum of wall deposition. Variations in air inlet temperature, feed temperature and rate and atomizer speed, within a limited range, resulted in no significant changes in the bulk density and particle size of

the product. The higher temperatures did result in some change in colour and an increase in insoluble solids. He concluded that Cooled plate experiments indicated that the problem of wall deposition is related to wall temperature and is minimized when the wall temperature is below the sticky point temperature of the product.

Jaya and Das (2007) studied relationship of moisture content, glass transition temperature and sticky point temperature of vacuum dried mango, pineapple and tomato with added maltodextrin and tricalcium phosphate). In that study, the ratios of maltodextrin (DE 38): fruit pulps were at 0.093:1, 0.065:1 and 0.033:1 respectively. The tricalcium phosphate at 0.015:1 was used for anti-caking in the three types of vacuum-dried powder. The difference between glass transition temperature and sticky point temperature however were found from 2.5 to 15.5°C depended on the nature of raw materials and amount of maltodextrin. The difference of these two temperatures was also found to vary with moisture contents. For pineapple powder, the glass transition and sticky point temperature appeared to be very close to each other (minimum difference of around 2.5°C).

Chegini *et al.* (2008) reported that the sticky point temperature of orange juice powder using maltodextrin, liquid glucose and methylcellulose as carriers was found to be at around 44 °C at 2% moisture.

Coulter and Breene (2010) successfully spray dried wide variety of fruits and vegetables using condensed milk as carrier in conventional milk drying equipment after sieving though a 0.70 mm screen. The proportion of skim milk solids ranged from zero per cent with peas and corn, 50 per cent with crane berry and blue berry and 60 to 70 per cent with tomatoes and other highly hygroscopic fruits like apple, banana and pineapple.

Mahendran (2010) prepared guava juice powder using maltodextrin as an additive by using freeze drying, spray drying and tunnel drying and found that spray drying may be the best alternative for producing guava powder with good stability.

Souza *et al*. (2009) studied about the Influence of spray drying conditions on the physical properties of dried pulp tomato. In this study a complete factorial experimental design was applied to determinate the influence of the variable inlet air temperature, feed flow rate, and atomizer speed on the physical properties of the tomato pulp powder. Results showed that these variables had a significant positive effect on the moisture content, apparent density, and particle size and no significant effects on the porosity and true density. The best spray drying conditions to produce lower moisture content and higher apparent density tomato powder were inlet air temperature of 200°C, feed flow rate of 276 g/min, and atomizer speed of 30000 rpm.

2.14 Quality Parameters

2.14.1 Moisture content

Drying is the standard method for determining the moisture content of materials. The material is heated under carefully specified conditions and the loss of weight is taken as a measure of the moisture content of the sample. Drying methods are simple, relatively rapid, and provide the simultaneous analyses of large numbers of samples (Pomeranz and Meloan, 1994).

The residual moisture content of spray-dried samples was determined by oven-drying the powders at 102 °C, determining the difference in weight, and expressing the weight loss as a per cent of the initial powder weight ((IS: SP: 18(part XI), 1981).

2.14.2 Total Soluble Solids (TSS)

Mahendran (2010) analysed the total soluble solids of Gauva juice t using a RFM Refractometer (Model: ATAGO-28E) equipped with a percentage sugar scale and expressed as °Brix.

2.14.3 Acid value

Mary *et al*. (2007) reported that the acidity of the spray dried banana powder decreased throughout the storage period of one year under ambient

conditions. This could be due to the increase in reducing sugars and pick up of moisture by the powder.

Mahendran (2010) measurement of titratable acidity was conducted using a standard 1% phenol/hthalein solution, titrated against 0.1N NaOH and the result was expressed as grams of anhydrous citric acid per 100g of sample.

2.14.4 Bulk density

Bhandari *et al.* (1993) described a method for the determination of bulk density in which measuring cylinder of known volume was tapped (50 times) after the powder was poured into it. The cylinder containing the powder was tapped on a flat surface to a constant volume. The final volume of the powder was recorded and the bulk density was calculated by dividing the sample weight by volume.

Goula and Adamapoulos (2008) described a method for the bulk density in which Bulk density (g/mL) was determined by gently adding 2 g of powder into an empty 10 mL graduated cylinder and holding the cylinder on a vortex vibrator for 1 minute. The ratio of the mass of the powder and the volume occupied in the cylinder determines the bulk density value.

2.14.5 Colour

Colour is actually different wavelengths of white light. A colorimeter quantifies colour by measuring three primary colour components of light viz., red, green and blue. This is usually done by preparing a sample according to directions and comparing its colour against a reference or series of references.

Colour change was consistently observed in strawberries (skin and pulp) freeze-dried at 25°C and 15 Pa (Carballido and Rubio, 1970).

Kalil and Sial (1974) studied the effect of these aspects with respect to the spray drying of mango juice, and showed that the atomization speed (40,000–500,000 rpm) had little effect on the colour, although an increase in the concentration of the additives (sodium alginate and glycerin monostearate) had a negative effect on product colour.

2.14.6 Wettability

The reconstitution properties (wettability, solubility and dispersibility) of skim milk powder is having particular importance to manufacturers and consumers as a benchmark of consumption quality and also has a direct impact on their perception of the overall product quality.

In the research study conducted by Fang *et al*. (2008) it was reported that the wettability of skim milk powder increased with lactose and protein content and decreased with fat content. The solubility decline of skim milk powder was due to denaturation of protein under drying.

Wettability (or wetting time) was determined by placing 3 g of dried powder around a pestle inside a funnel so that the pestle blocks the funnel opening. Then, the pestle was lifted to allow the powder to flow though the stem into a beaker of water. As soon as all the powder had flown into the beaker of water, a stop watch was started. The time (s) taken for complete wetting of the powder was noted as the wetting time. The experiment was done in triplicate (Falade and Omojola, 2010; Desousa *et al*., 2008).

2.14.7 Solubility index

The powder solubility index was determined by mixing 10g of powder to 100ml of distilled water at a temperature of 24 C in the mixing jar. After that the jar was Placed in the mixer and stirred for exactly 90 seconds which was allowed to settle. The period of standing after mixing, should not exceed 15 minutes. After removal of foam, the sample was thoroughly mixed with the spoon for 5 seconds. After that the mixture were immediately filled into a 14 ml centrifuge tube and centrifuged at 4000rpm for 5 minutes at the require speed. Immediately siphon off the transparent liquid to within 5ml of the surface of the sediment level, taking care not to disturb the sediment layer. Add about 25ml of distilled water at a temperature of 24 C. Invert and shake to mix the contents thoroughly. Again centrifuge at the required speed for 5minutes. Solubility index was obtained by holding the tube in a vertical position with the upper level of the sediment on a

level with the eye and reading the millimetres of sediment in the tube to the nearest graduated scale division (Fang *et al*., 2008).

2.14.8 Particle size

Ozkan *et al*. (2002) reported the scanning electron microscopy (SEM) of the milk powders, which gave an impression of the types of agglomerates that existed in the whole and skim milk powders. The differences between the SMP and WMP were mainly due to the significant variation in the surface composition of these milk powders.

Ji *et al*. (2008) studied the microstructure by Cryo-SEM and showed that casein/k-carrageenan aggregates were composed of many spherical subunits. These subunits were tightly connected with each other. No individual caseins or k-carrageenans were distinguishable. The FE-SEM after critical point drying showed the presence of individual casein micelles and k-carrageenan strands. Casein micelles appeared to be spherical with some protuberances on the surface.

2.14.9 Packaging and storage studies of spray dried products

Some of the findings on packaging and storage by other scientist on guava powder are furnished below:

Sharma *et al*. (2004) conducted the storage studies on foam mat dried hill lemon powder in poly propylene and aluminium laminated pouches. It was found that the moisture content increased from 19 to 133 per cent on dry basis, 2.86 times of browning with consequent losses of 20.98 per cent ascorbic acid, 1.72 per cent acidity and 0.63 per cent total sugar during the storage period of 6 months. However, powders packaged in aluminium laminated pouches experienced minimum changes in quality compared to those packaged in polypropylene pouches. The equilibrium relative humidity (ERH) studies of hill lemon powder showed that the powder was highly hygroscopic and therefore required to be stored in the RH of 18 to 25 per cent.

Table 2.2 Packaging and storage studies of spray dried products

Product	Packaging materials	Salient findings	Reference
Guava powder	Ployethelene bags	Retained the ascorbic acid in proportion to guage thickness during storage	Khurdiyaand Roy 1974
Sul/hited raw mango powder	Polethylene bags(400 guage)and brown paper	Stored for 6 months at room temperature without any deterioration	Dabhade Khedkar(1980)

Segini *et al*. (2004) compared the relationship between instrumental and sensory analysis of texture and colour of potato chips. The instrumental colour quantification was done by computerized video image analysis technique and the colour was expressed as L*a*b* values. Sensory evaluation of texture and colour was performed by a sensory panel especially trained in evaluating potato chips. Discriminated analysis showed that tenderness and crunchiness could predict correctly 90% of the data while fracture force correlated well with all sensory attributes.

Mary *et al*. (2007) studied the packaging and storage studies on spray dried ripe banana powder under ambient conditions and concluded that banana powder could be successfully stored under ambient conditions for one year by packing in nitrogen flushed aluminium foil laminated pouches with minimum changes in colour, flavour, texture, microbial load and organoleptic qualities.

Pua *et al*. (2008) had conducted an experiment on storage stability of jackfruit powder packaged in aluminium laminated polyethylene and metalized co-extruded biaxially oriented poly propylene. The total colour difference (ΔE), rates of adsorbed moisture and sensory attributes of drum-dried jackfruit powder packaged in aluminium laminated polyethylene (ALP) and metalized co-extruded biaxially oriented polypropylene (BOPP/MCPP) pouches stored at accelerated storage (38^0C, with 50%, 75% and 90% relative humidity (RH)) were determined over 12 weeks period. The changes intotal colour followed zero order reaction kinetics. The powder packaged in ALP significantly ($p < 0.05$) reduced total

colour change, rates of adsorbed moisture, lumpiness intensity of jackfruit powder and was rated higher in terms of overall acceptability over BOPP/MCPP.

2.14.10 Sensory Evaluation

Sensory evaluation is the scientific discipline used to evoke measures to analyse and interpret reactions to those characteristics of food as they are perceived by the senses of sight, smell, taste, touch and hearing. Sensory attribute of quality, guide the consumer in his selection of foods, also for determining the conformity of a food with established government or trade standard and food grade.

As the final criterion of food quality is human evaluation, the value of objective measurements must be evaluated by their correlation with sensory measurements. A successful implementation of sensory evaluation programme requires major components like proper laboratory facilities, sensory panels and rigorous training programme (Reece, 1979).

The selection, acceptance, and digestibility of a food are largely determined by its sensory properties. Evaluation of sensory properties, is, however, affected by personal preference. To minimize the effect of factor on personal preference, different procedure for safety evaluation has been devised and the results are evaluated by statistical methods (Zeuthen *et al*., 1990).

Measuring the sensory properties of food is basic for predicting acceptance of the food by the consumer represents major accomplishments for sensory evaluation, (Pal *et al.,* 1995).

According to Bodyfelt *et al*. (1998) the panelist should be trained for desirable and undesirable sensory attributes of the concerned product. Before starting, the panelists should feel that they are going to do an important activity and their contribution is very important.

Anonymous (1999) stated that organoleptic evaluation is a scientific discipline to evolve measures, analysis and interpret reactions to those characteristics of food and materials, as they are perceived by the sense of sight,

taste, smell, etc. Quality is a measure of the degree of excellence or degree of acceptability by consumer. Quality characteristic are classified into Sensory (colour, size, shape and defect, texture and %), Hidden (Nutritive value and Toxicity) and Quantitative (crop yield and finished product yield).

Rao and Gupta (2002) developed a spray dried orange juice blended skim milk powder. From the various samples that were obtained during the process Optimisation trials, representative samples of the 4 proportions with the best attributes were selected, based on organoleptic and quantitative observations. These representative powder samples were subjected to various physico-chemical and sensory attributes. A panel of five trained judges performed sensory evaluation.

Rao and Kumar (2005) studied the spray drying of mango juice-buttermilk blends. The sensory evaluation of resultant powder was judged by an in-house panel consisting of 5 experienced judges. The panelists were supplied with both powder as well as reconstituted form of mango-buttermilk blends. In case of reconstituted form, the powder was fully dispersed in warm water at 40°C to a solid level of 10 per cent and supplied to judges.

Falade and Aworh (2005) reported the study of sensory evaluation and consumer acceptance of osmosed and oven dried African star apple and African mango. It was found that there are no significant differences in all the sensory attributes of oven dried African star apple slices preosmosed in the sucrose solutions. However unosmosed and dried samples received consistent poor scores for all the sensory attributes. There was no significant differences in the quality attributes of preosmosed oven dried African mango except the taste.

Materials and methods

CHAPTER III
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 *Garcinia cambogia* powder.

3.1 Test sample

The *Garcinia cambogia* harvested in the month of May-2011 collected from different parts of Kerala were selected for the study. The ripened fruits were cleaned in running water. Immature, rotten and damaged fruits were discarded and the rinds after removing the seeds were collected. The moisture content, pH, titrable acidity, TSS, total solids and acidity of the ground rinds were estimated as per standard methods.

3.2 Standardisation of drying aid for proper drying

In order to minimize the stickiness during drying in the walls of the drying chamber and also to increase the solubility a drying aid, maltodextrin was selected for this study. Levels of 10, 12.5, 15, 17.5 and 20 % by weight of fruit juice maltodextrin were tested. Standardization of this drying aid was based on a sensory evaluation of a panel of four experienced judges using a 9 point hedonic scale. The sensory attribute such as odour, mouth feel and appearance of maltodextrin added fruit juice were selected for the study.

3.3 Optimisation of drying methods and its parameters

Drying of *Garcinia cambogia* juice for the production of powder was done using a tray dryer (Make: Narang Scientific Works (Pvt Ltd)), vacuum tray dryer (Milk Tech Engineers, Bangalore) and a spray dryer (Make: Anhydro, Denmark)

3.3.1 Tray drying:

Plate 3.1 Tray dryer

After grinding the rind, the samples were filtered and dried in a tray dryer (plate 3.1) at 60, 70 and 80^{0}C. The temperature inside the chamber was regulated using a thermostat. The samples were spread uniformly over the tray up to a thickness of 5mm. The weight of the sample was taken at an interval of 1 h till the moisture content of the samples become constant. The product was scraped out from the trays after proper drying and the flakes were then ground to fine powder in a dry grinder and packed for analysis. The products were packed in LDPE (400 gauges) and then kept in laminated (400 gauges) packs.

3.3.2 Vacuum tray drying:

The study was conducted using a vacuum tray dryer (Milk Tech Engineers, Bangalore) (plate 3.2) at 40, 45 and 50^{0}C at a constant absolute pressure of 100 mm/hg. Initial weight of the trays and the samples were noted. The samples were spread uniformly over the tray up to a thickness of 5mm. Trays were placed on to the header plate in the drying chamber after steady state condition was achieved.

There are a number of shelves inside the vacuum tray dryer on which the product laden trays are placed. The top most shelves are a dummy shelf to ensure proper heating and to block dried powder from escaping into the solvent extraction system. The shelves are manufactured in hollow construction with baffles cum stiffeners placed in between. Each shelf has an inlet and outlet nozzle. Each shelf is connected though these nozzles to an inlet and outlet header. Hot

media is passed though the inlet header and in turn to each shelf. The hot media flows though the shelves in a serpentine fashion ensuring faster heat transfer to the surface, which in turn heats up the trays placed on the shelves. The hot media flows out from the shelves through the outlet header. The inlet and outlet headers are designed such that the flow of the heating media is equally distributed into each of the shelves. Additional limpet coils are provided to further stiffen the body and also to pass the hot media. The chamber is provided with a heavy door with an adequate locking arrangement. The dryer chamber is connected though a vapour column to a shell and tube type heat exchanger, which in turn is connected to a condensate receiver. Vacuum is applied to the condensate receiver. Vapour evolved during the drying process is collected in the receiver after it is cooled in the heat exchanger. The vapour to be cooled is passed though the tube side of the heat exchanger, while cooling water is passed though the shell side. A cooling coil is present in the condensate receiver, to further cool any vapours entering the receiver before it is goes into the vacuum pump. The condensate receiver is connected to a vacuum trap, to ensure that any un cooled vapours arising from the receiver is trapped and allowing very minimal contents of the vapour to pass into the vacuum pump.

Plate 3.2 Vacuum tray dryer

The samples were taken out for weighing at 2h interval. The vacuum was broken and restored before and after the weight measurements. Drying was continued till a constant weight was attained. Each experiment was replicated

thrice and average values were used for analysis. Here also we have to scrap the product from trays and ground in a grinder. After that the products were packed in LDPE (400 gauges) and then kept in laminated (400 gauges) packs.

3.3.3 Spray Drying:

A pilot model spray drier ((Make: Anhydro, Denmark), shown in Plate 3.3 is a vertical co-current type with a water evaporation capacity of 6 kg/h was used for this experimental study.

Atomization capacity = Pneumatic/centrifugal

Air supply = With electrical heating system

The essential components of spray dryer were hot air supply system, in feed supply system, atomizer, drying chamber and powder recovery system. Hot air supply system consist of air filter (230 mm diameter, 130 mm height and a stainless steel having a screen of size 40μm) and electrical air heater for heating the air to a maximum temperature of 260ºC and this heated air is supplied uniformly to the chamber with the help of an air supply fan. The atomizer of this spray dryer is of rotary wheel type with an atomizer speed ranging from 10000-25000rpm. The hot air supply system is provided so that it moves down concurrently with the atomized product. The system is provided with a cyclone separator for the collection of trapped product particles with the outgoing air. In spray drying we used two atomizer speeds 17,000 and 22000 rpm, two temperatures 175 and 180°C and three feed rates 5, 5.5 and 6 l/h. This combination was attained by conducting preliminary trails to obtain a satisfactory product.

Plate 3.3 Spray dryer

3.4 Experimental design

The design for the experiments was a completely randomized design. Data were statically examined by analysis of variance and the means were separated by Duncan's Multiple Range Test in the case of tray and vacuum tray drying. In the case of tray and vacuum tray drying statistical analysis were conducted using SPSS software and in the case of spray drying M-stat software was used as it was a completely randomized three factorial experiment. For Sensory analysis means were separated by Kendall's coefficient of concordance test. The details of the process parameters are given below.

Independent variables

Table 3.1 Independent variables in different drying methods

Parameters	Tray drying	Vacuum tray drying	Spray drying
Temperature	60^0C, 70^0C and 80^0C	40, 45 and 50^0C.	170 and 180ºC
Nozzle type	-		Rotary wheel atomizer
Atomizer speed			17000, 22000
Feed flow rate			5, 5.5 and 6 l/h
Additives	Maltodextrin (15 per cent w/v)		
Storage period	6 Months		

Dependent variables

i. Moisture content ii. Total solids

iii. Acid value iv. pH

v. Bulk density vi. Solubility index

vii. Wettability viii. Colour

ix. Sensory evaluation

Development of process protocol for *Garcinia cambogia* powder

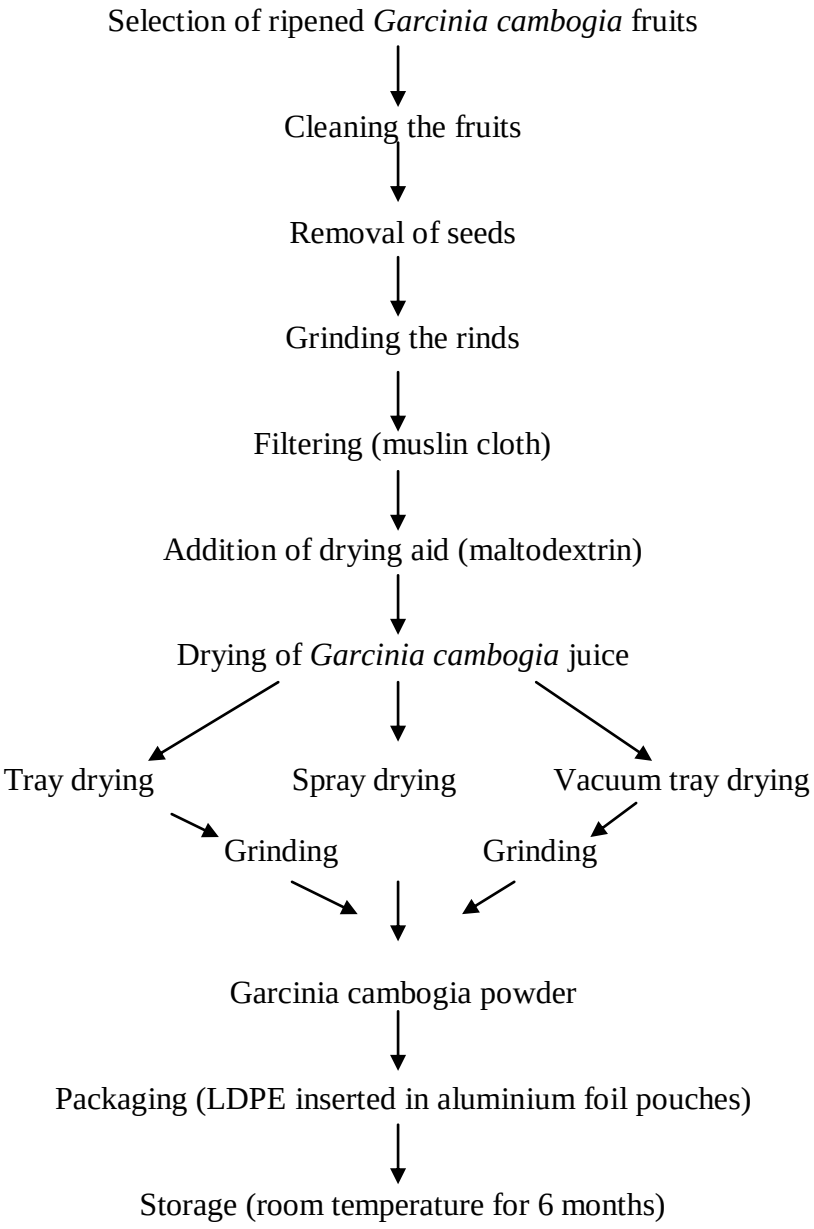


Fig.3.1. Process flow chart of production of *Garcinia cambogia* powder

3.5. Quality analysis of Garcinia cambogia powder

3.5.1 Moisture content

Moisture content of the sample was determined by weighing accurately about 5g of *Garcinia cambogia* powder into a flat bottomed glass or aluminium dish (with a cover) previously dried and weighed and heat the dish containing the material (after uncovering) in an electric oven maintained at 100^0C for about 3h. Cool the sample in a dessiccator and weigh with the cover on. Repeat the process of drying, cooling and weighing at 30 min intervals until the difference between two consecutive weighing is less than 1mg. Preserve the dish containing this dried material in a dessicator for the determination of other contents (Diamante *et al.*, 2009). The moisture content of the samples was calculated on a per cent wet basis, and the average value of the triplicate measurements was used.

Moisture content in% wet basis = $\frac{M_{initial} - M_{dried}}{M_{initial}} X100$

3.5.2 Total solids

The total solid content is a measure of the amount of material remaining after all the water has been evaporated (IS: SP: 18(part XI), 1981).

%Total solids= $\frac{M_{dried}}{M_{initial}} X100$

3.5.3 Acid value

Dilute 5g of the powder to 100ml with distilled water. Then reflux it to two and a half hour at a temperature of 50^oC. Pipette out 10ml of the sample and titrate it against standard NaOH solution using phenolphthalein as indicator. Express the acidity as percentage unhydrous hydroxyl citric acid (Ranganna, 1991).

Acid value (%)

= (titre value×normality of NaOH×vol made up×equivalent mass of acid)×100
(Volume of sample taken for estimation× volume of sample taken)

3.5.4 pH

The pH of the *Garcinia cambogia* powder was determined using a glass electrode pH meter (plat 3.4) (Make: TESTRONIX). The pH meter was standardized with double distilled water of pH 7.0 and buffers at pH 4.0 and 9.2.

Plate 3.4 pH meter

3.5.5 Bulk density

Bulk density of the *Garcinia cambogia* powder was determined by tapping method (Gong *et al*., 2008). Two grams of powder was loosely weighed into 10 ml graduated cylinder. The cylinder containing the powder was tapped on a flat surface to a constant volume. The final volume of the powder was recorded and the bulk density was calculated by dividing the sample weight by volume.

$$\text{Bulk density}\,(\text{g/cm}^3) = \frac{\text{Weight of the powder}}{\text{Volume of the powder}}$$

3.5.6 Particle size analysis by Scanning Electron Microscopy (SEM)

The morphology of *Garcinia cambogia* powders was determined using Scanning Electron Microscope (SEM) (plate 3.7) (JEOL JSM 5600LV, JEOL Ltd., Japan) using an acceleration voltage of 5 kV.

The scanning electron microscope (SEM) determines the particle size of a powder by using a beam of high energy electrons and electromagnet. The signals that derive from electron-sample interactions reveal information about the sample

including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. SEM can produce a largely magnified image by using electrons.

An auto fine coater (JFC – 1200) was used for coating the Garcinia cambogia powder (non conductive sample) with pure 24 carrot gold (conductive material) to a thickness of about 100A^{o} to prevent vapourization under high vacuum**.** The beam of electrons is produced at the top of the microscope by an electron gun. The electron beam follows a vertical path though the microscope, which is held within a vacuum. The beam travels though electromagnetic fields and lenses and the beam get focused towards the sample. Once the beam hits the sample, electrons and X-rays are ejected from the sample. Detectors collect these X-rays, back scattered electrons and secondary electrons and convert them into a signal. The signals are collected in a detector and are converted into image in the screen.

Plate 3.5 JFC – 1200 Auto fine coater (Part of SEM set up)

Plate 3.6 JEOL JSM 5600LV Scanning Electron Microscope for particle size analysis

3.5.6 Solubility index

The powder solubility index was determined by mixing 10g of powder to 100ml of distilled water at a temperature of 24 ºC in the mixing jar for 90 seconds. Immediately after the mixing the mixture were filled into a 14 ml centrifuge tube and centrifuged at 4000rpm for 5 minutes. Then the mixture was allowed for settlement. Solubility index is reported as the millimetres of sediment in the 14 ml centrifuge tube when it was holded in a vertical position (Fang *et al*., 2008; Desousa *et al*., 2008; Falade and Omojola, 2010). Analysis was done in triplicate.

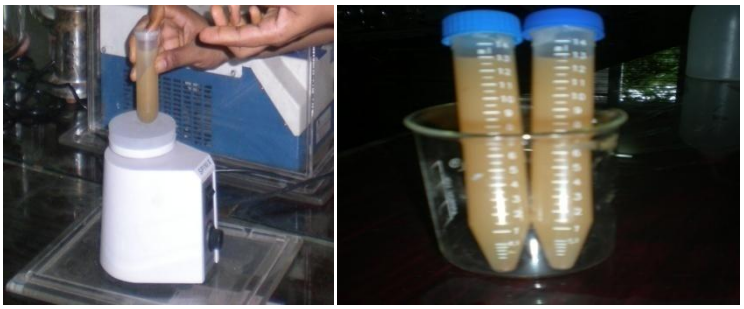


Plate 3.7 Experimental set up for Solubility index

3.5.7 Wettability

Wettability (or wetting time) was determined by placing 3 g of dried powder around a pestle inside a funnel so that the pestle blocks the funnel opening. Thereafter the powder was allowed to flow into a beaker of water by lifting the pestle and the time taken for the complete wetting of the powder in the beaker was noted and recorded as the wetting time. The experiment was done in triplicate (Falade and Omojola, 2010; Desousa *et al*., 2008).

3.5.8 Colour

Hunter lab colour flex meter (Make: Hunter Associates Laboratory, Reston, Virginia, USA) was used to study the effect of drying on the colour of the powder. It works on the principle of focussing the light and measuring the energy reflected from the sample across the entire visible spectrum. The colour meter has

filters that rely on "Standard Observe Curves" which define the amount of red, yellow, blue and green colours.

The L* value represents relative colour brightness ranging from total black (L*=0) to total white (L*=100). The a* value represents the colour hue ranging from red (+) to green (-). The b* value represents the colour hue ranging from blue (-) to yellow (+). Before measuring the colour of the samples, the instrument was standardized by placing each time with a white and black ceramic plate. The sample colour was measured by filling the powder in the transparent cup provided, without any void space at the bottom and the L*, a* and b* values were measured.

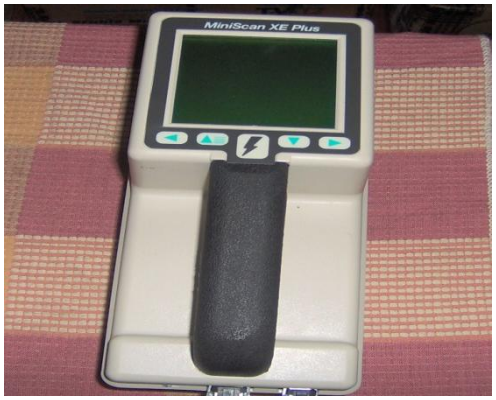


Plate 3.8 Hunter lab colour flex meter

3.6 Packaging studies of the *Garcinia cambogia* powder

The powder obtained from tray dryer, vacuum tray dryer and spray dryer is packed for shelf life studies. The samples were packed using a hand sealing machine and stored in ambient condition (temp 29-30^{0}C with 40-50% RH) and the different quality parameters of the powder were evaluated. *Garcinia cambogia* powder was packed in LDPE (400 gauges) and then kept in laminated (400 gauges) packs.

3.7 Storage studies

The most acceptable treatment was selected for storage studies at room temperature. Bio-chemical analysis of *Garcinia cambogia* powder obtained by tray drying, vacuum tray drying and spray drying were carried out to evaluate the quality deterioration during drying and storage. The moisture content, total solids,

acid value, hydroxy citric acid content, pH, bulk density, colour, solubility index and wettability were estimated in every one month duration using the standard procedures.

3.7.1. Sensory evaluation

Fish curry prepared from *Garcinia cambogia* powder were assessed for their sensory attributes like appearance, odour, flavour, taste and overall acceptability by using a 9-point Hedonic scale test with 10 panelists to find out the consumer acceptability.

9- Like extremely	8-Like very much
7-Like moderately	6-Like slightly
5-Neither like nor dislike	4-Dislike slightly
3-Dislike moderately	2-Dislike very much
1-Dislike extremely	

The samples were arranged in tables with specific codes. The responses was converted to numerical values and statistically analysed by Kendall's coefficient of concordance test.

Results and discussion

CHAPTER IV
RESULTS AND DISCUSSION

This chapter enunciates the experiments conducted to standardize the various parameters in the drying process of *Garcinia cambogia*. The chapter also discusses in detail the storage of the dried *Garcinia cambogia* powder and its quality.

4.1. Test sample

The *Garcinia cambogia* belongs to the family Clusiaceae, harvested in the month of May 2011collected from different parts of Kerala were selected for the study. The average value of the initial moisture content, acid value, total soluble solids and pH were estimated by standard methods explained in chapter III and the results were tabulated.

Table 4.1 Physico-chemical Composition of fresh *Garcinia cambogia* pulp

Constituents	$\overline{X}$ **±SD**
Moisture content (%wb)	86.6 ± 0.46
Acid value as hydroxyl citric acid	4.80 ± 0.11%
Total soluble solids	12 ± 0.71^{0}brix
pH	3.5 ± 0.11
Colour	
L(Lightness)	47.78 ± 0.23
a*(Redness)	6.395 ± 0.15
b*(Yellowness)	30.6 ± 0.19

$\overline{X}$ =Mean SD=Standard Deviation

From the table 4.1 the average value of moisture content was found to be 86.6% and the average value of chemical components, i.e., of hydroxyl citric acid, TSS and pH were 4.80%, 12^0 brix and 3.5 respectively. The colour values of the fresh *Garcinia cambogia* juice were estimated using a Hunter lab colourimeter. The L value indicates the lightness of the sample i.e. the colour tends towards the white colour.

4.2 Standardisation of drying aid for proper drying

Table 4.2 depicts the addition of maltodextrin on sensory quality of the juice.

Table 4.2 ANOVA table of sensory evaluation for standardisation of maltodextrin level

Sensory attribute	Sensory score and Sensory comments	Level of addition of maltodextrin (%)						
		Control	10	12.5	15	17.5	20	$CD_{0.01}$
Taste	Sensory score Max 9.0	7.5 ± 0.16 [a]	7.46 ± 0.24 [a]	7.4 ±0.21 [a]	7.39 ± 0.13 [a]	7.0 ± 0.08 [b]	6.9 ± 0.13 [b]	0.18
	Sensory comments	Sour	Sour	Sour	Sour	Slightly soluble	Slightly soluble	
Odour	Sensory score Max 9.0	7.96 ± 0.18 [a]	7.91 ± 0.26 [a]	7.87 ±0.77 [a]	7.82 ± 0.06 [a]	7.46 ± 0.11 [b]	7.15 ± 0.22 [c]	0.27
	Sensory comments	Characteristic fruit smell	Same as control	Same as control	Same as control	Slightly different from control	Totally different from control	
Mouth feel	Sensory score Max 9.0	8.12 ± 0.23 [a]	8.06 ± 0.17 [a]	8.03 ±0.18 [a]	7.98 ± 0.21 [a]	7.81 ± 0.16 [b]	7.50 ± 0.08 [c]	0.13
	Sensory comments	Syrupy (less viscous)	Same as control	Same as control	Same as control	Slightly different from control(more viscous)	Slightly different from control(more viscous)	
Colour and appearance	Sensory score	8.18 ± 0.10 [a]	8.12 ± 0.13 [a]	8.019 ±0.22 [a]	8.09 ± 0.02 [a]	7.81 ± 0.13 [b]	7.70 ± 0.12 [c]	0.21
	Sensory comments	Dark brown	Dark brown	Light brown	Light brown	Deep yellow	Deep yellow	

Standardisation of the drying aid was based on sensory evaluation of the mixture, moisture content and solubility of the powder. Sensory evaluation was done by a panel of four judges using a 9 point hedonic scale. From the table 4.2 it is observed that maltodextrin at the level of 10-15 % were on par with the control juice

on all attributes except the colour and appearance. The initial colour value of the *Garcinia cambogia* juice was recorded as 47.780, 6.395 and 30.600 for L, a* and b* values. Deviation of colour from dark brown to light brown may be due to the addition of higher level of white coloured maltodextrin. The addition of maltodextrin greater than 15% gives a dominant taste of maltodextrin which is not acceptable. Similar results were also reported by Weerachet *et al*. (2010) for pineapple juice having 12^0brix and Vongsawasdi *et al*. (2002). Hence the maltodextrin up to 15 % level were selected for further studies.

The effect of levels of maltodextrin on moisture content and solubility of dried powder is tabulated in table 4.3. It was observed that as the maltodextrin level increases, the moisture content of the powder decreases. This may be due to increase in solids in the feed that reduced the amount of free water. Moisture content with 15 per cent maltodextrin is 4.40 % (wb) close to the moisture content of tamarind powder of 4.00 % (wb) (Weerachet.*et al*., 2011)

The results in table 4.3 indicate that the solubility values in minutes decrease with increase in maltodextrin per cent. This is due to the fact that the addition of maltodextrin content raised the glass transition temperature (Tg) of powder, however, the increase in Tg was not linear. Thus, the agglomeration of maltodextrin rich powder will be obstructed as a consequence, the specific surface area of the powder was high in this case leading to the faster solubility (lower value of solubility in minute) of the powder. Similar results were also observed by Shrestha *et al*. (2007).

Table 4.3 The moisture content and solubility of the *Garcinia cambogia* powder

Maltodextrin content (%)	**Moisture content (%wb)**	**Solubility(min)**
10	10.02 ± 0.1	13 ± 0.2
12.5	7.19 ± 0.2	9 ± 0.7
15	4.40 ± 0.3	7.4 ± 0.3

By considering the effect of moisture content and solubility maltodextrin at 15 % level was selected for the further studies.

4.3 Optimisation of drying methods and its parameters

4.3.1 Effect of tray drying parameter on quality of Garcinia cambogia powder

Experiments were conducted in a tray dryer at 60, 70 and 80^0C. For the Optimisation of drying temperature, the effects of drying temperature on quality of the product were carried out. The different quality parameters analysed are shown below.

1. Moisture content
2. Colour value
3. Solubility index
4. Wettability
5. Total solids
6. Acid value and pH
7. Bulk density

4.3.1.1 Moisture content

Fig 4.1 shows the drying curves of *Garcinia cambogia* powder at 60^0C, 70^0C and 80^0C and the data are listed in table A.1 of appendix A. It can be observed that, the sample at 80^oC (T2) has taken only 6 hours to attain constant moisture content whereas 60^oC (T0) and 70^oC (T1) has taken 10 hours and 7 hours respectively i.e., increasing the drying air temperature tended to remove the moisture content faster.

As the temperature increases, drying time decreases. This may be due to the fact that increasing the drying air temperature speeded up the drying process, thus shortening the drying time. Similar results were reported by Doymaz (2005), Akpinar *et al*. (2003), Azzouz *et al*. (2002) and Ertekin and Yaldiz (2004). The increase in the air temperature of the drying chamber might cause a rapid increase in the temperature at the surface of the product, driving a quicker transfer of water at the surface of product to environment with higher drying rate.

For tray drying at 60^0C moisture content with respect to drying time can be expressed as

Moisture content = -9.9093+99.738 (R^2 =0.9039)……. (4.1)

Where x is the drying time (h).

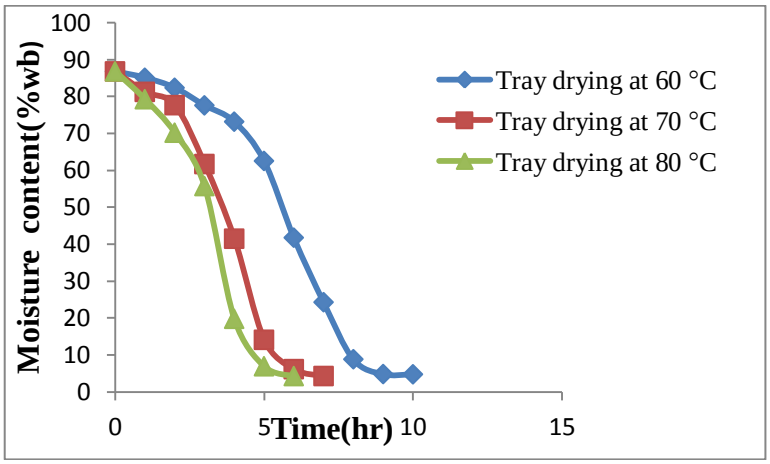


Fig.4.1 Drying characteristics of tray drying of *Garcinia cambogia*

4.3.1.2 Colour

Effect of type of drying on colour ('L', 'a', 'b') values of *Garcinia cambogia* powder is presented in fig 4.2.

The lightness (L), redness (+a*) and yellowness (+b*) values of the samples dried at 60, 70 and 80^{0}C were estimated using a Hunter lab colourimeter. From the table 4.4 it was seen that at 60^{0}C the value of +a* i.e. redness is very much higher when compared to the samples at 70 and 80^{0}C and this may be due to the fact that a prolonged time of drying of 10 h resulted in the non enzymatic browning. These results are in agreement with findings of Piga *et al*. (2004), Park and Kim (2007) and Quek *et al*. (2007).

Table 4.4 Colour value and drying time of tray dried *Garcinia cambogoia* powder

Treatment name	Drying time(h)	Colour value		
		L(Lightness)	+a*(Redness)	+b* (Yellowness)
T0(60°C)	10	70.156 ^{c}	13.6672 ^{b}	20.824 ^{b}
T1(70°C)	7	75.246 ^{a}	12.618 ^{a}	17.902 ^{a}
T2(80°C)	6	75.628 ^{a}	12.060 ^{a}	17.882 ^{a}
CD		1.163	0.711	0.340

It can be observed that the lightness (L) increases with increase in temperature which ranges from 70.156 to 75.628. The value of +a* i.e. redness is higher for 60^0C (13.667) compared to 70 and 80^0C and this may be due to the fact that a prolonged time of drying of 10h resulted the non enzymatic browning. Similar results were also observed by Maskan (2000), Tan *et al*. (2001).

The value of yellowness decrease with the increase in temperature and this may be due to the oxidation of some free radicals during drying. Similar colour alteration was reported by Vongsawasdi *et al*. (2002) for fruit and vegetable.

The mean value of redness and yellowness was found to be least for T2 which was on par with T1 and by considering the time of drying and the colour of the product T1 was selected as the best treatment.

4.3.1.3 Solubility index

Shittu *et al*. (2007) reported that the solubility index had relevance on consumption characteristics as it affects the sensory attribute such as taste perception. Solubility is used as the rate of dissolution to describe the powder reconstitution properties. Solubility index for 60, 70 and 80 ^{0}C were 0.50, 0.55 and 0.70 respectively. It was observed from the fig 4.2 that as the temperature increases the solubility index, which is expressed in ml were found to be increased. The reason is that at higher temperature, a hard surface layer is formed over the powder particles that prevent water from entering particles and therefore the percentage of insoluble solids is increased. Analogous observations have been reported by Walton (2000), Chauca *et al*. (2004), Quek *et al*. (2007) and Mahendran (2010).

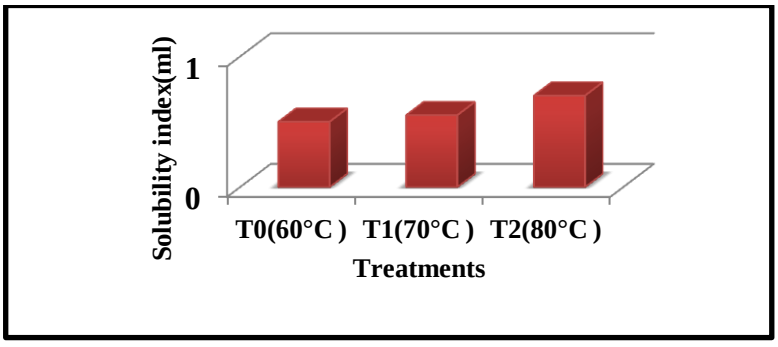


Fig.4.2 Effect of temperature on solubility index of tray dried *Garcinia cambogia* powder

4.3.1.4 Wettability

Wettability is generally considered as the ability of powder particles to overcome the surface tension between themselves and water. The wetting time of the powder should be low for good reconstitution. The effect of tray dryer on wetting time of the dried powder is presented in Table 4.5. The wetting time of the powder ranged from 93 to 98 s.

From fig 4.4 it can be seen that as the temperature increases, the time required for wetting of the powder increases which implies the wettability of the powder decreases. This may be due to reduced product residual moisture content. Similar results were found by Bhandari *et al*. (1993) and Jumah *et al*. (2000).

The results obtained for wettability were statistically analysed. The ANOVA associated with Duncan's simple Completely Randomized Design was implemented and found the most suitable combination as T0 (drying at 60°C) which is having the minimum value for wetting time as 93.0 and was grouped in level a. Also T1 (drying at 70°C) having a mean value of 93.8 were found to be on par with T0. So both T0 and T1 was found to be optimum and grouped in level a. The critical difference for wetting time was found to be 1.744.

Table 4.5 ANOVA table for wetting time of tray dried powder

Treatment name	**Wetting time(s)**
T0(60°C)	93.000 [a]
T1(70°C)	93.800 [a]
T2(80°C)	98.400 [b]
CD	1.744

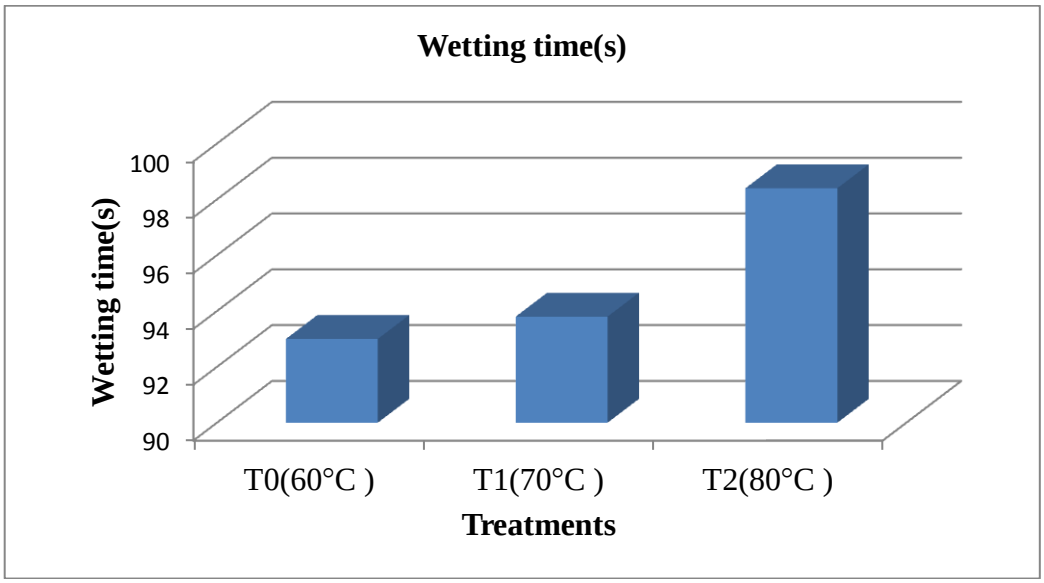


Fig.4.3 Effect of temperature on wetting time of tray dried *Garcinia cambogia* powder

4.3.1.5 Total solids

From the table 4.6 it was observed that as the temperature increases the total solids also increases. This may be due to the reduction in available free water. Similar results were also obtained by Elizangela *et al.* (2010), Akpinar *et al*. (2003), Madhiyanon *et al*. (2009) and Kurdia and Roy (1974).

The results obtained were statistically analysed and listed in table 4.6 and A.2 of appendix A. The ANOVA associated with Duncan's simple completely randomized design were implemented and revealed that temperature has no significant effect on total solids.

Table 4.6 Effect of temperature on total solids of tray dried powder

Treatment	Total solids
T0(60^0C)	95.598
T1(70^0C)	95.618
T2(80^0C)	95.626

4.3.1.6 Acid value and pH

The acid value (% hydroxyl citric acid) was found to be decreased when the temperature increased and pH was found to be increased when temperature decreased. This may be due to the lactonisation of hydroxyl citric acid. Similar trend was also observed by Benny (2003). Acid value for 60, 70 and 80 °C were 20.811, 20.811 and 19.424 and pH was 1.872, 1.868 and 2.002 respectively. The trend of acid value and pH on temperature rise are shown in the fig 4.4 and fig 4.5 respectively.

The ANOVA table 4.7 revealed that there was a significant effect of temperature on pH (CD value = 0.191) with a minimum mean value of 1.868 for T2 i.e. tray drying at 70°C. Hence T2, drying at 70°C was found to be the best considering the quality parameter pH

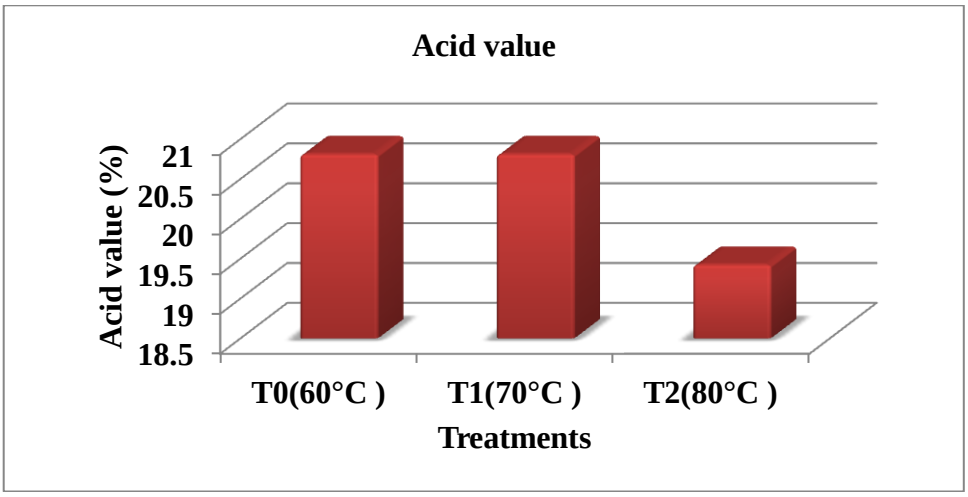


Fig. 4.4 Effect of temperature on acid value of tray dried *Garcinia cambogia* powder

Table 4.7 ANOVA table for pH of tray dried powder

Treatment	pH
T0(60°C)	1.872 [a]
T1(70 °C)	1.868 [a]
T2(80 °C	3.206 [b]
CV	0.188
C.D (0.05)	0.191

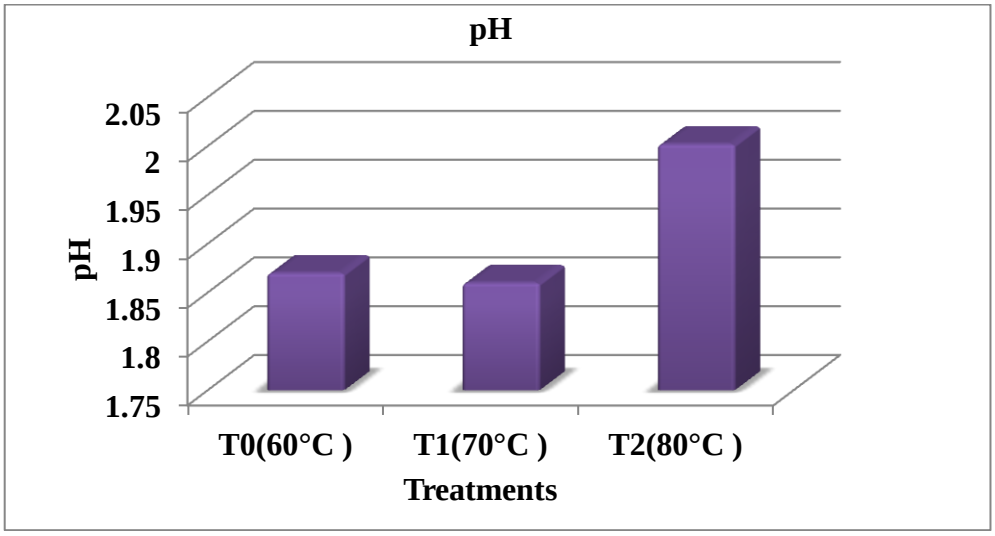


Fig. 4.5 Effect of temperature on pH of tray dried *Garcinia cambogia* powder

4.3.1.7 Bulk density

The bulk density (BD) is a measure of packing characteristics of particulate solids. Bulk density determines whether the prescribed weight of material will fit into its designated container or not. The aggregate powder bulk density was found to be influenced by the types of drying and the conditions of drying.

In this study, from the fig 4.6 it was observed that as the temperature increases bulk density decreases. The bulk density is an important characteristic for the packaging design and the calculation of transportation volume. The bulk density of *Garcinia cambogia* powder was in agreement with those of tamarind powder produced by Jittanit *et al*. (2011) ranging from 0.478 to 0.816. The higher drying temperature resulted higher rate of moisture evaporation from the sample resulting in a higher porosity and lower bulk density of the dried powder. Similar results were reported by Sertwasana (2010), Walton (2000) and Jumh *et al*. (2000).

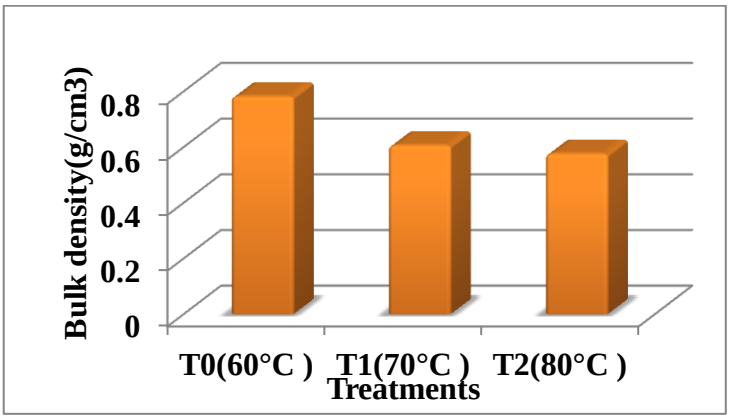


Fig. 4.6 Effect of temperature on bulk density of tray dried *Garcinia cambogia* powder

Statistical analysis of bulk density revealed that they are significant at 1% level. Minimum mean value for bulk density which is preferable, were observed for sample T2 (80°C) of 0.576. The treatment T1 (70°C) having a mean value of 0.606 was on par with T2 and grouped as level "a". So T1 and T2 were found to be the best treatment with regard to the quality parameter bulk density.

4.3.1.8 Optimisation of tray drying parameters

For identifying the best treatment for tray drying all the quality parameters were analysed statistically using SPSS software and listed in the table table A.2 and A.3 of appendix A. It is inferred from the table 4.8 that all the quality parameters except moisture content were significant at 1% level.

Table 4.8 Effect of tray drying temperature on quality parameters of *Garcinia cambogia* powder

Treatments	Colour value			W (s)	Total solids	Acid value (%)	pH	Bulk density (g/cm^3)
	L	a*	b*					
T0 (60°C)	70.16 ^{c}	13.67 ^{b}	20.82 ^{b}	93.00 ^{a}	95.59^{b}	20.81	1.87 ^{a}	0.782 ^{c}
T1 (70°C)	75.25 ^{a}	12.62 ^{a}	17.90 ^{a}	93.80 ^{a}	95.62 ^{a}	20.81	1.86^{a}	0.606 ^{a}
T2 (80°C)	75.68 ^{a}	12.06 ^{a}	17.88^{a}	98.00 ^{b}	95.63^{a}	19.42	3.21^{b}	0.576 ^{a}
CV	0.05	0.06	0.29	0.01	0.38		0.18	17.250
CD	1.16	0.71	0.34	1.74	0.29		0.19	0.043

SI = Solubility index W = Wettability

Lightness should be more for a good powder. The maximum mean value of L (lightness) was observed for treatment T2 (tray drying at 80°C), which was on par

with T1. So both treatments were considered as optimum in terms of lightness. Redness, (a* value) was found to be higher for T0. The increased value of redness indicated the non enzymatic browning caused by the prolonged drying time of 10 hours. The least a* value which was good, may be obtained in the case T2. T1 was on par with T2. So we can select either of the two treatments. Higher acid value was obtained for both the samples dried at 60 and 70°C. The pH value and total solids for T1 (70 °C) were found to be significantly different from other samples with a CD value of 0.191. So we can take T1 as the best treatment. Bulk density was found to be significant for T2 (80°C). But T1 was on par with T2. The solubility index and wetting time were found to be increased as the drying temperature increased to (T2) 80°C, which indicates that the powder prepared at 60°C, T0 was having high solubility and less wetting time i.e. having good reconstitution properties. But the T1 was also having more or less similar values for both these properties and the T0 require a prolonged drying time and non enzymatic browning had happened. Also the acid value in percentage of hydroxyl citric acid retained more in the case T1. So the best treatment is T1 (70°C). Considering all the quality parameters the optimum was T1 which was found to be significant at 1 per cent level and was used for further studies.

4.3.2 Vacuum tray drying

The samples were dried as a single layer with thickness of 5mm at the drying temperatures of 40, 45 and 50^0C at 100 mm/hg. For the optimisation of drying temperature, the effects of drying temperature on quality of the product were carried out. The different quality parameters analysed were shown below.

1. Moisture content
2. Colour value
3. Solubility index
4. Wettability
5. Total solids
6. Acid value and pH
7. Bulk density

4.3.2.1 Moisture content

Here also the drying time is shorter when the temperature is higher, drying time for 40, 45 and 50^0C were 16, 12 and 8 h respectively, which is explained by the increase in the drying rate. The drying curve is shown in fig 4.7 and the data listed in table A.3. This increase is due to the increased heat transfer potential between the air and the products, thus favouring the evaporation of water from the product (Handerson, 1974). The higher drying temperature usually resulted in faster drying time generating the powder with low moisture content. Such an influence of drying air temperature on the drying rate was noted in earlier researches by Wang *et al*., 2007, Figiel (2010), Therdthai and Zhou (2009), Togrul and Pehlivan (2003), Sacilik and Elicine, 2006, and Dimitrios *et al*. (2011). Moisture content with respect to drying time for V0 can be expressed as

Moisture content (% wb) = -6.1731x+100.4(R^2 = 0.90855) …… (4.2)

Where x is the drying time (h)

Considering the moisture content, V2 (dying at 50^0C) was found to be optimum.

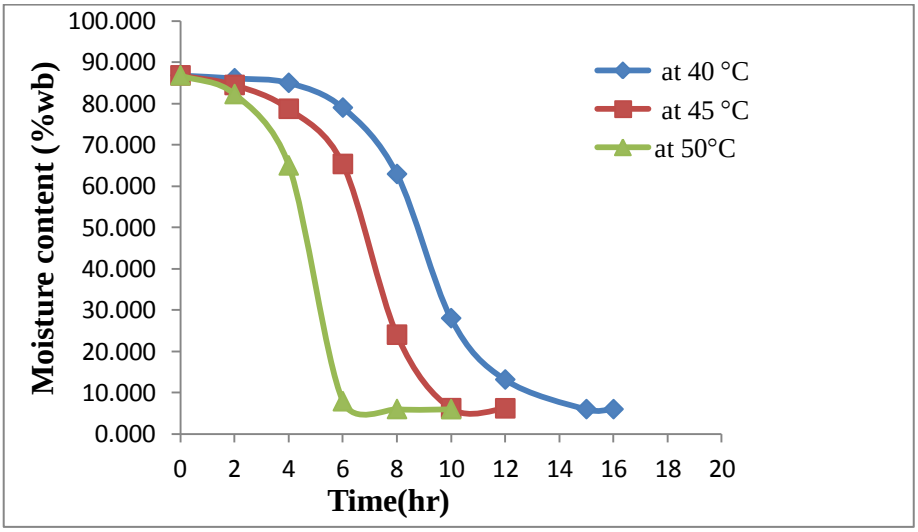


Fig.4.7 Drying characteristics of vacuum tray drying of *Garcinia cambogia* powder

4.3.2.2 Colour

For vacuum tray drying it was observed from fig 4.8 that the a* value "(redness) was more for vacuum tray dried sample dried at 40°C. This might be due

to the non enzymatic browning of the product in the presence of air due to prolonged drying time. Similar trend was reported by Mary *et al*. (2007).

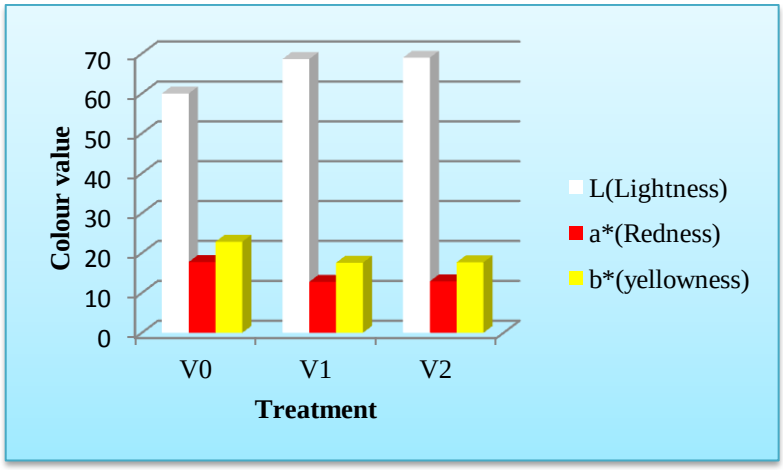


Fig. 4.8 Effect of temperature on colour value of vacuum tray dried *Garcinia cambogia* powder

Tabe 4.9 Colour value and drying time of vacuum tray dried *Garcinia cambogoia* powder

Treatment name	Drying time (h)	Colour value		
		L	a	b
V0(60°C)	16	68.00 [b]	13.55 [b]	17.37 [b]
V1(70°C)	12	68.63 [a]	12.78[a]	17.58 [a]
V2(80°C)	10	68.17 [a]	12.90[a]	17.68 [a]

4.3.2.3Solubility index

It was observed that for vacuum tray drying the solubility index varied between 0.8 to 1 ml. The solubility indices were 0.8, 0.85 and 1 for 40, 45 and 50°C respectively. This shows that water solubility index increased with increasing temperatures. The reason is at higher temperature, a hard surface layer is formed over the powder particles that prevent water from entering particles and therefore the percentage of insoluble solids is increased. The investigations carried out by Chauca *et al*. (2004), Sertwasana (2010), Rodriguez *et al*. (2005) and Mahendran (2010) shows similar results.

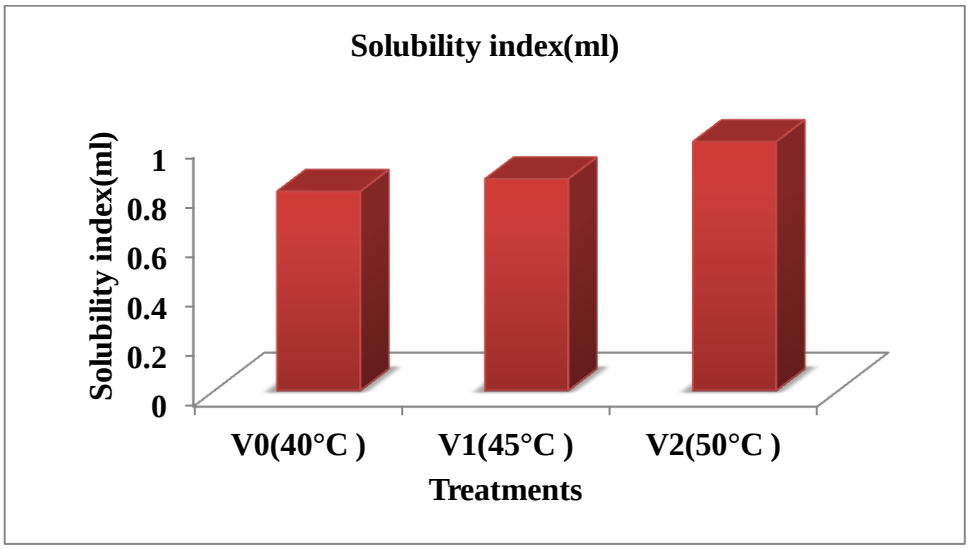


Fig. 4.9 Effect of temperature on solubility index of vacuum tray dried *Garcinia cambogia* powder

4.3.2.4 Wettability

The effect of temperature of the vacuum tray dryer on wetting time of the vacuum tray dried powder is presented in fig 4.10. The wetting time of the powder ranged between 102 to 112 s, 102, 104 and 112s for 40, 45 and 50^{o}C. The trend was similar to tray drying i.e. increasing the inlet air temperature results an increase in wetting time which results from the reduced product residual moisture content. The wetting time for other works have also showed similar findings (Bhandari *et al*. (1993) and Jumah *et al*. (2000). From statistical analysis table V2 (50°C) was found to be significantly different compared to V0 (40°C) and V1 (45°C). V1 was found to be on par with V0. So both V0 and V1 were found to be the best treatment with regard to wettability.

Table 4.10 ANOVA table for wetting time of vacuum tray dried powder

Sl.No.	Treatment	Wettability
1	V0	102.80 [a]
2	V1	104.40 [a]
3	V2	112.20 [b]
	CD	3.12

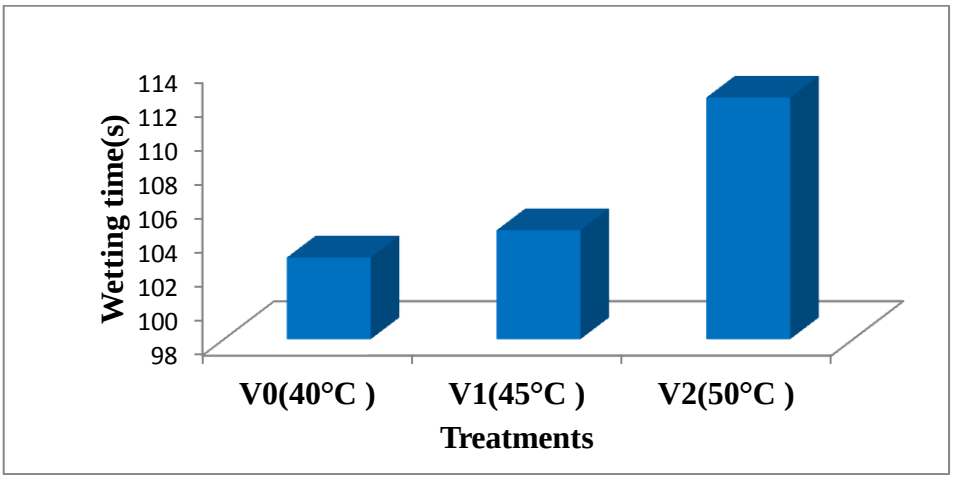


Fig. 4.10 Effect of temperature on wetting time of vacuum tray dried *Garcinia cambogia* powder

Considering the effect of quality parameters drying time, colour, solubility index and wettability, the best treatment is V1 (vacuum tray dried sample at 45°C).

4.3.2.5 Total solids

Similar to tray drying in the vacuum tray drying also total solid content increased, when temperature increased. Analogous results were also obtained by Menges and Ertekin (2006), Lahsani *et al*. (2004) and Lee and Kim (2009).

Statistical analysis was done and the results are listed in table 4.11.

Table 4.11 Effect of temperature on total solids of vacuum tray dried powder

Treatment	Total Solids
V0	94.002 [b]
V1	94.67 [a]
V2	94.802 [a]
CD	0.256

The Analysis of variance (ANOVA) associated with Duncan's simple completely randomized design were implemented. From the table 4.11 it was observed that the treatment V2 was found to have the maximum mean value for total solids (94.802) and V1 (45°C) was on par with V2 with a CD value of 0.256. So both V1 and V2 were found to be optimum.

4.3.2.6 Acid value and pH

It was observed from the fig 4.12 and 4.13 that similar to tray drying for vacuum drying also there was an increase in total titratable acidity and a decrease in pH. The acid value (% hydroxyl citric acid) was found to be decreased when the temperature increased. The pH has an opposite effect. The reason may be that at increased in temperature, lactonization of hydroxyl citric acid happen. Acid value for 40, 45 and 50°C were 22.12, 22.12 and 20.8 respectively and pH values of 40, 45 and 50°C were 1.758, 1.756 and 1.872. Similar results were presented by Thankitsunthorn *et al*. (2009) and Hassan and Mehmet (2012).

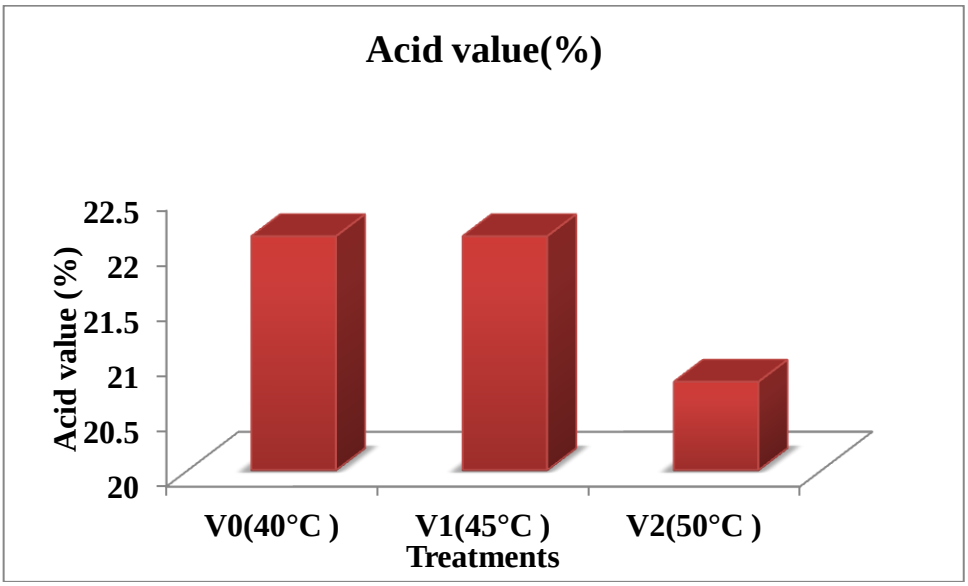


Fig. 4.11 Effect of temperature on acid value of Vacuum tray dried *Garcinia cambogia* powder

As the samples V0 and V1 having an acid value 22.12 % which retained maximum acid value. These two treatments were found to be the best treatment in terms of acid value.

Table 4.12 ANOVA table for pH of vacuum tray dried powder

Treatment	pH
V0	1.758[a]
V1	1.756[a]
V2	1.872[b]
CD	0.056

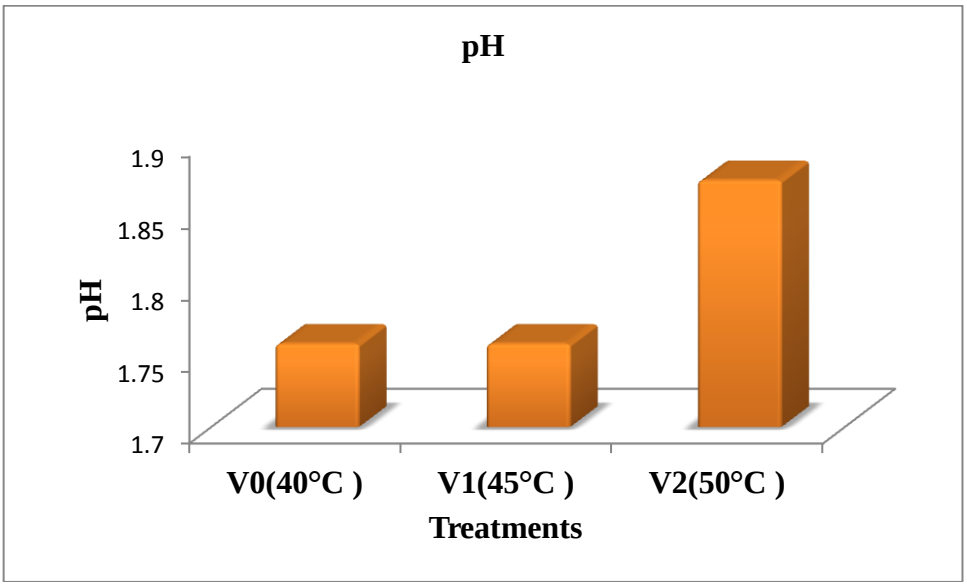


Fig. 4.12 Effect of temperature on pH of Vacuum tray dried *Garcinia cambogia* powder

Statistical analysis was done using SPSS 17.0 software and the data were shown in table A.5 and A.6 of appendix A. It is revealed from the table 4.13 that there was a significant effect on pH content of the sample during drying. Sample dried at 40°C (V0) were found to be significant at 1 per cent level. But V1 was on par with V0**.** So both V0 and V1 were found to be optimum in terms of pH**.**

4.3.2.7 Bulk density

As in the case of tray drying, for vacuum tray drying also the bulk density of *Garcinia cambogia* powders was significantly affected by the drying temperature, with decreasing density observed with increased drying temperature. The initial bulk densities for 40, 45 and 50°C were 0.8, 0.7148 and 0.6348 respectively. This might be due to the fact that a product of higher moisture content would tend to have a higher bulking weight caused by the presence of water which is considerably denser than the dry solid. These results closely agree Jaya and Das (2004), Phoungchandang and Sertwasana (2010), Sertwasana (2010) and Al-asheh (2003).

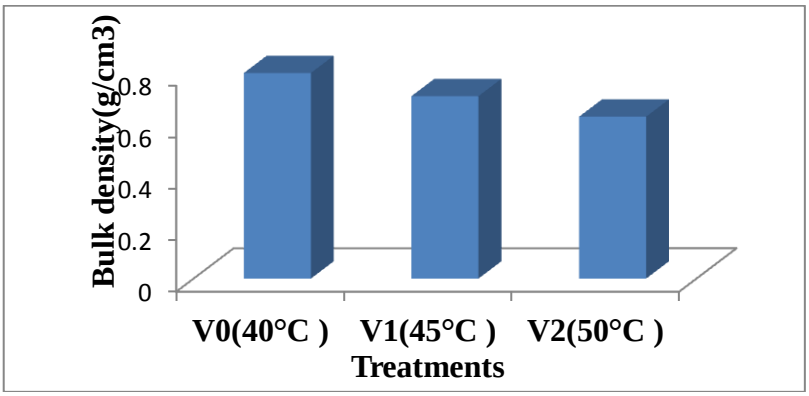


Fig. 4.13 Effect of temperature on bulk density of Vacuum tray dried *Garcinia cambogia* powder

ANOVA (Table 4.13) for the effect of temperature on bulk density revealed that temperature significantly influenced the bulk density values (1% significant level). The treatment V2 (50°C**)** was having an optimum bulk density and V1 (45°C) were on par with V2 (50°C) and both the treatments V1 and V2 were taken as the best treatment.

Table 4.13 ANOVA table for bulk density of vacuum tray dried powder

Treatment	Bulk Density (g/cm^3)
V0	0.800 [c]
V1	0.7148 [b]
V2	0.635 [a]

Table 4.14 Effect of vacuum tray drying temperature on quality parameters of *Garcinia cambogia* powder

T	Colour value			SI (ml)	W (s)	Total solids	Acid value (%)	pH	Bulk density (g/cm^3)
	L	a*	b*						
V0 (40°C)	68.000 [b]	13.55 [b]	17.37 [b]	0.80	102.80 [a]	94.00 [b]	22.1	1.76 [a]	0.800 [c]
V1 (45°C)	68.640 [a]	12.78 [a]	17.58 [a]	0.85	104.40 [a]	94.67 [a]	22.1	1.75 [a]	0.715 [b]
V2 (50°C)	68.170 [a]	12.90 [a]	17.68 [a]	1.00	112.20 [b]	94.80 [a]	20.8	1.87 [b]	0.635 [a]
CV	0.959	0.51	0.01		0.005	0.821			0.000
CD	0.402	0.25	0.57		3.117	0.242		0.05	0.000

T = Treatments SI = Solubility index

4.3.2.8 Optimisation of vacuum tray drying parameters

Effects of temperature on different treatments were analysed for Optimisation. The results obtained were statistically analysed. The analysis of variance using Dunncan's simple completely randomized design was implemented. The results of statistical analysis were listed in the table A.5 and A.6 of appendix A. It is inferred from the table 4.14 that all the quality parameters had a significant ($p<0.05$) effect on temperature.

Lightness value which should be more for a good powder was observed maximum value for treatment V2 (vacuum tray drying at 50°C), which was on par with V1. So both treatments were considered as optimum in terms of lightness. Redness, (a* value) was found to be higher for V0. The increased value of redness indicated the non enzymatic browning. The redness (a*) and yellowness (b*) value should be less, which was obtained in the case V2. V1 was on par with V2. So either of the two treatments can be selacted. Higher acid value was obtained for both the samples dried at 40 and 45°C. The pH value for V0 (40°C) were found to be significant. But V1 (at 45°C) were found to be on par with V0. So we can also select V1 as the best treatment. Bulk density was found to be significant for V2 (at 50°C). But V1 was on par with V2. The solubility index and wettability were found to be decreased as the drying temperature increased to V2 (50°C), which indicates that the powder prepared at 40°C, V0 having good reconstitution properties i.e. more solubility and less wetting time for powder. But the V1 was also having more or less similar values for both these properties and the V0 require a prolonged drying time and non enzymatic browning had happened. Also the acid value in percentage of hydroxyl citric acid retained more in the case V1. So the best treatment is V1 (45°C). Considering all the quality parameters the optimum was V1 (45°C) which was found to be significant at 1 per cent level and was used for further studies.

4.3.3 Spray drying

In spray drying we used two atomizer speeds 17,000 and 22000 rpm, two temperatures 175 and 180°C and three feed rates 5, 5.5 and 6 l/h. Different treatments used for study were shown in fig 4.14.

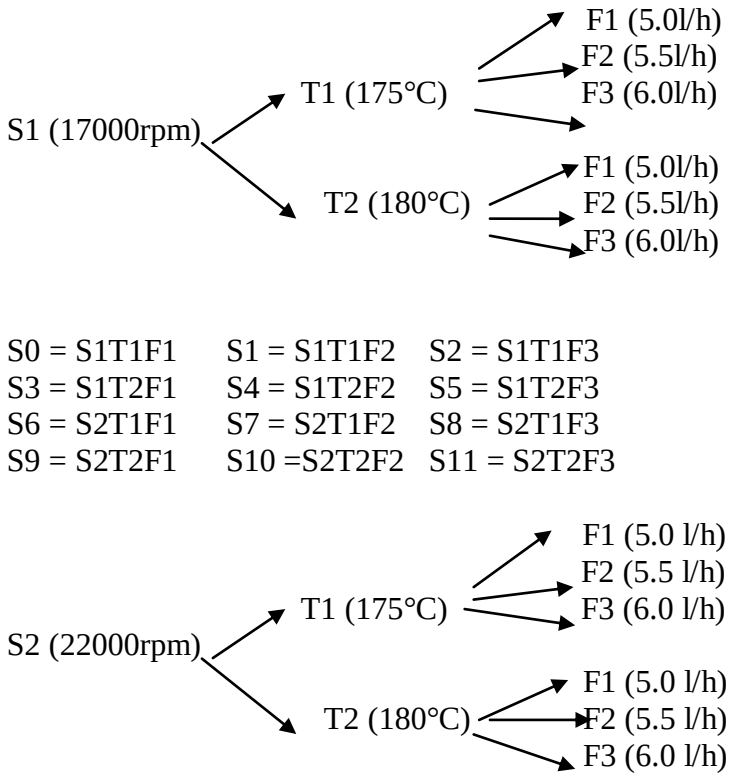


Fig 4.14 Treatments of spray drying

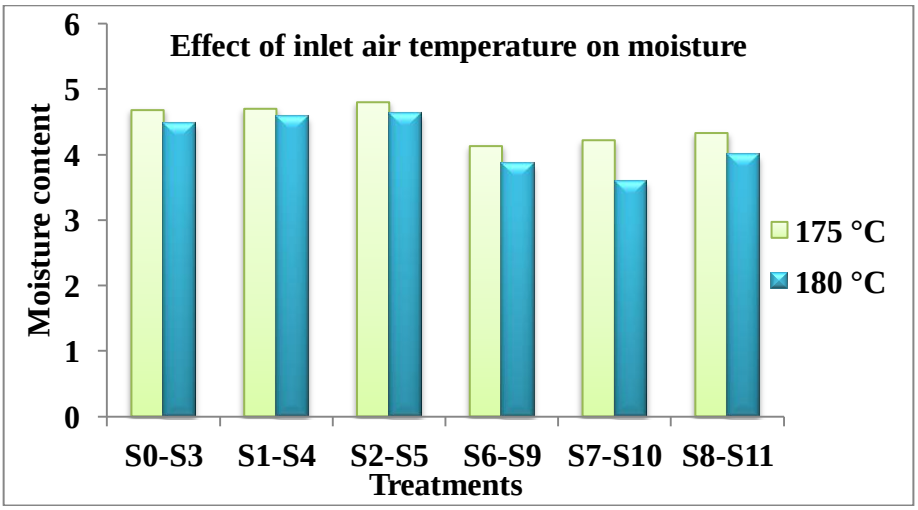
To find out the best treatment, different quality parameters and their effects on drying conditions were studied. The quality parameters tested are shown below.

1. Moisture content
2. Colour value
3. Total solids
4. Acid value and pH
5. Bulk density
6. Solubility index
7. Wettability

4.3.3.1 Effect of spray drying parameters on moisture content

The effect of spray drying parameters on moisture content of *Garcinia cambogia* powder is shown in fig 4.15 to 4.17.

From the fig 4.15 it can be observed that there is a gradual decrease in moisture content as the inlet air temperature increased from 175 to 180°C at constant atomizer speed and feed flow rate. This is because at higher inlet air temperature, the rate of heat transfer to the particle is greater and provides higher driving force for evaporation. The result was consistent with other findings of Papadakis *et al*. (2006), Yadollahinia *et al*. (2009) Goula and Amorpoulose (2005) and Goula *et al*. (2004). Based on the results it is inferred that spray drying of the product keeping the air-inlet temperature at 180°C resulted in good quality powder without any objectionable defects in terms of moisture content parameter.



S0 = S1T1F1 S1 = S1T1F2 S2 = S1T1F3
S3 = S1T2F1 S4 = S1T2F2 S5 = S1T2F3
S6 = S2T1F1 S7 = S2T1F2 S8 = S2T1F3
S9 = S2T2F1 S10 =S2T2F2 S11 = S2T2F3

Fig. 4.15 Effect of inlet air temperature on moisture content of spray dried *Garcinia cambogia* powder

.From fig 4.16 it can be observed that at constant feed flow rate and inlet air temperature when the atomizer speed increases from 17000 to 22000 rpm, there is a reductioin in moisture content. The reason is that at higher atomizer speed, smaller droplets are produced and more moisture is evaporated resulting from the increased contact surface. The results are in agreement with the research findings Knipschildt

(1986), Sudheer Babu (2009) and Ganesan (1996). Uniform drying and maximum % retention was observed at 22000 rpm and was considered as optimum.

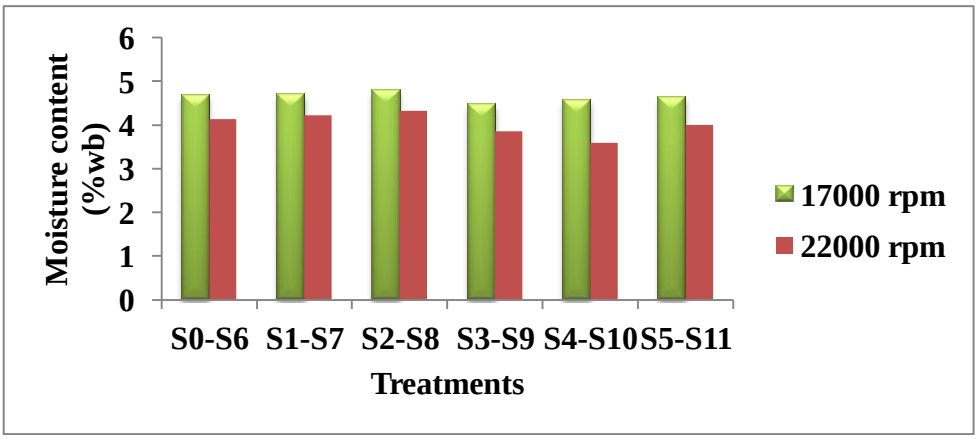
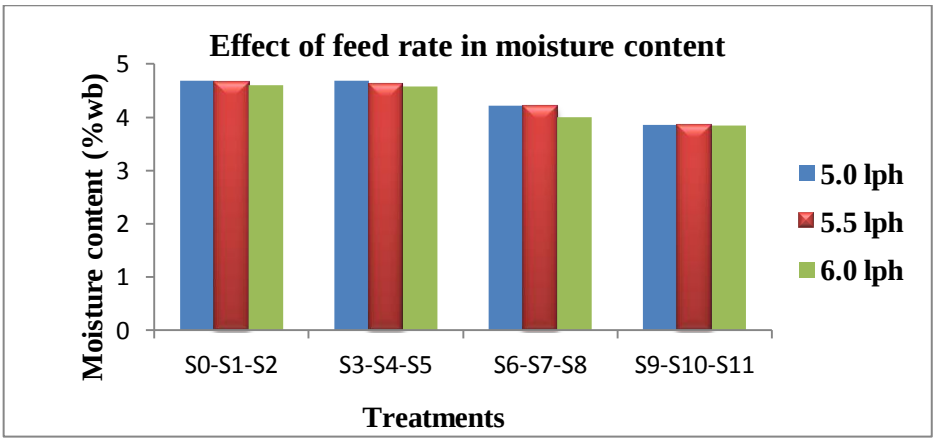


Fig. 4.16 Effect of atomizer speed on moisture content of spray dried *Garcinia cambogia* powder

From fig 4.17 it was observed that as the feed flow rate increased from 5 to 6l/h at constant atomizer speed and inlet air temperature, moisture content increased. This may be due to the production of larger droplets containing more moisture. Similar results were observed for both 17000 and 22000 rpm atomizer speed. Analogous results were also observed by Jumah *et al*. (2000), Patel *et al*. (2009) and Masters (1991). So the *Garcinia cambogia* powder prepared at 22000 rpm at 180°C and a feed rate of 5.5 l/h was found to be good in terms of moisture content parameter.



S0 = S1T1F1 S1 = S1T1F2 S2 = S1T1F3
S3 = S1T2F1 S4 = S1T2F2 S5 = S1T2F3
S6 = S2T1F1 S7 = S2T1F2 S8 = S2T1F3
S9 = S2T2F1 S10 =S2T2F2 S11 = S2T2F3

Fig. 4.17 Effect of feed rate on moisture content of spray dried *Garcinia cambogia* powder

The results for moisture content were statistically analysed and listed in table 4.15 and table B.1 of appendix B. It is a factorial completely randomized design and analysis was done using M stat software. The differential response over differential atomizer speed temperature and feed flow rate were all are significant at 1% level except feed flow rate temperature interaction.

Table 4.15 Effect of spray drying on moisture content

Sl.No	Treatment name	Speed of the atomizer(rpm)	Temperature (°C)	Feed rate (l/h)	Table of means for Moisture content (%wb)
1	S0 (S1T1F1)	17000	175	5.0	4.68
2	S1 (S1T1F2)	17000	175	5.5	4.703
3	S2 (S1T1F3)	17000	175	6.0	4.803
4	S3 (S1T2F1)	17000	180	5.0	4.477
5	S4 (S1T2F2)	17000	180	5.5	4.577
6	S5 (S1T2F3)	17000	180	6.0	4.627
7	S6 (S2T1F1)	22000	175	5.0	4.133[c]
8	S7 (S2T1F2)	22000	175	5.5	4.217
9	S8 (S2T1F3)	22000	175	6.0	3.863
10	S9 (S2T2F1)	22000	180	5.0	3.863[a]
11	S10 (S2T2F2)	22000	180	5.5	3.593[a]
12	S11 (S2T2F3)	22000	180	6.0	4.000[b]
	CD				0.131

When all the flow factors atomizer speed, temperature and feed flow rate were taken into consideration the least mean value of moisture content 3.593 (%wb) noted at atomizer speed 22000rpm, temperature 180°C and feed flow rate 5.5 l/h was found to be significantly different (CD = 0.131) from all other treatments and grouped as level 'a'. So S10 (S2T2F2) was the best treatment in terms of moisture content.

4.3.3.2 Effect of spray drying parameters on Colour of Garcinia cambogia powder

Effect of spray drying parameters of *Garcinia cambogia* powder is presented in Table 4.16. from the table 4.16 it was observed that at constant atomizer speed and feed flow rate , when increasing the inlet air temperature from 175 to 180°C the lightness value decreased and redness (+a*) and yellowness(+b*) value increased. . This may be due to enzymatic browning or due to darkening of the product. This implied the colour of the powder has become darker a higher inlet air temperature. Similar results were also observed by Quek *et al*. (2007).

From the table 4.16 it was observed that when the atomizer speed increased from 17000 to 22000 rpm at constant atomizer speed and feed flow rate, the lightness decreased and +a* and +b* value increased. The darker colour may be due to the higher water removal occurring when higher inlet air temperatures were used, leading to concentration of pigments. Similar results were also observed by Phoungchandang and Sertwasan (2010).

The experiments were conducted in 3 feed flow rates 5.0, 5.5 and 6.0 l/h and the table indicates that there is decrease in colour value L when feed flow rate increased from 5.0 to 6.0 l/h and a decrease in +a* and +b*. This may be due to enzymatic browning or due to darkening of the product.

Results were analysed statistically. Analysis of variance revealed that there is significant difference in atomizer speed, temperature and feed flow rate as also all two factor interaction. So when considering the differential response over differential atomizer speed temperature and feed flow rate on colour L, a* and b* values S0 (S1T1F1) was the best treatment having CD values 0.277, 0.153 and 0.460 respectively.

Table 4.16 Effect of spray drying on colour value of *Garcinia cambogia* powder

Sl. No	Drying condition				Table of means of colour		
	Treatment	S (rpm)	T (°C)	F (l/h)	L	a*	b*
1	S0 (S1T1F1)	17000	175	5.0	94.42[a]	3.94[a]	20.07[a]
2	S1 (S1T1F2)	17000	175	5.5	94.39[a]	4.20[b]	20.56[b]
3	S2 (S1T1F3)	17000	175	6.0	93.13	4.67	20.98[c]
4	S3 (S1T2F1)	17000	180	5.0	93.90	4.43[b]	22.04
5	S4 (S1T2F2)	17000	180	5.5	93.70	4.62	22.77
6	S5 (S1T2F3)	17000	180	6.0	92.90	4.77	23.04
7	S6 (S2T1F1)	22000	175	5.0	94.36[a]	4.35[b]	20.57[b]
8	S7 (S2T1F2)	22000	175	5.5	94.32[a]	4.45[c]	20.98[c]
9	S8 (S2T1F3)	22000	175	6.0	93.10[a]	4.56	21.00[c]
10	S9 (S2T2F1)	22000	180	5.0	93.89	4.57	22.20
11	S10 (S2T2F2)	22000	180	5.5	93.70	4.72	23.02
12	S11 (S2T2F3)	22000	180	6.0	93.40	4.78	23.34
	CD				0.28	0.15	0.46

T = Temperature S = Atomizer speed F= Feed flow rate

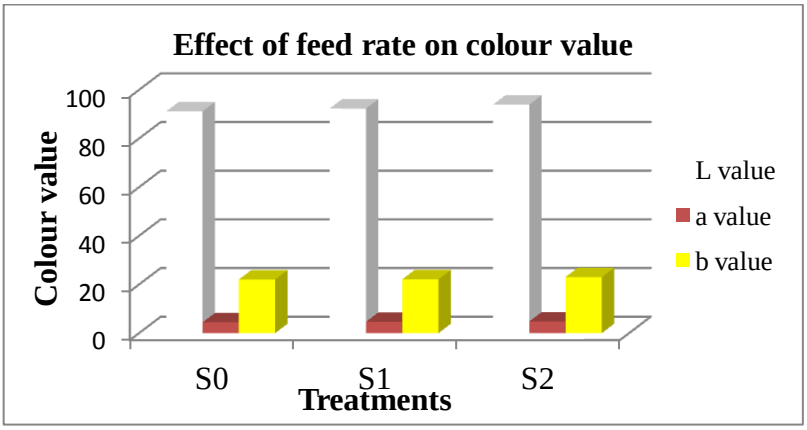
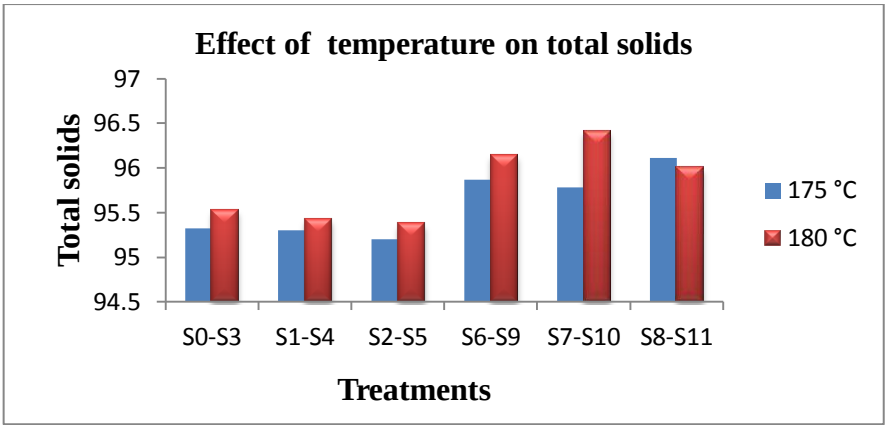


Fig. 4.18 Effect of feed rate on colour value of spray dried *Garcinia cambogia* powder

4.3.3.3 Effect of spray drying parameters on Total solids

The effect of spray drying parameters on total solid are presented in fig 4.19 to 4.21.

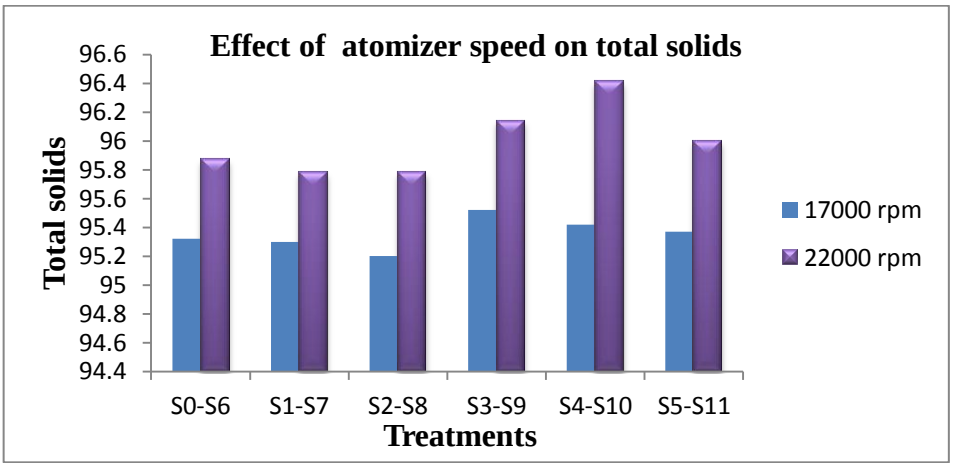
From fig 4.19 it was observed that at constant atomizer speed and feed flow rate, increasing the inlet air temperature increases the total solids. This is due to the fact that as the temperature increased, the heat transfer potential between the air and the products increased; favouring the evaporation of water from the product (Handerson, 1974) and total solids get increased. Similar results were also obtained by Singh and Patel (2003), Schultz *et al*. (2007), Awang *et al*. (2011) and Menges and Ertekin (2006).



S0 = S1T1F1 S1 = S1T1F2 S2 = S1T1F3
S3 = S1T2F1 S4 = S1T2F2 S5 = S1T2F3
S6 = S2T1F1 S7 = S2T1F2 S8 = S2T1F3
S9 = S2T2F1 S10 =S2T2F2 S11 = S2T2F3

Fig. 4.19 Effect of temperature on total solids of spray dried *Garcinia cambogia* powder

From the fig 4.20 it was observed that at constant inlet air temperature and feed flow rate, increasing the atomizer speed, total solid content is increased. This is due to the fact that at higher atomizer speed, smaller droplets are produced and more moisture is evaporated resulting from the increased contact surface resulting increase in total solids. This is also verified by the findings of Knipschildt (1986) and Brennan *et al.* (2007).



S0 = S1T1F1 S1 = S1T1F2 S2 = S1T1F3
S3 = S1T2F1 S4 = S1T2F2 S5 = S1T2F3
S6 = S2T1F1 S7 = S2T1F2 S8 = S2T1F3
S9 = S2T2F1 S10 =S2T2F2 S11 = S2T2F3

Fig. 4.20 Effect of atomizer speed on total solids of spray dried *Garcinia cambogia* powder

From fig 4.21 it was observed that increasing the feed flow rate from 5 to 6 l/h, at constant inlet air temperature and atomizer speed, results a decrease in total solids. This is due to the increase in moisture content. Similar results were also reported by Jumah, *et al.* (2000), Kristina *et al*. (2002), Masters (1991), Genc *et al* (2009), Chegini and Ghobadian (2008) and Goula *et al*. (2004).

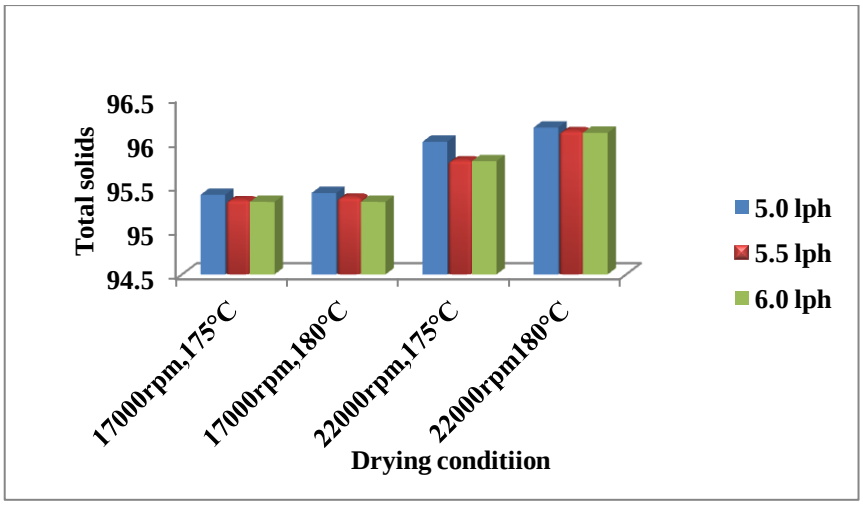


Fig. 4.21 Effect of feed flow rate on total solids of spray dried *Garcinia cambogia* powder

The significance of the effects of atomizer speed, inlet air temperature and feed flow rate on total solids of the *Garcinia cambogia* powder was analysed and

the analysis of variance is furnished in table 4.17 and table B.9 of appendix B. the results indicated that the variables and their interactions for all the treatments were found to be significant at 1 per cent level. Among the different treatments, the effect of single factors atomizer speed S2 (22000 rpm) having a mean value of 95.811, spray dryer inlet air temperature T2 (180°C) having a mean value of 95.811 and feed flow rate F2 (5.5 l/h) having a mean value of 95.561, two factor interactions S2T2, T2F2 and S2F2 and three factor interaction S10 (S2T2F2) having the maximum mean value of 96.407 (CD value = 0.131) was found to be significant and recorded as group 'a'.

Table 4.17 Effect of spray drying on total solids of *Garcinia cambogia* powder

Sl.No	Treatment name	Drying condition			Means of total solids
		Speed of the atomizer(rpm)	Temperature (°C)	Feed rate (l/h)	
1	S0 (S1T1F1)	17000	175	5.000	95.320
2	S1 (S1T1F2)	17000	175	5.500	95.297
3	S2 (S1T1F3)	17000	175	6.000	95.197
4	S3 (S1T2F1)	17000	180	5.000	95.523
5	S4 (S1T2F2)	17000	180	5.500	95.423
6	S5 (S1T2F3)	17000	180	6.000	95.373
7	S6 (S2T1F1)	22000	175	5.000	95.867[c]
8	S7 (S2T1F2)	22000	175	5.500	95.783[c]
9	S8 (S2T1F3)	22000	175	6.000	95.673
10	S9 (S2T2F1)	22000	180	5.000	96.137[b]
11	S10 (S2T2F2)	22000	180	5.500	96.407[a]
12	S11 (S2T2F3)	22000	180	6.000	96.000
	CD				0.131

4.3.3.4. Effect of spray drying parameters on Acid value and pH

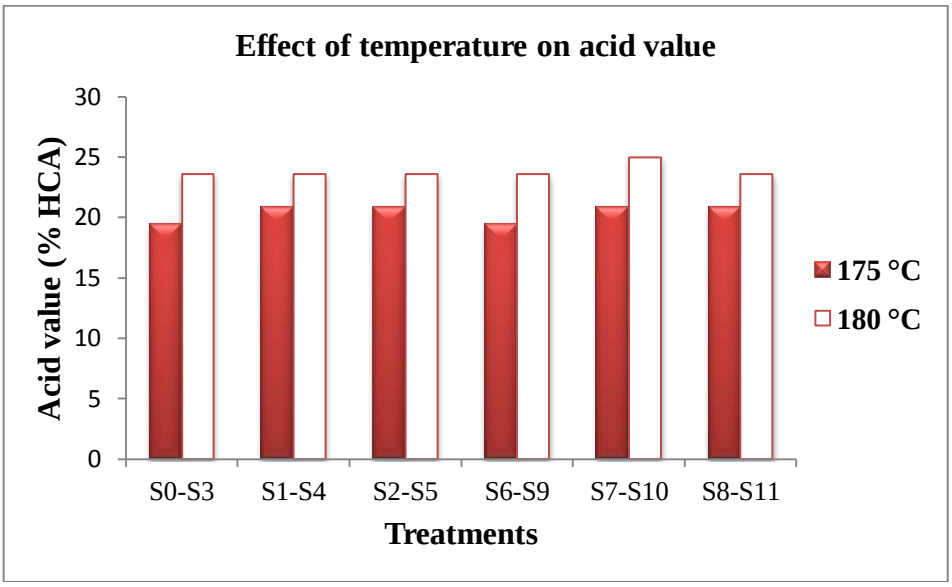
Effect of spray drying parameters on acid value and pH of Garcinia cambogia powder are shown in table 4.18.

In spray drying increasing the inlet air temperature cause an increase in acid value and a decrease in pH. It is inferred from the table 4.18 that for all the treatments at constant atomizer speed and feed flow rate, increasing the inlet air

temperature cause an increase in acid value and a decrease in pH. Also at constant inlet air temperature increasing the atomizer speed also results in an increased acid value and reduced pH. The reason is that the sample moisture content reduced and the product became more concentrated. Similar results were also observed by Rodriguez *et al*. (2005). At constant atomizer speed and inlet air temperature, when the feed rate increased from 5 to 6 l/h proper trend was not observed in acid value. These may be due to non uniform drying of the samples. So in terms of acid value S10 (S2T2F2) at an atomizer seed 22000 rpm, inlet air temperature of 180°C and feed flow rate 5.5 l/h were found to be the best.

Table 4.18 Effect of spray drying parameters on acid value and pH

Treatment	Speed of the atomizer(rpm)	Temperature (°C)	Feed rate (l/h)	Acid value (%)	Means of pH
S0	17000	175	5.0	19.42	1.860
S1	17000	175	5.5	20.81	1.813[c]
S2	17000	175	6.0	20.81	1.823[c]
S3	17000	180	5.0	23.59	1.560[a]
S4	17000	180	5.5	23.59	1.610[b]
S5	17000	180	6.0	23.59	1.713[b]
S6	22000	175	5.0	19.42	1.820
S7	22000	175	5.5	20.81	1.787[b]
S8	22000	175	6.0	20.81	1.817
S9	22000	180	5.0	23.59	1.560[a]
S10	22000	180	5.5	24.97	1.600[a]
S11	22000	180	6.0	23.59	1.717[b]
	CD value				0.054



S0 = S1T1F1 S1 = S1T1F2 S2 = S1T1F3
S3 = S1T2F1 S4 = S1T2F2 S5 = S1T2F3
S6 = S2T1F1 S7 = S2T1F2 S8 = S2T1F3
S9 = S2T2F1 S10 =S2T2F2 S11 = S2T2F3

Fig. 4.22 Effect of temperature on acid value of spray dried *Garcinia cambogia* powder

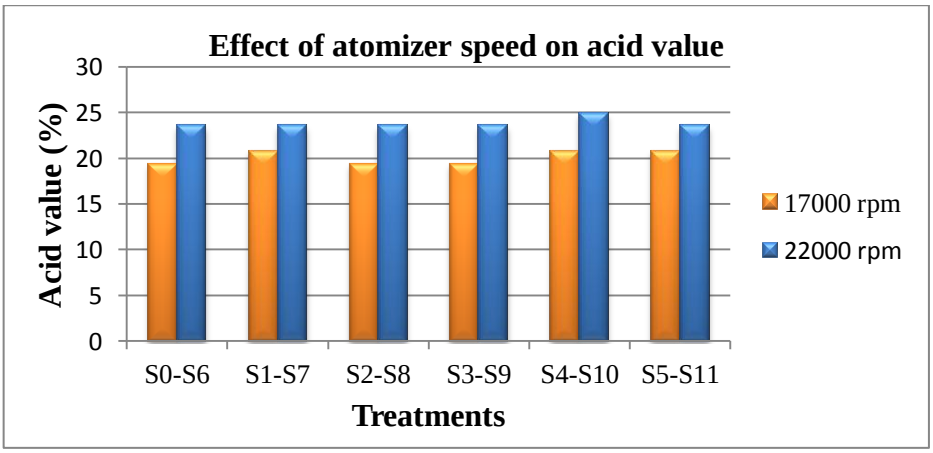
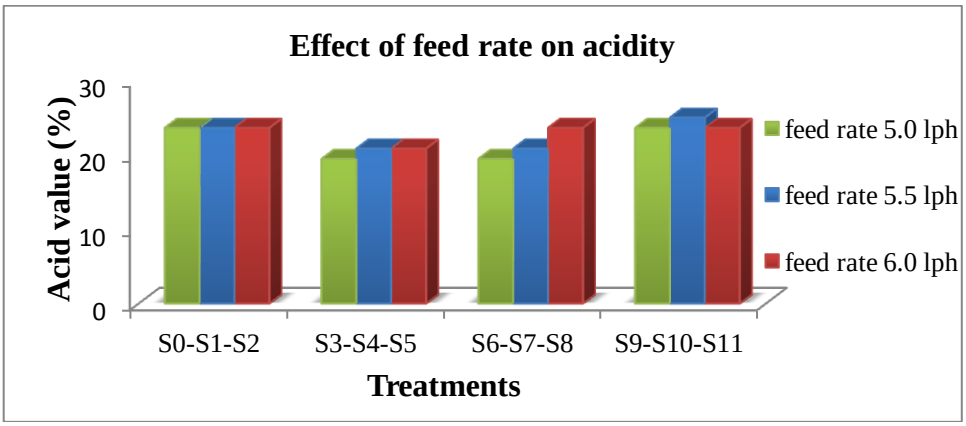


Fig. 4.23 Effect of temperature on atomizer speed of spray dried *Garcinia cambogia* powder



S0 = S1T1F1 S1 = S1T1F2 S2 = S1T1F3
S3 = S1T2F1 S4 = S1T2F2 S5 = S1T2F3
S6 = S2T1F1 S7 = S2T1F2 S8 = S2T1F3
S9 = S2T2F1 S10 =S2T2F2 S11 = S2T2F3

Fig. 4.24 Effect of feed rate on acid value of spray dried *Garcinia cambogia* powder

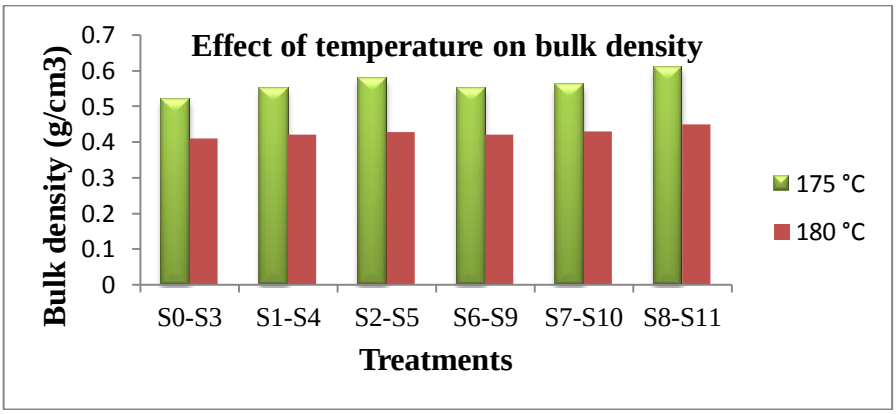
The ANOVA analysis for the effect of pH on spray drying are shown in table 4.18 and table B.9 of appendix B. From the table, it was found observed that the pH was significantly influenced by all the independent variables studied and the interactions between the independent variables were also found to be significant. Also, it could be observed that the effects of single factors, atomizer speed 22000 rpm (S2) having a mean value for pH of 1.736, inlet air temperature of 180°C (T2) and feed flow rate 5.5 l/h (F2), two factor interactions S2T2, T2F2 and S2F2 and three factor interactions S2T2F2 were found to be significant (CD value = 0.054) at 1 per cent level and grouped as 'a', which is the best treatment for *Garcinia cambogia* powder preparation.

When the differential response over differential atomizer speed, temperature and feed flow rate were taken into consideration, S9 which is having the minimum mean value was considered as best. But from table 4.15 it was found that S10 and S3 were on par with S9. So we can select these S3, S9 and S10 as best with regard to pH (CD value = 0.054).

4.3.3.5. Effect of spray drying parameters on Bulk density

Effect of spray drying parameters on bulk density of *Garcinia cambogia* powder are shown from fig 4.25 to 4.27.

As it can be drawn from fig 4.25 increased inlet air temperature at constant atomizer speed and feed flow rate cause a reduction in bulk density as evaporation rates are faster and products dry to a more porous fragmented structure. Walton (2000) reported that increasing the drying inlet air temperature generally produces a decrease in bulk density, and there is greater tendency for the particles to hollow. The effect can also be referred to the fact that a product of lower moisture content would tend to have a lesser bulk weight caused by the decrease in water content which is considerably less than the dry solid. Similar results were reported by Masters (2004), Chegini *et al*. (2008), Grabowski *et al*. (2008), Dolisky *et al*. (2000) and Walton (2000). Also when the bulk density increases the stickiness of the powder increases and the quality reduced (Goula and Adamopoulos, 2008: Shrestha *et al*., 2007), as particles stick together leave less interspaces between them and consequently results in a bulker volume. Hence the inlet air temperature of 180°C found to be best in terms of bulk density values.



S0 = S1T1F1 S1 = S1T1F2 S2 = S1T1F3
S3 = S1T2F1 S4 = S1T2F2 S5 = S1T2F3
S6 = S2T1F1 S7 = S2T1F2 S8 = S2T1F3
S9 = S2T2F1 S10 =S2T2F2 S11 = S2T2F3

Fig. 4.25 Effect of temperature on bulk density of spray dried *Garcinia cambogia* powder

From the fig 4.26 it can be observed that at constant inlet air temperature and feed flow rate, increasing the atomizer speed reduces the bulk density. The reason is

that increasing the atomizer speed results in reduction in droplet size and as this small droplet are spread on a larger surface, bulk density is reduced. Similar results were also obtained by Greenwald and King (1981), Francisconi (2003), Abadio *et al*. (2004) and Hassan and Mehmet (2012).

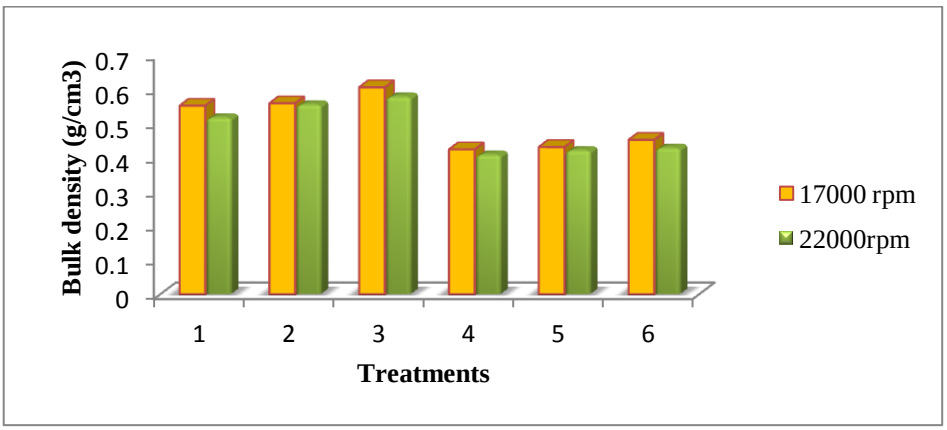


Fig. 4.26 Effect of atomizer speed on bulk density of spray dried *Garcinia cambogia* powder

From the figure 4.27 it was observed that at constant inlet air temperature and atomizer speed, increasing the feed flow rate causes an increase in bulk density. This may be due to the increase in residual moisture content (water density was higher due to dry solid density). Similar results were also observed by Masters (1991), Athanasia *et al*. (2008) and Al-kahtani *et al*. (1990).

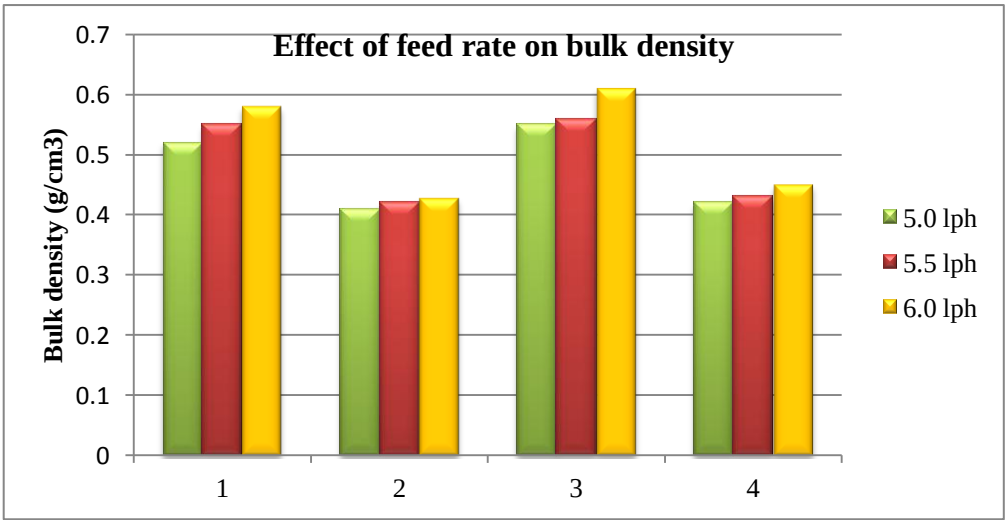


Fig. 4.27 Effect of feed rate on bulk density of spray dried *Garcinia cambogia* powder

Table 4.19 Effect of spray drying parameters on bulk density of *Garcinia cambogia* powder

Sl. No	Treatment name	Drying condition			Means of Bulk density (g/cm^3)
		Speed of the atomizer (rpm)	Temperature (°C)	Feed rate (l/h)	
1	S0 (S1T1F1)	17000	175	5.0	0.552
2	S1 (S1T1F2)	17000	175	5.5	0.555
3	S2 (S1T1F3)	17000	175	6.0	0.578
4	S3 (S1T2F1)	17000	180	5.0	0.517^{c}
5	S4 (S1T2F2)	17000	180	5.5	0.559
6	S5 (S1T2F3)	17000	180	6.0	0.606
7	S6 (S2T1F1)	22000	175	5.0	0.420^{a}
8	S7 (S2T1F2)	22000	175	5.5	0.421^{a}
9	S8 (S2T1F3)	22000	175	6.0	0.428^{a}
10	S9 (S2T2F1)	22000	180	5.0	0.408^{a}
11	S10 (S2T2F2)	22000	180	5.5	0.412^{a}
12	S11 (S2T2F3)	22000	180	6.0	0.452^{b}
	CD				0.022

The significance of the effect of atomizer speed, inlet air temperature and feed rate on bulk density of the powder was statistically analysed and the Analysis of variance is furnished in table B.4 and B.9 of appendix B. It was observed that when speed alone was taken into consideration bulk density of 0.485 g/cm^3 was noted in 17000 rpm relative to 0.504 in 22000 rpm and was found to be significantly different. Bulk density of 0.427 was noted in 180°C relative to 0.561 in 170°C, when temperature alone was considered and was found to be significantly different (CD value=0.01). The minimum mean value for feed rate was found for 5.0 l/h (CD value=0.011). But feed rate of 5.5 l/h was on par with 5.0 l/h. So we can take either of these as best. Atomizer speed-temperature, best combination was bulk density of 0.463 at 17000 rpm and 170°C and was found to be significant. Temperature-feed flow rate was found to be best at bulk density of 0.416 at 180°C and 5 l/h followed by bulk density of 0.426 at 180°C and 5.5 l/h (CD = 0.0384).

When three factor interactions were taken into consideration, bulk density which should be least for better powder, observed minimum mean value (0.412) for S10 (S2T2F2). Hence S10 (S2T2F2) i.e. having a 22000rpm speed 180 and 5.5 l/h was taken as the best treatment which was significantly different from other treatments (CD value = 0.022).

4.3.3.6. Effect of spray drying parameters on solubility index of Garcinia cambogia powder

Solubility index value should be less for a good quality powder i.e. the powder is more soluble. Effect of spray drying parameters on solubility index of *Garcinia cambogia* powder was shown in table 4.20.

From the table 4.20 it was observed that for spray drying the value of solubility index varied between <0.1 to 0.3 ml. This table show that water solubility index increased with increasing inlet air temperature, at constant atomizer speed and feed flow rate. The reason is that, increasing the inlet air temperature increases the drying rate and as a result, the moisture content of the powder is reduced, which also increases the insoluble solid (Knipschildt, 1986; Jumah *et al*., .2000; Kristina et *al*., 2002). At higher temperature, a hard surface layer is formed over the powder particles that prevent water from entering particles and therefore the percentage of insoluble solids is increased. The investigations carried out by Walton (2000) show a similar conclusion.

From the table 4.20 it was also observed that increasing the atomizer speed at constant inlet air temperature and feed rate the insoluble solid is increased. Higher atomizer speed resulted in smaller particle size and quicker drying due to the larger surface area, and consequently prevents the ‘‘skinning’’ over of the droplets. Knispchildt (1986) concluded that increasing the atomizer speed, the insoluble solid is reduced and as a result, the solubility of the powder is improved. In our study all the samples dried at 22000 rpm was having the least solubility index value of less than 0.1 i.e. the solubility was better for these powders. Doulglas (1992) observed the same results. So the product prepared at 22000 rpm was found to be the best.

Increasing the feed flow rate reduces the percentage of insoluble solids, because of the higher droplet moisture content and thinned dried layer on the

powder particles. Similar results were also observed for Greenwald and King (1981) and Jumah *et al*. (2000).

Table 4.20 Effect of spray drying parameters on solubility index of *Garcinia cambogia* powder

Treatment name	Speed of the atomizer(rpm)	Temperature (°C)	Feed rate (l/h)	Solubility index (ml)
S0	17000	175	5.0	0.2
S1	17000	175	5.5	0.1
S2	17000	175	6.0	<0.1
S3	17000	180	5.0	0.3
S4	17000	180	5.5	0.2
S5	17000	180	6.0	0.1
S6	22000	175	5.0	<0.1
S7	22000	175	5.5	<0.1
S8	22000	175	6.0	<0.1
S9	22000	180	5.0	<0.1
S10	22000	180	5.5	<0.1
S11	22000	180	6.0	<0.1

4.3.3.7. Effect of spray drying parameters on wettabilty of Garcinia cambogia powder

From table 4.21 it was observed that increasing the inlet air temperature at constant atomizer speed and feed flow rate results an increase in average wetting time. This may be due to reduced residual moisture content. Similar results were also found by Bhandari *et al*. (1993) and Jumah *et al*. (2000).

From table 4.21 it was also observed that at constant inlet air temperature and feed flow rate, increasing the atomizer speed reduces the wetting time, which indicates that the wettability of the powder increased. This may be due to increase in contact surface area as small droplets are produced at increased atomizer speeds. Similar results were also observed by Chegini and Ghobadian (2008)

From the table 4.21 it was observed that increasing the feed flow rate reduces the average wetting time. This may be due to the increased residual moisture content which results in faster wetting of the powder in water. Similar results were also observed by Jumah *et al*. (2000).

Table 4.21 Effect of spray drying parameters on wettability of *Garcinia cambogia* powder

Sl.No	Treatment name	Drying condition			Means of Wetting time(s)
		Speed of the atomizer (rpm)	Temperature (°C)	Feed rate (l/h)	
1	S0 (S1T1F1)	17000	175	5.0	89.000
2	S1 (S1T1F2)	17000	175	5.5	88.000
3	S2 (S1T1F3)	17000	175	6.0	85.000[c]
4	S3 (S1T2F1)	17000	180	5.0	90.33
5	S4 (S1T2F2)	17000	180	5.5	89.000
6	S5 (S1T2F3)	17000	180	6.0	87.000
7	S6 (S2T1F1)	22000	175	5.0	86.000
8	S7 (S2T1F2)	22000	175	5.5	84.000[c]
9	S8 (S2T1F3)	22000	175	6.0	83.000[b]
10	S9 (S2T2F1)	22000	180	5.0	87.000
11	S10 (S2T2F2)	22000	180	5.5	79.000[a]
12	S11 (S2T2F3)	22000	180	6.0	81.000[b]
	CD				1.704

Table 4.21 presents the Analysis Of Variance of the effects of different combinations of atomizer speed, inlet air temperature and feed flow rate on wetting time of the aggregate powder. It was observed from the table that the wetting time was significantly influenced by all the independent variables studied. The interactions between the independent variables studied were also found to be significant. It could be further observed that the effects of single factors, atomizer speed 22000rpm (S2), inlet air temperature 180°C (T2) and feed flow rate 5.5 l/h, S10 (S2T2F2) having mean value of wetting time 79.000 s and having a CD value 1.704 was significant at 1 per cent level and were grouped as ‘a’, which is considered as the best treatment for *Garcinia cambogia* powder for powder production.

4.3.3.8 Optimisation of spray drying parameters

The effect of the spray-dryer parameters such as atomizer speed, inlet air temperature and feed flow rate on quality of *Garcinia cambogia* powder in terms of

bulk density, moisture content, colour values, total solids, acid value and pH bulk density, solubility index and wettability were studied.

Table 4.22 Optimisation of spray dried parameters for *Garcinia cambogia* powder

T	Table of means							
	MC (%wb)	**TS**	**pH**	**Bulk density (g/cm^3)**	**L**	**a***	**b***	**W**
S0	4.68	95.32	1.86	0.552	91.167	4.433	22.04	89.0
S1	4.70	95.29	1.81^{c}	0.555	92.300	4.620	22.08	88.0
S2	4.80	95.19	1.82^{c}	0.578	93.900	4.773	23.04	85.0^{c}
S3	4.48	95.52	1.56^{a}	0.517^{c}	94.310^{b}	3.940^{b}	20.27^{a}	90.0
S4	4.58	95.42	1.61^{a}	0.559	95.093^{ab}	3.200	20.56^{ab}	8.09
S5	4.63	95.37	1.71^{b}	0.606	93.133	4.673	23.87	87.0
S6	4.13^{c}	95.87^{c}	1.82	0.420^{a}	92.317	4.567	22.20	86.0
S7	4.22	95.78^{c}	1.79^{b}	0.421^{a}	93.567	4.723	23.02	84.0^{c}
S8	3.86	95.67	1.82	0.428^{a}	94.433	4.780	21.62	83.0^{b}
S9	3.86^{a}	96.14^{b}	1.56^{a}	0.408^{a}	94.420	4.353	20.56	87.0
S10	3.59^{a}	96.41^{a}	1.60^{a}	0.412^{a}	97.900^{a}	3.827^{a}	22.54^{c}	80.0^{a}
S11	4.00^{b}	96.00	1.72^{b}	0.452^{b}	94.310	4.560	20.95	81.0^{b}
CD	0.131	0.131	0.05	0.022	0.277	0.153	0.46	1.7

T = Treatment MC = Moisture content TS = Total solids

W = Wettability

The results show that all of the operating parameters affect the powder physical properties significantly. An increase in inlet air temperature increases the total solids, average time of wettablity, and insoluble solids and decreases the bulk density and moisture content of the powder. An increase in atomizer speed increases the bulk density and average time of wettability of powder and decreases the particle size, moisture content, and insoluble solids of powder. An increase in feed flow rate increases the bulk density and moisture content of the powder and decreases the average time of wettablity and insoluble solids of powder.

The *Garcinia cambogia* powder prepared at 22000 rpm, 180°C and 5.5 l/h i.e. treatment S10 (S2T2F2) was found to be the best based on the powder quality properties analysed. The *Garcinia cambogia* powder produced at optimized

condition showed low moisture content, pH, bulk density and high total solids, acid value and good colour value, which are essential for the storage of any food powder. The important factor affecting any food powder is its reconstitution properties, which include solubility index and wettability. The obtained values of wetting time and solubility index were found to be low. Thus it could be concluded that all the reconstitution properties of the optimized powder were all above the satisfactory limits. The optimized process parameters for the powder are presented in table 4.23. Also statistical analysis revealed that all the quality parameters were found to be significant at 1 per cent level and included in level 'a' for S10. So S10 was the best treatment and used for further studies.

Table 4.23 Optimized process parameters for the production of *Garcinia cambogia* powder by spray drying

Sl. No.	Process parameters	Optimized conditions
1	Speed of the atomizer	22000 rpm
2	Inlet air temperature	180°C
3	Feed flow rate	5.5 l/h

4.4 Storage studies

Effect of Quality attributes of tray, vacuum and Spray dried *Garcinia cambogia* Powder during Storage

The optimized samples from tray, vacuum tray and spray drier were packed in LDPE pouches, which were inserted in a laminated aluminium pack, hermetically sealed (as shown in plate 4.1) and kept at ambient condition during the month of June 2011 were analysed in every one month for proper quality evaluation as per the method explained in chapter III. In the case of tray drying the standard sample selected was at 70^{o}C, in the case of vacuum tray drying at 45^{o}C and in spray drying at 22000 rpm, 180^{o}C and 5.5 l/h feed flow rate were selected. The shelf life of product will be explored with the experimental results on the quality evaluation parameters (given below).

Plate 4.1 Optimized samples used for storage studies

4.4.1 Effect of type of drying on moisture content of Garcinia cambogia powder during storage

It can be observed that, the sample at 70^{o}C tray drying has taken only 7 hours to attain constant moisture content, for vacuum tray drying 12 hours and less than 10 min for spray drying. So the time consumption is very less in spray drying. And for both tray and vacuum tray drying we have to scratch the product from the equipment and grind. The drudgery is reduced in case of spray drying as we were getting the powder directly. Moisture content of spray dried powder was very low compared to tray and vacuum tray dried powders. Similar results were obtained by Muralikrishna *et al.* (1969) who had a final moisture content of 2.24 % in the spray-dried powder. After four months of storage there was cake formation for the vacuum tray dried sample (shown in plate 4.2). So the vacuum tray dried sample was rejected from the further studies.

Plate 4.2 Cake formed vacuum tray dried sample after three months of storage

Increase in moisture content of the *Garcinia cambogia* powder was 37.40 and 33.50 % at tray, and spray drying temperatures after six months. The increase in the moisture content during storage may be due to the exposure of *Garcinia cambogia* powder to atmospheric conditions during filling and sealing of dried materials in the package. Also the increase in moisture content may be due to accumulation of water molecule in the powder which may be due to permeability of the packaging material. Similar results of increase in moisture content were reported by Mishra *et al*., (2002) for apple powder.

From the fig 4.28 it can be observed that the quality found to be low for tray dried sample from the 6th month and in the spray dried sample the quality was retained and comparable with the initial value. So spray drying was optimized for storability of above 6 months. The increase in moisture content was also observed to be less for spray dried powder.

Table 4.24 Effect of drying on moisture content during storage of *Garcinia cambogia* powder

Drying condition	**Moisture content (%wb) Vs. Storage period (Months)**						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Tray drying at 70^{o}C (T1)	4.382	4.812	5.544	5.786	6.2	7.0	7.0
Vacuum tray drying at 45^{o}C (V1)	5.500	5.770	6.300	8.600	-	-	-
Spray drying at 22000 rpm, 180^{o}C, 5.5 l/h (S10)	3.590	4.140	4.300	5.000	5.4	5.4	5.4

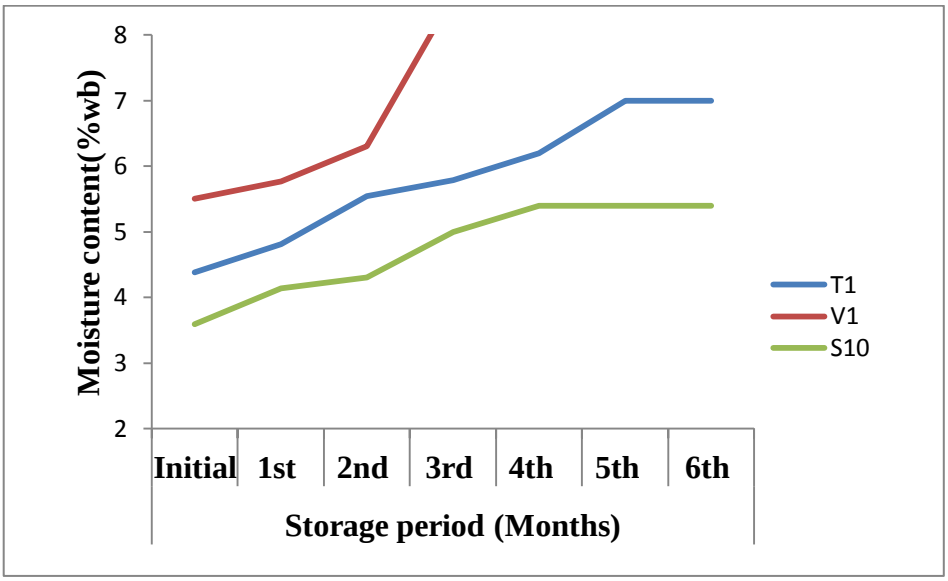


Fig 4.28 Effect of drying on moisture content of *Garcinia cambogia* powder during storage

The effect of drying method and storage on moisture content of *Garcinia cambogia* powder were analysed statistically and presented in Table C.1 of appendix C. From the table it was observed that the variables and their interactions for all the treatments were significant at 1 % level. Among the different treatments, the effect of spray drying (S10) and first month on moisture content were highly significant and recorded as group 'a'.

4.4.2 Effect of type of drying on Total solids of Garcinia cambogia powder during storage

Table 4.25 shows the effect of type of drying on total solids of *Garcinia cambogia* powder in storage. From the table it was observed that as the storage period increases the total solid value decreased for all the three types of drying. This is due to the increase in moisture content during storage. After four months of storage there was cake formation for the vacuum tray dried sample and the quality of the tray dried sample were found to be deteriorating from the 6^{th} month onwards. So both these samples were rejected. So spray drying was optimized for storability of above 6 months.

Table 4.25 Effect of type of drying on total solids of *Garcinia cambogia* powder during storage

Drying condition	Total solids (% wb) Vs. Storage period (Months)						
	Initial	1st	2nd	3rd	4th	5th	6th
Tray drying at 70°C (T1)	95.54	95.18	94.45	94.01	93.78	93.59	93.59
Vacuum tray drying at 45°C (V1)	94.50	94.23	93.70	91.40	-	-	-
Spray drying at 22000 rpm, 180°C, 5.5 l/h (S10)	96.41	95.86	95.68	94.60	94.80	94.80	94.86

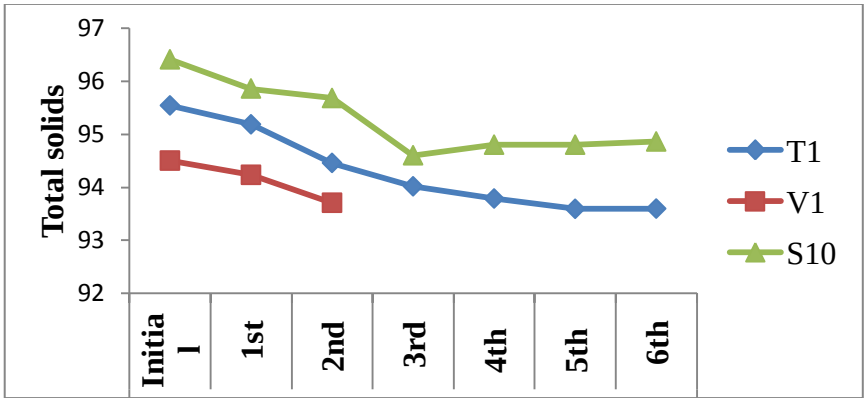


Fig 4.29 Effect of drying on total solids during storage of *Garcinia cambogia* powder

The effect of drying method and storage on total solids of *Garcinia cambogia* powder were analysed statistically and presented in Table C.2 of appendix C. From the table it was observed that the variables and their interactions for all the treatments were significant at 1 per cent level. Among the different treatments, spray drying (S10) highly significant and recorded as group 'a'. These observations made it clear that the best quality of the product was achieved for spray dried sample at 22000 rpm 180°C and 5.5l/h.

4.4.3 Effect of type of drying on Acid value of Garcinia cambogia powder during storage

The acid value (% hydroxyl citric acid) of the dried powder was analysed at every month interval and the results are shown in fig 4.30 below. Graphs obtained after plotting the% acidity value and storage shows that the acid content of all the samples decreased with storage period. The per cent decrease in acid value were less for spray drying (11.11%) followed by tray drying (26.67%). Most of the quality of *Garcinia cambogia* is by this hydroxyl citric acid content, which is more in the case of spray dried powder, and is considered to be the best. Vacuum tray dried samples were rejected after 3 months if storage due to caking of the powder and for tray dried sample the quality found to be deteriorating from the 4th month onwards. So both these treatments were rejected and S10 (S2T2F2), which is spray drying at 22000 rpm 180^{o}C and 5.5 l/h was considered to be optimum having a storability of above 6 months.

Table 4.26 Effect of type of drying on acid value of *Garcinia cambogia* powder during storage

Drying condition	Acid value (%) Vs. Storage period (Months)						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Tray drying at 70^{o}C (T1)	20.81	20.81	20.81	20.81	15.26	15.26	15.26
Vacuum tray drying at 45^{o}C (V1)	22.19	22.20	22.20	20.81	-	-	-
Spray drying at 22000 rpm, 180^{o}C, 5.5 l/h (S10)	24.97	24.97	24.97	24.97	22.19	22.19	22.19

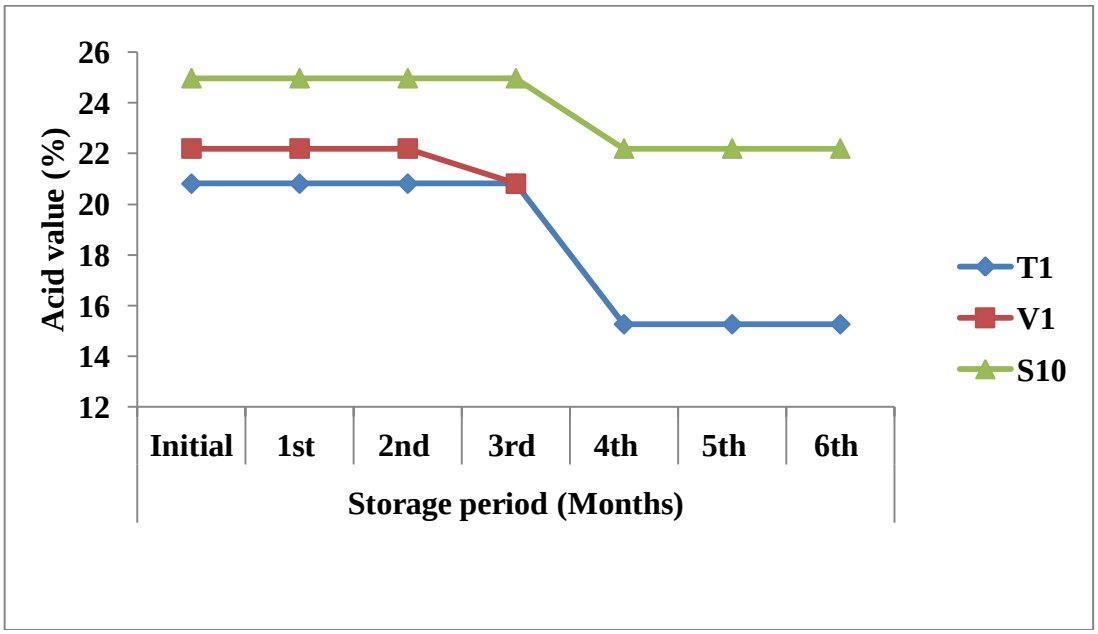


Fig 4.30 Effect of drying method on acid value during storage

4.4.4 Effect of type of drying on pH of Garcinia cambogia powder during storage

From the table 4.27 it was seen that there was slight increase in the pH during the storage. The pH was found to be less for spray dried sample which is 1.676 as it have a higher acid value and most of the quality of the *Garcinia cambogia* powder was the effect of this acid content and the quality is therefore more retained in spray drying and this was superior powder than the powder prepared from other two other. Also the effect of drying method and storage on pH of *Garcinia cambogia* powder were analysed statistically and presented in Table C.3 of appendix C. From the table also it was observed that the variables and their interactions for all the treatments were significant at 1 per cent level. Among the different treatments, the effect of spray drying (S10) were highly significant and recorded as group 'a'. As vacuum tray dried sample was already rejected after 6 months of storage due to caking and also for tray drying the quality found to be deteriorating from the 6^{th} month S10 was the best.

Table 4.27 Effect of type of drying on pH of *Garcinia cambogia* powder duringstorage

Drying condition	pH (% wb) Vs. Storage period (Months)						
	Initial	1st	2nd	3rd	4th	5th	6th
Tray drying at 70°C (T1)	1.860	1.866	1.902	1.959	2.038	2.038	2.054
Vacuum tray drying at 45°C (V1)	1.756	1.860	1.902	2.026	-	-	-
Spray drying at 22000 rpm, 180°C, 5.5 l/h (S10)	1.676	1.678	1.688	1.760	1.870	1.870	1.870

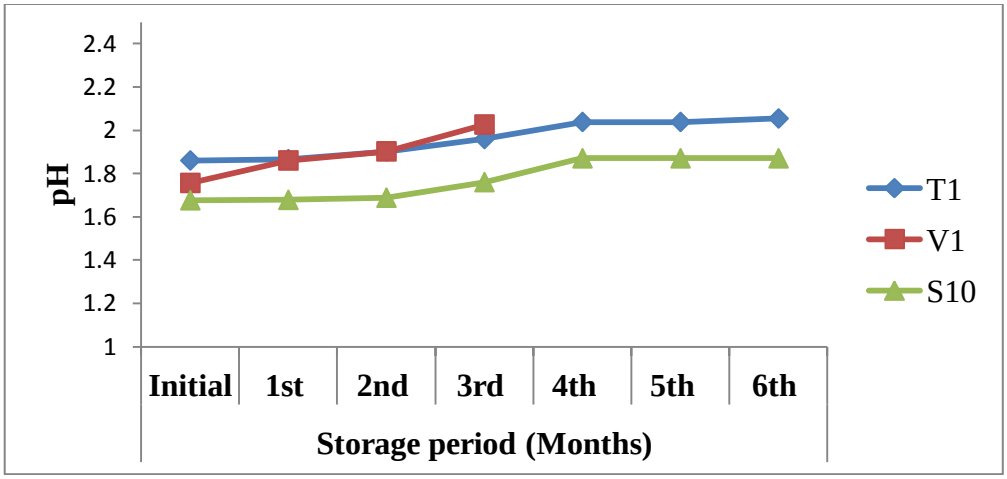


Fig 4.31 Effect type of drying on pH during storage

4.4.5 Effect of type of drying on Bulk density of Garcinia cambogia powder during storage

Effect of drying type on bulk density of *Garcinia cambogia* powder during storage by tray, vacuum tray and spray drying is presented in fig 4.32. From the figure it was observed that the increase of bulk density of tray and spray dried powder after 6 months were 26.58 and 26.17. This might be due to the fact that a product of higher moisture content would tend to have a higher bulking weight caused by the presence of water which is considerably denser than the dry solid.

Similar results were reported by Chegini and Ghobadian (2008) for spray dried orange juice powder.

Due to cake formation of the vacuum tray dried sample after 3 months of storage and the deterioration of quality of the tray dried powder after 6 months, these two samples were rejected. As the quality is retained in the case of S10 (S2T2F2) i.e. spray drying at 22000 rpm 180^{o}C and 5.5 l/h was considered to be optimum having a storability of more than 6 months.

The effect of drying method and storage on bulk density of *Garcinia cambogia* powder were analysed statistically and presented in Table C.4 of appendix C. From the table it was observed that the variables and their interactions for all the treatments were significant at 1 per cent level. Among the different treatments, the effect of spray drying (S10) were highly significant and recorded as group 'a'.

Table 4.28 Effect of type of drying on bulk density of *Garcinia cambogia* powder during storage

Drying condition	Bulk density (g/cm^3) Vs. Storage period (Months)						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Tray drying at 70^{o}C (T1)	0.681	0.714	0.75	0.774	0.822	0.855	0.862
Vacuum tray drying at 45^{o}C (V1)	0.715	0.755	0.8038	0.804	-	-	-
Spray drying at 22000 rpm, 180^{o}C, 5.5 l/h (S10)	0.428	0.446	0.485	0.534	0.534	0.540	0.540

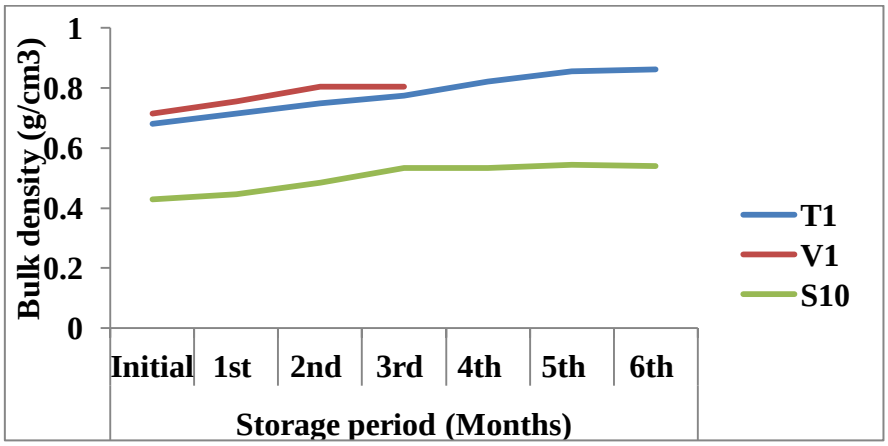


Fig 4.32 Effect of type of drying on bulk density during storage

4.4.6 Effect of type of drying on Colour of Garcinia cambogia powder during storage

Lightness wasfound to be retained more for S10 ie., spray dried powder at 22000 rpm, feed flow rate 5.5 l/h and temperature 180^{o}C. Also the colour value 'a' (redness) were found to be less and 'b' (yellowness) was of appreciable. These observations made it clear that the best quality of the powder was achieved for spray dried sample considering the colour parameter.

The effect of drying method and storage on colour parameters of *Garcinia cambogia* powder were analysed statistically and presented in table C.5 to C.7 in the appendix C. From the tables it was observed that the variables and their interactions for all the treatments were significant at 1 per cent level. Among the different treatments, the effect of spray drying (S10) was found to be significantly different from the other treatments for though out the storage period and recorded as group 'a'.

Table 4.29 Effect of type of drying on colour parameters of *Garcinia cambogia* powder in storage

sample	Colour Parameters		
	L	a	b
T1	75.246	12.618	17.902
V1	68.688	12.782	17.576
S10	94.380	4.723	23.020

4.4.7 Effect of type of drying on Solubility index of Garcinia cambogia powder during storage

Effect of type of drying on solubility of *Garcinia cambogia* powder by tray drying and vacuum tray drying during storage is presented in Fig 4.33 and from table it was evident that solubility index obtained from spray dried powder recorded the lowest (<0.1) and this indicates the solubility was more here and during storage period the quality is retained. The initial solubility index of tray dried powder was 0.4 ml and for vacuum tray drying it was 0.6. For these two when the storage period increases the solubility index increased (solubility reduced). Decrease of solubility of tray dried and vacuum tray dried *Garcinia cambogia* powder were 14.75 % and 14.8 % respectively and for spray drying the solubility index was found to be constant during the whole storage period of 6 months. Decrease in solubility in tray dried and vacuum tray dried *Garcinia cambogia* powder might be due to the increased amount of moisture in the product which led to caking of the powder, thereby reducing its solubility. Similar results were reported for spray dried mango milk powder by Sharma *et al*., 2004. It was evident from the figure that the *Garcinia cambogia* powder obtained from spray dried powder recorded the highest solubility value. Vacuum tray dried samples were rejected due to the cake formation after 3 months and for tray dried powder after 6 months of storage the quality found to be deterioted. So S10 was optimized as best sample.

Table 4.30 Effect of type of drying on solubility index of *Garcinia cambogia* powder during storage

Drying condition	Solubility index (ml) Vs. Storage period (Months)						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Tray drying at 70 °C (T1)	0.4	4.8	5.5	5.8	6.2	6.4	6.3
Vacuum tray drying at 45 °C (V1)	0.6	5.8	6.4	8.6	-	-	-
Spray drying at 22000 rpm, 180 °C, 5.5 l/h (S10)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

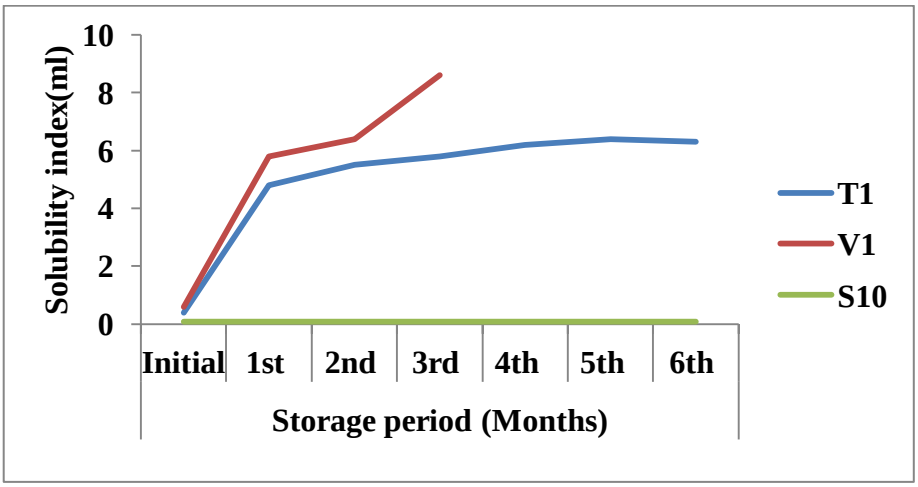


Fig 4.33 Effect of type of drying on solubilty index on storage

4.4.8 Effect of type of drying on wettability of Garcinia cambogia powder during storage

The significance of the effects of different drying methods, wettability of the *Garcinia cambogia* powder was statistically analysed and the analysis of variance is furnished in Table C.8 of appendix C.

Table 4.31 Effect of type of drying on wetting time of *Garcinia cambogia* powderduring storage

Drying condition	Wetting time (s) Vs. Storage period (Months)						
	Initial	1st	2nd	3rd	4th	5th	6th
Tray drying at 70 °C (T1)	95.0	97.33	98.0	99.00	102.60	103.80	104.25
Vacuum tray drying at 45 °C (V1)	104.4	103.80	105.0	109.20	-	-	-
Spray drying at 22000 rpm, 180°C, 5.5 l/h (S10)	80.0	86.70	87.6	88.60	88.90	89.00	89.20

From the Fig 4.34 When the storage time increases the wetting time also increases and it was clear that the wetting time was found to be low for S10 which is the best

treatment for *Garcinia cambogia* powder production. The treatment T1 and V1 were rejected due to the quality deterioration and caking respectively.

The effect of drying method and storage on wetting time on *Garcinia cambogia* powder were analysed statistically and presented in Table C.8 of appendix C. From the table it was observed that the variables and their interactions for all the treatments were significant at 1 per cent level. Among the different treatments, the effect of spray drying S10 (atomizer speed: 22000 rpm; Temperature: 180; Feed flow rate: 5.5 l/h) were highly significant and recorded as group 'a'. Analogous results were also reported by Singh and Rai (1998) and Patel *et al*. (2009).

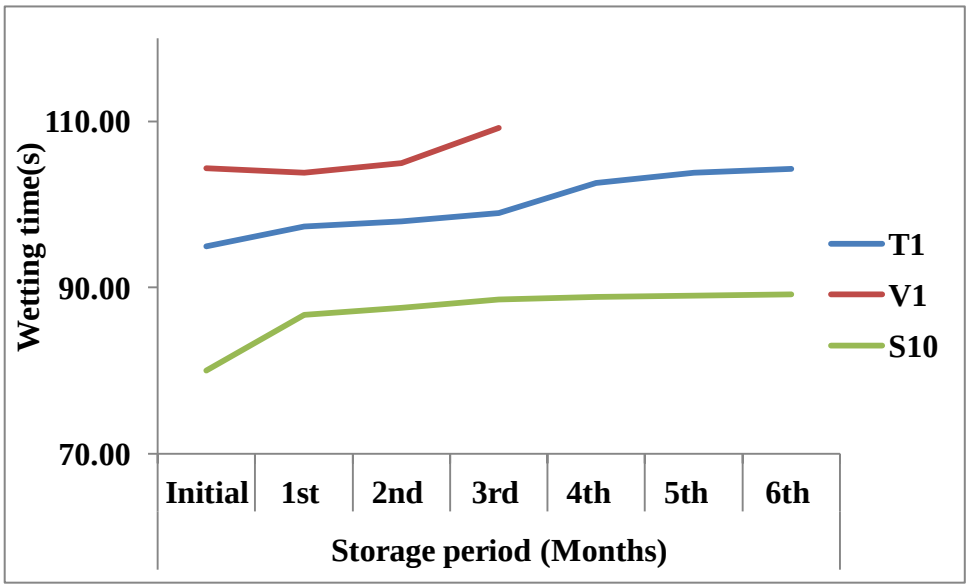


Fig 4.34 Effect of type of drying on wetting time of powder during storage

4.4.9 Particle size analysis

Considering all the quality parameters during tray vacuum and spray drying with storage period, the quality was retained more in the case of spray dried sample. So the optimum treatment was found to be spray drying. The morphology of the spray dried *Garcinia cambogia* powder which was produced at optimized process conditions was analysed with the help of Scanning Electron Microscope (SEM) and the observed images are presented in Plate 4.4.The spray dried *Garcinia cambogia* powder sample was having an average particle size of 8µm.

Plate 4.3 Tray dried sample

Plate 4.4Vacuum tray dried sample

Plate 4.5 Spray dried sample

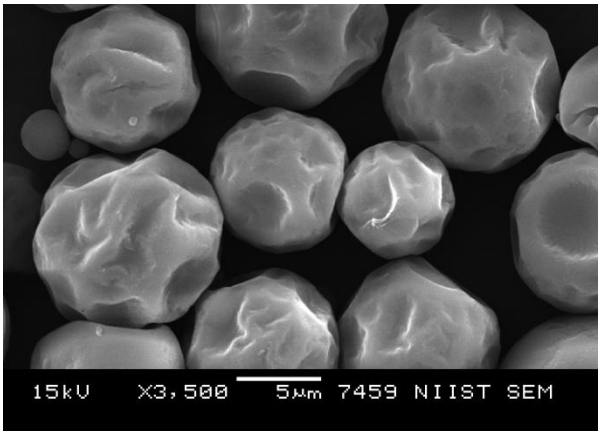


Plate 4.6 Scanned microscopic image of spray dried powder

4.4.10 Sensory analysis

Sensory quality is the ultimate measure of product quality and success. Sensory analysis comprises a variety of powerful and sensitive tools to measure human responses to foods and other products. Effect of type of drying on sensory score of fish curry prepared using the *Garcinia cambogia* by tray drying (T1), vacuum tray drying (V1) and spray drying (S10) are presented in Appendix A.2. It is observed from Fig4.22 that different treatments studied, the fish curry prepared using S10 (spray dried *Garcinia cambogia* powder) showed superior quality due to retaining of quality parameters within the powder.

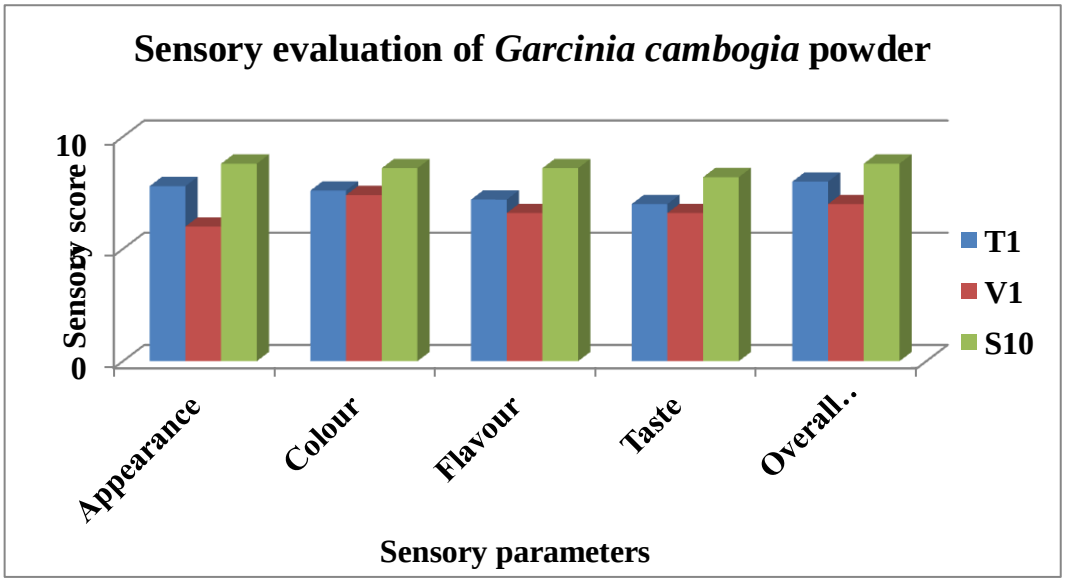


Fig.4.35 Sensory evaluation of *Garcinia cambogia* powder

The *Garcinia cambogia* powder was used for fish curry preparation after 6 months of storage at ambient condition as described in Section 4.4.

Plate 4.7 Fish curry prepared from developed *Garcinia cambogia* powder

Table 4.32 Kendall's coefficient of concordance test for mean rank for sensory evaluation

Treatment	Mean Rank				
	Appearance	**Colour**	**Flavour**	**Taste**	**Overall acceptability**
T1	1.95	1.95	2.20	2.00	1.70
V1	1.25	1.35	1.45	1.35	1.35
S10	2.80	2.7	2.35	2.65	2.65

The results obtained were statistically analysed and the results indicated that all the Kendall wall coefficient of appearance, colour, flavour, taste and overall acceptability character was significant. Hence the mean rank scores of treatment S10 could be taken to judge the superiority of one treatment over the other.

4.4.11 Cost economics for spray drying

The cost of production for *Garcinia cambogia* powder is calculated based on the data available from the market. The cost incurred for the production of 100g of *Garcinia cambogia* powder was Rs.45/- and the calculations were shown in the appendix E.

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

Apart from the important spices such as pepper, ginger and cardamom, *Garcinia cambogia* also an important spice which is small, sweet, exotic fruit grown in Southern part of India, mainly Kerala. It give a distinctive sour flavour to dishes and regarded as the best natural medicine for controlling obesity, tumers, ulsers, constipation and rheumatism. Spices have been mainly used as seasoning to make processed foods more delicious. Apart from their flavouring properties, spices have been accepted as potent natural antimicrobial in food preservation for extending shelf life for longer periods. The use of spices in food may also be vindicted from their medicinal and antimicrobial properties.

The major problem faced by the farmers at present is drying this fruit as the harvesting of this fruit coincides with the south west monsoon. Due to the high moisture content present it cannot be stored for a longer time. The most common preservation technique adopted in Kerala is sun drying followed by smoke drying. Even if, sufficient sunlight is available it takes six to seven days for proper drying. The lengthy time of drying cause mould growth and affect the quality of the product. Instead of storing the fruit as dried rind, milling powder from the fresh fruit not only increases the shelf life but also reduces the bulk weight. Apart from this it makes easy to use as powder compared with squeezing juice from dried rind. Hence the project was undertaken to develop a process protocol for *Garcinia cambogia* powder from the fresh fruit.

Fresh *Garcinia cambogia* harvested in the month of May 2011 was selected for the study and the fresh pulp analysed for moisture content (86.6 ±0 .46%), Acid value as hydroxyl citric acid (4.80 ± 0.11%), pH (3.5 ± 0.11), and total soluble solids (12±0.71^{0}brix) as per standard procedures. The colour of the sample was estimated using a Hunter lab colourimeter for Lightness (47.78 ± 0.23), Redness (+a*) (6.395 ± 0.15) and yellowness (+b*) (30.6 ± 0.19) values.

As this *Garcinia cambogia* contains organic acid, commonly used drying aid maltodextrin was added to enhance drying. A level of 15 % maltodextrin was

optimized for getting a less hygroscopic powder with lower moisture content and better reconstitution properties.

Based on the results obtained in this study the following important conclusions were obtained.

1) For the Optimisation of the temperature the quality of the powder was analysed for moisture content, total solids, colour value, solubility index, wettability, acid value, pH and bulk density, solubility index and wettability. The statistical analysis of the experimental data showed that the tray dried sample at 70°C having a moisture content of 4.382(%wb) total solid content (95.617), colour value, lightness (75.246), redness (12,618) and yellowness (17.902), solubility index of 0.55 ml, wetting time (93.800s) acid value (20.814), pH (1.868) and bulk density (0.606 g/cm^3) which take only 7hs to attain the constant moisture content as the best treatment.

2) The moisture content of the vacuum tray dried samples 40, 45 and 50 °C were reached constant moisture content during different interval 16, 12 and 10 hs respectively. Statistical analysis was done using one way ANOVA and found that the vacuum tray dried sample, which is dried at 50 °C having a moisture content (5.500%wb), total solid content (94.670), colour value, lightness (68.6380, redness (12.782) and yellowness (17.576), solubility index (0.85 ml), wetting time (104.400 s), acid value (22.120), pH (1.756) and bulk density ($0.640\,g/cm^3$) was found to be the best treatment.

3) For spray drying the effect of the three operating parameters such as atomizer speed, temperature and feed flow rate on different quality parameters were analysed and the statistical analysis was done using M-stat software as it was a three factor completely Randomized Design. The spray dried sample S10, having an atomizer speed 22000 rpm, temperature 180°C and feed flow rate 5.5 l/h, which is having the least moisture content of 3.59%wb, total solid content of 96.41, colour values, lightness 97.896, redness 3.827 and yellowness 17.576, having the least solubility index value of less than 0.1, wetting time of 80s, acid value of 24.973, pH of 1.676,

bulk density of 0.428 and a particle size of 8µm was found to be significantly different from the other treatments and was selected as the best treatment.

4) The optimized samples from the tray dryer T1 (tray dried sample at 70°C), vacuum tray dryer V1 (Vacuum tray dried sample at 45°C) and spray dryer S10 (spray dried sample at 22000rpm, 180°C and 5.5.l/h) were packed in LDPE (400 gauge) packs and inserted into a laminated aluminium pack (400 gauge) hermetically sealed and kept for storage studies at ambient conditions during the month of June 2011. The samples were analysed in every one month duration for quality parameters such as moisture content, total solid content, colour value, solubility index, wettability, acid value, pH and bulk density for the Optimisation of drying method. It was found that all the quality parameters were best and retained better for spray drying method, sensory attributes also found best for this method. Statistical analysis of sensory was done by Kendall's coefficient of concordance test and all the attributes mean rank was found to be greater for spray dried sample.

5) In a nutshell, the best quality *Garcinia cambogia* powder (particle size of 8µm) was obtained when the fresh juice was dried in a spray dryer at 22000 rpm, 180°C for a feed flow rate of 5.5 l/h. The storability of the powder was more than 7 months.

6) Cost of production of *Garcinia cambogia* by spray drying was estimated as Rs.45/100g of dried powder.

References

REFERENCES

Abadio, F. D. B. 2004. Physical properties of powdered pineapple (Ananas comosus) juice: Effect of maltodextrin concentration and atomization speed. *J. Fd. Engng*. 64(3): 285-287.

Abraham, D., Carla, S. S. and Amanda, C. 2004. The air drying behaviour of osmotically dehydrated jackfruit slices. Drying-Proceedings of the International drying symposium. International Institute of Tropical Agriculture, Nigeria, pp. 2120-2126.

Adhikari, B., Howes, T., Bhandari, B. R., and Troung, V. 2003. Characterization of the surface stickiness of fructose-maltodextrin solutions during drying. *Int. J. Fd. Properties.* 21: 17-34.

Adhikari, B., Bhandari, B. R., and Troung, V. 2000. Fruit juice drying. *J. Fd. Sci*. 3(2): 41-48.

Adhikari, B., Howes, T., Bhandari, B. R. and Troung, V. 2004. Effect of addition of maltodextrin on drying kinetics and stickiness of sugar and acid-rich foods during convective drying experiments and modeling. *J. Fd. Engng*. 62: 53-68.

Agnieszka, K. and Krzyszt, G. 2010. Evaluation of drying models of apple (var. McIntosh) dried in a convective dryer. *Int. J. Fd. Sci. Technol*. 45: 891–898.

Akanbi, C. T., Adeyemi, R. S. and Ojo, A. 2005. Drying characteristics and sorption isotherm of tomato slices. *J. Fd. Engng.* 6 (3):34-45.

Akpinar, E. K., Bicer, Y. and Yildiz, C. 2003. Thin layer drying of red pepper. *J. Fd. Engng.* 59: 99-104.

Al-asheh, S. 2003. The use of experimental factorial design for analysing the effect of spray dryer operating variables on the production of tomato powder. *Trans. Inst. Chem. Engng.* 81(C): 81-88.

Ali, M., Saeid, M. and Mohammad, H. K. 2011. Evaluation of energy consumption in different drying methods. *Energy Conversion and Manage*. 52(2):1192–1199.

Al-kahtani, H. A. and Hassan, B. H. 1990. Spray drying of roselle (*Hibiscus sabdariffa L.*) extract. *J. Fd. Sci.* 55: 1073-1076.

Anonymous. 1999. Let's Preserve Pickles. Cooperative Extension Service, Purdue University, West Lafayette, Ind. Available:http//unu.edu/unpress /ununbooks [23 July 2011].

[Anonymous]. 2002. Study overview-Super Citrimax Full Strength. Available: http://www.interhealthusa.com/images/docs/sx-sellsheet-studyover.pdf [12 Septem.2011].

Athanasia, G., Adamopoulos., and Konstantinos. 2008. Effect of Maltodextrin addition during spray drying of tomato pulp in dehumidified Air: II- Powder properties. *Drying Technol*. 26(6): 726-737.

Avaltroni, F., Bouquerand, P. E. and Normand, V. 2004. Maltodextrin molecular weight distribution influence on the glass transition temperature and viscosity in aqueous solutions. *Carbohydrate polym.* 58(3): 323-334.

Awang, B., Yan, Y. F., Suhaimi, M. D., Yasir, B. A., and Nurkhairi, M. J. 2011. Production of fresh seaweed powder using spray drying technique. *J. Appl. Sci.* 11(2): 2340-2345.

Azoubel, P. M., Cipriani, D. C., Aouar, A .A., Antonio, G.C., and Murr, F. E. X. 2005. Effect of concentration on the physical properties of cashew juice. *J. Fd. Engng.* 66: 413-417.

Azzouz, S., Guizani, A., Jomaa, W., and Belghith, A. 2002. Moisture diffusivity and drying kinetic equation of convective drying of grapes. *J. Fd. Engng.* 55: 323–330.

Baker, C.G.J. and. Masters, K. 1997. Industrial drying of foods: Spray Drying. Blackie Academic and Professional, London, 234p.

Bates, T., Hatashi, H., and Ohashi, T. 2001. Some of the additives used in spray drying of food liquid. *Drying Technol.* 12 (2): 151–177.

Barbosa-Cánovas, G. V., Ortega-Rivas, E., Juliano, P., and Yan, H. 2005. Drying in food powders - physical properties, processing and functionality (1st Ed.). Kluwer Academic / Plenum Publishers., N.Y, pp.271-304.

Barbosa-Canovas. G. and Vega-Mercado, H. 1996. Dehydration of foods, Chapman and Hall International. Thomson Publishing, N.Y., pp212-217.

Be Miller, N. J. and Whistler, R. L. 1996. Carbohydrates in food chemistry (3rd Ed). Marcel Dekker, pp. 157-220.

Behera, T.K., Sagar, V.R. and Udal, S. 2006. Effect of drying condition on the quality of dehydrated selected leafy vegetables. *J. Fd. Sci. Technol*. 43(6): 579-582.

Benny, A. 2003. Study on hydroxyl citric acid in Garcinia. PhD (Chem) thesis , MG university, Kothamangalam.

Bhandari, B. R. and Howes, T. 1999. Implication of glass transition for the drying and stability of dried foods. *J. Fd. Engng.* 40: 71-79.

Bhandari, B. R., Datta, N., and Howes, T. 1997. Problems associated with spray drying of sugar rich foods. *Drying Technol*. 15: 671-684.

Bhandari, B. R., Senoussi, A., Dumoulin, E. D., and Lebert, A. 1993. Spray drying of concentrated fruit juices. *Drying Technol*. 11(5): 1081-1092.

Bodyfelt, F. W., Tobias, J. and Trout, G. M.1998. Sensory evaluation of cheese. In: Sensory evaluation of dairy products, AVI/Van Nostrand Reinhold, N.Y., pp.300–375.

Boonyai, P., Bhandari, B., and Howes, T. 2004. Stickiness measurement techniques for food powders: A review. *Powder Technol*.145:34-46.

Brazel, C. S. 1999. Microencapsulation of gelatin and carboxy methy cellulose, European Patent No. 0937496A2.

Breene, W. M. and Coulter, S. T. 2010. Properties of spray-dried combinations of milk and fruits and vegetables. *Drying Technol*. 50 (7): 1049–1054.

Brennan, J. G., Herrera, J., and Jowitt, R. 2007. A study of some of the factors affecting the spray drying of concentrated orange juice. *J. Fd. Technol*. 6(3): 295–307.

Camerlingo, C., Zenone, F., Delfino, I. D., Diano, N., Mita, D.G., and Lepore, M. 2007. Investigation on clarified fruit juice composition by using Visible Light Micro-Raman Spectroscopy. *Sensors*. 7: 2049-2061.

Cano-Chauca, M., Stringheta, P. C., Ramos, A. M., and Cal Vidal, J. 2005. Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. *Innovative Fd. Sci. Emerging Technol.*. 6: 420-428.

Carballido, A. and Rubio, J. L. 1970. Aplicacion de la liofilizacion a la conservation de fresones. *Anales De Bromalogia*. 22: 229-254.

Carol, C. and Breen, S.1967. Optimisation of pomegranate (*Punica Granatum* L.) juice spray-drying as affected by temperature and maltodextrin content. *Int. J. Fd. Sci. Technol*. 47(1): 167–176.

Carolina, C. F., Silvia, P. M. G., Izabela, D.A., Fernanda, Z. V., and Jose, M. A. 2012. Influence of carrier agents on the physiochemical properties of blackberry powder produced by spray drying. *Int. J. Fd. Sci. Technol*. 47(6): 1237-1245.

Cassano, A., Drioli, E., Galaverna, G., Marchelli, R., Di Silvestro, G., and Cagnasso, P. 2003. Clarification and concentration of citrus and carrot juices by integrated membrane processes. *J. Fd. Engng.* 57: 153-163.

Chandraratna, M. F. 1947. Garcinia in Ceylon. *Trop. Agricist.* 103: 34.

Chandrasekha, M. R., Ramasree, G., and Leela, N. 1966. Processing of groundnut in India as a source of foods. *Indian Fd. Packer*.24:15-24.

Chauca, M. C., Stringheta, P. C., Sardigna, L., and Cal-Vidal, J. 2004. Mango juice dehydration by spray drying using different carriers and functional characterization. Proceedings of the 14th Int. Drying Symposium; 22-25 August 2004, Sao Paulo, Brazil. pp. 205-212.

Chee, H., Romsos, D. R., and Leveille, G.A., 1977. Influence of ())-hydroxycitrate on lipigenesis in chickens and rats. *J. Nutri*. 107: 112–119.

Chegini, G. R., and Ghobadian, B. 2008. Effect of spray-drying conditions on physical properties of orange juice powder. *Drying Technol.* 23(3): 657-668.

Chegini, G.R., Khazaei, J., Ghobadian, B. and Goudarzi, A. M., 2008. Prediction of process and product parameters in an orange juice spray dryer using artificial neural networks. *J. Fd. Engng.*84: 534-543.

Cheuyglintase, K. and Morison, K. R. 2009. Crystal induction by dietary fiber in spray drying of fruit juice. Proceedings of the sixth Asia-Pacific Drying Conference; 16-21 January, 2009; Bangkok, Thailand, pp. 606- 613.

Cheuyglintase, K.2009. Spray drying of fruit juice with vegetable fibre as a carrier. Phd (Chemical and Process Engineering) thesis, University of Canterbury, Chistchurch, N. Z., pp. 56-59.

Clouatre, D and Rosenbaum, M.E.1994. The diet and health benefits of HCA (hydroxycitric acid). Keat publishers, New Cannan, pp. 11-40.

Clouatre, D and Rosenbaum, M.E.2001.Nutritional benefits of Garcinia. *J. Nutri.* 114: 109-113.

Dallas, C and James, M. D. 2002. Potassium hydroxycitric acid methods for pharmaceutical preparations for stable and controlled delivery, US Patent No.6447807B1.

Desousa, A. S., S. V. Borges, N. F. Magalhaes, H. V. Ricardo and A. D. Azevedo. 2008. Spray-dried tomato powder: reconstitution properties and colour. *Braz. Arch. Biol. Tech*. 51(4): 807-814.

Devahastin,S. 2000. Mujumdar's practice guide in industrial drying, Principle, equipment and new development. *Drying Technol*. 22(3): 627-630.

Diamante, L.M. 2009. Vacuum fried jackfruit: effect of maturity, pretreatment and processing on the physicochemical and sensory qualities. *Proceedings of the Nutritional Society of N. Z*, pp. 138–142.

Dimitrios, A., Albert, H. and Joachimm, M. 2011. Assessment of convection, hot-air combined with microwavevacuum and freeze-drying methods for mushooms with regard to product quality. *Int. J. Fd. Sci. Technol.* 46: 333–342.

Dolinsky, A., Maletskaya, K. and Snezhkin, Y. 2000. Fruit and vegetable powders production Technology on the bases of spray and convective drying methods. *Drying Technol.* 18(3): 747-758.

Doulglas, C.1992. Introduction to linear regression analysis. Mc Graw Hill, N.Y, 61p.

Downs, B.W., Bagchi, M., Subbaraju, G.V., Shara, M.A., Preuss, H.G., and Bagchi, D. 2005. Bioefficiency of a novel calcium-potassium saslt of hydroxy citric acid. *Mut. Res*. 579:149-62.

Doymaz, I. 2007. The kinetics of forced convective air-drying of pumpkin slices. *J. Fd. Engng.* 79: 243–248.

Doymaz, I. 2008. Convective drying kinetics of strawberry. *Chem. Engng. and Processing*. 47:914–919.

Doymaz, I. 2005. Drying behavior of green beans. *J. Fd. Engng.* 69: 161-165.

Drouzas, A.E., Tsami, E. and Saravacos, G.D. 2005. Microwave or vacuum drying of model fruit gels. *J. Fd. Engng.* 39:117-122.

Duke, J. and Bogenschutz, M. 2002. Hand book of medicinal Plants (2nd Ed.). CRC Press., Boca Raton, 529p.

Elizangela, G., Oliveria., Jassica, H.D., Kelly, M., and Valeria, T. 2010. Performance of different drying methods and their effects on the chemical quality attributes of raw cocoa material. *Int. J. Fd. Sci. Technol.* 45: 1564-1571.

Ertekin, C. and Yaldiz, O. 2004. Drying of egg plant and selection of a suitable thin layer drying model. *J. Fd. Engng.* 63: 349–359.

Falade, K. O. and Omojola, B. S. 2010. Effect of processing methods on physical, chemical, rheological, and sensory properties of okra (*Abelmoschus esculentus*). *Fd. Bioprocess Technol.* 3: 387–394.

Falade, K. O. and Aworh, O. C. 2005.Sensory evaluation and consumer acceptance of osmosed and oven dried African star apple and African mango. *J. Fd. Agric. Environ.* 3 (1): 91-96.

Fang, Y.., Selomulya, C. and. Chen, X. D. 2008. Measurement of food powder reconstitution properties. *Drying Technol.* 26: 3-14.

Francisconi, A. D. 2003. Effect of atomization speed and maltodextrin concentration. *J. Fd. Engg*. 7(2): 97-100.

Fazaeli, M., Emam, D. Z., Kalbasi, A., and Omid, M. 2012. Effect of processing conditions and carrier concentration for improving drying yield and other quality attributes of spray dried mulberry (Morus nigra) juice. *Int. J. Fd. Engg*. 8(1): 1-20.

Felllows, P.J. 2000. Food processing Technol. principles and practices. Ellis Horwood Publications, 67p.

Gabas, A. L., Telis, V. R. N., Sobral, P., and Telis-Romero, J. 2007. Effect of maltodextrin and arabic gum in water sorption thermodynamic properties of vacuum dried pineapple pulp powder. *J. Fd. Engng*. 82: 246-252.

Ganesan, V. 1996. Investigation on production of coconut skim milk powder. Phd (Agri. Engg.). Tamilnadu Agricultural University, Coimbatore, pp. 91-109.

Ganga, R. G.,Rama, R. G, Venkata, S, Gotumukkala. and Venkateswaralu, S. 2010. Double salts of Hydroxy citric acid and a process for preparing the same, US Patent No. 7741370 B2.

Genç, G., Narin, O. and Bayraktar. 2009. Spray drying as a method of producing silk sericin powders. *J. achievements in manufacturing and matr. Engng.* 37(1): 867.

Giri, S. K. and Prasad, S. 2007. Drying kinetics and rehydration characteristics of microwave-vacuum and convective hot-air dried mushooms. *J. Fd. Engng.*, 78: 512–521.

Gong, Z., Zhang, M., and Sun, J. 2008. Physico-chemical properties of cabbage powder as affected by drying methods. *Drying Technol. 25* (5): 913-916.

Goula A. M. and Adamopoulos,K. G. 2008. Influence of spray drying conditions on tomato powder properties. *Drying Technol*. 22 (5): 1129–1151.

Goula, A. M. and Adamapoulos, K. G. 2005. Spray drying of tomato pulp in dehumidified air. The effect on powder properties. *J. Fd. Engng.* 66(1): 35-42.

Goula, A. M. and Adamopoulos, K.G. 2004. Spray drying performance of a laboratory spray dryer for tomato powder preparation. *Drying Technol.* 21: 1273-1289.

Grabowski, J. A., Truong V. and Daubert C. R. 2008. Nutritional and rheological characterization of spray dried sweet potato powder. *Lebensmittel Wissenschaft Technol*. 41: 206-216.

Greenwald, C. G. and King, C. J. 1981.The effects of design and operating conditions on particle morphology for spray dried foods. *J. Fd. Process Engng.* 4 (3):171–187.

Greenwood, M. R. C., Cleary, M. P., and Gruen R. 1981. Effect of hydroxycitrate on development of obesity in the Zucker obese rat. *Am. J. Physiol*. 240: E72–80.

Gunko, S., Verbych, S., Bryk, M. and Hilal, N., 2006. Concentration of apple juice using direct contact membrane distillation. *Desalination*. 190: 117-124.

Gupta, A. S. 1978. Spray drying of citrus juice. *American Inst. of Chemical Engineers,* 7th Annual meeting; 3-5pp. paper no.55f.

Handerson. 1974. Progress in developing the thin layer drying equation. *Trans. ASAE.* 17:1167-1172.

Hassan, A., Al-kahtani., Bakri, H., and Hassan. 2006. Spray Drying of Roselle (*Hibiscus sabdariffa* L.) Extract. *J. Fd. Sci*. 55 (4): 1073–1076.

Hassan, V. and Mehmet. 2011. Optimisation of pomegranate (*Punica Granatum* L.) juice spray-drying as affected by temperature and maltodextrin content. *Int. J. Fd. Sci. Technol.* 47(1):167–176.

Hassan, O. and Mehmat. 2012. Effects of extracts obtained from Nepeta italic L. and Nepeta Cilicia Boiss, Apud Bentham on Antioxidant enzymes. *J. Biol. and Chem*. 40(2):149-154.

Hayamizu, K., Hirakawa, H., Oikawa, D., Nakanishi, T., Takagi, T., Tachibana, T., and Furuse, M. 2003. Effect of *Garcinia cambogia* extract on serum leptin and insulin in mice. *Fitoterapia*. 74: 267-273.

Ho Minh Thao and Athapol, N. 2011. Physiochemical properties of Sweet Potato and Mung Bean Starch and Their Blends for Noodle production; *J. Fd. Processing and Technol.* 2(1): 105.

Hui, J. K., and Lee, J. H. 2008. Vacuum drying kinetics of Asian white radish (Raphanus sativus L.) slices. *LWT – Fd. Sci. Technol*. 42:180-186.

Huntington, D. H., 2004. The influence of the spray drying process on product properties. *Drying Technol.* 22(6): 1261-1287.

Ibnusaud, I., Thomas T. P., and Thomas, B. A. 2000. Convenient method for the large scale isolation of Garcinia acid, U. S. Patent No. 6, 147228.

İbrahim, D. and Mehmet, P. 2003. The thin-layer drying characteristics of corn. *J. Fd. Engng* . 60(2): 125–130.

Ishihara, K., Oyaizu, S., Onuki, K., Lim, K., and Fushik, T. 2000. Chronic hydroxycitrate administration spares carbohydrate utilization and promotes lipid oxidation during exercise in mice. *J. Nutr.* 130: 2990-2995.

IS: SP: 18 (Part XI). 1981. Hand book of food analysis. Part XI. Dairy Products. Beuro of Indian standards, Manak Bhavan, New Delhi.

Jaya, S and Das, H. 2009. Glass transition and sticky point temperatures and stability/Mobility diagram of fruit powders. *Fd. Bioprocess Technol*. 2(1): 89-95.

Jaya, S. and Das, H. 2007. Glass transition and sticky point temperatures and stability/mobility diagram of fruit powders. *Fd. Bioprocess Technol.* 1-7p.

Jaya, S. and Durance, T. D. 2009. Compressive characteristics of cellular solids produced using vacuum-microwave, freeze, vaccum and hot air dehydration methods. *J. Porous Matr.*16: 47–58.

Jaya, S., and Das, H. 2003. A vacuum drying model for mango pulp. *Drying Technol.* 21: 1215–1234.

Jaya, S. and Das, H. 2004. Effect of maltodextrin, glycerol monostearate and tricalcium phosphate on vacuum dried powder properties. *J. Fd. Engng.* 63:125-134.

Jayaprakasha G. K. and Sakariah K. K. 2000. Determination of hydroxycitric acid in commercial samples of *Garcinia cambogia* extracts by liquid chomatography using Ultra-violet detection. *J. Liq. Chomatogr. Relat*. 23: 915-923.

Jayaprakasha, G. K. and Sakariah, K. K. 2002. Determination of organic acids in leaves and rinds of *Garcinia indica* by HPLC. *J. Pharm. Biomed. Anal*. *28*: 379-384.

Jayashree, E., Chempakam, B., John Zachariah, T., and Alaguselvi, K. 2010. Thin layer modeling for drying of black pepper in agricultural waste fired reverse flow drier. *Drying Technol.* 23(2): 124-130.

Jena, B. S., Jayaprakasha, G. K., Singh, R. P., and Sakariah, K. K. 2002. Chemistry and biochemistry of hydroxycitric acid from Garcinia. *J. Agric. Fd. Chem*. 50: 10-22.

Jena, S and Das, H. 2007. Modelling for vacuum drying characteristics of coconut presscake. *J. Fd. Engng*. 9(1): 92–99.

Jin, Z., Yingwei, Y., and Qiu, W. 2003. Drying of Pearl Barlett (Pyrus sp.). *Int. J. Fd. Sci. Technol.* 23: 300–312.

Ji, S., Corredig, M. and Goff, H. D. 2008. Production and functional properties of micellar casein/k-carrageenan aggregates. *Int. Dairy J*. 18: 64-71.

Jittanit, W., Chantara, M., Deying, T., and Ratanavong, W. 2011. Production of tamarind powder by drum dryer using maltodextrin and Arabic gum as adjuncts. *Songklanakarin J. Sci. Technol.* 33 (1): 33-41.

Joe, F. N., Vivaldo, S. J. and Romero, J. T.2004. Ascorbic acid degradation during convective drying of persimmons with fixed temperature inside the fruit. Drying 2004 – *Proceedings of the 14th Int. Drying Symposium* (IDS 2004), 22-25 August, 2004; Sao Paulo, Brazil, pp. 1836-1843.

Joy, C. M. and Jose, K. P. 1998. Kudampuliyekurichu Kurachu Kariyangal, *Spice India (Malayalam)* 11(5): 19–20.

Juliana ,V.S., Monserrat, C.S., Arturo, R.S., Marco, A.S. and Guadalupe, L.S. 2011. Fluidized bed and tray drying of thinly sliced mango (*Mangifera indica*) pretreated with ascorbic and citric acid. *Int. J. Fd Sci. and Technol.* 32: 1296 – 1302.

Jumah, R.Y., Tashtoush, B., Shaker, R.R., and Zraiy, A.F. 2000. Manufacturing parameters and quality characteristics of spray dried jameed. *Drying Technol.* 18 (5): 967–984.

Kalil, M. A., and Sial, M. B. 1974. Spray drying of mango juice powder. *Mesopotamia J. Agric.* 9(2): 47-56.

KAU, [Kerala Agricultural University]. 2001. Three Decades of Spices research at KAU, Thissur, pp. 99-101.

Kavak, A, E. Y and Bicer. 2008. Mathematical modelling of thin layer drying process of long green pepper in solar dryer and under open sun energy conversion and management. 49(6): 1367-1375.

Kirtikar, K. R. and Basu, B. D. 1984. Indian Medicinal Plants. In: Blatter, E. (Ed.). Allahabad, 45p.

Knipschildt, M. E.1986. Recent Developments in spray drying of milk. *Drying Technol.* 7(2): 213-221.

Kristina, S., Malin, C., Pontus, L., Helena, L. and Kjell, B. 2002. The effect of process variable on the degradation and physical properties of spray dried insulin intended for inhalation. *Int. J. Pharmaceutics*. 233:227–237.

Kudra,T. 2003. Sticky region in drying - Definition and identification. *Drying Technol.* 21(8): 1457-1469.

Kurdia, D.S. and Roy, S.K.1974.St udies on guava powder by cabinet drying. *Indian Fd. Pack*. 28(5): 5-9.

Lahsasni, S., Kouhila, M., Mahouz, M., Idlimam, A., and Jamali, A. 2004. Thin layer convective solar drying and mathematical modeling of prickly pear peel (Opuntia ficus indica). *Energy*. 29: 211–224.

Langrish, T. A. G., Chan, W. C. and Kota, K. 2007. Comparison of maltodextrin and skim milk wall deposition rates in a pilot-scale spray dryer. *Powder Technol.* 179: 84-89.

Laxminarayana, G. S, Ghosh, B. C., and Kulkarni S. 1997. Technology of ready-to-use banana milk shake powder. *J. Fd. Sci*. Technol. 34: 41-45.

Lee, J. H. and Kim, H. J. 2009. Vacuum drying kinetics of Asian white radish (*Raphanus sativus*L.) slices. *LWT – Fd. Sci. Technol.* 42: 180–186.

Lenart, A. 1996. Osmo-convective drying of fruits and vegetables: Technology and application. *Drying Technol.* 14(2): 391-413.

Lewis, Y. S. and Neelakantan, S. 1965. Hydroxycitric acid – The principal acid in the fruits of *Garcinia cambogia. Phytochemistr*y .*4*: 619-625.

Li, H. and Morey, R. V. 1984. Thin-layer drying of yellow dent corn. *Trans. Am. Soc. Agric. Engrs.* 27(2): 581–585.

Liu, Z., Zhou, J., Zeng, Y. and Ouyang, X. 2006. The enhancement and encapsulation of *Agaricus bisporus* flavour. *J. Fd. Engng.*.6: 391–396.

Madhiyanon, T ., Phila, A. and Soponronnarit, C. 2009. Models of fluidized bed drying for thin-layer chopped coconut. *Appl. Therm. Engng.* 29:2849-54.

Mahendran ,P., Sabitha, K. E. and Devi, C.S. 2002. Prevention of HCl-ethanol induced gastric mucosal injury in rats by *Garcinia cambogia* extract and its possible mechanism of action. *Indian J. Exp. Biol*. 40(1): 58-62.

Mahendran, T. 2010. Quality of instant guava drink powder: Physico-chemical properties and sensory characteristics of dehydrated guava concentrate: Effect of drying method and maltodextrin concentration. Department of

Agricultural Chemistry, Faculty of Agric., Eastern University of Sri Lanka, Chenkalady. *Trop. Agric. Res. and Ext.* 13(2): 48-54.

Majeed, M., Badmaev, V., and Rajendran, R. 1998. Potassium hydroxycitrate for the suppression of appetite and induction of weight loss. US Patent No. 5783603.

Marilia. A., Jose. R. D.F. and Jose. R. L.2004. Study on coffee berry drying by using a vibrated tray operating in batch with recycle. *Proceedings of the fourteenth International Drying Symposium*; 22-25 August, 2004; Brazil, pp. 1955-1962.

Mary, A. E., John, P. J., and Vijayanand, D. 2007. Packaging and storage studies on spray dried ripe banana powder under ambient conditions. *J. Fd. Sci. Technol.* 44(1): 16-21.

Maskan,M. 2000. Microwave/air and microwave finish drying of banana. *J. Fd. Engng.* 44:71-78.

Masters, K. 1991. Spray drying handbook (5^{th} Ed.). Longman Scientific and Technical, Harlow, 616–617p.

Masters, K. 1997. Industrial drying of foods; Spray drying. In: Baker, C G J. (Ed.), Blackie Academic and Professional, London, 25p.

Masters, K. 2004. Applying spray drying to customize powder manufacture. *Chinese J. Chemical Engng.* 12(6): 744-749.

Mattes, R. and Bormann, L. 2000. Effects of hydroxycitric acid on appetite variables. *Physiol.and Behav.* 71(2): 87-94.

Menges, H.O. and Ertekin, C. 2006. Mathematical modelling of thin layer drying of golden apples. *J. Fd. Engng*. 77:119–125.

Mishra, H. N., Jacob, J. K. and Srinivasan, L. 2002. Preparation of apple powder and evaluation of its shelf life. *Beverage Fd. Wld.* 29 (1): 49-52.

Mujumdar, A.S. 1995. Handbook of Industrial Drying (2nd Ed.). Marcel Dekker, N.Y., p. 21.

Muralikrishna, M., Nanjundaswamy, A.M., and Siddappa, G.S. 1969. Guava Powder Preparation, Packaging, and Storage Studies. *J. Fd. Sci. Technol.* 6: 93-98.

Mustafa Ozilgen, G. G., Mehmet ,M., and Itila ,T. 1995. Colour change and weight loss of apple slices during drying. Inter. *J. Fd. Engng.* 201(1): 40-45

Nachiket, K., Pramod, B., and Ajay Verma, C. 2007. Changes in textural and optical properties of oyster mushoom during hot air drying. *J. Fd. Engng.*78: 1207–1211.

Nantawan, T and Hasaya, N. 2011. Characterization of hot air drying and microwave vacuum drying of fingerroot (Boesenbergia pandurata). *Int. J. Fd. Sci. Technol.* 46: 601–607.

Nath, S. and Satpathy, G. R. 1998. A systematic approach for investigation of spray drying processes. Tomato Pulp in Dehumidified Air: II. Powder Properties. *Drying Technol.* 16: 1173–1193.

Neha, B., Punam, K and Yadav, Y. K.2008. Study of dehydration characteristics of garlic. *J. Dairying.*27 (3): 238 – 240.

Nindo C.I., Sunb, T., Wang, S.W., Tanga, J., and Powers, J.R. 2003. Evaluation of drying technologies for retention of physical quality andantioxidants in asparagus (*Asparagus officinalis, L.*). *Lebensm. Technol*. 36: 507–516.

Nurul A. Z., lizawati, M. D., liza, M. D., Salleh., and Idayu,M. 2005. Effect of drying parameters and geometry on papaya quality. *J. Fd. Sci. Technol*. 21(1): 123-126.

Osman, A.F.,and Endut, N. E. 2009. Spray Drying of Roselle-Pineapple Juice Effects of inlet temperature and maltodextrin on the physical properties.

Second Int. Conference on Environmental and Computer Science; 28, December, 2009, Dubai. p.30.

Ozkan, N., Walisingheand, N. and Chen, X. D. 2002. Characterization of stickiness and cake formation in whole and skim milk powders. *J. Fd. Engg*. 55: 293-303.

Pal, D., Sachdeva S., and Singh, S.1995. Methods for determination of sensory quality of foods: A critical appraisal. *J. Fd. Sci. Technol.* 32(5): 357-367.

Palmer, H. H. 1959. Food theory and practice. John Wiley and Sons, N.Y., pp. 109–111.

Pamidighantam , P. R., Allani, N., Jaganmohan , L.R., and Govardhana, D. R. 2007. Studies on the effects of microwave drying and cabinet tray drying on the chemical composition of volatile oils of garlic powders. *Eur. Fd. Res. and Technol.* 224 (6): 791-795.

Papadakis, S., Gardeli, C. and Tzia, C. 2006. Spray drying of raisin juice concentrate. *Drying Technol.* 24:173-180.

Park, J. H., and Kim, C. S. 2007. The stability of colour and antioxidant compounds in paprika (*Capsicum annuum* L.) powder during the drying and storage process. *Fd. Sci. Bio. Technol.* 16(2): 187-192.

Patel, H. G., Hirpara, K., and Jana, A. 2009. Synergy of dairy with non-dairy Ingredients or product. *Afr. J. Fd. Sci.* 5(16): 817-832.

Peter, K. V.2 004. Handbook of Herbs and Spices. Wood head Publishing Ltd., New Delhi, 456p.

Phoungchandang, S and Sertwasan, A. 2010. Spray drying of ginger juice and physiochemical properties of ginger powder. *Sci. Asia*. 36: 40-45.

Piga, A., Pinna, I., Ozer, K. B., Agabbio, M., and Aksoy, U. 2004. Hot air dehydration of fig (*Ficus carica* L.): Drying kinetics and quality loss. *Int. J. Fd. Sci. Technol. 39* (7): 793-799.

Pomeranz, Y. and Meloan, C.E. 1994. Food Analysis Theory and Practice (3rd Ed.). Chapman and Hall, One Penn Plaza, N.Y., 34p.

Pua, C. K., Tan, C. P., Mirlosseini, H., Abdul, R. R. and Russel, G. 2008. Storage stability of jackfruit (*Artocarpus heterophyllus*) powder packaged in aluminium laminated polythene and metalized co extruded biaxially orienyed polypropylene during storage. *J. Fd. Engng.* 89: 419-428.

Quek S. Y., Chok, N. K. and Swedlund, P. 2007. The Physicochemical properties of spray dried watermelon powders. *J. Fd. Sci.* 46 (5): 386-392.

Ramaswamy, H. and Marcotte, M. 2006. Food processing: Principles and applications. FLA: CRC Press, Boca Raton , 78p.

Ramos, A. M. and Ibarz, A. 1998. Density of juice and fruit puree as a function of soluble solids content and temperature. *J. Fd. Engng.*. 35: 57-63.

Randy, F. 2011. Instant pineapple juice powder. Btech (Fd. Technol.) thesis, Swiss German University, Indoesia. Available: http//www.sgu.ac.id.pdf [27 June 2011].

Ranganna, S. 1991. Handbook of analysis and quality control for fruit and vegetable products. Tata Mc-Graw Hill Publishing Co. Ltd, New Delhi, 56p.

Rao, R. H. G and Gupta, P. M. 2002. Development of spray dried orange juice blended skim milk powder. *Drying Technol.* 82: 523-529.

Rao, R. H. G. and Kumar, A. H. 2005. Spray drying of mango juice - buttermilk blends. *J. Fd. Tech*.85: 395-404.

Reece. 1979. Grocery trade; Food industry and trade; Food; Vocational guidance; Marketing. Gregg Division, Mc Graw-Hill., N.Y, 202p.

Rittrut, W. and Siripatana, C. 2006. Drying characteristics of Garcinia atroviridis. Walailak .*J. Sci. Tech.* 3(1): 13-32.

Rodriguez, G.R., Gonzales, G. R., Grajales, L. A., and Ruiz, C. M. 2005. Spray-drying of cactus pear juice: effect on the physicochemical properties of powder and reconstituted product. *Drying Technol.* 23(1): 955–973.

Ruiz, C. M., Lucia, C. E. M., Carlos, A. A., Raul, G. G., Mario, M.S., and Alicia,G.L. 2009. Spray drying of passion fruit juice using lactose-maltodextrin blends as the support material. *J. Fd. Sci. Tech.* 20(2): 675-680.

Sabinsa, G. 2009. Safty validation of *Garcinia cambogia* extract as a dietary supplement. *Int. J. pharmaceuitical Sci. res.* 2(6): 1480-1494.

Sablani, S.S., Kasapis, S. and Rahman, M.S. 2007. Evaluating water activity and glass transition concepts for food stability. *J. Fd. Engng.* 78: 266-271.

Sablani, S.S., Myhara, R. M., and Taylor, M. 2000. Unification of fruit moisture sorption isotherms using artifi cial neural networks. In: *Proceedings of the 12th International Drying Symposium*. Elsevier, Amsterdam, Netherlands.

Sacilik, P. C. and Elicine, O. 2006. Drying characteristics and kinetics of coffee Berry. Revista Brasileira de Produtos Agorindustriais. *Eur. Fd. Res. Technol*. 229(2), 329-337.

Sajeev, K. V. 2012, Aug.9. Cardamom, chilli help spices export top $2 billion in 2011-12. The Hindu. p.10.

Saju, K. A. 1998. *Kodampuli* cultivation in Kodagu. *Spice India.* 11(7): 15.

Saravacos, G. D., Tsiourvas, D.A. and Tsami, E.2002. Effect of temperature on the water adsorption isotherms of sultana raisins. *J. Fd. Sci.* 51(2): 381-383.

Schultz, E. L., Mazzuco, M. M., Machado, R. A. F., Bolzan, A., Quadri, M. B., and Quadri, M. G. N. 2007. Effect of pre-treatments on drying, density and shinkage of apple slices. *J. Fd. Engng. 78*(3): 1103-1110.

Segini,S., Pedreschi, F., and Dejmek, P. 2004. Volume measurement methods of potato chips. ,*Int. J. Fd. Properties*.7(1):37-44.

Serap, K and Can, E. 2011. Vacuum drying kinetics of barbunya bean (*Phaseolus vulgaris* L. *elipticus* Mart.). *The Philipp. Agric. Scientist*. 94(3): 285-286.

Sertwasan, A. 2010. Spray drying of ginger juice and physiochemical properties of ginger powder. *Sci. Asia*. 36:40-45.

Shahidi, F. and Han, X. Q. 1993. Encapsulation of food ingredients. *Crit. Rev. Fd. Sci. Nutri.* 33(6): 501-547.

Sharma, S.K., Mulvaney. S.J., and Rizvi, S.S. 2000. Food process engineering: Theory and laboratory experiments. Wiley-interscience, N.Y., US, 34p.

Sharma, S. K., Sharma, P. C and Lalkanshal, B. B. 2004. Storage studies of foam mat dried hill lemon juice powder. *J. Fd. Sci. Technol*. 41(1): 9-13.

Shittu, T. A., Awonorin, S.O., and Raji, A. O. 2007. Evaluating some empirical models for predicting water absorption in African breadfruit (Treculia africana) seeds.*Int. J. Fd. Properties.* 7(3):585-602.

Shrestha, A. K., Ua-Arak, T., Adhikari, B. P., Howes, T. and Bhandari, B. R. 2007. Glass transition behavior of spray dried orange juice powder measured by differential scanning calorimetry (DSC) and thermal mechanical compression test (TMCT). *Int. J. Fd. Properties*.103: 661-673.

Singh, S and Patel, S.T. 2003. Development of a mushoom-whey soup powder. *Int. J. Fd. Sci. and Technol.* 38: 217–224.

Singh, S. and Rai, T. 1998. Storage studies of whey powder. *J. Dairying Fd. Home Sci*. 24: 184-189.

Soni, M. G., Burdock, G. A., Preuss, H. G., Stohs, S. J., Ohia, S. E. and Bagchi, D. 2004. Safety assessment of hydroxycitric acid and super citriMax, a novel calcium/potassium salt. *Fd. Chem. Toxicol.* 42(9): 1513-1529.

Souza, A. S., Borges, S.V ., Magalhaes, N. F., Ricardo, H. V., Cereda.M. P. and Daiut, E. R. 2009. Influence of spray drying conditions on the physical

properties of dried pulp tomato. *Cienc. Tecnol. Aliment. Campinas*. 29(2): 291-294.

Stallings, W., Blount, T. F., Srere, P. A. and Glusker, J. P. 1979. Structural studies of hydroxycitrate and their relevance to certain enzymatic mechanisms. *Arch. Biochem. Biophys.* 193: 431-448.

Stuchly, S.S. and Stuchly, M.A. 1983. Microwave drying: Potential and Limitations. In: Mujumdar, A.S. *Advances in Drying, Volume II*. Washington, N.Y., London: Hemisphere Publishing Corporation, pp. 53-71.

Sudeerbabu, P. 2009. Process stanadardisation for the commercial production of rasona ksheerapakam-a dairy based nutraceuitical. Phd (Dairy Technol.) thesis, Gandhian University, tamilnadu, pp. 50-52.

Sulivan, A.C. and Triscari, J. 1977. Metabolic regulation of a control for lipid disorders- In influence of hydroxy citrate on experimentally induces obesity in rodents. *The Am. J. Clin. Nutri.* 30: 767-776.

Sunjka, P.S., Orsat, V. and Raghavan, G.S.V. 2008. Microwave/vacuum drying of cranberries (Vacccinium macrocarpon). *American J. Fd. Technol.*3:100–108.

Suresh Kumar, P, Sagar, V. and Uadal Singh. 2005. Effect of tray load on drying kinetics of mango, guava and aonla. *J. scient. ind. res.* 65:659-664.

Suvarnakuta, T., Lin, T. M., Durance, T. D. and Scaman, C. H. 2005. Characterization of vacuum microwave, air and freeze dried carrot slices. *Elsevier Appl. Sci.* 31(2): 111.

Tan, M., Chua, K. J., Mujumdar, A. S. and Chou, S. K. 2001. Effect of osmotic pretreatment and infrared radiation on drying rate and colour changes during drying of potato and pineapple. *Drying Technol.* 19: 2193-2207.

Tang, J. and Yang, T. 2004. Dehydrated vegetables: Principles and systems. Handbook of vegetable preservation and processing, Marcel Dekker, N.Y. pp.335-372.

Thankitsunthorn, S., Thawornphiphatdit, C., Laohaprasit, N. and Srzednicki, G. 2009. Effects of drying temperature on quality of dried Indian Gooseberry powder. *Int. Fd. Res. J.* 16: 355-36.

Therdthai, N. and Zhou, W. 2009. Characterization of microwave vacuum drying and hot air drying of mint leaves (Mentha cordifolia Opiz ex Fresen). *J. Fd. Engng.* 91: 482–489.

Togrul, N. and Pehlivan, K. 2003. Thin-layer drying characteristics of kurut, a Turkish dried dairy by-product. *Int. J. Fd. Sci.* Technol. 26 (9): 1080-1086.

Trimen, H. A. 1983.Handbook of the flora of ceylon. Dulal and Company, London, 453p.

Truong, V. and Bhandari, B., Howes, T. 2005. Optimisation of co-current spray drying process of sugar rich foods: Part I- Moisture and glass transition temperature profile during drying. *J. Fd. Engng.* 71(1): 55-65

Tsotsas, K. and Mujumdar, A,S. 2007. A Review of: Power Technol. and pharmaceutical processes. Elsevier Sci., Amsterdam, Netherlands.

Vaillant, F., Jeanton, E., Dornier, M., Brien, G. M., Reynes, M. and Decloux, M. 2001, Concentration of passion fruit juice on an industrial pilot scale using osmotic evaporation. *J. Fd. Engng.* 47: 195-202.

Vega-Mercado, H, Gongora-Nieto, M. M. and Barbosa-Canovas, G. V. 2001. Advances in dehydration of foods. *J. Fd. Engng. 49*: 271-289.

Vongsawasdi, P., Nopharatana M.,Tangbumrungpong, D. and Apinunjarupong S. 2002. Production of Instant Fruit and Vegetable Juice by Spray Dryer and Microwave-Vacuum Dryer. *Drying Technol.* 25(3): 257-277.

Wealth of India (Raw Materials). 1956. *Vol. IV*. Publications and Information Directorate, Council of Scientific and Industrial Research, New Delhi.

Walstra, P. 2003. Physical chemistry of foods. Marcel Dekker, N.Y. pp.210-212.

Walton, D. E. 2000. The morphology of spray dried particles: a qualitative view. *Drying Technol.* 18(9): 1943-1986.

Wang, J., Wang, J.S., and Yu, Y. 2007. Microwave drying characteristics and dried quality of pumpkin. *Int. J. Fd. Sci. Technol.* 42: 148–156.

Wang' Y.G. and Wang, L. 2000. Structures and properties of commercial maltodextrins from corn, potato, and rice Starches. *Fd. Res. Int.* 52 (8): 296–304.

Watt, G. 1972. Dictionary of the Economic Products of India; Periodical Export: Delhi, India, 464p.

Weerachet, W., Niti-Att, S., and Techanuntachaikul, S.O. 2010. Study of spray drying of pineapple juice using maltodextrin as an adjunct. *Chiang Mai J. Sci.* 37(3): 498-506.

Weerachet J., Maythawee, C., Tithiya, D., and Wantanee, R.2011. Production of tamarind powder by drum dryer using maltodextrin and Arabic gum as adjuncts. Songklanakarin. *J. Sci. Technol*. 33 (1): 33-41.

Wenniger and Michael P. 2001. Nutritional weight loss agent, US Patent No. 7311929.

William, G. A. 1971. *Industrial Drying*. Chemical and Process Engng. Series. Leonardo Hill. London, UK, pp.23-37.

Wu, L., Orikasa, T. Y. Ogawa and Tagawa, A. 2007. Vacuum drying characteristics of eggplants. *J. Fd. Engng.* 83: 422-429.

Yadollahinia, A., Latifi, A., and Mahdavi, R. 2009. New method for determination of potato slice shinkage during drying. *Comput. and Electronics in Agric. 65*(2): 268-274.

Yu, W., Shu, B.and shi-ying, X . 2007. Study on microencapsulation of lycopene by spray drying. *J. Fd. Engng. 76*(4): 664-669.

Zeuthen, P., Cheftel, J. C., Efiksson, C., Gormley, T. R., Linko, P., and Paulus, K. 1990. *Processing and quality of foods: High temperature/short time (HTST) processing (Volume 1):- Guarantee for high quality foods with a long shelf life*. *Elsevier Appl. Sci.* 1(2): 355–361.

Appendices

Appendix A

Table. A Percentage moisture content during tray drying

	Moisture content (%wb)										
Time(h)	0	1	2	3	4	5	6	7	8	9	10
Temp (^{o}C)											
60	86.80	85.09	82.38	77.61	73.20	62.56	41.77	24.29	8.83	4.82	4.75
70	86.80	81.26	77.67	61.71	41.49	14.10	6.15	4.29			
80	86.80	79.28	70.21	55.75	19.79	6.94	4.28				

Table A.2 ANOVA table for optimization of tray drying

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	0.002	2	0.001	0.02	0.978
		Within Groups	0.554	12	0.046		
		Total	0.556	14			
2	**Total solids**	Between Groups	0.002	2	0.001	0.02	0.978
		Within Groups	0.554	12	0.046		
		Total	0.556	14			
3	**pH**	Between Groups	5.950	2	2.975	32.41	0.000
		Within Groups	1.101	12	0.092		
		Total	7.051	14			
4	**Bulk density**	Between Groups	0.124	2	0.062	76.45	0.000
		Within Groups	0.010	12	0.001		
		Total	0.134	14			
5	**Lightness**	Between Groups	93.328	2	46.664	125.41	0.000
		Within Groups	4.465	12	0.372		
		Total	97.793	14			
6	**a***	Between Groups	6.659	2	3.329	12.51	0.001
		Within Groups	3.192	12	0.266		
		Total	9.851	14			
7	**b***	Between Groups	28.656	2	14.328	233.58	0.000
		Within Groups	0.736	12	0.061		
		Total	29.392	14			
8	**Wettability**	Between Groups	74.533	2	37.267	23.29	0.000
		Within Groups	19.200	12	1.600		
		Total	93.733	14			

SS = Sum of Squares Ms =Mean square

Table A.3 Effect of tray drying temperature on quality parameters of *Garcinia cambogia* powder

Treatments	Colour value			S (ml)	W (s)	Total solids	Acid value (%)	pH	Bulk density (g/cm^3)
	L	a*	b*						
T0(60°C)	70.156 [c]	13.667 [b]	20.824 [b]	93.0 [a]	93.0 [a]	95.598 [b]	20.81	1.8720 [a]	0.782 [c]
T1(70°C)	75.246 [a]	12.618 [a]	17.902 [a]	93.8 [a]	93.8 [a]	95.618 [a]	20.81	1.868 [a]	0.606 [a]
T2(80°C)	75.628 [a]	12.06 [a]	17.882 [a]	98.4 [c]	98.0 [b]	95.626 [a]	19.42	3.206 [b]	0.576 [a]
CV	0.046	0.065	0.287		0.01	0.375		0.188	17.250
CD	1.163	0.711	0.340	1.7	1.7	0.296		0.191	0.0436

W= Wettability S= Solubility index

Table A.4 Percentage moisture content during vacuum tray drying

	Moisture content(%wb)								
Time(h)	0	2	4	6	8	10	12	14	16
Temp(^oC)									
40	86.80	86.10	85.00	79.00	62.92	28.00	13.15	5.98	5.97
45	86.80	86.80	84.47	78.71	65.34	24.00	6.20	6.17	
50	86.80	86.80	82.28	65.00	7.89	6.00	5.97		

Table A.5ANOVA table for the Optimisation of vacuum tray drying

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	1.632	2	0.816	39.05	0.00
		Within Groups	0.251	12	0.021		
		Total	1.883	14			
2	**Total solids**	Between Groups	1.632	2	0.816	39.05	0.00
		Within Groups	0.251	12	0.021		
		Total	1.883	14			
3	**pH**	Between Groups	0.044	2	0.022	27.907	0.00
		Within Groups	0.009	12	0.001		
		Total	0.054	14			
4	**Bulk density**	Between Groups	0.068	2	0.034	159.961	0.00
		Within Groups	0.003	12	0		
		Total	0.071	14			
5	**Lightness**	Between Groups	0.556	2	0.278	6.069	0.015
		Within Groups	0.55	12	0.046		
		Total	1.106	14			
6	**a***	Between Groups	0.323	2	0.162	10.743	0.002
		Within Groups	0.181	12	0.015		
		Total	0.504	14			
7	**b***	Between Groups	0.245	2	0.122	5.344	0.022
		Within Groups	0.275	12	0.023		
		Total	0.52	14			
8	**Wettability**	Between Groups	252.933	2	126.467	41.239	0
		Within Groups	36.8	12	3.067		
		Total	289.733	14			

SS = Sum of Squares Ms =Mean square

TableA.6 Effect of Vacuum tray drying on quality parameters of *Garcinia cambogia* powder

Treatments	Colour value			Solubility index(ml)	Wettability (s)	Total solids	Acid value (%)	pH	Bulk density (g/cm^3)
	L	a*	b*						
V0(40°C)	68.00 [b]	13.55 [b]	17.374 [b]	0.80	102.800 [a]	94.000 [b]	22.12	1.76[a]	0.800
V1(45°C)	68.64 [a]	12.78[a]	17.576 [a]	0.85	104.400 [a]	94.670 [a]	22.12	1.76 [a]	0.715
V2(50°C)	68.17 [a]	12.90[a]	17.682 [a]	1.00	112.200 [b]	94.800 [a]	20.8	1.87 [b]	0.635
CV	0.959	0.507	0.010		0.0050	0.821			
CD	0.402	0.254	0.573		3.117	0.242		0.056	

Appendix B

Results of statistical analysis conducted for optimizing the Spray drying parameters

ANOVA table for spray drying

Experiment Model Number 3:

Three Factor Completely Randomized Design

Table B.1 Effect of spray drying parameters on moisture content of *Garcinia cambogia powder*

Analysis of variance table for moisture content of spray dried *Garcinia cambogia* powder

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F Value	CD	Probability
2	Factor A(Speed)	1	3.484	3.484	531.751	0.053	**
4	Factor B(Temperture)	1	0.745	0.745	113.745	0.053	**
6	AB	2	0.127	0.127	19.413	0.076	**
8	Factor C(Feed rate)	2	0.102	0.102	15.499	0.065	**
10	AC	2	0.029	0.029	4.459	0.092	**
12	BC	2	0.017	0.017	2.638	0.092	ns
14	ABC	2	0.039	0.039	5.952	0.131	**
-15	Arror	24	0.007	0.007			
	Total	35	4.888				

Table B.2 Effect of spray drying parameters on total solids of *Garcinia cambogia powder*

Analysis of variance table for total solids of spray dried *Garcinia cambogia* powder

K Value	Source	Degrees of freedom	Sum of squares	Mean square	F Value	CD	Probability
2	Factor A(Speed)	1	3.484	3.484	531.7512	0.0535	**
4	Factor B(Tempearture)	1	0.745	0.745	113.7455	0.0535	**
6	AB	2	0.127	0.127	19.4132	0.0756	**
8	Factor C(Feed rate)	2	0.203	0.102	15.4987	0.0655	**
10	AC	2	0.058	0.029	4.4590	0.0924	*
12	BC	2	0.035	0.017	2.6380	0.0924	ns
14	ABC	2	0.078	0.039	5.9521	0.1308	**
-15	Arror	24	0.157	0.007			
	Total	**35**	**4.888**				

Coefficient of variation: 0.08 CD – Critical difference value, ** Significant at 1% level

ns- Non significant

Table B.3 Effect of spray drying parameters on pH of Garcinia *cambogia powder*

Analysis of variance of table for pH

K Value	Source	DF	SS	MS	F Value	CD	Probability
2	Factor A(Speed)	1	0.002	0.002	1.4222	0.0221	ns
4	Factor B(Temperature)	1	0.336	0.336	299.0224	0.0221	**
6	AB	2	0.001	0.001	0.9877	0.0221	**
8	Factor C(Feed rate)	2	0.035	0.018	15.6222	0.0271	**
10	AC	2	0.001	0.000	0.2741	0.0384	ns
12	BC	2	0.046	0.023	20.4220	0.0384	**
14	ABC	2	0.000	0.000	0.1654	0.0543	**
-15	Arror	24	0.027	0.001			
	Total	**35**	**0.448**				

Coefficient of variation: 1.95%, DF – Degrees of freedom, SS – Sum of Squares,

MS – Mean squares, CD – Critical difference value, ** Significant at 1% level

Table B.4 Effect of spray drying parameters on Bulk density of *Garcinia cambogia* powder

Analysis of variance table for bulk density

K Value	Source	DF	SS	MS	F Value	CD	Probability
2	Factor A(Speed)	1	0.002	0.002	1.4222	0.0221	ns
4	Factor B(Tempearture)	1	0.336	0.336	299.0224	0.0221	**
6	AB	2	0.001	0.001	0.9877	0.0221	ns
8	Factor C(Feed rate)	2	0.035	0.018	15.6222	0.0271	**
10	AC	2	0.001	0.000	0.2741	0.0384	ns
12	BC	2	0.046	0.023	20.4220	0.0384	**
14	ABC	2	0.000	0.000	0.1654	0.0543	ns
-15	Arror	24	0.027	0.001			
	Total	**35**	**0.181**				

Coefficient of variation: 1.95%, DF – Degrees of freedom, SS – Sum of Squares,

MS – Mean squares, CD – Critical difference value, ** Significant at 1% level

Table B.5 Effect of spray drying parameters on Lightness (L) of *Garcinia cambogia powder*

Analysis of variance table for lightness *Garcinia cambogia* powder during spray drying

K Value	Source	DF	SS	MS	F Value	CD	Probability
2	Factor A(Speed)	1	12.402	12.402	423.6406	0.1128	**
4	Factor B(Tempearture)	1	32.967	32.967	1126.1025	0.1128	**
6	AB	2	0.327	0.327	11.1632	0.1596	**
8	Factor C(Feed rate)	2	16.596	8.298	283.4430	0.1383	**
10	AC	2	3.426	1.713	58.5085	0.1957	**
12	BC	2	26.365	13.183	450.2978	0.1957	**
14	ABC	2	2.574	1.287	43.9540	0.2767	**
-15	Arror	24	0.703	0.029			
	Total	**35**	**95.358**				

Coefficient of variation: 0.18% DF – Degrees of freedom SS – Sum of Squares,

MS – Mean squares CD – Critical difference value ** Significant at 1% level

Table B.6 Effect of spray drying parameters on redness (a* value) of Garcinia *cambogia powder*

Analysis of variance table for redness of Garcinia *cambogia powder* during spray drying

K Value	Source	DF	SS	MS	F Value	CD	Probability
2	Factor A(Speed)	1	0.967	0.967	108.5776	0.0622	**
4	Factor B(Tempearture)	1	4.299	4.299	482.7000	0.0622	**
6	AB	2	0.548	0.548	61.4898	0.0882	**
8	Factor C(Feed rate)	2	2.771	1.385	155.5699	0.0762	**
10	AC	2	0.802	0.401	45.0246	0.1078	**
12	BC	2	1.501	0.754	84.6347	0.1078	**
14	ABC	2	0.544	0.272	30.5437	0.1526	**
-15	Error	24	0.214	0.009			
	Total	**35**	**11.651**				

Coefficient of variation: 2.19%, DF – Degrees of freedom SS – Sum of Squares,

MS – Mean squares, CD – Critical difference value ** Significant at 1% level

Table B.7 Effect of spray drying parameters on yellowness (a* value) of Garcinia cambogia powder

Analysis of variance table for lightness for yellowness (b* value) of *Garcinia cambogia* powder

K Value	Source	DF	SS	MS	F Value	CD	Probability
2	Factor A(Speed)	1	0.232	0.232	2.8615	0.1879	ns
4	Factor B(Tempearture)	1	6.9808	6.9808	85.2039	0.1879	**
6	AB	2	0.027	0.027	0.3358	0.2657	ns
8	Factor C(Feed rate)	2	7.733	3.867	47.6914	0.2317	**
10	AC	2	20.434	10.217	126.0166	0.3254	**
12	BC	2	4.855	2.428	29.9434	0.3254	**
14	ABC	2	2.471	1.236	15.2413	0.4603	**
-15	Error	24	1.946	0.081			
	Total	**35**	**44.608**				

Coefficient of variation: 1.30% DF – Degrees of freedom SS – Sum of Squares,

MS – Mean squares CD – Critical difference value ** Significant at 1% level

Table B.8 Effect of spray drying parameters on wettability of *Garcinia cambogia* powder

Analysis of variance table for wettability of *Garcinia cambogia* powder during spray drying

K Value	Source	DF	SS	MS	F Value	CD	Probability
2	Factor A(Speed)	1	215.111	215.111	193.6000	0.6958	**
4	Factor B(Tempearture)	1	1.778	1.778	1.6000	0.6958	ns
6	AB	2	32.111	32.111	28.9000	0.9840	**
8	Factor C(Feed rate)	2	128.389	64.194	57.7750	0.8521	**
10	AC	2	16.722	8.361	7.5250	1.2049	**
12	BC	2	12.056	6.028	5.4250	1.2049	**
14	ABC	2	13.722	6.861	6.1750	1.7041	**
-15	Error	24	26.667	1.111			
	Total	**35**	**446.556**				

Coefficient of variation: 1.30% DF – Degrees of freedom SS – Sum of Squares,

MS – Mean squares CD – Critical difference value ** Significant at 1% level

Table B.9 Analysis of variance table for different quality parameters of *Garcinia cambogia* during spray drying

Sl. No	Treatment	S(rpm)	T (°C)	Feed rate (l/h)	Table of means							
					MC (%wb)	Total solids	pH	Bulk density (g/cm^3)	L	a*	b*	Wettability
1	S0 (S1T1F1)	17000	175	5.000	4.680	95.320	1.860	0.552	91.167	4.433	22.04	89.00
2	S1 (S1T1F2)	17000	175	5.500	4.703	95.297	1.813^{c}	0.555	92.300	4.620	22.08	88.00
3	S2 (S1T1F3)	17000	175	6.000	4.803	95.197	1.823^{c}	0.578	93.900	4.773	23.04	85.00^{c}
4	S3 (S1T2F1)	17000	180	5.000	4.477	95.523	1.560^{a}	0.517^{c}	94.310^{b}	3.940^{b}	20.27^{a}	90.33
5	S4 (S1T2F2)	17000	180	5.500	4.577	95.423	1.610^{a}	0.559	95.093^{ab}	3.200	20.56^{ab}	89.00
6	S5 (S1T2F3)	17000	180	6.000	4.627	95.373	1.713^{b}	0.606	93.133	4.673	23.87	87.00
7	S6 (S2T1F1)	22000	175	5.000	4.133^{c}	95.867^{c}	1.820	0.420^{a}	92.317	4.567	22.20	86.00
8	S7 (S2T1F2)	22000	175	5.500	4.217	95.783^{c}	1.787^{b}	0.421^{a}	93.567	4.723	23.02	84.00^{c}
9	S8 (S2T1F3)	22000	175	6.000	3.863	95.673	1.817	0.428^{a}	94.433	4.780	21.62	83.00^{b}
10	S9 (S2T2F1)	22000	180	5.000	3.863^{a}	96.137^{b}	1.560^{a}	0.408^{a}	94.420	4.353	20.56	87.00
11	S10 (S2T2F2)	22000	180	5.500	3.593^{a}	96.407^{a}	1.600^{a}	0.412^{a}	97.900^{a}	3.827^{a}	22.54^{c}	79.00^{a}
12	S11 (S2T2F3)	22000	180	6.000	4.000^{b}	96.000	1.717^{b}	0.452^{b}	94.310	4.560	20.95	81.00^{b}
	CD				0.131	0.131	0.054	0.022	0.277	0.153	0.460	0.277

S=Speed of the atomizer MC = Moisture content T = Temperature

Appendix C

Changes in quality parameters of *Garcinia cambogia* powder during storage

Table C.1 Changes in moisture content of *Garcinia cambogia* powder during storage

Treatments	Moisture content (%wb) Vs. Storage period (Months)						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
T1	4.382 [b]	4.816[b]	4.816 [b]	5.768 [b]	6.216 [b]	6.41 [b]	6.418 [b]
V1	5.500 [c]	5.768 [c]	5.768 [c]	8.594 [c]	-	-	-
S10	3.588 [a]	3.588 [a]	3.588 [a]	5.402 [a]	5.990 [a]	05.990[a]	5.990 [a]
CV	0.466	1.568	0.670	1.095	0.626	0.730	0.137
CD	0.265	0.144	0.145	0.174	0.232	0.214	0.265

T1-Tray dried sample at 60°C V1-Vacuum tray dried sample at 45°C
S10-Spray dried sample at 180°C 22000 rpm and 5.5 l/h

Table C.2 Changes in total solids of *Garcinia cambogia* powder during storage

Treatments	Total solids Vs. Storage period (Months)						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
T1	95.598 [b]	95.184[b]	95.184 [b]	94.014 [b]	93.780 [b]	93.590[b]	91.594 [b]
V1	94.500 [c]	94.232 [c]	94.232 [c]	91.622 [c]	-	-	-
S10	96.410 [a]	95.864 [a]	95.864 [a]	94.598 [a]	94.000[a]	94.000[a]	94.002 [a]
CV	0.466	2.464	0.700	0.120	0.604	0.216	0.026
CD	0.265	0.115	0.115	0.527	0.235	0.392	3.585

T1-Tray dried sample at 60°C V1-Vacuum tray dried sample at 45°C
S10-Spray dried sample at 180°C 22000 rpm and 5.5 l/h

Table C.3 Changes in pH of *Garcinia cambogia* powder during storage

Treatments	pH Vs. Storage period 9Months)						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
T1	1.868 [c]	1.866c	1.866 [b]	1.959 [b]	2.038 [b]	2.038 [b]	2.038 [b]
V1	1.756 [b]	1.860 [c]	1.860 [c]	2.026 [c]	-	-	-
S10	1.676 [a]	1.678 [a]	1.678 [a]	1.760 [a]	1.868[a]	1.868[a]	2.354[a]
CV	8.626	0.000	17.521	0.000	17.521	5.84	0.000
CD	0.002	0.001	0.001	0.001	0.044	0.076	0.000

T1-Tray dried sample at 60°C V1-Vacuum tray dried sample at 45°C
S10-Spray dried sample at 180°C 22000 rpm and 5.5 l/h

Table C.4 Changes in Bulk density of *Garcinia cambogia* powder during storage

Treatments	Bulk density Vs. Storage period (Months)						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
T1	0.674 [b]	0.7054 [b]	0.7054 [b]	0.7744 [b]	0.8058 [b]	0.8366 [b]	0.8404 [b]
V1	0.7148 [c]	0.7558 [c]	0.7558 [c]	0.8538 [c]	-	-	-
S10	0.4280 [a]	0.4460 [a]	0.4460 [a]	0.5336 [a]	0.5356[a]	0.5438[a]	0.5440[a]
CV	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

T1-Tray dried sample at 60°C V1-Vacuum tray dried sample at 45°C
S10-Spray dried sample at 180°C 22000 rpm and 5.5 l/h

Table C.5 Changes in Lightness (L) of *Garcinia cambogia* powder during storage

Treatments	Lightness Vs. Storage period (Months)						
	Initial	1st	2nd	3rd	4th	5th	6th
T1	75.246[b]	74.600[b]	70.538[b]	0.774[b]	68.860[b]	68.860[b]	67.174[b]
V1	68.638[c]	67.220[c]	64.000[c]	0.854[c]	-	-	-
S10	93.890[a]	93.375[a]	93.366[a]	93.357[a]	93.320[a]	93.300[a]	93.290[a]
CV	0.057	0.199	0.093	0.173	0.031	0.307	0.078
CD	0.254	0.409	0.409	0.438	1.036	0.329	0.650

T1-Tray dried sample at 60°C V1-Vacuum tray dried sample at 45°C
S10-Spray dried sample at 180°C 22000 rpm and 5.5 l/h

Table C.6 Changes in Yellowness (a*) of *Garcinia cambogia* powder during storage

Treatments	Storage period						
	Initial	1st	2nd	3rd	4th	5th	6th
T1	12.618[b]	12.004[b]	12.004[c]	13.524[b]	14.334[b]	15.242[b]	15.420[b]
V1	12.782[b]	12.996[b]	12.996[b]	14.476[c]	-	-	-
S10	4.570[a]	4.670[a]	4.800[a]	4.802[a]	4.812[a]	4.889[a]	4.902[a]
CV	0.332	5.750	0.273	0.1025	0.072	0.138	0.059
CD	0.314	0.076	0.760	0.570	0.681	0.491	0.745

T1-Tray dried sample at 60°C V1-Vacuum tray dried sample at 45°C
S10-Spray dried sample at 180°C 22000 rpm and 5.5 l/h

Table C.7 Changes in Yellowness (b*) of *Garcinia cambogia* powder during storage

Treatments	Storage period						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
T1	17.902[c]	18.038[c]	18.038[c]	18.952[c]	19.420[b]	19.864[b]	20.046[b]
V1	17.576[b]	18.696[b]	18.696[b]	21.204[b]	-	-	-
S10	22.220[a]	22.760[a]	22.768[a]	22.786[a]	22.878[a]	23.578[a]	23.590[a]
CV	2.46	0.177	1.252	0.834	0.292	0.265	4.38
CD	0.115	0.139	0.510	0.200	0.338	0.354	0.087

Table C.8 Changes in Wettability of *Garcinia cambogia* powder during storage

Treatments	Storage period						
	Initial	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
T1	95.000[b]	97.334[b]	97.334[b]	99.000[c]	102.6000[b]	103.800[b]	104.600[b]
V1	104.400[b]	103.800[c]	103.800[c]	106.200[c]	-	-	-
S10	79.000[a]	82.000[a]	82.000[a]	21.786[a]	88.600[a]	89.400[a]	89.400[a]
CV	0.066	0.177	0.112	0.021	0.0122	0.159	0.0112
CD	2.293	1.361	1.361	1.258	1.650	1.446	1.730

T1-Tray dried sample at 60°C V1-Vacuum tray dried sample at 45°C
S10-Spray dried sample at 180°C 22000 rpm and 5.5 l/h

Table C.9 ANOVA table for the effect of different quality parameters for *Garcinia cambogia* powder during initial month of storage

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	9.227	2.000	4.613	124.75	0.00
		Within Groups	0.444	12.000	0.037		
		Total	9.671	14.000			
2	**Total solids**	Between Groups	9.188	2.000	4.594	123.81	0.00
		Within Groups	0.445	12.000	0.037		
		Total	9.634	14.000			
3	**pH**	Between Groups	0.093	2.000	0.047	27.74	0.00
		Within Groups	0.020	12.000	0.002		
		Total	0.113	14.000			
4	**Bulk density**	Between Groups	0.241	2.000	0.121	1083.99	0.00
		Within Groups	0.001	12.000	0.000		
		Total	0.242	14.000			
5	**Lightness**	Between Groups	2354.53	2.000	1177.23	34412.9	0.000
		Within Groups	0.41	12.000	0.034		
		Total	2354.94	14.000			
6	**a***	Between Groups	262.501	2.000	131.251	2538.58	0.000
		Within Groups	0.620	12.000	0.052		
		Total	263.12	14.000			
7	**b***	Between Groups	77.226	2.000	38.613	5886.11	0.000
		Within Groups	0.079	12.000	0.007		
		Total	77.304	14.000			
8	**Wettability**	Between Groups	1514.53	2.000	757.267	273.71	0.000
		Within Groups	33.20	12.000	2.767		
		Total	1547.733	14.000			

Table C.10 ANOVA table for the effect of different quality parameters for *Garcinia cambogia* powder during first month of storage

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Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	11.944	2	5.972	531.338	0.00
		Within Groups	0.135	12	0.011		
		Total	12.079	14			
2	**Total solids**	Between Groups	6.72	2	3.36	466.034	0.00
		Within Groups	0.087	12	0.007		
		Total	6.807	14			
3	**pH**	Between Groups	0.114	2	0.057	126.86	0.00
		Within Groups	0.005	12	0		
		Total	0.12	14			
4	**Bulk density**	Between Groups	0.276	2	0.138	457.69	0.00
		Within Groups	0.004	12	0		
		Total	0.28	14			
5	**Lightness**	Between Groups	2556.779	2	1278.389	14468.02	0.000
		Within Groups	1.06	12	0.088		
		Total	2557.839	14			
6	**a***	Between Groups	256.177	2	128.089	37611.19	0.000
		Within Groups	0.041	12	0.003		
		Total	256.218	14			
7	**b***	Between Groups	52.278	2	26.139	2244.96	0.000
		Within Groups	0.14	12	0.012		
		Total	52.417	14			
8	**Wettability**	Between Groups	1253.635	2	626.817	643.38	0.000
		Within Groups	11.691	12	0.974		
		Total	1265.326	14			

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Table C.11 ANOVA table for the effect of different quality parameters for *Garcinia cambogia* powder during second month of storage

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	11.940	2	5.972	531.3	0.00
		Within Groups	0.140	12	0.011		
		Total	12.080	14			
2	**Total solids**	Between Groups	6.720	2	3.360	466.0	0.00
		Within Groups	0.087	12	0.007		
		Total	6.807	14			
3	**pH**	Between Groups	0.110	2	0.057	126.9	0.00
		Within Groups	0.010	12	0.000		
		Total	0.120	14			
4	**Bulk density**	Between Groups	0.280	2	0.138	457.7	0.00
		Within Groups	0.004	12	0.000		
		Total	0.280	14			
5	**Lightness**	Between Groups	2556.780	2	1278.389	14468.0	0.00
		Within Groups	1.060	12	0.088		
		Total	2557.839	14			
6	**a***	Between Groups	256.177	2	128.089	37611.1	0.00
		Within Groups	0.041	12	0.003		
		Total	256.218	14			
7	**b***	Between Groups	52.278	2	26.139	22445.0	0.00
		Within Groups	0.140	12	0.012		
		Total	52.417	14			
8	**Wettability**	Between Groups	1253.635	2	626.817	643.3	0.00
		Within Groups	11.691	12	0.974		
		Total	1265.326	14			

Table C.12 ANOVA table for the effect of different quality parameters for *Garcinia cambogia* powder during third month of storage

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	30.369	2	15.184	949.42	0.00
		Within Groups	0.192	12	0.016		
		Total	30.561	14			
2	**Total solids**	Between Groups	24.865	2	12.433	84.88	0.00
		Within Groups	1.758	12	0.146		
		Total	26.623	14			
3	**pH**	Between Groups	0.191	2	0.096	380.87	0.00
		Within Groups	0.003	12	0.000		
		Total	0.194	14			
4	**Bulk density**	Between Groups	0.278	2	0.139	2720.13	0.00
		Within Groups	0.001	12	0.000		
		Total	0.279	14			
5	**Lightness**	Between Groups	3015.596	2	1507.798	14909.20	0.000
		Within Groups	1.214	12	0.101		
		Total	3016.809	14			
6	**a***	Between Groups	353.076	2	176.538	1032.63	0.000
		Within Groups	2.052	12	0.171		
		Total	355.127	14			
7	**b***	Between Groups	22.398	2	11.199	544.38	0.000
		Within Groups	0.247	12	0.021		
		Total	22.645	14			
8	**Wettability**	Between Groups	879.600	2	439.800	527.76	0.000
		Within Groups	10.000	12	0.833		
		Total	889.600	14			

Table C.13 ANOVA table for the effect of different quality parameters for *Garcinia cambogia* powder during fourth month of storage

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	24.349	2	12.175	433.875	0.00
		Within Groups	0.337	12	0.028		
		Total	24.686	14			
2	**Total solids**	Between Groups	24.323	2	12.161	422.346	0.00
		Within Groups	0.346	12	0.029		
		Total	24.668	14			
3	**pH**	Between Groups	0.095	2	0.048	64.333	0.00
		Within Groups	0.009	12	0.001		
		Total	0.104	14			
4	**Bulk density**	Between Groups	0.364	2	0.182	8563.073	0.00
		Within Groups	0.000	12	0.000		
		Total	0.364	14			
5	**Lightness**	Between Groups	3134.309	2	1567.155	2774.519	0.000
		Within Groups	6.778	12	0.565		
		Total	3141.087	14			
6	**a***	Between Groups	380.200	2	190.100	779.360	0.000
		Within Groups	2.927	12	0.244		
		Total	383.127	14			
7	**b***	Between Groups	26.553	2	13.276	222.411	0.000
		Within Groups	0.716	12	0.060		
		Total	27.269	14			
8	**Wettability**	Between Groups	1106.533	2	553.267	386.000	0.000
		Within Groups	17.200	12	1.433		
		Total	1123.733	14			

Table C.14 ANOVA table for the effect of different quality parameters for *Garcinia cambogia* powder during fifth month of storage

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	26.535	2	13.267	542.78	0.00
		Within Groups	0.293	12	0.024		
		Total	26.828	14			
2	**Total solids**	Between Groups	29.645	2	14.823	182.67	0.00
		Within Groups	0.974	12	0.081		
		Total	30.619	14			
3	**pH**	Between Groups	0.331	2	0.165	62.25	0.00
		Within Groups	0.032	12	0.003		
		Total	0.363	14			
4	**Bulk density**	Between Groups	0.432	2	0.216	6017.84	0.00
		Within Groups	0.000	12	0.000		
		Total	0.432	14			
5	**Lightness**	Between Groups	3113.684	2	1556.842	27384.87	0.000
		Within Groups	0.682	12	00.057		
		Total	3114.366	14			
6	**a***	Between Groups	439.100	2	219.550	1727.65	0.000
		Within Groups	1.525	12	0.127		
		Total	440.625	14			
7	**b***	Between Groups	45.246	2	22.623	340.36	0.000
		Within Groups	0.798	12	0.066		
		Total	46.044	14			
8	**Wettability**	Between Groups	1081.733	2	540.867	491.69	0.000
		Within Groups	13.200	12	1.100		
		Total	1094.933	14			

Table C.15 ANOVA table for the effect of different quality parameters for *Garcinia cambogia* powder during sixth month of storage

Sl. No	Parameters		SS	df	MS	F	Sig.
1	**Moisture content**	Between Groups	53.324	2	26.662	211.69	0.00
		Within Groups	1.511	12	0.126		
		Total	54.835	14			
2	**Total solids**	Between Groups	31.824	2	15.912	2.35	0.00
		Within Groups	81.146	12	6.762		
		Total	112.970	14			
3	**pH**	Between Groups	0.191	2	0.096	380.87	0.00
		Within Groups	0.003	12	0.000		
		Total	0.194	14			
4	**Bulk density**	Between Groups	0.469	2	0.235	1606.69	0.00
		Within Groups	0.002	12	0.000		
		Total	0.471	14			
5	**Lightness**	Between Groups	3372.936	2	1686.468	7593.98	0.000
		Within Groups	2.665	12	0.222		
		Total	3375.601	14			
6	**a***	Between Groups	453.748	2	226.874	777.54	0.000
		Within Groups	3.501	12	0.292		
		Total	457.250	14			
7	**b***	Between Groups	73.432	2	36.716	8571.33	0.000
		Within Groups	0.051	12	0.004		
		Total	73.483	14			
8	**Wettability**	Between Groups	1966.533	2	983.267	627.61	0.000
		Within Groups	18.800	12	1.567		
		Total	1985.333	14			

Appendix D

Table D.1 SCORE CARD for sensory analysis

Garcinia added Fish curry	Appearance	Colour	Flavour	Taste	Overall acceptability

Instruction: At least take one mouthful of sample. Please take a sip of water before testing the next sample.

Quality attributes

9 – Like extremely	8 – Like very much	7 – Like moderately
6 – Like slightly	5 – Neither like or dislike	4 – Dislike slightly
3 – Dislike moderately	2 – Dislike very much	1 – Dislike Extremely

Name:

Signature:

Date:

Table D.2 Sensory evaluation of *Garcinia cambogia* added fish curry

Treatment used for fish curry preparation	Appearance	Colour	Flavour	Taste	Overall acceptability
Tray dried (T1)	7.8	7.6	7.2	7.0	8.0
Vacuum tray dried (V1)	6.0	7.4	6.6	6.6	7.0
Spray dried (S10)	8.8	8.6	8.6	8.2	8.8

Appendix E

1. Cost of operation of plant/hr

Cost of machineries

1). Reception tank	: Rs.50000/-
2). Cleaner	: Rs. 30000/-
3). Slicer and filter equipment	: Rs. 40000/-
4). Grinder	: Rs. 220000/-
5). Spray dryer	: Rs. 1500000/-
6). Packing machine	: Rs. 200000/-
Initial cost (C)	: Rs. 2040000/-

Assumptions

Useful life, L	: 15 years
Annual working hr, T	: 600 hrs
Salvage value, S	: 10% of initial cost
Interest on initial cost, r	: 12% annually
Repairs and maintenance	: 5% of initial cost
Insurance and taxes	: 2% of initial cost
Electricity charge	: Rs. 5.5/ unit
Labour wages (8 working hours/ day)	: Rs. 200/day
Cost of pack	: Rs.5/-
Time for cutting, grinding, filtering and drying	: 25 min
Time for filling and sealing of the pack	: 2 min

a. Fixed cost

1). Depreciation : $\frac{C-S}{L}$

: Rs. 122,400/yr

2). Interest on average investment : $\frac{C+S}{2} x \mathrm{r}$

: Rs. 134,640/-

3). Insurance and taxes : 2 % of initial cost

: 40,800/year

Total fixed cost : Rs.297,840/-

b. Variable cost

1). Repair and maintenance : 5% of initial cost

2). Electricity cost

Power consumtion/year : 12kW

Cost of energy consumption/year : (PowerX duration cost of 1unit)/1000

: 39,600/-

2) Annual labour cost

Labour charge (8 working hours/day) : 200/day

Number of labourers : 4

Annual labour cost (75 working days/year) : Rs.60,000/year

Total variable cost : Rs. 201,600/-

Total cast : Fixed cost + Variable cost

: Rs. 297840 + Rs. 201600

: Rs. 499,440/-

Cost of operation of the plant/ hour(C_o) : $\frac{Total\ cost}{T}$

: Rs. 832.4/-

Time required for drying operation : 50 min

Total cost of drying operation : $\frac{834.2 X 50}{60}$

: Rs.693.75/-

2. Labour cost for *Garcinia cambogia* powder

Cost of 100 packs(C_c) : Rs. 500/-

Qantity of *Garcinia* juice including maltodextrin: 15 l

Quantity of fruits required (q_g) : 20 kg

Cost of Garcinia fruit(Rs.80/kg)+ maltodextrin (Rs.350/kg) : Rs.2650/-

Time of cutting, slicing, grinding and filtering : $\frac{t_1 X q_g}{60}$

: 8 hours appox.

Number of packs : 100

Time required for filling and sealing : $\frac{t_2 X q_p}{60}$

: $\frac{2X100}{60}$

: 3 hours

Total working hours : 11 hours

Labour cost wages (C_L) : $\frac{11X200}{8}$

: Rs. 275/-

Total expenditure for packing 100 packs : Rs.275+ Rs. 500+ Rs. 2650+Rs. 416.2+ Rs. 693.75

: Rs 4534.95/-

Total expenditure for 100g packs : Rs. 45/-

Abstract

DEVELOPMENT OF PROCESS PROTOCOL FOR *Garcinia cambogia* POWDER

By

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(2010 – 18 - 105)

ABSTRACT OF THE THESIS REPORT

Submitted in partial fulfillment of the requirement for the degree of

Master of Technology

in

Agricultural Engineering

(Agricultural Processing and Food Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

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2012

ABSTRACT

The major problem faced by the farmers regarding the processing of *Garcinia cambogia* is difficulty in drying of this fruit as the harvesting period coincides with the southwest monsoon also if not processed quickly fungal infection may takes place. And the currently adopted sun drying method takes long time and affects the quality of the product. Drying of *Garcinia cambogia* juice into powdered particles gives a considerable reduction in volume, easy to use and is an effective method for prolonging the shelf life. Therefore, a research study was conducted to develop a process protocol for *Garcinia cambogia* powder from the fresh fruit itself. Powder samples were obtained by drying the *Garcinia cambogia* juice using spray dryer (atomizer speeds 17000rpm and 22000rpm, inlet air temperature 175 and 180^{o}C and feed flow rates 5, 5,5 and 6 l/h), tray drying (at 60, 70 and 80^{o}C) and vacuum tray drying (40, 45 and 50^{o}C) techniques. *Garcinia cambogia* juice at 12^{0}brix was used to prepare the fruit juice powder. In order to reduce the stickiness and also to increase the yield of the powder, maltodextrin (15% based on sensory evaluation, moisture content and solubility) the most widely used additive was used. The method of drying parameter was optimized on the basis of quality of the powder such as moisture content, total solids, colour, acid value, pH, bulk density solubility index and wettability. The quality of the powder obtained using spray dryer at an inlet air temperature of 180^{0} C, speed of the atomizer 22000 rpm and feed rate as 5.5 l/h (with an average particle size (8 µm), bulk density (0.412 g/cm^3), moisture content (3.5939%wb) and total solids (96.407) was superior to those obtained by vacuum tray dried and tray dried product. So spray drying was selected as the best method for the production of *Garcinia cambogia* powder which have a storability of above 7 months with good reconstitution properties (wetting time, 80 S) and solubility index ,<0.1mm).