

**FOAM MAT DRYING OF GUAVA PULP**  
**(*Psidium guajava* L.)**

**THESIS**

**Submitted to**  
**Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola**  
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## DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation in the thesis entitled “**FOAM MAT DRYING OF GUAVA PULP (*Psidium guajava L.*)**” or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/ publication of any University or scientific organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

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Dated: / /2018

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## CERTIFICATE

This is to certify that thesis entitled “**FOAM MAT DRYING OF GUAVA PULP (*Psidium guajava L.*)**” submitted in partial fulfillment of the requirement for the degree of “**Master of Technology in Agricultural Engineering (Process and Food Engineering)**” of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Sapkal Arti Bhikaji** under my guidance and supervision.

The subject of the thesis has been approved by the Student’s Advisory Committee.

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## Table of Content

<b>Sr. No.</b>	<b>Particulars</b>	<b>Page</b>
A	Declaration of student	i
B	Certificate	ii
C	Acknowledgement	iii
D	List of Tables	vi
E	List of Figures	vii
F	List of Plates	viii
G	List of Abbreviations	ix
H	Thesis Abstract	xi-xii
I	INTRODUCTION	1-5
II	REVIEW OF LITERATURE	6-23
III	MATERIAL AND METHODS	24-40
IV	RESULTS AND DISCUSSION	41-69
V	SUMMARY AND CONCLUSIONS	70-74
VI	LITERATURE CITED	75-82
	APPENDIX	83-99
	VITA	100

## A) List of Tables

Table	Title	Page
1.1	Nutritional value of Guava ( <i>Psidium guajava</i> L.)	3
3.1	Independent process variables and their levels for foamed guava pulp	30
3.2	Experimental structure with coded levels of process variables for foamed guava pulp using Box-Behnken design	30
3.3	Mathematical model used for guava pulp	35
3.4	Levels of independent variables for drying of guava pulp	40
4.1	Experimental data of foam properties of guava pulp	41
4.2	ANOVA for effect on foam expansion of guava pulp	42
4.3	ANOVA for effect on foam density of guava pulp	44
4.4	ANOVA for effect of foam stability of guava pulp	46
4.5	Constraints for optimization of various process parameters of foamed guava pulp	49
4.5.1	Solutions for optimization of various process parameters of foamed guava pulp	49
4.6	Predicted and experimental values of response at optimum process conditions for foaming properties of guava pulp	49
4.7	Effect of temperature and drying method on drying time of foamed and non-foamed guava pulp	50
4.8	Overall values for statistical parameters used in drying of foamed and non-foamed guava pulp	56
4.9	Effect of foamed and non- foamed guava pulp on drying method and quality parameters	57
4.10	Constraints for optimization for drying method and quality parameters of foamed and non-foamed guava pulp	66
4.11	Solutions for optimization drying method and quality parameters of foamed and non-foamed guava pulp	68
4.12	Predicted and experimental values of response at optimum process conditions for drying of foamed and non-foamed guava pulp	69

## B) List of Figures

Figures	Title	Page
3.1	Flow chart for production of guava pulp powder	26-27
4.1	Effect on foam expansion of guava pulp	43
4.2	Effect on foam density of guava pulp	45
4.3	Effect of foam stability of guava pulp	47
4.4	Superimposed Contour plots of different foam responses for optimization of guava pulp	48
4.5 a	Effect of drying time on moisture content of foamed and non foamed sun and tray drying of guava pulp	51
4.5 b	Effect of drying time on moisture content of foamed and non foamed microwave drying of guava pulp	52
4.6 a	Effect of drying time on drying rate of foamed and non foamed sun and tray drying of guava pulp	53
4.6 b	Effect of drying time on drying rate of foamed and non foamed microwave drying of guava pulp	54
4.7 a	Effect of moisture content on moisture ratio of foamed and non foamed sun and tray drying of guava pulp	54
4.7 b	Effect of moisture content on moisture ratio of foamed and non foamed microwave drying of guava pulp	55
4.8	Effect of drying time on foamed and non foamed guava pulp	58
4.9	Effect of reducing sugar on foamed and non foamed guava pulp	59
4.10	Effect of total sugar on foamed and non foamed guava pulp	59
4.11	Effect of non reducing sugar on foamed and non foamed guava pulp	60
4.12	Effect of ascorbic acid on foamed and non foamed guava pulp	61
4.13	Effect of $\beta$ - carotene on foamed and non foamed guava pulp	61
4.14	Effect of colour on foamed and non foamed guava pulp	62
4.15	Effect of water activity on foamed and non foamed guava pulp	64
4.16	Effect of overall acceptability on foamed and non foamed guava pulp	65
4.17	Optimization of foamed and non foamed guava pulp	67

### **C) List of Plates**

<b>Plate</b>	<b>Title</b>	<b>Page</b>
3.1	Hot air oven	24
3.2	Sample of guava	25
3.3	Tray dryer	32
3.4	Microwave oven	33
3.5	Chroma meter	38
3.6	water activity	39
4.1	Foamed and non-foamed guava pulp powder	63

## **D) List of Abbreviations**

%	:	Per cent
@	:	At the rate
°C	:	Degree Celsius
Anon	:	Anonymous
ANOVA	:	Analysis of Variance
Avg.	:	Average
BIS	:	Bureau of Indian Standard
BBD	:	Box-Behnken Design
CMC	:	Carboxyl Methyl Cellulose
C.V.	:	Coefficient of Variance
CAET	:	College of Agricultural Engineering and Technology
Cm	:	Centimeter
d.b.	:	Dry basis
d.f.	:	Degree of Freedom
dia.	:	Diameter
Deptt.	:	Department
DM	:	Dry matter
e.g.	:	For example
Engg.	:	Engineering
<i>et al.</i>	:	And others
etc.	:	Etcetera
EMC	:	Equilibrium moisture content
Eqn	:	Equation
FAO	:	Food and Agricultural Organization
Fig.	:	Figure
FMC	:	Final Moisture Content
FMCD	:	Factorial Multilevel Catecogic Design
g	:	Gram
GMS	:	Glycerol mono state
H	:	Hour
Ha	:	Hectare
HP	:	Horse Power

i.e.	:	That is
IMC	:	Initial moisture content
Kg	:	Kilogram
kg h <sup>-1</sup>	:	Kilogram per hour
kW	:	Kilowatt
Lit/sec	:	Liter per second
M	:	Meter
m <sup>2</sup>	:	Meter square
m.c.	:	Moisture content
mg	:	Milligram
min.	:	Minute
Mm	:	Millimeter
ml	:	Milliliter
MR	:	Moisture ratio
m/s	:	Meter per Second
MT	:	Metric tonne
no.	:	Number
nm	:	Nanometer
NS	:	Not significant
PDKV	:	Panjabrao Deshmukh Krishi Vidyapeeth
PGI	:	Post Graduate Institute
RH	:	Relative Humidity
RSM	:	Response Surface Methodology
Std. Dev.	:	Standard deviation
S.S.	:	Sum of Squares
SEM	:	Standard Error of Mean
viz.	:	Namely
W	:	Watt
w.b.	:	Wet basis

## **E) Thesis Abstract**

- a) Title of the thesis : **FOAM MAT DRYING OF GUAVA PULP (*Psidium guajava L.*)**
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## **ABSTRACT**

Guava (*Psidium guajava L.*), which belongs to the Myrtaceae family, is a native of tropical America. Guava fruit has a characteristic flavor, to which its acidity (pH 4.0 to 5.2). It is rich in vitamin C (260 mg /100g) and a fair source of calcium, phosphorus, iron and vitamin A.

Foams were prepared from guava pulp by adding foaming agent i.e Glycerol mono stearate (0.1 – 0.5%), Carboxy Methyl Cellulose (1 - 5%) and whipping time for 5 – 25 min. Box-Behnken design (BBD) under RSM

was employed for optimization of foaming treatment especially whipping time. The initial moisture content (wb) of foamed and non foamed guava pulp was found to be 83.25% and 86.90%. The optimized condition was selected for GMS concentration 0.5%, CMC 3% whipping time 22.95 min for maximum foam expansion 14.83%, minimum foam density 0.89 g/cm<sup>3</sup> and maximum foam stability 98.174% with desirability 0.887.

The foamed and non foamed guava pulp was dried at different drying methods i.e. sun (temp. 30-32 °C and RH-40%), tray (60 °C) and microwave (360 W power). The final moisture content (db) of dried foamed and non foamed guava pulp powdered was in the range of 5.88 – 9.27%. The drying rate was found to be as in the range 2.46 - 38.01 g/min. The drying time was found to be as in the range of 64 - 570 min. Lewis model was found to be the most satisfactory among the models to represent the thin-layer drying of foamed and non-foamed guava pulp.

A Factorial Multi-level Categorical Design (FMCD) was employed for optimization of drying methods. The best results were found in microwave drying according to minimum drying time (64 min), reducing sugar (4.19%), total sugar (7.38%), and non-reducing sugar (3.22%), water activity (0.282) and maximum (ascorbic acid 220.20 mg/100mg),  $\beta$ -Carotene (299.07 mg/100mg), colour (72.06), overall acceptability 7.96 with maximum desirability 0.962.

The fresh guava pulp foamed by using GMS 0.5%, CMC 3% and whipping time 22.95 min dried in microwave drying gives quality powder with overall acceptability of 7.96.

# CHAPTER I

## INTRODUCTION

### 1.1 Background information

Guava (*Psidium guajava* L.), which belongs to the Myrtaceae family, is a native of tropical America and grows well in tropical and subtropical regions. Guava (*Psidium guajava* L.), 'The apple of the tropics' is one of the most delicious and nutritious fruit crops grown in India. Most of the guava produced around the world is consumed fresh. Marketing of processed products such as puree, paste, canned slices in syrup or nectar is limited. Clarified and cloudy guava juices are currently produced and may have greater market potential, but optimal process conditions for these products have not been determined.

Guava (*Psidium guajava* L.) is one of the most well-known edible tree fruits grown widely in more than sixty countries throughout the tropical and sub-tropical regions in the world. In India, it occupies an area of 0.26 million hectares with annual production of 3.66 million tonnes (Saxena and Gandhi, 2014). Guava fruits are normally consumed as fresh or processed into several products like jam, jelly, cheese, nectar, etc. (Boora, 2012). There is a great demand of guava fruits in both domestic and international markets for fresh and processing purposes. The share of guava in fresh fruit export from India is mere 0.65 per cent which can be further boosted, if fruit is properly handled after harvest to earn more foreign exchange (Mitra *et al.*, 2008).

Guava is a perishable fruit and highly prone to bruising and mechanical injuries. Due to such perishability, control of fruit ripening is fundamental and this generates the necessity to search for new technologies to increase shelf life, reach distant markets and thus improve the marketing process (Mitra *et al.*, 2012). Skin colour is the best maturity index in guava (Mercado-Silva *et al.*, 1998; Kader, 1999 and Asrey *et al.*, 2008) as it could be monitored non-destructively during fruit ripening and storage.

Fruits attaining maturity show signs of changing colour from pale green to yellowish green. If the fruit is to be shipped to distant markets, it should be mature, full sized and of firm texture, but without an obvious colour break on the surface. Fruits for local market can be harvested in a more advanced stage of maturity (Singh, 2007). However, harvesting fruits at appropriate stage of maturity is critical in maintaining the post-harvest quality of guava fruits (Azzolini *et al.*, 2004 and Patel *et al.*, 2015). Storage under low temperatures has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and disease incidence. On the other hand, enzymatic reactions occur slowly at low temperatures, extending shelf life of perishables (Bron *et al.*, 2005).

India is the world's largest producer of guava followed by China, Thailand, Indonesia, Pakistan, Mexico, Brazil, Bangladesh, Nigeria, Philippines, Vietnam, Kenya and Egypt (FAO, 2011). Although, it is very rich nutritionally, still world trade of guava fruits is limited owing to its highly perishable nature, limited post-harvest life and susceptibility to chilling injury (Rai *et al.* 2010). Due to perishable nature, its fruits undergo rapid post-harvest ripening in under ambient conditions (Bashir and Abu Goukh 2003).

India is the world's second largest producer of fruits next only to China, main fruits produced in India are mango, apple, citrus, guava, grape, aonla, pineapple, papaya and banana. The major fruits growing states are Maharashtra, Tamilnadu, Karnataka, Andhra Pradesh, Bihar, Uttar Pradesh and Gujarat. The area, production and productivity of guava in 2016-2017 are 0.05 lakh hectares, 0.60 lakh tonnes and 12104 kg/ha respectively (**Source:** Agricultural Statistics at a Glance 2016-17).

Guava is a very popular fruit; it is generally a good source of lycopene, beta-carotene, vitamin C, protein, fat, carbohydrate, fibers, minerals, vitamin B & B2 and is an excellent source. Guava is considered to be superior to several other fruits by virtue of its commercial and

nutritional value. It is rich in vitamin C and a fair source of calcium, phosphorus, iron and vitamin A.

## 1.2 Importance and needs of the study

Drying is the oldest known method of preserving food. Historically, food was dried in the sun. Drying has many advantages. By removing most of the moisture from a food, microorganisms can't grow in it. Fruits and vegetables are dried to enhance storage stability, minimize packaging requirement and reduce transport weight. Foam-mat drying is one of the promising new developments in the field of drying aqueous foods.

**Table 1.1 Nutritional value of Guava (*Psidium guajava* L.)**

Sr. No.	Nutrients	Value per 100 grams
<b>A. Proximate</b>		
1	Water(g)	80.8
2	Energy(kcl)	68
3	Protein(g)	2.55
4	Total lipid or fat( g)	0.95
5	Ash(g)	1.39
6	Carbohydrate(g)	14.32
7	Fiber, total dietary(g)	5.4
8	Sugar, total(g)	8.92
<b>B. Minerals</b>		
1	Calcium, Cu (mg)	18
2	Iron, Fe (mg)	0.26
3	Magnesium, Mg (mg)	22
4	Phosphorus, P (mg)	40
5	Potassium, K (mg)	417
6	Sodium, Na (mg)	2
7	Zinc, Zn (mg)	0.23
8	Copper, Cu (mg)	0.23
9	Manganese, Mn (mg)	0.15
10	Selenium, Se (mg)	0.6
<b>C. Vitamins</b>		
1	Ascorbic acid ,C (mg)	228.3
2	Thiamine, B1 (mg)	0.067
3	Riboflavin, B2 (mg)	0.04
4	Niacin, B5 (mg)	1.084
5	Pyridoxine, B6 (mg)	0.11
6	Tocopherol, E (mg)	0.73
<b>D. Other</b>		
1	Carotene, beta, (mg)	374
2	Lycopene, (meg)	5204

(Source: Nutritional composition and volatile compound in Guava, fresh produce @ 2007 Global Science Books)

Foam-mat drying is comparatively fast process. This method offers a wide scope for application in fruit juice processing industry as it enables the dehydration of heat sensitive foods or which are difficult-to-dry, sticky and viscous under relatively mild conditions without undue quality change. Foam produce can be dried easily and fast. Foam-mat drying of tomato, mango, pineapple, lemon, banana and guava juice/pulp etc. can be done to produce powder. This technology is finding an increasing application and importance on commercial scale mostly in the drying of liquids that tender a high quality concentrate such as milk, fruit, juices, soluble coffee, etc. (Kadam *et al.*, 2010).

### **1.3 Objective of the study**

1. Effect of foaming agent on foam characteristics of guava pulp.
2. To study the drying characteristics of foamed guava pulp.
3. To study the quality parameters of guava pulp powder

### **1.4 Hypothesis**

Foam-mat drying is a process by which a liquid or semi-liquid is whipped to form a stable foam, and subsequently dehydrated by thermal means. The application of foam-mat drying to many heat-sensitive food materials, including fruit juices was reported (Hertzendorf and Moshy 1970). Foam mat drying which leads to increase of drying rate and significant reduction in drying time; improved the sensory, nutritional and functional properties of the product. The foam mat dried products are highly stable against deteriorative microbial, chemical and biochemical reactions. Shorter drying time not only reduces the dryer load but also increases the dryer throughput by 32 and 22% for foamed pulp (Rajkumar *et al.* 2006). The foam mat drying variables i.e. foam formation, density and stability are affected by chemical nature of the fruit, soluble solids, pulp fraction, type and concentration of foaming agent, and type and concentration of foam stabilizer (Hart *et al.* 1963).

### **1.5 Scope and limitations**

Drying of foams can be conducted at comparatively low temperatures, so it can easily be used for preserving the nutrient content of fruits. Guava can be converted into value added products like powder by foam-mat drying. The powder can be used for preparation of nectar, ice cream flavor and ready to eat fruited cereals, instant soup cubes etc.

## CHAPTER II

### REVIEW OF LITERATURE

This chapter deals with the review of the research work carried out by various works related to principles of foam mat drying and the application of foam mat drying in food processing. The available information related to the present investigation was referred and reviewed here under the following sub-heads.

#### 2.1 Drying of guava

#### 2.2 Foaming agents used for foam mat drying

#### 2.3 Foam mat drying of fruits

#### **2.1 Drying of guava**

Suresh kumar *et al.*, (2006) studied the effect of tray load on drying kinematics of mango, guava and anola. The osmosed slices and segments were dehydrated in cabinet dryer, low temperature drier and vacuum dryer with the tray load of 0.30, 0.35, 0.40 and 0.45 g/cm<sup>2</sup>. The tray load of 0.40 g/cm<sup>2</sup> was optimum quantity in drying of better quality osmo-dehydrated product by both vacuum and cabinet drier.

Taiwo and Adeyemi (2009) reported the influence of blanching on the drying and rehydration of banana slices. This study examined the effect of blanching (60°C; 10 min) followed by drying (50 to 80 °C) and rehydrating at 100 °C for 15 to 60 min on product characteristics (shrinkage, dry matter loss, moisture loss, electrical conductivity and rehydration capacity) of ripe and unripe banana samples.

Osorio and Jose (2011) studied the two food products (powders) were obtained by hot-air drying or lyophilisation methods on the whole guava fruits. The powders were characterized by sensory and thermal analyses (TGA-DSC), infrared spectroscopy (IR), and X-ray diffraction (XRD) and scanning electron microscopy (SEM). Thermal, morphological and structural characterizations showed a similar behavior for the two solids. TGA-DSC and IR showed the presence of pectin as the main

constituent of solids. A semi-crystalline profile was evidenced by XRD, and lamellar/spherical morphologies were observed by SEM.

Patil *et al.*, (2014) studied was conducted to produce spray dried guava powders using three different maltodextrin concentrations (7%, 9.5% and 12%) as the encapsulating agent and three different inlet temperatures 170 °C, 180 °C and 185 °C. In this study, the effects of some processing parameters on moisture content, drying yield, bulk density, solubility, of spray dried guava powders were investigated. The best processing conditions to obtain a free flowing and least hygroscopic guava powder by spray drying were: inlet temperature above 185 °C.

Modi *et al.*, (2015) conducted the drying kinetics of guava fruit (*Psidium guajava L.*) by thin layer. Drying operation was carried out at 55 °C, 60 °C and 65 °C temperatures, at slice thickness of 2.5 mm, 4 mm and 6 mm at 1 and 1.5 m/sec velocities. Drying rate was found to increase with the increase in air temperature and thus reduced the drying time.

Ali *et al.*, (2016) carried out a comprehensive study to examine the influence of different drying treatments; under direct sunlight, freezing, convection oven (50, 60, 70, 80 and 90 °C) and microwave oven (100, 250, 440, 600 and 1000 W) on ascorbic acid concentration and colour quality of guava. The colour of guava slices became yellowish with an increase in temperature and power of conventional and microwave ovens, respectively.

Deise *et al.*, (2016) studied the physical and chemical changes in guava raisin (*Psidium guajava L.*) produced by osmotic dehydration and drying convective. The guava was cut into slices of 3.0 × 2.0 × 0.9 cm, dehydrated and dipped in sucrose syrup at concentrations of 40, 50 and 60 °Brix, at temperatures of 30, 40 and 50 °C. The process was again supplemented by convective drying at temperatures of 50, 60 and 70 °C. From the results it was recommended that the production of guava passes under dehydrating conditions of 60 °Brix at 50 °C and further drying temperature of 60 °C is efficient.

Fahim *et al.*, (2016) studied the impact of the dehydration process on guava by using of the parabolic trough solar concentrator. The guavas

were cut into two pieces and dip in the solution of 1% potassium Meta-Bi-Sulphate and dried with the temperature of 65 °C at 25% humidity level; drying time was 19 hours. From the result, it was noted that the moisture content was reduced by up to 11% in the month of October due to the highly solar intensity. Similarly, the drying rate of the product was noted in 0.033 g H<sub>2</sub>O dm/cm<sup>2</sup>hr higher than November and December 0.032 g H<sub>2</sub>O dm/cm<sup>2</sup>hr and 0.029 g H<sub>2</sub>O dm/cm<sup>2</sup>hr. However, the results showed that the efficiency of PTSC for the month of October was noted 30% higher than the month of November and December 25% and 23% and moisture content were reduced up to 11%, 13% and 15%.

Shishir *et al.*, (2016) investigated the physical properties of its powder dried using lab plant spray dryer SD-05. The juice (brix 10.0±0.1) of pink guava puree was mixed with MD at 10%, 15% and 20% and dried using temperatures 150, 160 and 170 °C at a feed flow rate 350 ml/hr. Quality powder in terms of final moisture content, particle size, powder yield, bulk density, tapped density, flow ability and color was found to be yielded at drying temperature of 150 °C with 15% maltodextrin.

Tripathy *et al.*, (2016) observed the uniform sizes of guava (*Psidium guajava L.*) unblanched, blanched and blanched with KMS samples were dried at three different temperatures (50, 60 and 70 °C) at constant velocities and power (20, 40 and 60 W). Drying rate of unblanched guava slices had highest at 50 °C and 70 °C and the drying rate of samples at 60 °C had highest for blanched samples in tray drier. In microwave, the drying rate of KMS blanched samples had highest at 20, 40 and 60 W. Moisture loss increased from guava with increased in power of microwave and time of drying.

Jarupla *et al.*, (2017) reported the osmotic dehydration of guava slices was carried out by osmo-tray drying process and to study the moisture loss and solid gain during osmotic dehydration and tray drying. During osmotic dehydration of guava slices, 4 mm thick cut guava slices were used. The sample to solution ratio of 1:10 was kept constant for all experiments. Three temperature levels of osmotic solution (room temperature 35 °C, 45 °C, and 55 °C) and three concentration levels of

Sugar solution (40%, 50% and 60%) along with 0.2% KMS were used. The three time intervals (3, 6 and 9 hours) were selected for studying the moisture loss and solids gain kinetics. After osmosis at predetermined time interval, the guava slices were drained completely and dried to 4 to 6 per cent (% d.b.) using tray dryer.

## **2.2 Foaming agents used for foam mat drying**

Bates (1964) studied the foam-mat drying of tropical fruits using two types of foam inducers, namely modified soybean protein (D-100) and glycerol mono stearate (GMS), observed that even less than 0.25 per cent of D-100 was adequate to produce foam of a density 300 to 400 kg/m<sup>3</sup> for most of the systems studied with or without the use of foam-stabilizer. Similarly, 0.5% GMS was able to produce foam of density 330-360 kg/m<sup>3</sup> in some system (papaya puree), but, on the other hand, it was impossible to foam this puree with normal quantities of soya protein.

Berry *et al.*, (1965) studied the effect of whipping time on grape fruit foam using GMS as the foaming agent and found that increasing the whipping time from 6.5 to 15 minute did not result in significant change in bubble size. However, after 15 minute some break down occurs at a very slow rate and even after 30 minute of 18 whipping, foam still posed a good bubble size. The concentration of surfactant (foaming agent) in the range of 1 to 3% showed a decrease in bulk density till 8 minute of stirring time after which the foam structure collapsed resulting in an increase in the foam density. A criterion for good foam stability was its uniformity and the lack of fluid drainage in 60 minutes after its preparation. These characters can be observed in foams with bulk densities below 300 kg/m<sup>3</sup>. In general, best results can be obtained when the smaller amount of surfactant is added, and for the shortest stirring, to obtain a bulk density of 260 kg/m<sup>3</sup>. Foam prepared under these conditions showed stability to drainage for over 1 hour.

Djelveh *et al.*, (1994) studied the influence of mechanical mixing, gas input rate and a gas spurger on the foaming capacity of a model food under steady-state and found it to remain dependent on the gas flow rate.

Also, rotational speed up to 1000 to 2000 rev/min improved the foaming capacity without any adverse effect on foam density.

Kabirullah and Wills (1988) worked the functional properties of sunflower seed protein, although the foam expansion was not influenced by changes in pH of the material the stability decreased with its increase. An increase in protein concentration increased both the expansion as well as stability of the foam. Similarly, higher stirring time did not appreciably affect foam expansion but increased the foam stability, whereas higher stirring speed increased foam expansion significantly but foam stability only slightly.

Falade *et al.* (2003) prepared foam-mat drying of cowpea using glyceryl mono stearate (GMS) and egg albumin (EA) as foaming agents. GMS and EA were incorporated into cowpea paste (22, 25 and 28% total solids) at 2.5, 5.0, 7.5, 10.0, 12.5 and 15% (w/w), and whipped for 3, 6, 9, 12, 15, 18 and 21 min maintaining 15, 25 and 35 °C foaming temperatures. Cowpea foams were dried at 60 °C for 48 min. Minimum foam densities were obtained in cowpea foams with GMS and EA after 9 and 21 min of whipping, respectively. EA-stabilized foams were unstable for drying. Sensory evaluation showed no significant difference in the quality attributes of okra produced from fresh and reconstituted GMS-stabilized cowpea powders.

Sankat and Castaigne (2004) developed foams of ripe bananas and the forced air-drying characteristics of banana foam mats were studied. Fresh banana puree with a density of 0.93 g/ml was foamed to a density of 0.50 g/ml after 12 min of whipping by the addition of 10 g/100 g soy protein as a foam inducer. Banana foam mats were dried at temperatures from 45 °C to 90 °C in a forced air, cabinet dryer, to a hard, porous and brittle solid which was amenable to grinding so as to produce a dehydrated banana powder. The drying time was directly related to the thickness of the foam mats. Increasing the air velocity from 0.62 to 1.03 m/s did not profoundly influence the drying rate.

Kudra and Ratti (2006) studied the foam-mat drying of tomato paste and a variety of fruit pulps and juices. Convective drying of both foamed

and non-foamed apple juice dried in a 19 mm layer at 55 °C has indicated higher drying rates for foamed juice which resulted in reduced drying time from 500 to 200 min. Due to the porous structure of dried foam and accelerated approach to equilibrium at the end of drying, it was possible to obtain dry product in contrast to non-foamed juice which dries to viscous syrup in the same time scale. The energy consumption for drying of foamed apple juice was found to be 20 per cent of that for drying of non-foamed juice. The dryer throughput was calculated as 0.83 and 0.68 kg/m<sup>2</sup>h, foamed and non-foamed juice respectively. Because of higher throughput and shorter drying time, the foam-mat dryer can be smaller which would reduce capital costs by about 11% for a belt conveyor dryer and by 10% for a drum dryer.

Rajkumar *et al.*, (2006) conducted preliminary trials for foam mat drying of alphonso mango pulp using batch type cabinet dryer. From the trial, it was observed that the foamed mango pulp using egg albumen (10%) as foaming agent with methyl cellulose (0.5%) as stabilizing agent, dried at 60 °C with 1 mm foam thickness was found to be the best. For this foamed pulp, parameters such as viscosity ( $5.7 \pm 0.06$  Pa s), stickiness ( $18.9 \pm 0.1$  g force) and specific heat ( $3.66 \pm 0.02$  kJ/kg°C) values were determined. The drying study showed that the time required to dry the fresh (non-foamed) and foamed mango pulps were 75 and 35 min, respectively. Based on the preliminary drying results, a continuous type foam mat dryer (lab model) with a capacity of drying 2.5 kg/day of 8 h was developed to dry the mango pulps. It was observed that the changes were comparatively lower in foam dried flakes than in non-foam dried flakes using continuous type foam mat dryer.

Lomakina *et al.*, (2006) studied the foaming properties and factors affecting foaming properties of egg white. Foaming properties are evaluated by foaming capacity (FC) and foam stability (FS). The factors affecting the foam properties include: Season, Beating time, Blending, temperature and other.

Rajkumar *et al.*, (2007a) observed that foam mat drying of Alphonso mango pulp using various food foaming agents, namely soy protein (0.25,

0.5, 1.0, and 1.5%) with methyl cellulose (0.5%), glycerol mono stearate (0.5, 1.0, 2.0 and 3.0%), and egg albumen (2.5, 5.0, 10 and 15%) with methyl cellulose (0.5%). Drying was carried out in a batch type thin layer dryer at four drying temperatures (60, 65, 70, and 75 °C) on 1, 2, or 3 mm thickness foamed samples. The optimum concentrations of each foaming agent were determined to be 1% soy protein, 2% glycerol mono stearate, and 10% egg albumen. All were obtained after 25 min whipping time. The treatment of mango pulp with 10% egg albumen and 0.5% methyl cellulose and drying at 60 °C (1 mm foam thickness), retained the highest nutritional quality characteristics than the other treatments.

Rajkumar *et al.*, (2007b) studied the thin layer dryer to dry the foamed mango pulp. The mango pulp (Totapuri variety) was foamed by the addition of egg albumen at different concentrations such as 5, 10 and 15% and the foam was stabilized with the addition of methyl cellulose at 0.5% concentration. The foamed pulp was dried at three drying temperatures *viz.*, 60, 65 and 70 °C with three foam thicknesses *viz.*, 1, 2 and 3 mm in the batch type thin layer dryer. Biochemical analysis results showed a significant reduction in ascorbic acid, total soluble solids and  $\beta$  carotene in the mango flakes dried at higher temperatures when compared to the flakes dried at 60 °C.

Thuwapanichayanan *et al.*, (2008) studied the combination of foaming and drying as an alternative method to produce crisp banana chips. Banana puree with egg albumen, which was used as the foaming agent, was foamed to the densities of 0.3, 0.5 and 0.7 g/cm<sup>3</sup>. Banana foam mats with 5 mm thickness were then dried to the moisture content of 0.03 kg/kg dry basis at 60, 70 and 80 °C and superficial air velocity of 0.5 m/s. The experimental results showed that the extensive porous structure of foams with lower densities resulted in higher drying rates, moisture diffusivities and shrinkage. The drying temperature and the egg albumen concentration did not influence the textural properties of the final products, however to produce quality banana chips, the initial foam density of 0.5 g/cm<sup>3</sup> and drying temperature of 80 °C were recommended.

Thirupathi *et al.*, (2008) studied foam-mat drying of whole egg liquids at different temperatures viz., 60, 65 and 70 °C and at different foam-mat thicknesses of 1, 3 and 5 mm. The percentage of foam expansion for whole egg liquid was found to be  $243.5 \pm 12.5\%$ . From the statistical analysis of foam mat dried egg powders, it was observed that one mm thickness samples dried at 60 °C retained higher biochemical and nutritional content when compared to samples dried at 65 and 70 °C for 3 and 5 mm foam thicknesses respectively. The rehydration ratio, foam ability of rehydrated foam mat dried whole egg and solubility of foam were observed as  $3.70 \pm 0.2$ ,  $236 \pm 13.5$  and  $93.5 \pm 5.3\%$  respectively.

Raharitsifa *et al.*, (2009) studied the freeze-drying of foamed and non-foamed apple juice and whipped foams with methyl cellulose and egg albumin at different concentrations. Foamed and non-foamed juice samples having different thickness and different initial weight were frozen at  $-40$  °C and then freeze-dried at 20 °C for 48 h under vacuum. A mathematical model based on artificial neural networks was developed to represent foam kinetics and temperature curves during freeze drying. Foaming reduced process time for equal sample thickness. However, lower density of foamed materials decreases weight load to the dryer.

Zheng *et al.*, (2009) studied the microwave-assisted foam mat drying method for the dehydration of black currant pulp with glyceryl mono stearate (GMS) and soy protein isolated (SPI) with food grade as a foaming agent. A reasonable foaming additive formula for the black currant pulp with optimum expansion and high stability was 6% GMS and 3% g SPI as foam inducers and the 10 ml carboxylic methyl cellulose (CMC) with concentration of 0.5% as foam stabilizer, and stirring time of 6 minutes. The parameters including the initial microwave intensity of 14.0 W/g and thickness of material layer of 5 mm were recommended for the continuous microwave belt drier to dry the foamed black currant pulp.

Falade and Okocha (2010) investigated the foam-mat-dried plantain and cooking banana. Plantain and banana pastes mixed with different concentrations (0.005, 0.01, 0.015 and 0.02%) of Glycerol mono stearate (GMS) were whipped and the resulting foams were air dried at 60, 70 and

80 °C. Higher GMS concentration and longer whipping time resulted in lower foam densities. Generally, cooking banana foams showed lower foam density compared to plantain foam. Lower drying temperatures and concentration of GMS resulted in longer drying time. The quality attributes such as pH (4.41 - 4.80), titratable acidity (0.06–0.08) and water absorption capacity (56.75 - 64.02%) of the reconstituted pastes varied with commodity, drying temperature and GMS concentration.

Kadam *et al.*, (2010) investigated impact of drying air temperature (65, 75 and 85 °C) and milk as foaming agent in different concentration levels (0%, 10%, 15%, 20% and 25%) on the chemical properties of foam-mat dried mango juice powder. Chemical properties such as total sugars, ascorbic acid, total carotenes, minerals, total acid, pH, total soluble solids (TSS) and microbial load (fungal and bacterial) of foam-mat dried mango powder were determined. Microbial load was not detected in foam-mat dried mango powder. It was found that addition of 10% milk as foaming agent and drying at 65 °C temperature gave better results.

Bag *et al.*, (2011) studied foam expansion and foam stability of the bael (*Aegle marmelos L.*) fruit pulp. Foams were prepared from various pulp concentrations (PC) by adding different concentration of glycerol mono stearate (GMS) and methyl cellulose (MC) for different 24 whipping time (WT). The optimum conditions achieved after the numerical and graphical optimization for maximum foam expansion and stability was: GMS (3.10 g/100 g pulp), MC (0.32 g/100 g pulp), PC (13.2 °Brix), and WT (2 min). The desirability of 0.712 was achieved at this optimum point. The predicted values of foam density and foam drainage volume were 0.658 g/cm<sup>3</sup> and 1.75 ml, respectively, at optimum parameters while the experimental values were 0.635±0.02 g/cm<sup>3</sup> and 1.75±0.12 ml, respectively.

Kadam and Balasubramanian (2011) determined effect of drying air temperature and foaming agent (egg albumin) for production of tomato powder using foam-mat drying. Samples were prepared using tomato juice (4 °Brix total soluble solids), incorporating egg albumin as foaming agent (0, 5, 10, 15 and 20% w/w). Foamed tomato juice (300 ± 0.5 g) was spread

on rectangular trays (2.5 mm thickness) and kept in tray dryer at 60, 65 and 70 °C air temperature. Incorporation of 10% egg albumin with 5 min of whipping time was found optimum for stable foam formation. The increase in foaming agent level enhanced the drying process (up to 15% egg albumin) and thereafter followed a decreasing trend. Foamed tomato juice can be dried in 510 and 450 min at 60 and 70 °C drying air temperature, respectively, with best acceptability. Effective moisture diffusivity of tomato juice ranged from  $2.026 \times 10^{-8}$  to  $3.039 \times 10^{-8}$  m<sup>2</sup>/s.

Kadam *et al.*, (2011a) reported that foam mat drying is a lucrative process of mandarin (kinnow) pulp for powder production. Foam mat drying experiments were carried out at 65, 75 and 85 °C drying air temperatures using carboxyl methyl cellulose, milk and egg white as foaming agents at different concentrations levels to get dried mandarin powder. Quality of the reconstituted dried Mandarin pulp-powder was evaluated for 6 month.

Kadam *et al.*, (2011b) studied the influence of various drying air temperatures (65, 75 and 85 °C) and different foaming agents such as carboxyl methyl cellulose (CMC), milk and egg white on the biochemical properties of foam mat dried tomato powder. It was observed that there was a decrease in the total sugars, ascorbic acid, lycopene, and total acid, however, pH slightly increased compared to fresh tomato juice composition and no microbial (fungal and bacterial) growth was noticed.

Thaisong and Rojanakorn (2011) investigated effect of concentration of carboxyl methyl cellulose (CMC) (0, 0.25, 0.5 and 1.0%) and whipping time (0, 10, 20 and 25 min) on mango foam. It was found that incorporation of 0.5% CMC and whipping time of 25 min produced the foam with the lowest density. Drying experiments showed that falling rate period was observed for mango foam dried at 60, 65 and 75 °C. The activation energy of mango foam drying was found to be 22.22 kJ/kmol.

Balasubramanian *et al.*, (2012) optimized the foaming conditions for tomato juice. Three process parameters namely concentration of egg albumin (EA) as foaming agent, carboxyl methyl cellulose (CMC) as foam stabilizer and whipping time (WT) were optimized. The levels for various

input variables were EA: 5% to 15%, CMC: 0.10% to 0.60% & WT: 3 to 7 min. The predicted levels of responses generated were expansion ratio: 91.49%, foam density: 0.558 g/cc & drainage volume: 10 ml, which on validation was found closer to experimental value.

Febrianto *et al.*, (2012) determined the best treatment combination between the concentration and type of filler to produce milk powder with the best physical and chemical properties which made with foam mat drying method. At a concentration of filler, there are 3 levels, for maltodextrin (10%, 15%, and 20% w/w fresh milk), while for the Arabic gum (3%, 6%, and 9% w /w fresh milk). The results showed for the filler concentration of 6% gum Arabic, and maltodextrin concentration of 15%. The best results obtained from the milk powder with the type of filler maltodextrin concentration of 15% with a yield value of 19.40%, 71.08% solubility, water content 3.73% and 10.2 % protein content.

Ibidapo and Erukainure (2012) studied the nectar of ripe pawpaw fruits (*Carica papaya L.*). After the pre-processing operations such as washing, peeling, slicing and dicing, the pawpaw fruit was steam blanched and subsequently processed into puree by homogenizing with distilled water (2:1, w/w) and frozen in a domestic freezer at -18 °C for 48 h. Papaya nectars (10 and 20 °Brix) were processed from frozen puree and the resultant nectars were made into stabilized product by foam mat drying methods. Egg albumin was used as foam stabilizing agent at concentration of 10, 15 and 20%, while whipping was accomplished at 3, 6, 9, 12 and 15 min, respectively. The results showed that egg albumin concentration affected the stability of the 20 °brix nectar and egg albumin at 20% concentration produced more stable foam at 3 min.

Kadam *et al.*, (2012) studied the physic-chemical and microbial quality of foam-mat dried pineapple powder. Pineapple pulp was foamed using two foaming agents, tri-calcium phosphate (TCP) (0, 0.25, 0.50, 0.75, and 1.0%) and egg white (EW) (0, 0.50, 1.0, 1.50, and 2.0%). Carboxy methyl cellulose (0.25%) was used as foam stabilizer, and drying was carried out at 65, 75 and 85 °C in tray drier followed by pulverizing the dried product into fine powder. Statistical analysis using LSD revealed that

sample dried using 1% TCP at 65 °C was the best with 4.60% total sugars, 2.71% reducing sugars, 4.05 mg per 100 g ascorbic acid, 0.35% total acid, 0.29 mg per 100 g iron, 2.24 mg per 100 g phosphorous, and 6.58 g per 100 g calcium and zero bacterial and fungal growth.

Kandasamy *et al.*, (2012a) studied the produce of papaya powder using glycerol mono-stearate as foaming agent (1, 2, 3 and 4% w/w) with whipping time of 5, 10 and 15 min. The foam expansion was significantly influenced by pulp concentration and levels of the foaming agent at 1% level. The maximum stable foam formation was 90% at 3% glycerol mono stearate with 9 °Brix pulp concentration and whipping time of 10 min. The resulting foams were dried at air temperatures of 60, 65 and 70 °C with foam thickness of 2, 4, 6 and 8 mm in a batch type cabinet dryer under air flow rate of 2.25 m<sup>3</sup>/min. The papaya powder obtained from the foam thickness of 4 mm and dried at 60 °C was found to be optimum.

Kandasamy *et al.*, (2012b) studied the egg albumin was incorporated into papaya pulp at 5, 10, 15 and 20 % (w/w) and whipped for 5, 10, 15 and 20 min in room temperature. The maximum stable foam formation was 125.62 % at 15 % egg albumin and whipping time of 15 min. The resulting foams were dried at air temperatures of 60, 65 and 70 °C with foam thickness of 2, 4, 6 and 8 mm under air flow rate of 2.25 m<sup>3</sup>/min. The papaya powder obtained from the foam thickness of 2 mm and dried at 60 °C was found to be optimum to produce the foam mat dried papaya powder.

Kandasamy *et al.*, (2012c) investigated the papaya pulp was foamed by incorporating methyl cellulose as foaming agent at different concentrations of 0.25, 0.50, 0.75 and 1.00% on w/w basis. The maximum stable foam formation was 83% at 0.75% methyl cellulose with 9 °Brix pulp and whipping time of 15 min. The foam expansion was significantly influenced by pulp concentration and levels of the methyl cellulose at 1% level. The foamed pulp was dried at air temperature of 60, 65 and 70 °C with foam thickness of 2, 4, 6 and 8 mm in a batch type cabinet dryer. Biochemical analysis results showed a significant reduction in ascorbic acid,  $\beta$ -carotene and total sugars in the foamed papaya dried product at

higher foam thickness (6 and 8 mm) and temperature (65 and 70 °C) due to destruction at higher drying temperature and increasing time. The sensory evaluation of the quality attributes of papaya powder juice showed significant reduction in colour, taste, flavour and overall acceptability at 65 and 70 °C. The papaya powder obtained from the pulp of 9 °Brix added with 0.75% methyl cellulose, whipped for 15 min and dried with a foam thickness of 4 mm at a temperature of 60 °C was found to be optimum condition for production of papaya powder.

Khan and Pandey (2012) investigated the dried malta juice concentrate with various levels of carboxyl methyl cellulose (CMC) ranging between 0.08 and 0.016 kg per kg of malta solid. Glycerol mono stearate (GMS), whole milk powder (WMP) and tri-calcium phosphate (TCP) were added at the levels varying between 0.005 to 0.015, 0.02 to 0.06 and 0.0025 to 0.0045 kg/kg of malta solid, respectively. Based on properties of malta powder, optimum level of ingredients obtained by using simultaneous optimization of flow ability time, degree of caking and solubility were: 7.92% carboxyl methyl cellulose, 85 °C temperature, 1.55% whole milk powder, 0.225% tri-calcium phosphate and 0.271% glycerol mono stearate.

Krasaekoopt and Bhatia (2012) prepared yogurt powder by foam-mat drying. Two types of foaming agents as methyl cellulose and egg albumin were used at different concentrations as 0.5, 1.0, 1.5 and 2.0% for methyl cellulose and 1, 2, 3 and 4% for egg albumin, respectively. The mixture of plain yogurt and foaming agent were blended by using high speed mixer (900 W) for 5, 7, 9 and 12 min. Three percentage of egg albumin with the mixing time of 12 min provided better foam characteristics. The yogurt foam was then dried at 50, 60 and 70 °C for 3 h. The dried yogurt was blended and kept in an air tight container. Yogurt powder (15%) was dissolved in cold water (85 ml) and then mixed well. Orange flavour (0.1 g) and colour (0.1 g) were added into the product. The highest viscosity product was obtained when 60 °C yogurt powder was used. Sensory qualities of drinking yogurt of all treatments were not

significantly different. The yogurt powder (60 °C) had water activity of 0.348 with moisture content of 8.5%.

Wilson *et al.*, (2012) studied foam mat drying of mango pulp (Dussehari variety) using 0, 3, 5, 7 and 9% egg white as foaming agent and then dried at air drying temperature of 65, 75 and 85 °C. Based on above parameters it was resolved that foam mat drying using 3% egg white at 65 °C air drying temperature was the best combination.

Kaushal *et al.*, (2013) studied the seabuckthorn berries for preparation of fruit leather by modifying the foam mat drying technique. The conversion of seabuckthorn juice/pulp into foam was standardized by whipping the pulp after addition of CMC 0 to 3% at 5 °C and drying the resultant foam in dehydrator (55±2 °C) to moisture content of about 12 to 14%.

Chakrabort *et al.*, (2014) optimized the foam mat drying conditions of potato (kufrichandramukhi) based on functional properties of dried powder. During the preparation of the mat maximum foam expansion of 25% was found with interactive effect of 10 minutes of magnetic stirring and 2% concentration of glycerol mono-stearate (GMS). The optimum drying condition obtained was at 60 °C for 135 minutes with 2% GMS. The value of percentage of final moisture content, coefficient of reconstitution, browning index, and percentage gelatinized starch was  $1.89 \pm 0.551$ ,  $0.914 \pm 0.025$ ,  $0.013 \pm 0.00175$  and  $70.00 \pm 1.645$ , respectively was found at optimum drying condition.

Kandasamy *et al.*, (2014) optimized the process parameters for production of papaya powder using foam-mat drying. Papaya pulp was foamed by incorporating methyl cellulose (0.25, 0.5, 0.75 and 1%, w/w), glycerol mono stearate (1, 2, 3 and 4 %, w/w) and egg white (5, 10, 15 and 20%, w/w) as foaming agents. The maximum stable foam formation was 72, 90 and 125 % at 0.75% methyl cellulose, 3% Glycerol Mono Stearate and 15% egg white respectively with 9 °Brix pulp and whipping time of 20 min. The foamed pulp was dried at air temperature of 60, 65 and 70 °C with foam thickness of 2, 4, 6, 8 and 10 mm in a batch type cabinet dryer. The papaya powder obtained from the pulp of 9 °Brix added with 3%

glycerol-mono-stearate, whipped for 20 min and dried with a foam thickness of 4 mm at a temperature of 60 °C was found to be optimum to produce the foam-mat dried papaya powder.

Auisakchaiyoung *et al.*, (2015) determined the effect of methyl cellulose (MC) concentration and whipping time on the properties of Gac fruit aril foam. Gac fruit aril mixed with methylcellulose at a respective mass concentration of 1.0, 1.5 and 2.0% was whipped for 0, 10, 20 and 25 min. The Gac fruit aril foam mats (1, 2 and 3 mm-thick) were dried at 60, 70 and 80 °C with a constant air velocity of 0.5 m/s. The optimum condition for forming foam was 1.5 % methylcellulose after 25 min whipping. Gac fruit aril foam (1 mm thick) dried at 70 °C for 60 min exhibited the greatest amount of lycopene,  $\beta$ -carotene and total phenolic compounds as well as antioxidant activity.

Das *et al.*, (2015) determination of moisture ratio at different time and also find out the best mathematical model for foam mat drying of pumpkin pulp. Pumpkin pulp was foamed using 3% and 4% glycerol mono stearate (GMS) as foaming agent and then dried at drying temperature of 50 °C and 60 °C. Moisture diffusivity was varied from  $2.026 \times 10^{-8}$  -  $6.079 \times 10^{-8}$  m<sup>2</sup>/s.

Durge *et al.* (2015) studied the foam mat drying of sapota pulp by using pectin, egg albumin and methyl cellulose at different levels. Foam expansion and foam stability increased with increasing concentration of pectin and methyl cellulose. The optimum foam expansion of 60.35% and foam stability of 77.13% were obtained with the addition of pectin and methyl cellulose to sapota pulp at optimum concentration of 2.21% and 4.41%, respectively. The foam expansion was very low (25%) with egg albumin.

Sangamithra *et al.*, (2015) studied the independent variables were the concentration of egg albumen (EA), carboxyl methyl cellulose (CMC) and whipping time (WT). The optimum conditions for foaming process were EA (11.59% w/w), CMC (0.59% w/w) and WT (3.97 min). The un-foamed muskmelon pulp took longer time to dry to the final moisture content of 2% dry basis than foamed pulp.

Veerapandian *et al.*, (2015) observed the foam properties of mixed vegetable juice, phytochemical and antimicrobial properties of powder were analyzed. The foam expansion, foam stability and solubility index were increased from 79.2 to 104%; 68.7 to 97% and 79 to 92%, respectively. Foam density was decreased from 0.2 to 0.17 g/cm<sup>3</sup>. Total phenol and Beta-carotene content were varied from 13.4 to 8.6 mg/g and 3.86 to 2.45 mg/g, respectively. The maximum antibacterial and antifungal activities were observed as 9±0 and 9± 0.5 mm, respectively of minimum inhibition zone for the powder dried at 50 °C with 30% of foaming agent and the minimum antibacterial and antifungal activities were observed as 7±0.5 and 6±0.5 mm, respectively was observed in powder dried at 70 °C with 10% of foaming agent concentration.

Ismaila *et al.*, (2016) observed the foams using different level of stabilizers concentration at level of 5%, 7.5%, 10%, 12.5%, 15%. Glycerol mono-stearate stabilized foam was found to be stable after whipping of air into the mixture for 3, 6, 9, 12, 15, 18, 21 minutes at 10 °C, 20 °C and 30 °C respectively. Minimum foam density was observed at 6 minute whipping time after which the foam begins to increase.

Norhazirah *et al.*, (2017) carried out the foams from *Nigella sativa* solution by adding different concentrations of egg albumen (2.5%, 8.75%, and 15% w/w) and methyl cellulose (0, 0.5% and 1% w/w), using whipping times of 2, 5, and 8 min. The drying temperature was set at 50 to 70 °C, with a foam thickness of 1, 2 and 3 mm. The optimum recorded conditions for the foaming process were 15% of egg albumen concentration, 0.69% of methyl cellulose concentration, and a whipping time of 8 min. Thus, the optimum conditions for the drying process were 60 °C, with 2 mm of foam thickness.

### **2.3 Foam mat drying of fruits**

Hart *et al.*, (1963) influenced by soluble solids content of the sample, and type and concentration of the added foam inducer. Pulp content of the sample and mixing time had negligible effect on stability of the foam. In general, when the content of soluble solids in the sample was low, more amounts of foaming agent and stabilizers are required to be added. If the

sample food was relatively free of pulp, the foam must be whipped to a very low specific gravity in order to acquire the necessary stiffness.

Berry and Froscher (1969) observed the cold pressed peel oil to high quality 50 °Brix commercial orange concentrate and foam-mat dried, or diluted to single strength juice and freeze-dried using different platen temperatures. Amounts of peel oil ranged from 0.026% to 0.106% for samples to be foam-mat dried, and from 0.011% to 0.109% for freeze drying. Among the foam-mat dried samples, that to which the lowest oil had been added yielded 62% retention in the dried product. The sample to which 0.054% oil had been added yielded 56% retention and the sample to which 0.106% oil had been added retained 73% in the dried product.

Lovri *et al.* (1970) obtained tomato powder with 3% moisture by foam-mat drying tomato paste (29% solids). Samples of powder were stored at various temperatures (-10 +2 +20 and +37 °C), atmospheres (air, nitrogen) and humidity (with and without in-package desiccation), and colour changes were observed for periods of up to 1 year. Storage at +20 °C was more favourable for colour retention than storage at +2 °C, or -10 °C. Storage in an inert atmosphere improved colour retention. At +37 °C non-enzymatic browning, accompanied by formation of water, caused rapid darkening although carotenoid pigments were not lost to a great extent.

Alakali *et al.* (2009) studied the kinetics of moisture uptake by foam mat dried powder from mango pulp was evaluated at four temperatures (10, 20, 30 and 40 °C) and two relative humidity (55 and 80%), while moisture sorption data for shelf life prediction was determined at the same temperatures and eight water activities from 0.032 to 0.925. The rate of moisture uptake was higher at 55 than at 80% storage relative humidity.

Widyastuti and Srianta (2011) developed functional drink based on foam-mat dried papaya. Papaya slurry was formed by adding egg white of 10, 15 and 20% w/w. The foamed papaya slurry was dried by using hot air drying at 60 °C for 5 hours. Drying yield increased with increase in egg white concentration. Moisture content, reconstitution and water holding capacity of the products were in the range from 2.91 to 3.09%, from 81.34 to 83.42% and from 6.19 to 6.34 g/g respectively. Foam-mat dried papaya

was dry blended with skim milk powder at 6:4; 5:5; 4:6 w/w ratio. Consuming formulated-product twice a day could supply 9.54% of recommended daily intake of dietary fiber.

Chaves *et al.*, (2013) characterized the foams of purple Brazilian cherry (*Eugenia uniflora L.*) pulp made with different additives. Drying was done at 55 °C for 2 h. It was concluded that the physic-chemical characterization was satisfactory and was in accordance with the Brazilian standards for agro-industrial products.

## CHAPTER III

### MATERIAL AND METHODS

The experiment to accomplish the desired objectives was performed in the Department of Agricultural Process Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The effect of addition of different levels of foaming agent, foam stabilizer and whipping time on properties of foam was investigated.

The foaming properties of guava pulp were determined at different levels of foaming agent concentration, stabilizer concentration and whipping time. The drying and colour kinetics for foamed and non-foamed guava pulp was studied. Details of the materials used and the methodology for experimental investigations have been discussed as under:

#### 3.1 Moisture content, % (wb)

The moisture content of guava pulp with adding foaming agents and without adding foaming agents for different level was determined by using hot air oven at  $105 \pm 2$  °C for 24 h as shown in plate 3.1. First weight of sample was measured then put the sample in oven and percentage moisture content was calculated by using the following formula (AOAC, 2000).

$$\text{Moisture content, \% (wb)} = \frac{\text{Initial weight (g)} - \text{Final weight after drying (g)}}{\text{Initial weight (g)}} \times 100 \dots 3.1$$



Plate 3.1 Hot air oven

### 3.2 Preparation of samples

The fresh guava fruit purchase procured from the local Akola Market. Fully ripe guava was taken then washed and weighed on the weighing balance. Ripe guava was cut into a sliced manually using stainless steel knife the samples shows in plate 3.2 then the cut slice taken into a food processor, to gets a guava pulp and addition of foaming agents i.e. GMS and CMC powder, in different concentration then it was whipped to form foam of guava pulp.



a) Fully ripe guava



b) Cut slice of guava

Plate 3.2 Sample of guava

### 3.3 Ingredients

Ripe Guava, Carboxy Methyl cellulose (CMC) and Glycerol Mono Stearate (GMS)

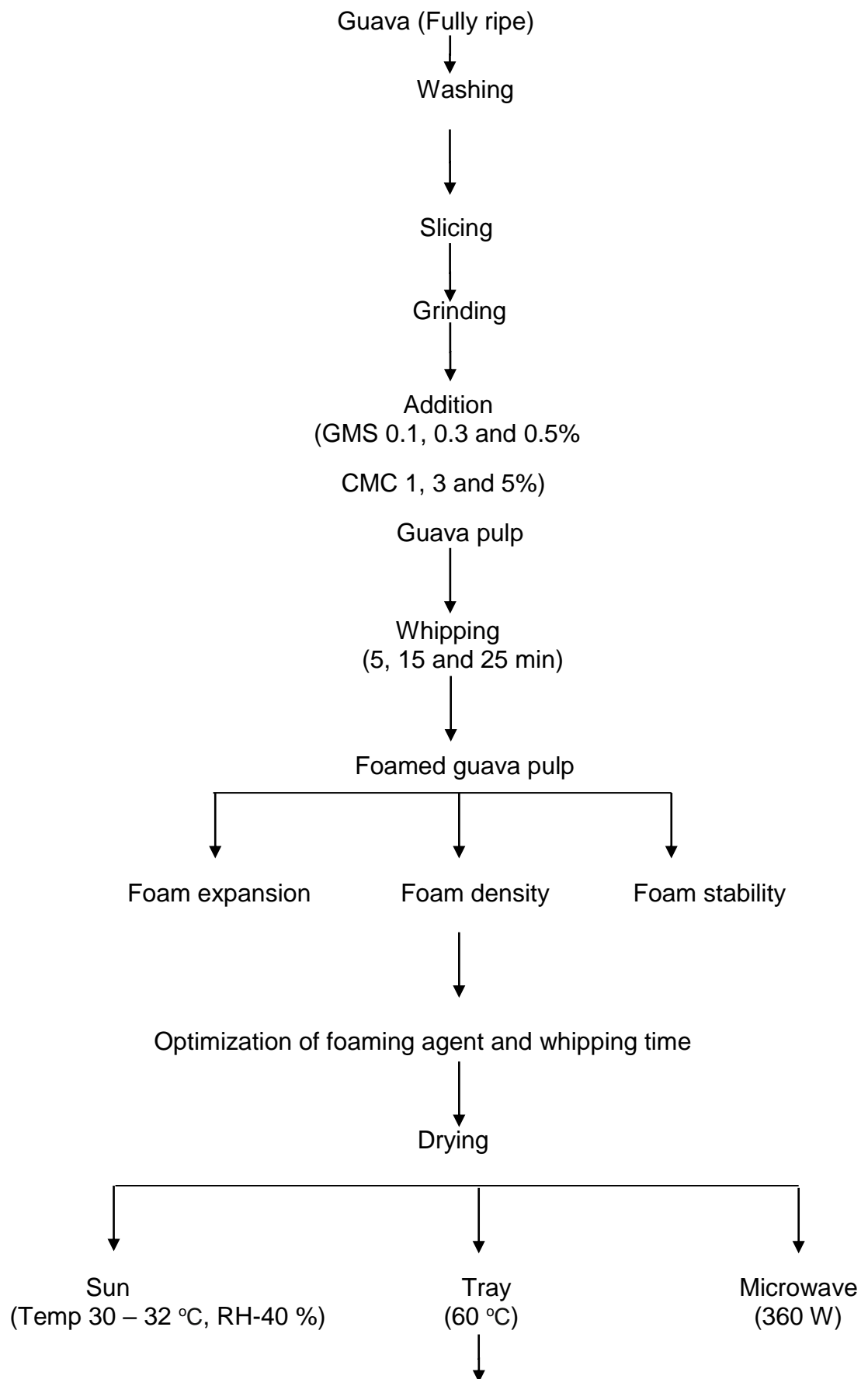
### 3.4 Equipment and apparatus

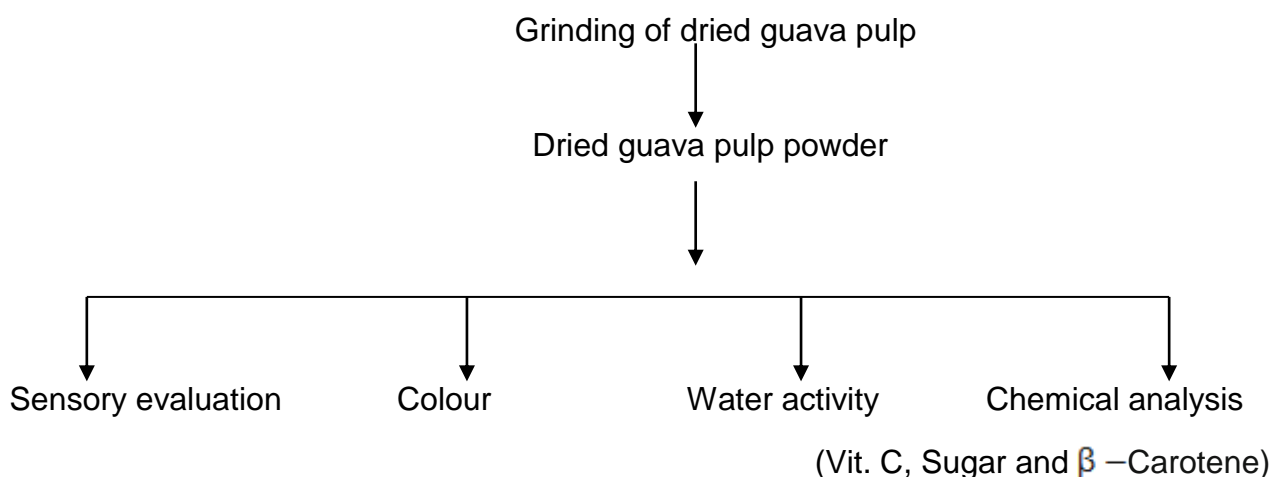
Microwave oven, Electrical Food Processor, Electronic Weighing Balance, Blender, Digital Vernier Caliper, Hot Air Oven, chroma meter, water activity meter and spectrophotometer were used for the study.

### 3.5 Process for Preparation of guava pulp powder

Processed guava pulp was taken and weighed on a balance. The foaming agents was added into the guava pulp at different

**Flow chart for production of guava pulp powder is given below:**





**Fig. 3.1 Flow chart for production of guava pulp powder**

level of concentration such as GMS 0.1, 0.3 and 0.5%, CMC 1, 3 and 5% and with different whipping time 5, 15 and 25 min. Optimization of guava pulp at different levels of GMS, CMC and Whipping time was carried out at three different drying methods i.e. sun drying (temp. 30-32 °C and RH- 40%), tray drying (60 °C) and microwave drying (360 W) up to desired moisture content. Then grinding the dried guava pulp into a food processor and prepared the powder. Then the guava pulp powder were packed in polyethylene bag and kept at room temperature.

### 3.6 Variables under Study

Variables selected for this study were classified as independent variables and dependent variables.

#### Independent variables:

1. Glycerol mono stearate (GMS) : 0.1%, 0.3% and 0.5%
2. Carboxy methyl cellulose (CMC) : 1%, 3% and 5%
3. Whipping time : 5 min, 15 min and 25 min

#### Responses

1. Foam expansion
2. Foam density
3. Foam stability

### 3.7 Foaming treatment

The foamed guava concentrate was prepared by giving foaming treatment to the prepared guava pulp by adding different levels of foaming agents, foaming stabilizer and whipping it for different time period. The foaming agent and foaming stabilizer was added to guava pulp concentrate at room temperature. The level of foaming agent was taken for study and optimization of concentration of GMS (0.1-0.5%), CMC (1-3%), and whipping time (5-25 min) done by Box - Behnken design under response surface methodology (Design expert version 11.0.3.0).

### 3.8 Foaming properties

The foam expansion, foam stability and foam density were determined as described by Akiokato *et al.*, (1983) and Rajkumar *et al.*, (2007 b).

#### 3.8.1 Foam expansion

Foam expansion is the initial volume of guava pulp before whipping to the final volume of guava pulp after whipping.

$$\text{Foam expansion (\%)} = \frac{V_1 - V_0}{V_0} \times 100 \quad \dots 3.2$$

Where,

$V_0$  = Initial volume of guava pulp, cm<sup>3</sup>.

$V_1$  = Final volume of foam guava pulp, cm<sup>3</sup>.

#### 3.8.2 Foam stability

Foam stability was determined by leaving 100 ml of the foamed guava pulp in a transparent graduated beaker kept at room temperature for 2 hrs. The foam drainage in terms of volume reduction was measured as an index for the foam stability for every 30 min by using the following relationship.

$$\text{Foam stability (\%)} = \Delta_0 \frac{\Delta t}{\Delta v} \times 100 \quad \dots 3.3$$

Where,

$\Delta_0$  = volume of foam at zero time.

$\Delta V$  = change in foam volume during the time interval  $\Delta t$ .

### 3.8.3 Foam density

The density of the foamed guava pulp was determined by dividing the mass of fresh pulp by the final volume of foam.

$$\text{Foam density (g/cm}^3\text{)} = \frac{m}{V_1} \times 100 \quad \dots 3.4$$

Where,

M = mass of fresh pulp.

$V_1$  = final volume of foam.

## 3.9 Optimization of process parameters

The optimization of process parameters for maximum foam expansion of guava pulp, maximum foam stability and minimum foam density were carried out using numerical optimization technique with the help of (BBD) in Design Expert version 11.0.3.0.

### 3.9.1 Experimental design for optimization of foamed guava pulp

The Box-Behnken experimental design was selected for the optimization of process variables i.e. foaming agent, foam stabilizer and whipping time using Response surface methodology.

The optimized condition for three variables and three levels of drying method including 17 trails formed by three replications was used. This design was selected as it fulfilled the most of the requirements needed for optimization of the drying condition. Box-Behnken design was conducted to work out the range of independent variables and their three levels for foamed guava pulp (Table 3.1).

**Table 3.1 Independent process variables and their levels for foamed guava pulp**

Independent variables	Symbol			Levels		
				-1	0	1
GMS (%)	A1	A2	A3	0.1	0.3	0.5
CMC (%)	B1	B2	B3	1	3	5
Whipping Time (min)	C1	C2	C3	5	15	25

### 3.9.2. Analysis of design

The analysis was done independently for each response variable with the help of response surface methodology (RSM) by using a statistical package, Design Expert Version 11.0.3.0 2018. The regression coefficients were estimated through least square method. The adequacy of the fitted model was tested through the analysis of variance showing lack of fit and coefficient of correlation. For each responses variables, N (17) observations were obtained as shown in Table 3.2.

**Table 3.2 Experimental structure with coded levels of process variables for foamed guava pulp using Box-Behnken design**

Sr. No.	GMS (%)		CMC (%)		Whipping time (min)	
	Coded	Actual	Coded	Actual	Coded	Actual
1	-1	0.1	0	3	-1	5
2	0	0.3	-1	1	-1	5
3	0	0.3	0	3	0	15
4	1	0.5	-1	1	0	15
5	0	0.3	0	3	0	15
6	0	0.3	0	3	0	15
7	-1	0.1	1	5	0	15
8	0	0.3	1	5	-1	5
9	0	0.3	0	3	0	15
10	1	0.5	-1	1	0	15
11	0	0.3	1	5	1	25
12	-1	0.1	-1	1	0	15
13	1	0.5	0	3	1	25
14	0	0.3	0	3	0	15
15	-1	0.1	0	3	1	25
16	1	0.5	0	3	-1	5
17	0	0.3	-1	1	1	25

### **3.9.3 Optimization of guava pulp**

The process variables for foamed guava pulp were optimized by response surface methodology. In order to optimize the process variables, only those responses were selected for optimization, which were found to have non-significant lack of fit. The three dimensional plots and contour plots (graphical method) according to the fitted model and fixed variable were drawn.

### **3.9.4 Verification of Optimum Responses**

The optimum responses were verified by conducting the experiment under optimum conditions. The responses such as foam expansion, foam density and foam stability at optimum conditions were compared to the values predicted.

### **3.10 Drying of guava pulp**

1. Foamed guava pulp
2. Non – foamed guava pulp

#### **3.10.1 Independent parameters**

##### **Different drying methods**

Sun drying : Atmospheric temperature (30-32 °C, RH- 40%)

Tray drying : 60 °C

Microwave drying : 360 W

#### **3.11 Drying methods**

##### **3.11.1 Sun drying**

Sun drying is the process in which drying can be done in natural atmospheric condition. For drying of foamed and non-foamed guava pulp accurately 100 g of samples taken with three replications. The sample kept in the plates and placed where adequate amount of sunlight available. Drying time was prepared from 9 h to 17 h. During drying, the samples were weighed at an interval of 30 minutes until the samples attained constant weight of guava pulp. The sun drying of guava pulp was done during the month of February at 30-32 °C temperature and RH 40%.

### 3.11.2 Tray drying

The dryer consists of drying chamber, blower, heaters and thermostat. The insulating chamber consisted of air circulating fan that moved air through heaters. The drying chamber size was 150×100×40 cm accommodating 12 aluminium trays in the dryer with three heaters of 1000 W capacity and the dial thermometer range 0 to 200 °C was installed. Trays were arranged one above the other with the clearance between two successive trays to permit air circulation. The drying temperatures were taken as 60 °C at constant drying air velocity of 1.5 m/s in drying chamber.

A tray drier used for drying studies is shown in Plate 3.3. The dryer was run for half an hour in order to stabilize the desired temperature inside the chamber. The foamed guava pulp was evenly spread on the stainless steel plate and the plate was then placed in tray dryer. The foamed and non-foamed guava pulp was dried at 60 °C temperature. The plates were taken out of the in drying chamber at regular 30 min interval for determination of weight loss. The drying was continued till constant moisture content (db) of guava pulp with adding foaming agent and without adding foaming agent was attained.



**Plate 3.3 Tray dryer**

### 3.11.3 Microwave drying

Microwave oven is one of the most widely used household appliances. Drying of foamed and non-foamed guava pulp of experiments was conducted in Microwave oven as shown in plate 3.4, with inside

chamber (450 × 350 × 300 mm). The guava pulp was dried in microwave 360 W. All measurements were replicated thrice and the average readings were reported. The drying data was recorded until the sample attained constant moisture content (db).



**Plate 3.4 Microwave oven**

### **3.12 Drying Characteristics**

The initial moisture content of fresh guava pulp samples were determined by the oven drying method, as described earlier. The dry matter (%) and the weight of dry matter in sample were calculated as follows (Mohsenin, 1980).

#### **3.12.1 Dry matter**

$$DM (\%) = 100.0 - IMC (w.b) \quad \dots 3.5$$

$$\text{Weight of DM} = \text{Initial mass of sample} \times \frac{DM (\%)}{100} \quad \dots 3.6$$

Where,

DM = Dry matter of the sample, g

IMC = Initial moisture content, (%)

#### **3.12. 2 EMC (Equilibrium moisture content %)**

The EMC values were determined by drying of guava pulp samples in the various drying methods as mentioned above until the mass loss of the sample ceased. The final moisture content values were calculated from this constant weight and it was used as an EMC value for calculation of the moisture ratio (Mohsenin, 1980).

### 3.12.3 Drying rate

The moisture content data recorded during experiments were analysed to determine the moisture loss from guava pulp in the particular time interval. The drying rate of sample was calculated by following equation (Mohsenin, 1980).

$$R = \frac{\text{WML (kg)}}{\text{Time interval (min)} \times \text{DM (kg)}} \quad \dots 3.7$$

Where,

R = Drying rate at time  $\theta$ , kg water/ kg dm min

WML = Initial weight of sample – Weight of sample after time  $\theta$

### 3.12.4 Moisture ratio (MR)

The moisture ratio (MR) at each moisture content level was determined by the following equation (Mohsenin, 1980).

$$MR = \frac{M - M_{\infty}}{M_o - M_{\infty}} \quad \dots 3.8$$

Where,

MR = Moisture ratio

M = Moisture content at any time, % (db)

M<sub>o</sub> = Initial moisture content, % (db)

M<sub>∞</sub> = Equilibrium moisture content, % (db)

### 3.13 Modelling of Convective drying of guava pulp

To determine the most suitable drying equations, the experimental drying data were fitted in the various drying models (Table 3.3). The coefficient of determination was the main criteria for deciding acceptability and subsequently selecting the best equation. In addition to the coefficient of determination, the goodness of fit was determined by various statistical parameters such as reduced mean square of the deviation  $\chi^2$  and root mean square error  $E_{RMS}$ , mean bias error (MBE). For quality fit, R<sup>2</sup> value should be higher or close to one and  $\chi^2$  and  $E_{RMS}$  values should be lower (Pangavhane *et al.*, 1999; Togrul and Pehlivan, 2002; Erketin *et al.*, 2004; Demir *et al.*, 2004). The above parameters were calculated as follows:

**Table 3.3 Mathematical model used for guava pulp**

Sr. No.	Name of the model	Model /equation	References
1	Lewis/ Newtons' model	MR = exp(-k*t)	Lewis 1921
2	Page	MR = exp(-K*t^y)	Zhang and Litchfield (1991)
3	Logarithmic	MR = a* exp(-k*t) +c	Yaldiz <i>et al.</i> (2001)
4	Magee	MR=a + k*t <sup>1/2</sup>	Midilli <i>et al.</i> (2002)

a, b, c, k and n = model coefficients, t = drying time, min and MR = moisture ratio

$$\chi^2 = \frac{\sum_{i=1}^N (M_{R,exp,i} - M_{R,pre,i})^2}{N - z} \quad \dots 3.9$$

$$E_{RMS} = \left[ \frac{1}{N} \sum_{i=1}^N (M_{R,pre,i} - M_{R,exp,i})^2 \right]^{1/2} \quad \dots 3.10$$

$$MBE = \frac{1}{N} \sum_{i=1}^N (MR_{exp,i} - MR_{pre,i}) \quad \dots 3.11$$

Where,

MR<sub>exp, i</sub> and MR<sub>pre, i</sub> are the experimental and predicted dimension less MR, respectively,

N = number of observations,

z = number of drying constants.

Depending on the equations used, models can be classified as theoretical, semi-empirical and empirical models to express and explain the thin layer drying of agricultural products. Theoretical models can be used for different materials and conditions, but contain diffusion or heat and mass transfer equations, and thus, the usability of these models is limited. Semi-theoretical models contain parameters directly related to material properties. The empirical equations give a satisfactory fit to all the experimental data and take less computing time in comparison to the theoretical equations. These proposed simple models can provide adequate representation of experimental results.

### 3.14 Chemical analysis

#### 3.14.1 Reducing sugar (%)

Reducing sugar was estimated by the spectrophotometer method reported by Sadasium and Manickam (1997) preparation of 3, 5 – Dinitro salicyolic (DNS) acid reagents for estimation of reducing sugars.

$$\text{Reducing sugar (\%)} = R (\mu\text{g/ml}) \times \frac{1}{1000000} \times \frac{100}{1} \times \frac{100}{\text{wt of sample (1.07)}} \quad \dots 3.12$$

$$\text{Reducing sugar (\%)} = R \times 0.00945$$

#### 3.14.2 Total sugar (%)

The total sugar was estimated by the spectrophotometer method reported by Sadasium and Manikam (1997) preparation of phenol sulphuric acid (PSA) for estimation of total sugars.

$$\text{Total sugar (\%)} = R (\mu\text{g/ml}) \times \frac{1}{100} \times \frac{100 \times 50}{\text{wt of sample (1.07)}} \times 100 \quad \dots 3.13$$

Where, R is the graph reading

#### 3.14.3 Non reducing sugar (%)

Non reducing sugar was estimated by subtracting the value of reducing sugar from total sugar reported by Sadasium and Manikam (1997).

$$\text{Non reducing sugar (\%)} = \text{Total sugar} - \text{Reducing sugar} \quad \dots 3.14$$

#### 3.14.4 Ascorbic acid (Vitamin C)

Ascorbic acid content was estimated by using 2, 6 – dichlorophenol indophenol dye as reported by Ranganna (1986) as follows. Ascorbic acid content of the guava pulp powder was calculated taking into consideration the dye factor.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{volume made up} \times 100}{\text{volume of filtered taken} \times \text{wt of sample take}} \quad \dots 3.15$$

#### 3.14.5 $\beta$ - carotene

The  $\beta$ -carotene was estimated by the spectrophotometer method reported by (Chandrasekar *et al.*, 2015) preparation of petroleum ether and

sodium sulphate solution for estimation of  $\beta$ -carotene by using the following formula and expressed in mg.

$$\beta \text{ -carotene (mg/100mg)} = A_{nm} \times V / 0.2592 \times W \times 1000 \quad \dots 3.16$$

Where,

$A_{nm}$  = absorbance value of guava pulp at 453 nm

V = total volume of petroleum ether solution made up 100 ml

W = wt of guava pulp, g

### 3.15 Quality Evaluation

Drying is most predominant factor which affects the quality; therefore, quality of dried guava pulp was evaluated on the basis of colour, water activity and sensory evaluation. All measurements were replicated thrice and the average readings were reported.

#### 3.15.1 Colour

Color is the basic qualitative characteristic determining attractiveness of dried products as well as the possibility of their further utilization. The assessments of food color area critical objective parameter that can be used as a quality index for the determination of conformity of food quality to specifications and for analysis of quality changes during food processing, storage and other factors (Giese 2000).

Thus scale L measures lightness (whiteness or darkness). The chromatic portion of the solid is defined by +a (red); -a (green); +b (yellow); -b (blue) as shown in Plate 3.5. In terms of three coordinates L, a and b, the data can be converted to total color difference ( $\Delta E$ ) chroma and hue angle as mentioned below:

$$\text{Total colour difference } (\Delta E) = ((L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2)^{1/2} \quad \dots 3.17$$

$$\text{Chroma} = \sqrt{a^2 + b^2} \quad \dots 3.18$$

$$\text{Hug angle} = \tan^{-1}(b/a) \quad \dots 3.19$$



**Plate 3.5 Chroma meter**

### **3.15.2 Water activity**

The water activity of the food is a measure of the availability of water as a solvent for reaction in food. Water activity is the ratio of partial pressure of water in the food to the saturated vapour pressure of water at the same temperature.

$$a_w = P_A / P_{Asat} \quad \dots 3.20$$

Where,

$a_w$  = Water activity.

$P_A$  = Vapour pressure of water exerted by food.

$P_{Asat}$  = Saturated vapour pressure of water at the same temperature

If a food is equilibrated in a sealed container and the equilibrium relative humidity of air equals RH, then

$$a_w = RH/100 \quad \dots 3.21$$

Water activity is a function of moisture content in the food and the temperature (Ratti and Mujumdar, 1996). Bound molecule of water in food can be defined by water activity. The sample in powder form was filled and third of the volume of the cup provided with the instrument. The instrument took about 1 to 5 min to display the water activity of the sample. A digital water activity meter as shown in plate 3.6



**Plate 3.6 water activity**

### **3.15.3 Sensory evaluation of developed guava powder**

Organoleptic quality of developed guava pulp powder was conducted on a 9-point hedonic scale (BIS: 6723 Part-II). The samples were evaluated in terms of color, flavor, taste, appearance. The average scores of all the 20 panellists were computed for different characteristics. Guava pulp powder was evaluated in different sensory attributes by a panel of 20 judges in College of Agricultural Engineering and Technology, Dr .PDKV, Akola. The score sheet was provided with product and panellists were requested to mark the product score according to their liking. Based on the individual marking the average score was computed.

### **3.16 Experimental design for optimization of foamed and non foamed guava pulp at different drying methods**

The Factorial Multilevel Categorical Design (FMCD) was selected for the optimization of process variables i.e. drying time, reducing sugar, total sugar, non-reducing sugar, ascorbic acid,  $\beta$ -carotene, water activity and overall acceptability. The optimized condition for two variables and three levels of drying method including 18 trails formed by three replications was used as shown in Table 3.4.

**Table 3.4 Levels of independent variables for drying of guava pulp**

Independent variables	Symbols		Levels	
	Coded	Un-coded	Coded	Un-coded
Sample	A	S	Level 1 of A Level 2 of A	Foamed Non foamed
Drying method	B	D	Level 1 of B Level 2 of B Level 3 of B	Sun (temp. 30-32 °C, RH-40%) Tray (60 °C) Microwave (360 W)

Figures in parenthesis shows drying temperature and microwave power in watt

### **Dependent parameters**

Drying time, reducing sugar, non reducing sugar, ascorbic acid,  $\beta$ -carotene, colour, water activity and overall acceptability

### **3.17 Optimization of guava pulp**

The process variables for foamed and non foamed guava pulp at different drying methods were optimized by Factorial Multilevel Categorical Design (FMCD). In order to optimize the process variables, only those responses were selected for optimization, which were found to have non-significant lack of fit. The three dimensional plots and contour plots (numerical method) according to the fitted model and fixed variable were drawn.

### **3.18 Verification of Optimum Responses**

The optimum responses were verified by conducting the drying experiment under optimum conditions. The responses such as drying time, ascorbic acid, total sugar, reducing sugar, non reducing sugar,  $\beta$ -Carotene, colour, water activity, and overall acceptability at optimum drying conditions were compared to the values predicted.

## CHAPTER IV

### RESULTS AND DISCUSSION

This chapter deals with the results of the investigations carried out on foam mat drying of guava pulp and quality analysis of dried product. The statistical analysis of experimental data are also presented and discussed in the following sections:

#### 4.1 Initial moisture content

The initial moisture content of guava pulp was determined by using oven drying method as described in Section 3.1. The average initial moisture content of guava pulp with adding and without adding foaming agents was found to be 83.25 and 87.38% (wb).

#### 4.2 Effect of foaming treatment on the foam properties of guava pulp

The experiments were conducted by giving foaming treatment to the prepared guava pulp by adding CMC (1 - 5%), GMS (0.1 - 0.5%) and whipping time (5 - 25 minutes). The each sample was analysed for their foaming properties i.e. foam expansion, foam stability and foam density. The complete experimental results for foamed guava pulp were presented in Table 4.1. The variation of foam properties due to process parameters were discussed in separate sections as below:

**Table 4.1 Experimental data of foam properties of guava pulp**

Sr. No.	Treatment combination			Foam responses		
	GMS (%)	CMC (%)	Whipping time (min)	Foam Expansion (%)	Foam Density (g/cm <sup>3</sup> )	foam Stability (%)
1	0.1	3	5	8.00	0.95	97
2	0.3	1	5	7.90	0.95	96
3	0.3	3	15	11.90	0.90	98
4	0.5	5	15	14.12	0.89	98
5	0.3	3	15	12.30	0.90	98
6	0.3	3	15	12.40	0.89	98
7	0.1	5	15	12.60	0.91	97
8	0.3	5	5	10.30	0.93	97
9	0.3	3	15	12.02	0.91	99
10	0.5	1	15	12.80	0.90	98
11	0.3	5	25	14.40	0.89	97
12	0.1	1	15	9.20	0.93	99
13	0.5	3	25	14.90	0.89	98
14	0.3	3	15	12.21	0.91	98
15	0.1	3	25	12.00	0.91	99
16	0.5	3	5	10.20	0.93	96
17	0.3	1	25	14.00	0.90	98

#### 4.2.1 Effect on foam expansion of guava pulp

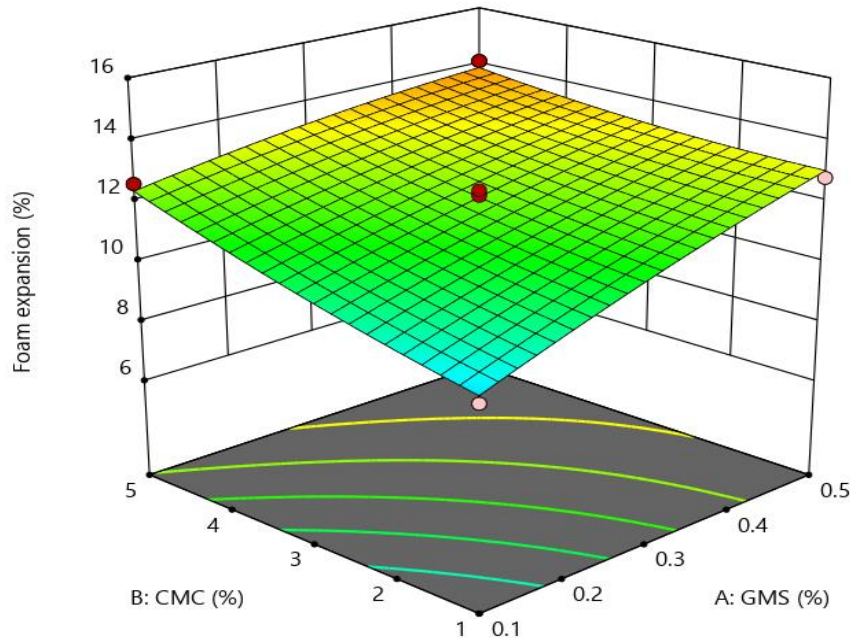
The concentration of CMC was increased from 1 – 5% the foam expansion of guava pulp was increased from 7.9– 14.9% at a whipping time 5-25 min as shown in Table 4.1. From Fig. 4.1 it was observed that the maximum foam expansion was found to be 14.9% for 0.5% GMS, 3% CMC and 25 min whipping time. Similarly the minimum foam expansion was found to be 7.9% for 0.3% GMS, 1% CMC and 5 min whipping time.

**Table 4.2 ANOVA for effect on foam expansion of guava pulp**

Source	Sum of square	Df	Mean square	F-value	p-value	
<b>Model</b>	69.40	9	7.71	59.39	< 0.0001	Significant
<b>A-GMS</b>	13.06	1	13.06	100.56	< 0.0001	
<b>B-CMC</b>	7.07	1	7.07	54.45	0.0002	
<b>C-Whipping time</b>	44.65	1	44.65	343.92	< 0.0001	
<b>AB</b>	1.08	1	1.08	8.33	0.0234	
<b>AC</b>	0.1225	1	0.1225	0.9435	0.3637	
<b>BC</b>	1.00	1	1.00	7.70	0.0275	
<b>A<sup>2</sup></b>	0.1372	1	0.1372	1.06	0.3382	
<b>B<sup>2</sup></b>	0.1593	1	0.1593	1.23	0.3046	
<b>C<sup>2</sup></b>	2.13	1	2.13	16.37	0.0049	
<b>Residual</b>	0.9088	7	0.1298			
<b>Lack of Fit</b>	0.7421	3	0.2474	5.93	0.0591	not significant
<b>Pure Error</b>	0.1667	4	0.0417			
<b>Cor Total</b>	70.30	16				
<b>Std. Dev.</b>	0.36					
<b>C.V. %</b>	3.04					
<b>R<sup>2</sup></b>	0.98					
<b>Adjusted R<sup>2</sup></b>	0.97					
<b>Predicted R<sup>2</sup></b>	0.82					

From Table 4.2 the Analysis of variance of the quadratic model was found to be fitted to the experimental data and statistical significance for foam expansion of guava pulp concentrate. The R<sup>2</sup> value was calculated by least square technique and found to be 0.98 showing good fit of the model to the data. There is only a 0.01% chance that an F-value this large could occur due to noise. The lack of fit F value was non-significant, which indicates that the developed model was adequate for predicting the response.

From Fig. 4.1 shows that the concentration of GMS, CMC and whipping time increases with increase in foam expansion. Similar results were reported by Kandasamy *et al.*, (2012) for papaya.



**Fig. 4.1 Effect on foam expansion of guava pulp**

#### 4.2.2 Effect on Foam density of guava pulp

The foam density of the foamed guava pulp concentrates for the experiment of 17 run varied from 0.8932 – 0.9511 g/cm<sup>3</sup> as shown in Table 4.1. The maximum foam density was obtained as 0.9512 g/cm<sup>3</sup> for 0.3% GMS, 1% CMC and 5 min whipping time. Similarly the minimum foam density was obtained as 0.8932 g/cm<sup>3</sup> for 0.5% GMS, 3% CMC and 25 min whipping time. The more air incorporated during whipping, the lower the foam density (Falade *et al.* 2003). Foam density was commonly used to evaluate the whipping properties. The foam density displayed a low value when more air was incorporated into the foam during whipping. The presence of more air in the foam increases the whipping ability. The foam density decreases when the concentration of GMS, CMC and whipping time increase. The foam density was higher in prolonged drying time leading to poor product quality.

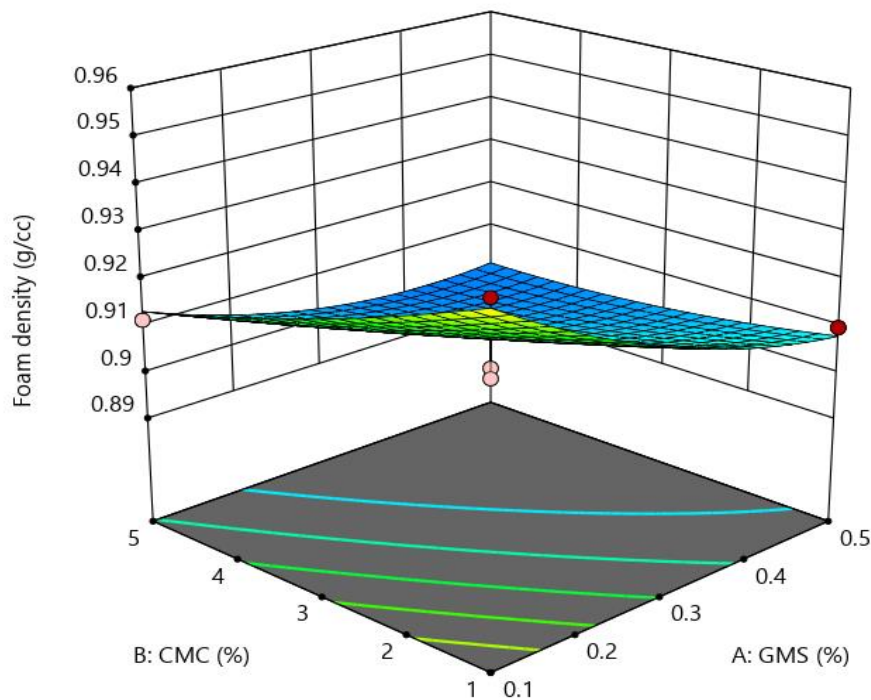
**Table 4.3 ANOVA for effect on foam density of guava pulp**

Source	Sum of Square	Df	Mean Square	F-value	p-value	
Model	0.0051	9	0.0006	12.52	0.0015	Significant
A-GMS	0.0009	1	0.0009	19.47	0.0031	
B-CMC	0.0005	1	0.0005	10.86	0.0132	
C-Whipping time	0.0030	1	0.0030	66.87	< 0.0001	
AB	0.0001	1	0.0001	1.75	0.2275	
AC	4.320E-06	1	4.320E-06	0.0948	0.7671	
BC	0.0001	1	0.0001	1.72	0.2308	
A <sup>2</sup>	0.0001	1	0.0001	2.29	0.1740	
B <sup>2</sup>	0.0000	1	0.0000	0.3341	0.5813	
C <sup>2</sup>	0.0004	1	0.0004	8.47	0.0227	
Residual	0.0003	7	0.0000			
Lack of Fit	0.0000	3	0.0000	0.2238	0.8755	not significant
Pure Error	0.0003	4	0.0001			
Cor Total	0.0055	16				
Std. Dev.	0.0067					
C.V. %	0.74					
R <sup>2</sup>	0.94					
Adjusted R <sup>2</sup>	0.87					
Predicted R <sup>2</sup>	0.79					

From the Table 4.3 the Analysis of variance of the quadratic model was found to be fitted to the experimental data and statistical significance for foam density of guava pulp concentrate. The R<sup>2</sup> values was calculated by least square technique and found to be 0.94 good fit of the model to the data. The model F-value of 12.52 implies the mode is significant. There is only a 0.15% chance that an F-value this large could occur due to noise. There is only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.05 indicate model terms are significant. Values greater than 0.10 indicate the model terms are not significant. The Lack of Fit F-value of 0.22 implies the Lack of Fit is not significant relative to the pure error. There is 87.55% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good to fit the model. The Predicted R<sup>2</sup> of 0.79 is in reasonable agreement with the Adjusted R<sup>2</sup> of 0.87.

From the response surface plot Fig. 4.2, it can be seen that the concentration of GMS, CMC and whipping time 0.1-0.5%, 1-5% and 5-25 min respectively increases when the foam density decreases from 0.96 –

0.89 g/cm<sup>3</sup>. However, a slight increase in foam density was found after a reduction in whipping time. The slight increase in the foam density was due to bubble collapse when the whipping time increased. During whipping air bubbles trapped in the foam and gave to lower foam density. Therefore, more air was incorporated in the foam as the whipping time increased which resulted in lower foam density. Similar results were reported by Durge *et al*, (2015) for gac fruit, Falade and Okocha (2010) for banana.



**Fig. 4.2 Effect on foam density of guava pulp**

#### 4.2.3 Effect on foam stability of guava pulp

The foam stability of the foamed guava pulp concentrates for the experiment of 17 run varied from 96 - 99% as shown in Table 4.1. The maximum foam density was obtained as 99%. Similarly the minimum foam density was obtained as 96%. A higher percentage for the foam stability implies a higher water holding capacity. The foam stability increases when the concentration of GMS, CMC and whipping time also increase as shown in Table 4.1. The analysis of variance was presented in Table 4.4 It was also observed that at higher whipping time, the foam stability was

decreased due to rupturing of foam bubbles and releasing of liquid phase intact in foam bubbles.

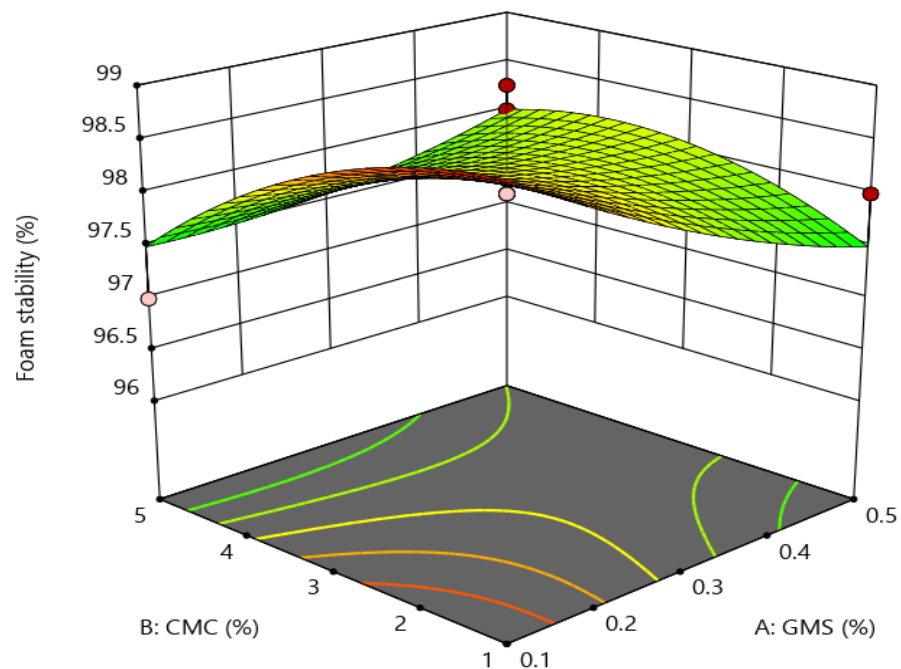
Foam stability reflects the water holding capacity of the foam and one way to determine the rate at which the liquid drains from it (Kampf *et al.* 2003). The stable foam structure is desirable for rapid drying and ease of removing the dried material from the tray. If foams break or drain excessively, drying time is increased, reducing product quality. The stability/drainage volume of foam is influenced by the thickness of the interface, foam size distribution, interface permeability, and surface tension. In foam-mat drying, foam stability is very critical because the foam should be able to retain its open structure throughout the drying process in order to increase the total surface area and capillary effect during drying (Hart *et al.* 1963).

**Table 4.4 ANOVA for effect of foam stability of guava pulp**

Source	Sum of Square	Df	Mean Square	F-value	p-value	
Model	11.23	9	1.25	3.79	0.0462	Significant
A-GMS	0.50	1	0.5	1.52	0.2572	
B-CMC	0.50	1	0.5	1.52	0.2572	
C-Whipping time	4.50	1	4.5	13.69	0.0076	
AB	1	1	1	3.04	0.1246	
AC	0	1	0	0	1.0000	
BC	1	1	1	3.04	0.1246	
A <sup>2</sup>	0.0947	1	0.0947	0.2883	0.6079	
B <sup>2</sup>	0.5157	1	0.5157	1.57	0.2505	
C <sup>2</sup>	3.04	1	3.0421	9.26	0.0188	
Residual	2.3	7	0.3285			
Lack of Fit	1.5	3	0.5	2.5	0.1985	not significant
Pure Error	0.8	4	0.2			
Cor Total	13.53	16				
Std. Dev.	0.5732					
C.V. %	0.5866					
R <sup>2</sup>	0.83					
Adjusted R <sup>2</sup>	0.8663					
Predicted R <sup>2</sup>	0.6114					

From the Table 4.4 the Analysis of variance of the quadratic model was found to be fitted to the experimental data and statistical significance for foam stability of guava pulp concentrate. The R<sup>2</sup> values was calculated by least square technique and found to be 0.83 good fit of the model to the

data. The Model F-value of 3.80 implies the model is significant. There is only a 4.62% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. The Lack of Fit F-value of 2.50 implies the Lack of Fit is not significant relative to the pure error. There is a 19.85% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good to fit the model. The Predicted  $R^2$  of 0.6114 is in reasonable agreement with the Adjusted  $R^2$  of 0.8663.

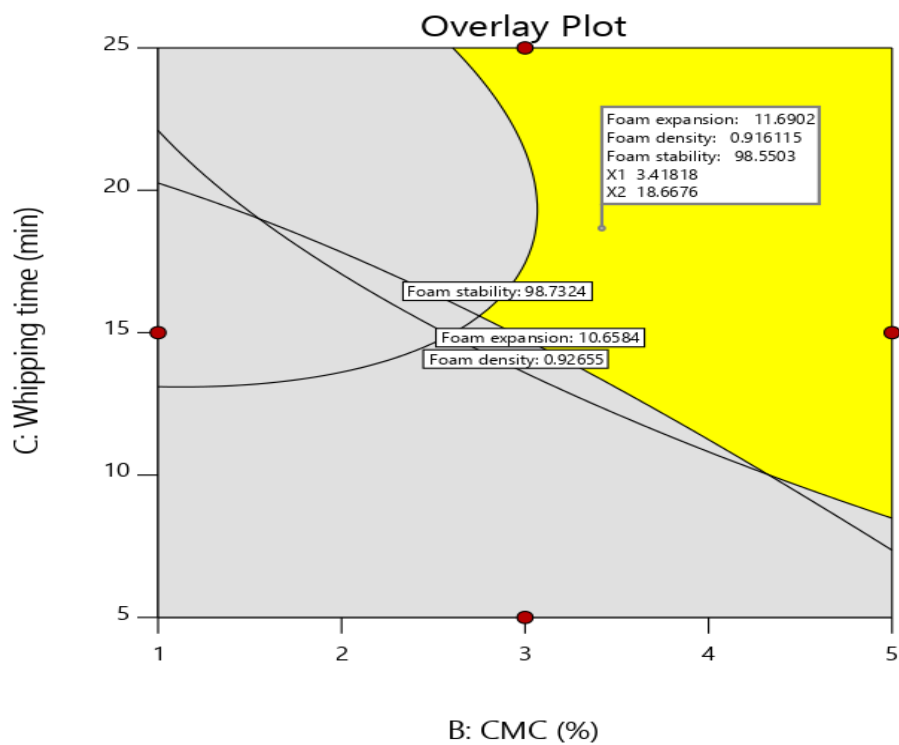


**Fig. 4.3 Effect of foam stability of guava pulp**

#### **4.3 Optimization of process parameters for guava pulp**

Graphical multi-response optimization technique was adopted to determine the workable optimum conditions for the foamed guava pulp concentrate. The contour plots for all responses were superimposed and regions that best satisfy all the constraints were selected as optimum conditions. These constraints resulted in 'feasible zone' of the optimum conditions (shaded area in the superimposed contour plots). The superimposed contour plots having common superimposed area for all responses were shown in Fig. 4.4.

The optimum range of process parameters for foamed guava pulp concentrate was: 0.32 - 0.49% GMS concentration, 2.51 - 1.68% CMC concentration and 22.93 - 24.99 min of whipping time. In order to optimize the process parameters for preparation of foamed guava pulp concentrate by numerical optimization; which finds a point that maximizes the desirability function. The optimum operating conditions for GMS concentration, CMC concentration and whipping time was 0.5%, 3% and 22.95 min. corresponding to these values of process variables, the value of foam expansion was 14.83%, foam density 0. 0.89 g/cm<sup>3</sup>, foam stability 98.17% and overall desirability 0.88 as shown in Table 4.5.



**Fig. 4.4 Superimposed Contour plots of different foam responses for optimization of guava pulp**

**Table 4.5 Constraints for optimization of various process parameters of foamed guava pulp**

Process parameter	Target	Experimental Range		Importance	Lower limit	Upper limit
		Low	High			
GMS (%)	In range	0.1	0.5	3	1	1
CMC (%)	In range	1	5	3	1	1
Whipping Time (min)	In range	5	25	3	1	1
Foam expansion (%)	maximum	7.9	14.9	4	1	1
Foam density (g/cm <sup>3</sup> )	minimum	0.893	0.951	3	1	1
Foam stability (%)	maximum	96	99	4	1	1

**4.5.1 Solutions for optimization of various process parameters of foamed guava pulp**

Sr. No.	GMS (%)	CMC (%)	Whipping time (min)	Foam expansion (%)	Foam density (g/cm <sup>3</sup> )	Foam stability (%)	Desirability
1	0.5	3	22.95	14.83	0.89	98.17	0.887

**4.4 Verification of the model for foaming properties of guava pulp**

The experiments were conducted at the optimum process conditions for testing the adequacy of foaming properties for predicting the response values.

**Table 4.6 Predicted and experimental values of response at optimum process conditions for foaming properties of guava pulp**

Response	Predicted mean	Experimental mean Value $\pm$ SD	SE	% Variation	Mean difference
Foam expansion, %	12.16	14.37 $\pm$ 2.69	0.1611	0.762	2.21
Foam density, g/cm <sup>3</sup>	0.9082	0.89 $\pm$ 0.02	0.003	0.0143	0.0182
Foam stability, %	98.20	98.17 $\pm$ 0.91	0.2563	1.2124	0.03

The observed experimental values (mean of 3 experiments) and values predicted are presented in Table 4.6. The experimental values were found to be very close to the predicted values. Therefore, it could be

concluded from above discussions that are quite adequate to assess the behaviour of the foaming properties.

#### 4.5 Drying characteristics

Drying data for various drying methods of guava pulp was presented in Appendix. The drying was carried out in foamed and non-foamed sun drying, foamed and non-foamed tray and foamed and non-foamed microwave oven drying methods. Drying behaviour was investigated for guava pulp dried at air temperature of 30 –32 °C and relative humidity 40% in sun, air temperature of 60 °C in tray and in microwave oven drying was done at 360 W. Table 4.6 shows drying time required to obtained final moisture content during drying of guava pulp by using different drying methods.

From Table 4.7 it shows that, the drying time was found maximum in non-foamed sun drying (570 min) with final moisture content 9.27% dry basis and minimum in foamed microwave oven (64 min at 360 W) with final moisture content 8.45 %.

**Table 4.7 Effect of temperature and drying method on drying time of foamed and non-foamed guava pulp**

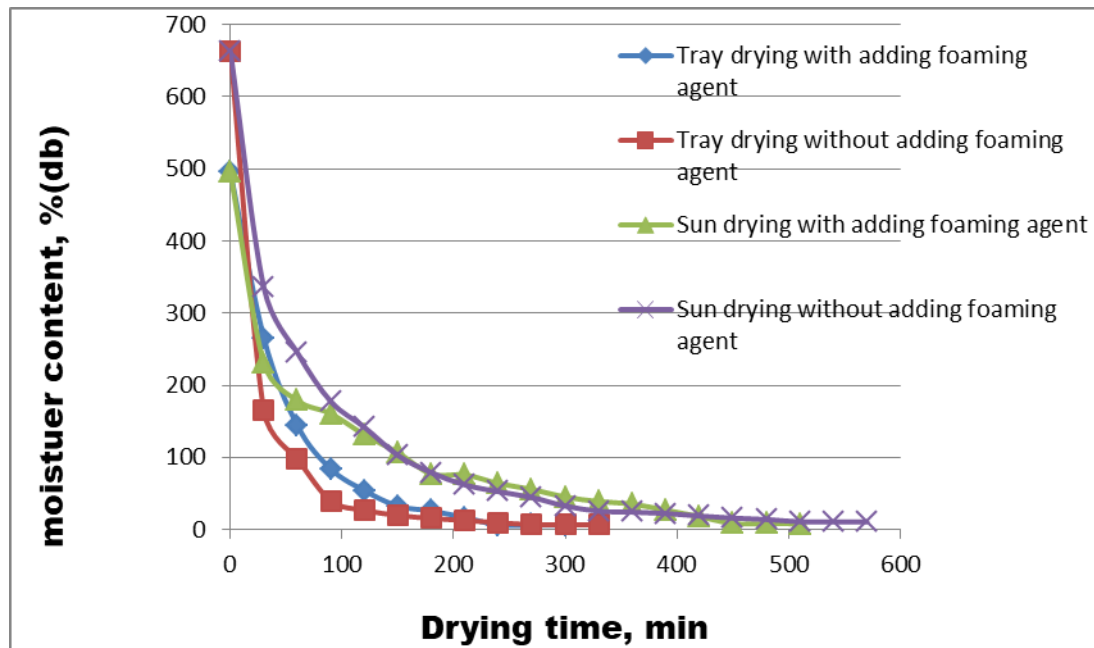
Sr. No.	Drying methods	Temperature (°C)	Relative humidity (%)	Drying time (min)	EMC (%)
1	Foamed Sun	30 –32 °C	40 %	510	8.26
2	Non-foamed sun	30 –32 °C	40 %	570	9.49
3	Foamed tray	60 °C	-	300	5.88
4	Non-foamed tray	60 °C	-	390	6.36
5	Foamed microwave	360 W	-	64	8.58
6	Non-foamed microwave	360 W	-	76	8.72

##### 4.5.1 Effect of drying time on moisture content of foamed and non-foamed guava pulp

The drying rates of foamed and non-foamed of guava pulp under different drying conditions are presented in Appendix. The drying rate curves are shown for the foamed and non-foamed guava pulps are shown in Fig. 4.9.

It was observed the drying rate was higher in the initial period of drying and subsequently it reduced with decrease in moisture content. The high drying rate at the start of drying is due to high surface moisture availability, which evaporates water rapidly. Further decrease in drying rate is owed to decrease in available moisture due to low driving force and low moisture diffusion from centre to surface of the dried product.

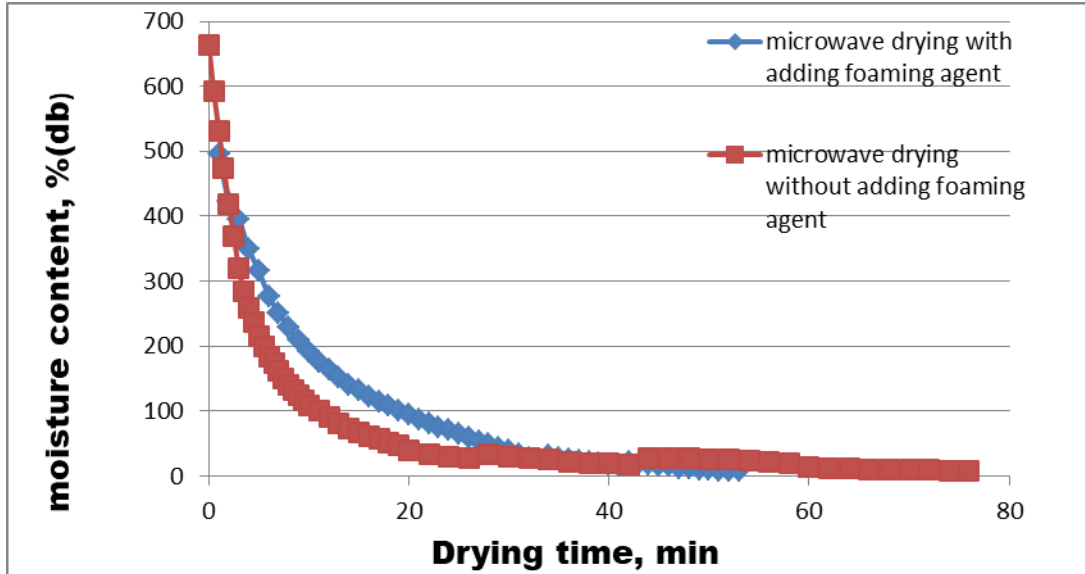
From the Fig 4.5 a maximum drying time was observed 570 min for sun drying without adding foaming agents and minimum drying was observed as 300 min for tray drying with adding foaming agents. The minimum final moisture content (db) was observed as 6.07% for foamed tray drying and maximum final moisture content (db) was observed as 10.68% for non-foamed sun drying.



**Fig. 4.5 a Effect of drying time on moisture content of foamed and non foamed sun and tray drying of guava pulp**

From the Fig. 4.5 b shows that in foamed microwave drying the drying time minimum was to be observed as 64 min while in non-foamed microwave drying the drying time maximum was to be observed 74 min. Initial the moisture content (db) of foamed microwave drying was high then it was decreased slowly then the final moisture content of foamed drying was to be found as 8.01% (db) it was minimum as compared to the non

foamed microwave drying it was maximum final moisture content (db) 8.66%. Similar results were reported by Mohammad *et al.*, (2014) for cantaloupe (*cucumis melo*), Kudra and Ratti (2006) for tomato paste.

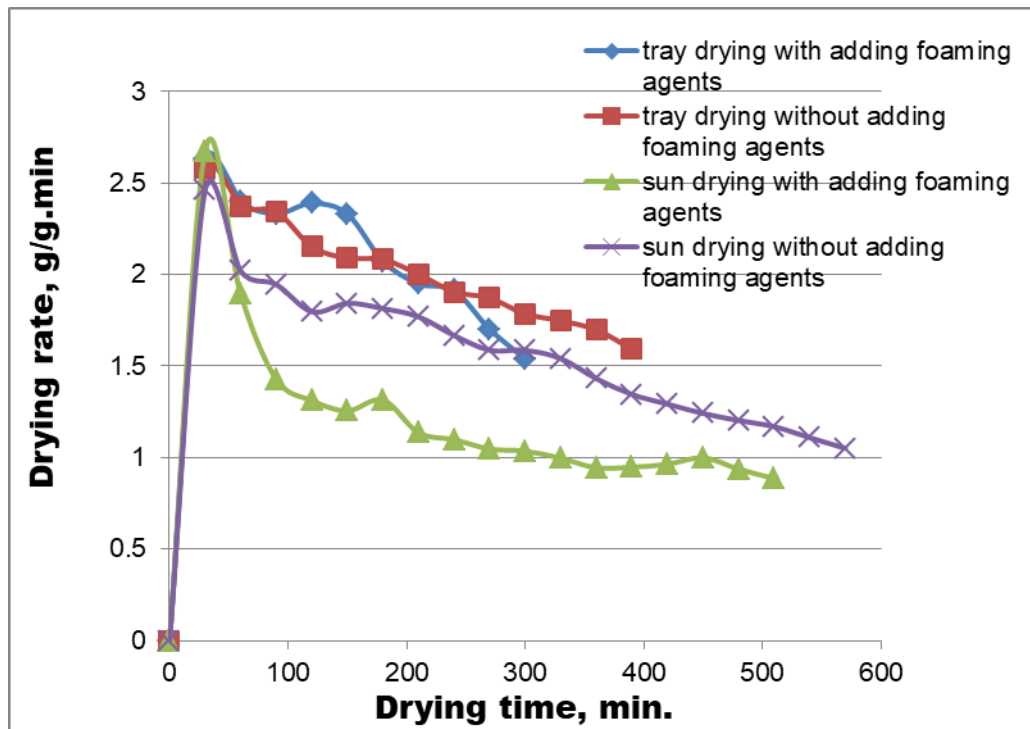


**Fig. 4.5 b Effect of drying time on moisture content of foamed and non foamed microwave drying of guava pulp**

#### **4.5.2 Effect of drying time on drying rate of foamed and non-foamed guava pulp**

The typical curves showing variation in drying rate with moisture content for drying of guava pulp by different methods are shown in Fig. 4.6 a. The initial drying rate was found to be 2.67, 2.46, 2.63 and 2.57 g /g.min for foamed sun, non foamed sun, foamed tray and non foamed tray drying and after drying up to nearly constant weight, the moisture content was reduced in the range of 5.82 to 9.27% (d.b).

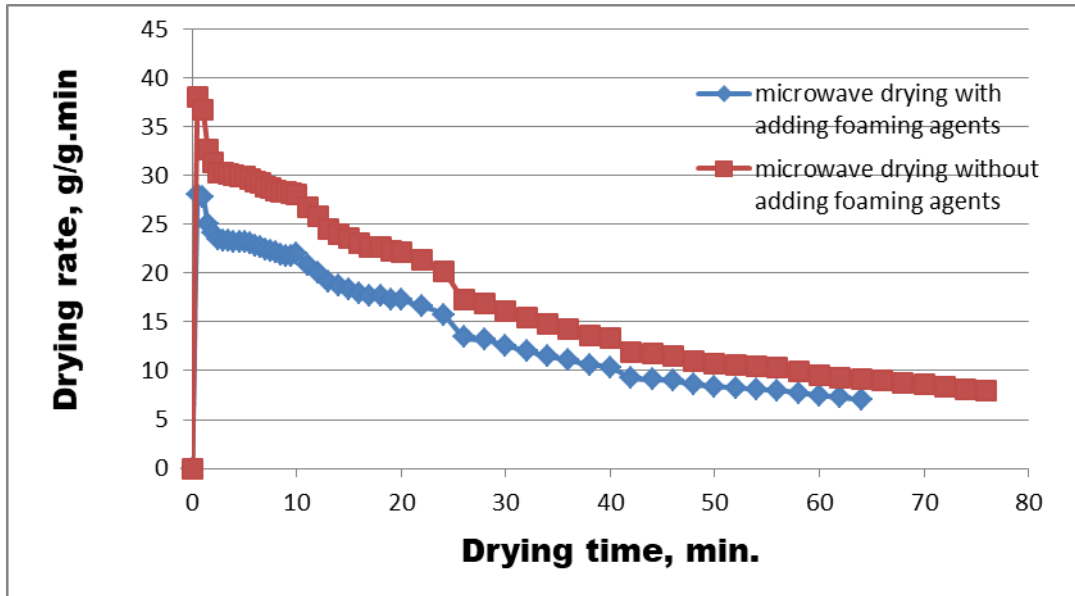
From Fig. 4.6 a with drying time 570, 510, 390 and 300 min for foamed sun, non foamed sun, foamed tray and non foamed tray it can be observed that drying rate from these curves of guava pulp samples decreased exponentially with increased drying time under all drying conditions.



**Fig. 4.6 a Effect of drying time on drying rate of foamed and non foamed sun and tray drying of guava pulp**

From fig. 4.6 b shows that the drying rate was low i.e. 28.11 g/g.min for non-foamed microwave and it was high as compared to the foamed microwave drying i.e. 38.01 g/g.min. The drying time of foamed microwave was less i.e. 64 min while drying time of non foamed microwave it was more 76 min. The reduction in the drying rate at the end of drying might be due to reduction in moisture content as drying advances and also the rate of migration of moisture from inner surface to outer surface decreases at the final stage of drying and hence recorded lower drying rates.

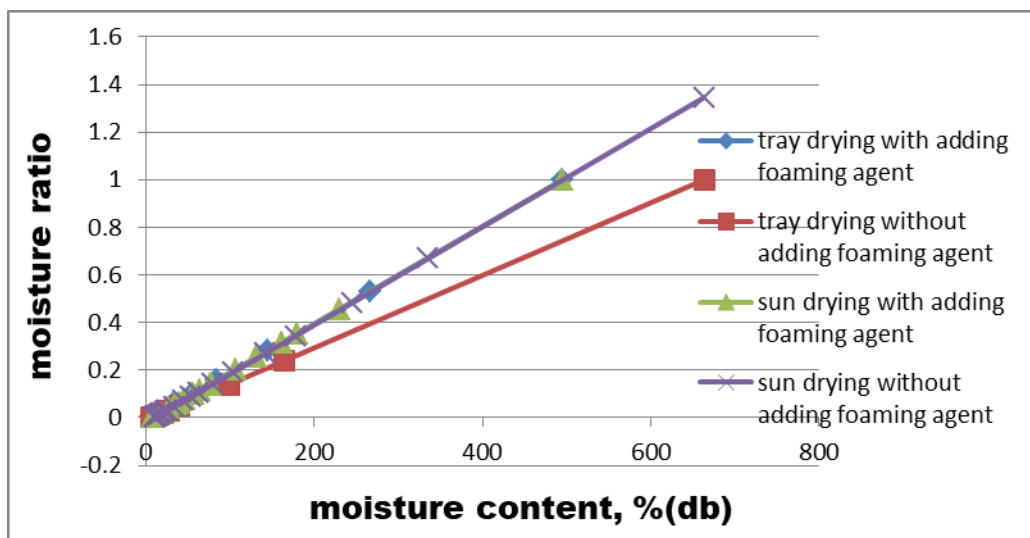
Similar results were reported by (Rajkumar *et al.* 2007 a), Kudra and Ratti (2006) for tomato paste, Rajkumar *et al.*, (2006) for mango pulp.



**Fig. 4.6 b Effect of drying time on drying rate of foamed and non foamed microwave drying of guava pulp**

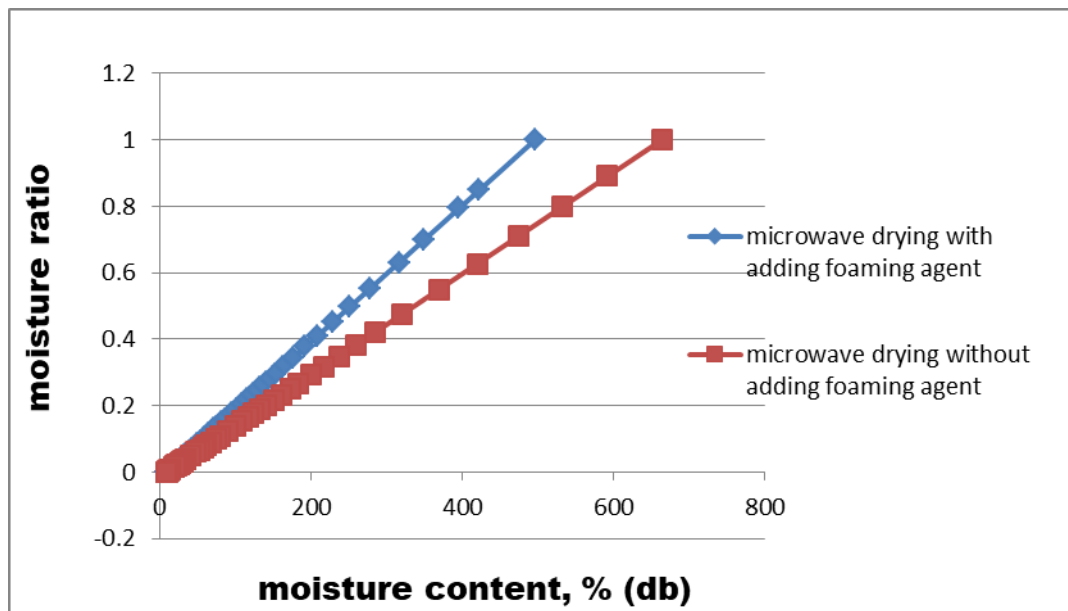
#### 4.5.3 Effect of moisture content on moisture ratio of foamed and non foamed guava pulp

From Fig. 4.7 a it was observed the initial moisture content high 663.35% for foamed sun, tray microwave drying and non foamed it was observed 495.59% (db). Increase in the air temperature reduced the time required to reach a certain level of moisture content. After drying up to nearly constant weight, the moisture content was reduced in the range of 5.88 to 9.27% (d.b) for non foamed tray and non foamed sun drying respectively.



**Fig. 4.7 a Effect of moisture content on moisture ratio of foamed and non-foamed sun and tray drying of guava pulp**

From Fig. 4.7 b shows that effect of the moisture content on moisture ratio it was observed that the initial moisture ratio was same but the moisture content (db) was to be observed 495.59 to 663.35% for foamed microwave and non foamed microwave drying respectively. After drying up to nearly constant weight, the moisture content was reduced in the range of 8.45 to 8.66% (d.b) for foamed and non foamed microwave drying.



**Fig. 4.7 b Effect of moisture content on moisture ratio of foamed and non foamed microwave drying of guava pulp**

#### 4.5.4 Modelling of drying curve

To determine the most suitable drying equation, the moisture ratio data of long pepper dried at different temperatures and drying time were fitted into the four thin-layer drying models in their linearized form using regression technique. Among all these models, the best model suitable to fit the data were selected on basis of highest values of  $R^2$  and the lowest value of reduced mean square of the deviation ( $\chi^2$ ) and root mean square error ( $E_{RMS}$ ) and MBE. The overall statistical parameters for different models used for dried foamed and non foamed guava pulp samples have been presented in Table 4.8. From Table 4.8 it shows that the  $R^2$  value was found greater than 0.8595 for all models except Magee (0.7522). Thus all

models were best fitted for drying of foamed and non foamed guava pulp in various drying method i.e. sun, tray and microwave power.

The result shows that the overall highest value of  $R^2$  and the lowest values of  $\chi^2$ ,  $E_{RMS}$ , and MBE were found to be 0.9831, 0.0399, 0.0095 and 0.0083 in Lewis Model. Hence Lewis model was found to be the most satisfactory among the models to represent the thin-layer drying of foamed and non-foamed guava pulp.

**Table 4.8 Overall values for statistical parameters used in drying of foamed and non-foamed guava pulp**

Sr. No.	Model	$R^2$	$\chi^2$	MBE	RMSE
1	Lewis	0.9831	0.0399	0.0095	0.0083
2	Page	0.8595	0.0304	0.1093	0.0255
3	Logarithmic	0.9907	0.2695	0.4648	0.0644
4	Magee	0.7522	0.0761	0.151	0.0651

This was another confirmation of the suitability of Page model to thin layer drying, which has been reported by Bhagyashree *et al.*, (2013) for long pepper, Koua *et al.*,(2009) for mango, banana and cassava, Doymaz (2006) for mint leaves and Arslan and Ozcan (2008) for rosemary leaves.

#### **4.6 Drying of foamed and non foamed guava pulp**

The experiments were conducted by giving foamed and non foamed guava pulp at different methods of drying i.e. sun (Temp-30-32 °C, RH-40 %), tray (60 °C), and microwave (360 W) drying. The each sample was analysed for their properties i.e. drying time (min), reducing sugar (%), total sugar (%), non reducing sugar (%), ascorbic acid (mg/100g),  $\beta$ -Carotene (mg/100g), colour, water activity and overall acceptability for optimized of foamed guava pulp i.e. GMS 0.5%, CMC 3% and whipping time 22.95 min. The complete experimental results for foamed and non foamed guava pulp were presented in Table 4.9.

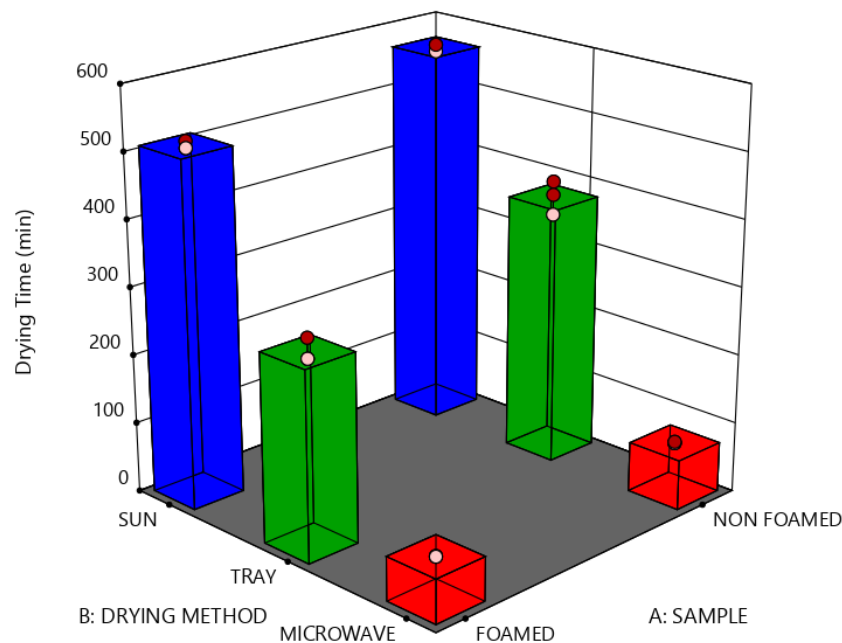
**Table 4.9 Effect of foamed and non- foamed guava pulp on drying method and quality parameters**

Sr. No.	Sample	Drying method	Drying time, min	Reducing sugar %	Total sugar %	Non reducing g %	Ascorbic acid mg/100g	β-Carotene mg/100g	Colour	Water activity	Overall acceptability
1	Foamed	Microwave	64	4.19	7.39	3.23	220.20	298.9	71.52	0.280	7.85
2	Non Foamed	Microwave	74	4.18	7.16	2.97	217.61	297.52	68.4	0.275	7.06
3	Foamed	Tray	300	4.28	8.00	3.09	216.77	292.03	70.06	0.388	7.87
4	Non Foamed	Tray	410	4.18	7.30	2.82	216.27	288.00	65.18	0.284	7.02
5	Foamed	Sun	520	4.38	8.26	3.87	215.97	291.64	70.62	0.313	7.01
6	Non Foamed	Sun	570	4.28	7.77	3.46	215.02	289.53	68.38	0.282	6.20
7	Foamed	Microwave	65	4.19	7.39	3.21	220.20	298.64	72.02	0.283	7.82
8	Non Foamed	Microwave	74	4.18	7.16	2.97	217.61	299.67	69.71	0.274	7.72
9	Foamed	Tray	270	4.28	8.20	3.09	216.77	295.57	70.12	0.381	7.84
10	Non Foamed	Tray	360	4.18	7.60	2.82	216.77	288.59	63.94	0.283	7.01
11	Foamed	Sun	510	4.38	8.26	3.87	215.98	291.65	70.58	0.321	7.02
12	Non Foamed	Sun	560	4.30	7.77	3.46	215.02	289.57	66.4	0.281	6.5
13	Foamed	Microwave	64	4.19	7.38	3.22	220.20	299.67	71.43	0.283	7.83
14	Non Foamed	Microwave	76	4.18	7.16	2.97	217.61	297.4	69.09	0.275	7.75
15	Foamed	Tray	270	4.28	8.10	3.10	216.77	294.15	69.48	0.381	7.85
16	Non Foamed	Tray	390	4.18	7.40	2.82	216.77	289.63	64.18	0.285	7.06
17	Foamed	Sun	510	4.38	8.26	3.87	215.96	291.66	68.96	0.314	7.07
18	Non Foamed	Sun	570	4.30	7.77	3.46	215.02	289.51	65.22	0.284	6.5

#### 4.6.1 Drying time

The drying time was found to be as 64 to 570 min. The maximum drying time was obtained as 570 min for sun drying without adding foaming agent. Similarly minimum drying was to be found as 60 min for microwave drying with adding foaming agent as shown in Fig. 4.8. Drying time of non foamed guava pulp at different method of drying was increased while the foamed the drying time was decreased.

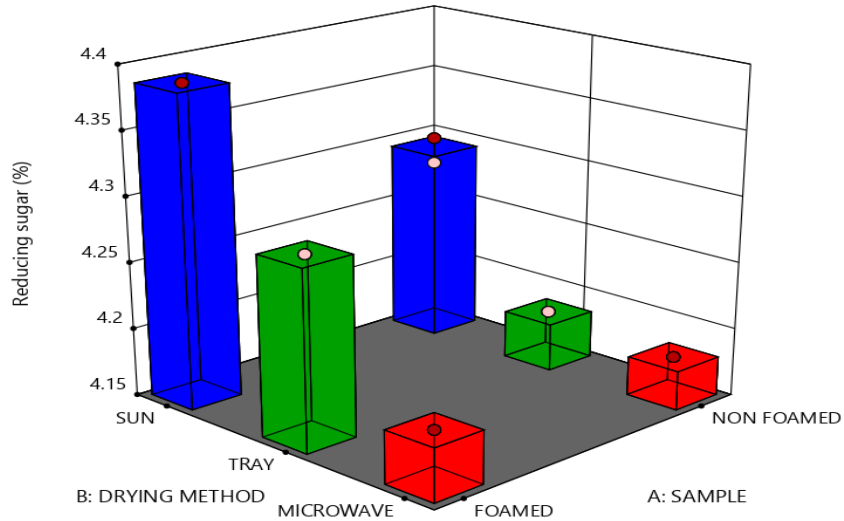
Similar results were reported by Kudra and Ratti (2006) for tomato paste, Rajkumar et al., (2006) for mango pulp, Kadam and Balasubramanian (2011) for tomato.



**Fig. 4.8 Effect of drying time on foamed and non foamed guava pulp**

#### 4.7 Effect of reducing sugar content on guava pulp (%)

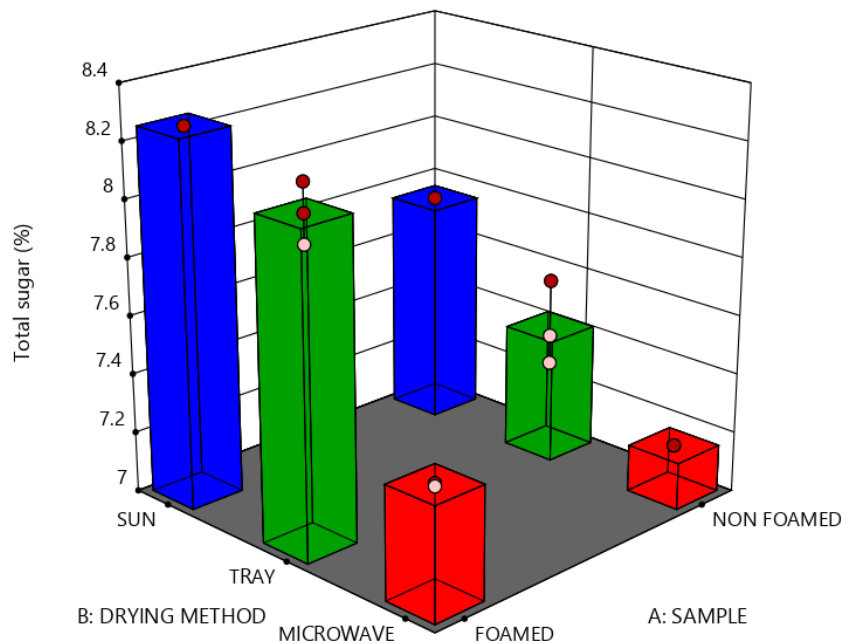
The reducing sugar content of guava pulp powder as described in section 3.14.1. The reducing sugar was to be found as in the range from 4.18 – 4.38%. The maximum reducing sugar was obtained as 4.38% for foamed sun drying. Similarly the minimum reducing sugar was obtained as 4.18% for foamed microwave drying as shown in Fig 4.9.



**Fig. 4.9 Effect of reducing sugar on foamed and non foamed guava pulp**

**4.8 Effect of total sugar content on guava pulp (%)**

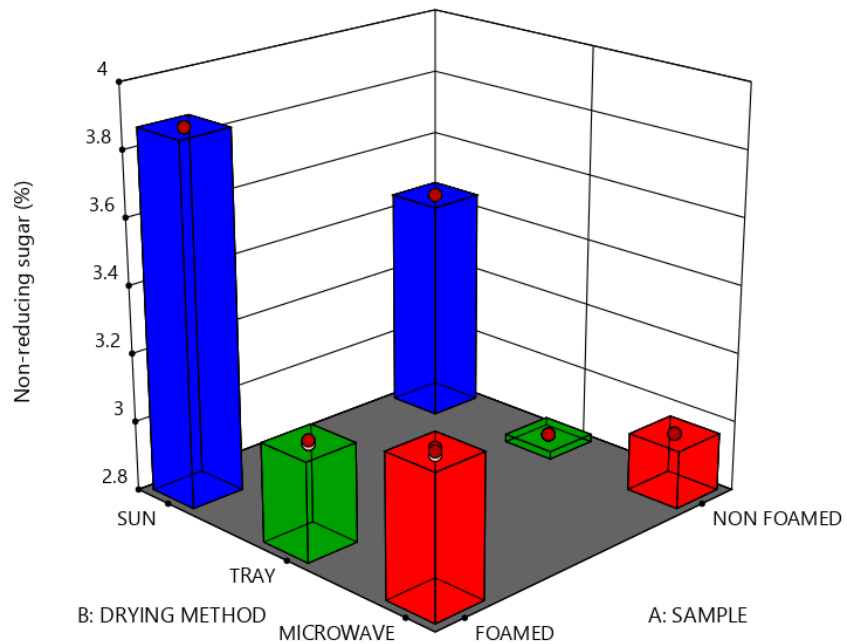
The total sugar content of guava pulp powder as described in Section 3.14.2. The total sugar was to be found as in the range from 7.16 – 8.26%. The minimum total sugar was obtained as 7.16% for non- foamed microwave drying. Similarly the maximum total sugar was obtained as 8.26% for foamed sun drying as given in Fig. 4.10.



**Fig. 4.10 Effect of total sugar on foamed and non foamed guava pulp**

#### 4.9 Effect of non- reducing sugar content on guava pulp (%)

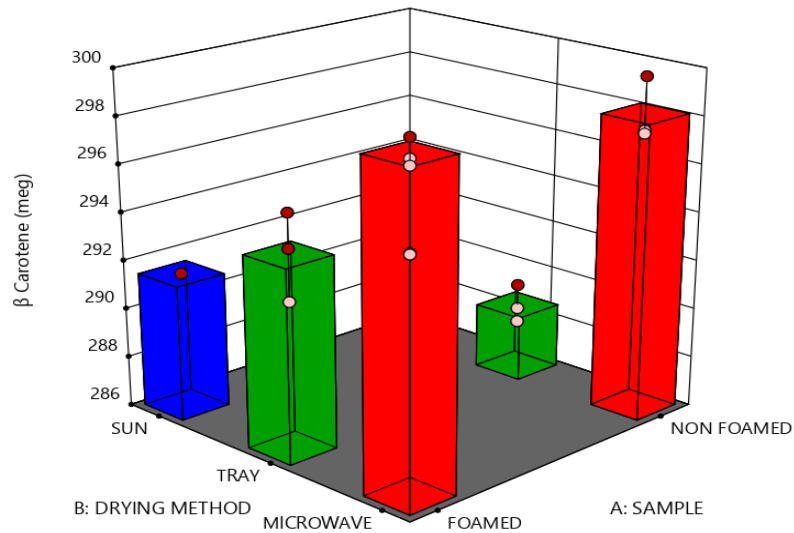
The non reducing sugar content of guava pulp as discussed in section 3.14.3. The non reducing sugar was to be found in the range from 2.82 – 3.87%. The maximum value of non- reducing sugar was to be obtained as 3.87% for foamed sun drying. Similarly the minimum value of non- reducing sugar was to be obtained as 2.82% for non foamed tray drying as given in Fig. 4.11.



**Fig. 4.11 Effect of non-reducing sugar on foamed and non foamed guava pulp**

#### 4.10 Effect of ascorbic acid (Vitamin-C) content on guava pulp

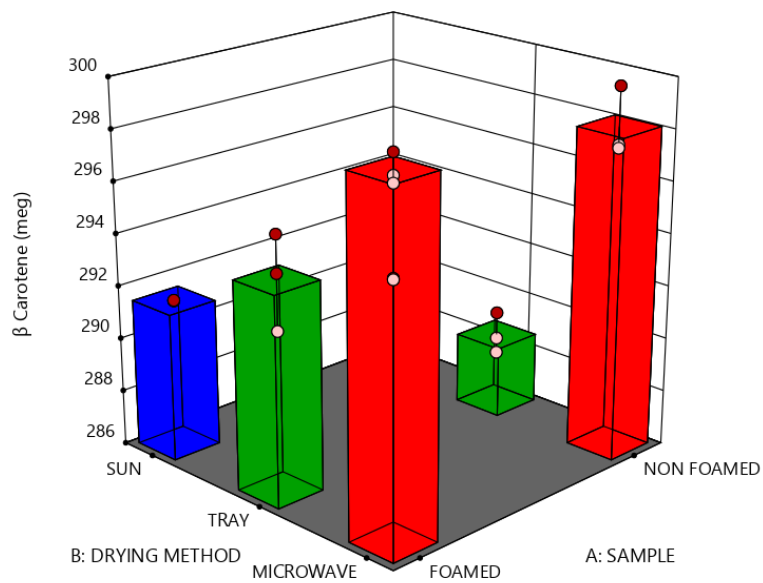
The ascorbic acid of guava pulp powder as described in Section 3.14.4. The ascorbic acid was obtained as in the range from 215.02 - 220.20 mg/100g. The maximum ascorbic acid was obtained as 220.20 mg/100g for foamed microwave drying. Similarly the minimum ascorbic acid was obtained as 215.02 mg/100g for non foamed sun drying as given in Fig. 4.12.



**Fig. 4.12 Effect of ascorbic acid on foamed and non foamed guava pulp**

#### 4.11 Effect of $\beta$ - carotene content on guava pulp (%)

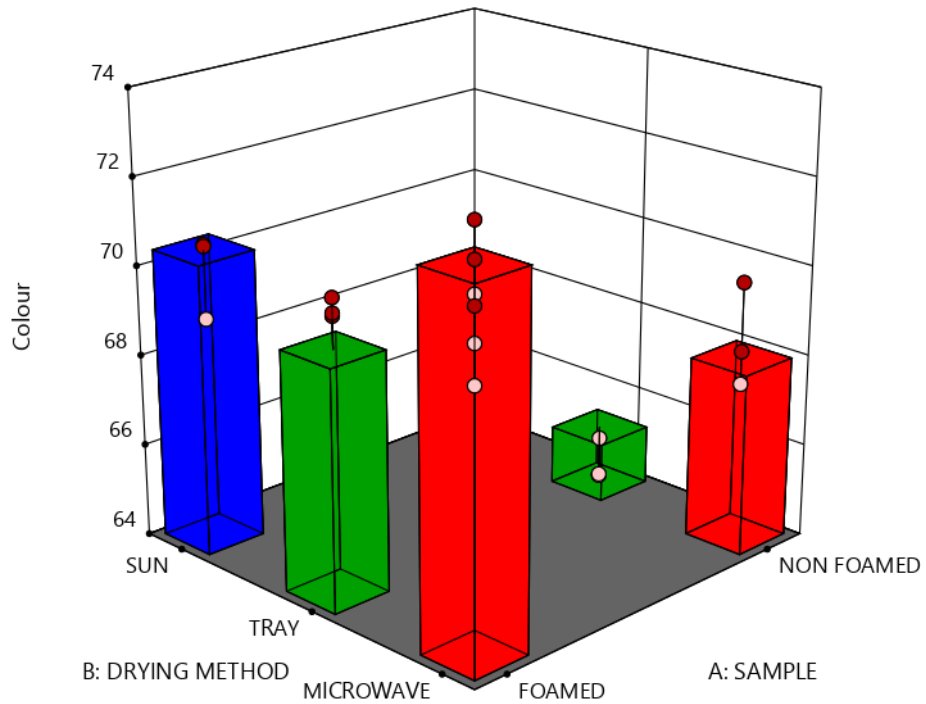
The  $\beta$ - carotene content of guava pulp powder as described in section 3.14.5. The  $\beta$ - carotene content was to be obtained as in the range from 288 – 299.67 mg/100g. The maximum  $\beta$ - carotene was obtained as 292.33 mg/100g for foamed microwave drying. Similarly the minimum  $\beta$ - carotene was obtained as 300.62 mg for foamed sun drying as given in Fig. 4.13.



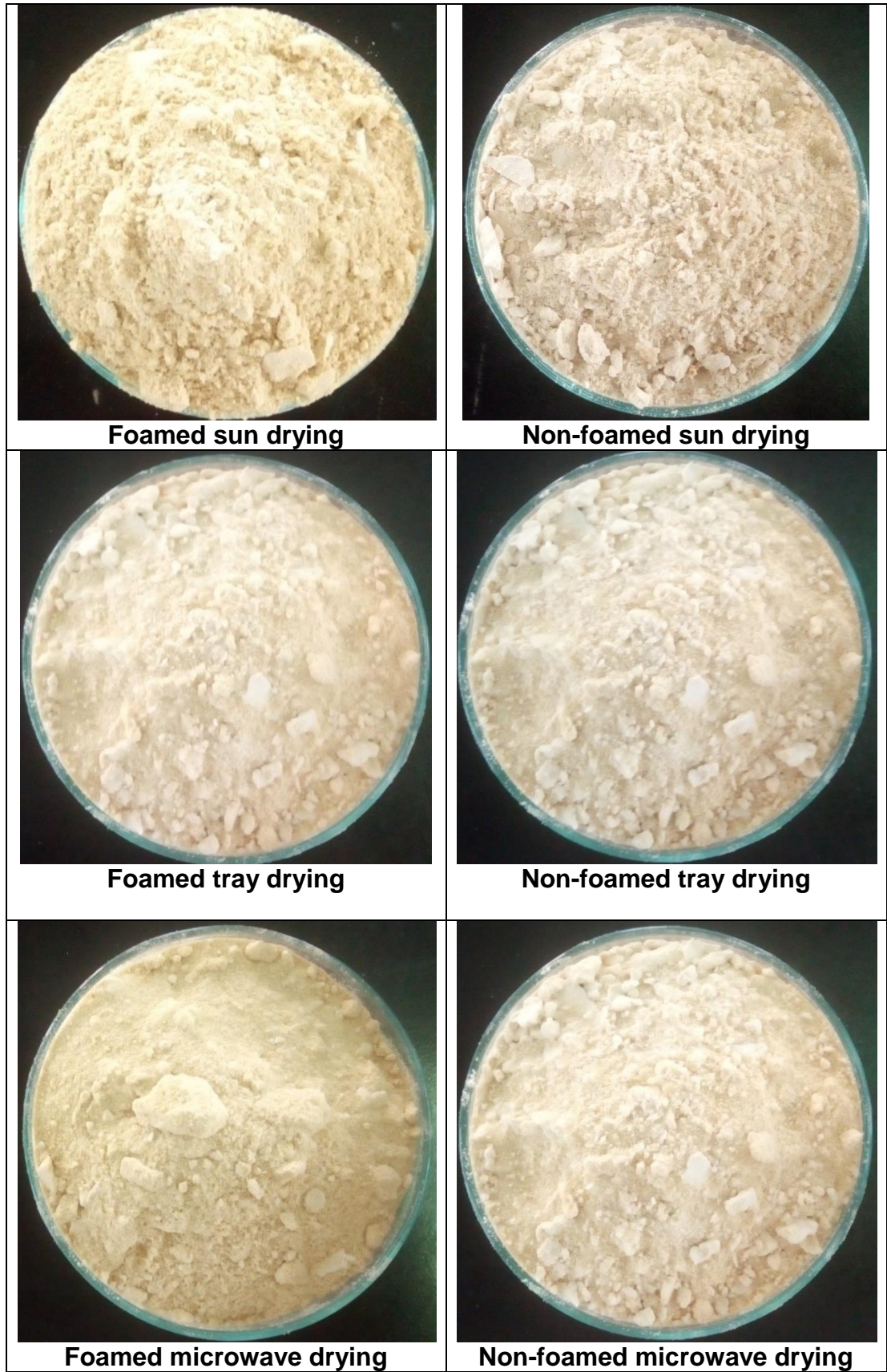
**Fig. 4.13 Effect of  $\beta$ - carotene on foamed and non foamed guava pulp**

#### 4.12 Effect of colour on guava pulp

Colour values of guava pulp powder. i. e L- value, a-value and b-value as described in Section 3.15.1. The colour L-value was to be found as in the range 63.94 – 72.02 as shown in Table 4.8. The maximum colour L-value was to be obtained as 72.02 for foamed microwave drying. Similarly the minimum colour L-value was obtained to be as 63.94 for non foamed tray drying as shown in Fig. 4.14.



**Fig. 4.14 Effect of colour on foamed and non foamed guava pulp**

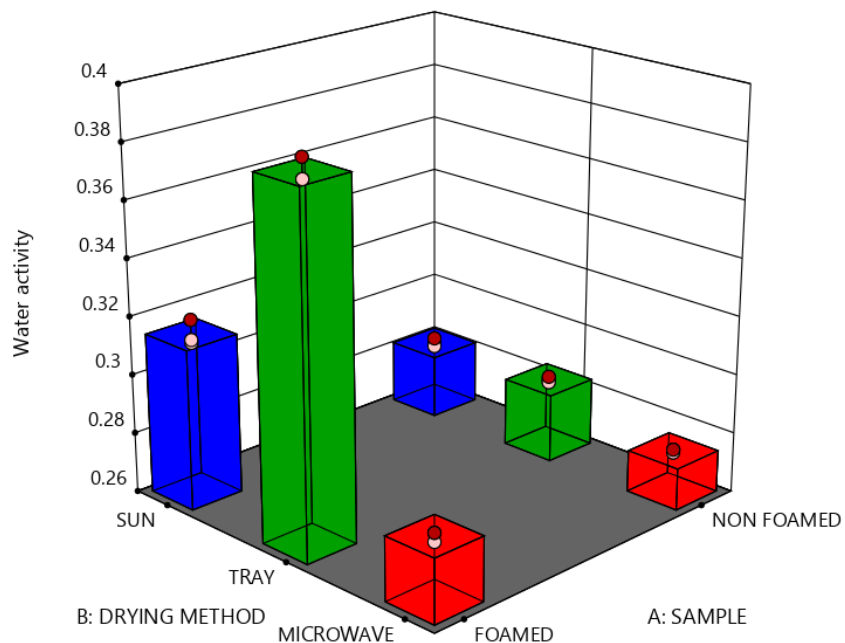


**Plate 4.1 Foamed and non-foamed guava pulp powder**

#### 4.13 Effect of Water activity on guava pulp

The water activity as described in section 3.15.2. The water activity of all samples of guava pulp was measured by using a water activity meter at room temperature.

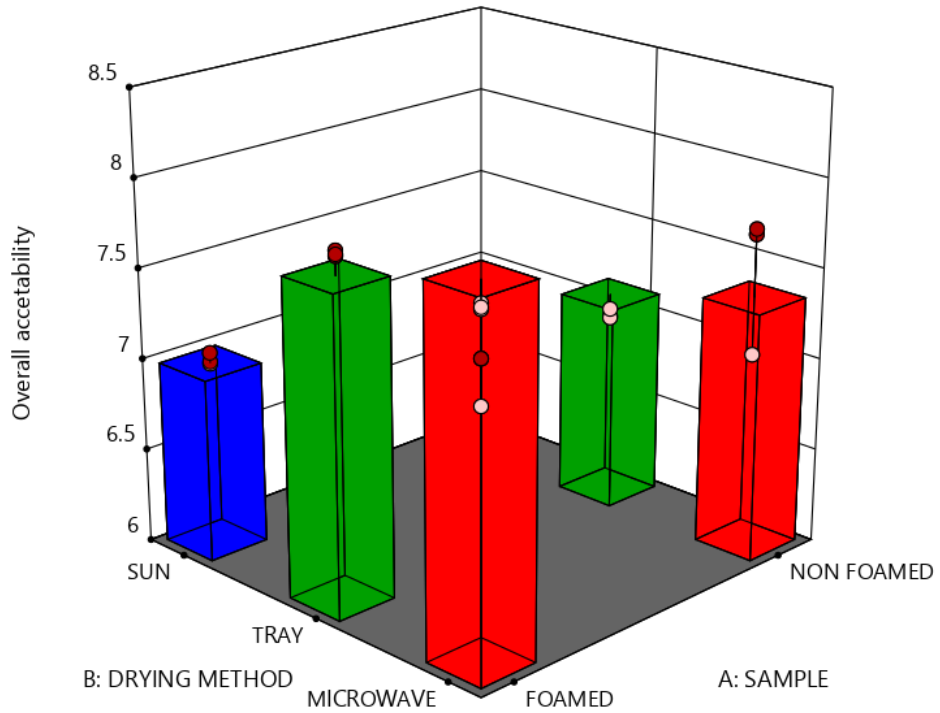
The water activity ranged between 0.274 - 0.388 for guava pulp powder as shown in Table 4.8 which is within safe limit to avoid microbial growth and enzymatic reactions. The maximum water activity was to be obtained 0.388 for foamed tray drying. Similarly the minimum water activity was to be obtained 0.274 for non foamed microwave drying Fig. 4.15. Thus, it can be seen that guava pulp powder prepared in this studied were found to be reach safe level of final moisture content (db) as in the range of 5.87- 9.26%.



**Fig. 4.15 Effect of water activity on foamed and non foamed guava pulp**

#### 4.14 Overall acceptability

The overall acceptability was found to be as in the range from 6.2 – 7.87. The maximum value of overall acceptability was found to be as 7.87 for foamed tray drying. Similarly the minimum overall acceptability was to be obtained as 6.2 for non foamed sun drying as given in Fig. 4.16.



**Fig. 4.16 Effect of overall acceptability on foamed and non foamed guava pulp**

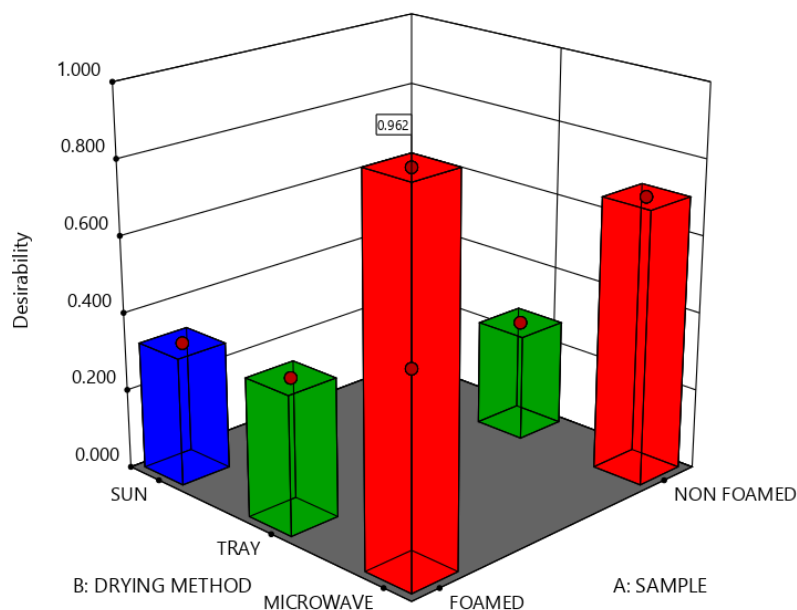
#### **4.15 Optimization of process parameters of foamed and non foamed guava pulp**

Factorial Multilevel Categorical technique was adopted to determine the optimum conditions for the foamed and non foamed guava pulp at different drying methods (sun, tray and microwave drying). The contour plots for all responses were superimposed and regions that best satisfy all the constraints were selected as optimum conditions. The 3D surface plots having common area for all responses were shown in Fig. 4.17.

**Table 4.10 Constraints for optimization for drying method and quality Parameters of foamed and non-foamed guava pulp**

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: Sample	in range	Foamed	Non foamed	1	1	3
B: drying method	in range	Microwave	Sun	1	1	3
Drying Time	minimize	60	570	1	1	3
Reducing sugar (%)	in range	4.18	4.38	1	1	3
Total sugar (%)	in range	7.16	8.26	1	1	3
Non-reducing sugar (%)	in range	2.82	3.87	1	1	3
Ascorbic acid (mg/100g)	maximize	215.02	220.20	1	1	3
β-Carotene(mg/100g)	maximize	288	299.67	1	1	3
Colour (L-value)	maximize	64.15	72.98	1	1	3
Water activity	minimize	0.274	0.388	1	1	3
Overall acceptability	maximize	6.2	7.87	1	1	3

From Table 4.10 the optimum condition of process parameters for foamed microwave and non foamed sun drying of guava pulp for 64 – 570 min drying time was obtained. In order to optimize the process parameters for preparation of foamed and non foamed guava pulp by numerical optimization; which finds a point that maximizes the desirability function. The optimum operating conditions of quality parameters for reducing sugar, total sugar and non reducing sugar was in the range as 4.18 - 4.38%, 7.16 - 8.26% and 2.82 - 3.87%. Corresponding to these values of process variables, the value of ascorbic acid 215.02 – 220.20 mg/100g, β-Carotene 288 – 299.67 mg/100g, Colour L-value 64.15- 72.98, water activity 0.274 – 0.388, overall acceptability 6.2 – 7.87 and overall desirability 0.962.



**Fig. 4.17 Optimization of foamed and non foamed guava pulp**

Based on above mentioned criteria the optimization was carried out. During optimization 6 solutions were obtained, out of which the one that suited the criteria most was selected. The most suitable optimum condition is given in the Table 4.11. Thus drying of foamed guava pulp with 360 W power for 64.33 min in microwave drying was found to be the best followed by non-foamed microwave drying for optimum response among the range of variables.

From Table 4.11 the drying time was less i.e. 64.33 min for foamed microwave drying method while the drying time was so high i.e. 74.66 min for non foamed microwave drying method. The reducing sugar 4.19%, total sugar 7.38%, non reducing sugar 3.22%, ascorbic acid 220.20 mg/100g,  $\beta$ -carotene 299.07, colour 72.09, water activity 0.282, overall acceptability 7.98 and desirability 0.962 were high for foamed microwave drying while in non foamed microwave drying was less i. e. reducing sugar 4.48%, total sugar 7.16%, non reducing sugar 2.97%, ascorbic acid 217.61 mg/100g,  $\beta$ -carotene 298.19, colour 68.08, water activity 0.275, overall acceptability 7.37 and desirability 0.715 respectively.

**Table 4.11 Solutions for optimization drying method and quality parameters of foamed and non-foamed guava pulp**

<b>Sr. No.</b>	<b>Sample</b>	<b>Drying method</b>	<b>Drying Time, min</b>	<b>Reducing sugar, %</b>	<b>Total sugar, %</b>	<b>Non-reducing sugar, %</b>	<b>Ascorbic acid, mg/100g</b>	<b>B Carotene, mg/100g</b>	<b>Colour (L)</b>	<b>Water activity</b>	<b>Overall accetability</b>	<b>Desirability</b>
1	Foamed	Microwave	64.33	4.19	7.38	3.22	220.20	299.07	72.09	0.282	7.96	0.962
2	Non foamed	Microwave	74.66	4.18	7.16	2.97	217.61	298.19	68.08	0.275	7.37	0.715
3	Foamed	Tray	280.00	4.28	8.10	3.09	216.77	293.91	69.34	0.383	7.73	0.360
4	Foamed	Sun	513.33	4.38	8.26	3.87	215.97	291.65	70.50	0.316	7.01	0.335
5	Non foamed	Tray	386.66	4.18	7.43	2.82	216.60	288.74	65.33	0.284	7.14	0.280
6	Non foamed	Sun	566.66	4.29	7.77	3.46	215.02	289.53	66.49	0.282	6.42	0.035

Lowest solutions for optimization of foamed and non-foamed guava pulp drying time was more required 566.66 min, reducing sugar 4.29 %, total sugar 7.77%, non reducing sugar 3.46%, ascorbic acid 215.02 mg/100g,  $\beta$ -carotene 289.53 mg/100g , colour 66.49, water activity 0.282, overall acceptability 6.42 and desirability 0.035 respectively was to be found for non foamed sun drying methods.

#### 4.16 Verification of the model for drying of foamed and non-foamed guava pulp

Drying experiments were conducted at the optimum process conditions for testing the adequacy of model equations for predicting the response values.

**Table 4.12 Predicted and experimental values of response at optimum conditions of foamed and non-foamed guava pulp.**

Response	Predicted mean	Experimental mean Value $\pm$ SD	SE	% Variation	Mean difference
Drying time, min	64.33	64 $\pm$ 23.32	7.4597	32.50	0.33
Reducing sugar, %	4.19	4.26 $\pm$ 0.23	0.0027	0.0118	0.07
Total sugar, %	7.38	7.63 $\pm$ 0.46	0.0430	0.1876	0.25
Non-reducing sugar, %	3.22	3.38 $\pm$ 0.42	0.0027	0.0119	0.16
Ascorbic acid, mg/100g	220.02	216.98 $\pm$ 1.60	0.0674	0.294	3.09
$\beta$ -carotene, mg/100g	299.07	294.06 $\pm$ 2.49	0.5663	2.468	5.01
Color (L) value	72.09	68.59 $\pm$ 0.46	0.5641	2.42	3.5
Water Activity	0.282	0.303 $\pm$ 0.0028	0.0015	0.0065	0.021
Overall acceptability, %	7.98	7.96 $\pm$ 0.19	0.0942	0.4043	0.02

The observed experimental values (mean of 3 experiments) and values predicted by the equations of the model are presented in Table 4.12. The experimental values were found to be very close to the predicted values. Therefore, it could be concluded from above discussion that model Eqns. are quite adequate to assess the behaviour of the drying method.

## CHAPTER V

### SUMMARY AND CONCLUSIONS

India is one of the largest fruit producing nations in the world growing the important fruit crops such as mango, apple, citrus, guava, grape, aonla, pineapple, papaya and banana. Food processing or preservation is to convert perishable foods such as fruits into stabilized products that can be stored for extended periods of time to reduce their postharvest losses. Due to the short shelf life, as much as 30 - 35% of fruits perish during harvest, storage, grading, transport, packaging and distribution.

Guava (*Psidium guajava L.*) is a native of tropical America and grows well in tropical and subtropical regions which belong to the Myrtaceae family. India is the world's largest producer of guava followed by China, Thailand, Indonesia, Pakistan, Mexico, Brazil, Bangladesh, Nigeria, Philippines, Vietnam, Kenya and Egypt. Guava fruits are normally consumed as fresh or processed into several products like jam, jelly, cheese, nectar, etc.

Foam-mat drying is a promising new development in the field of drying aqueous foods. This method offers a wide scope for application in vegetable puree and fruit juice processing industry as it enables the dehydration of heat sensitive foods or which are difficult-to-dry, sticky and viscous under relatively mild conditions without undue quality change. Foam-mat drying of tomato, mango, and pineapple, lemon, banana and guava etc. juice/pulp can produce powder.

The present investigation was proposed with the aim to develop with the following objectives.

- 1 Effect of foaming agent on foam characteristics guava pulp.
- 2 To study the drying characteristics of foamed guava pulp.
- 3 To study the quality parameters of guava pulp powder.

In present study fully ripe and good quality of guava was procured from local market of Akola. Various unit operations like washing, cutting,

grinding, pulping, mixing, whipping were conducted to extract guava pulp. The moisture content of guava pulp was determined.

In the present investigation the whipping time (5-25 min) of the guava pulp was carried with adding different level of concentration of GMS (0.1-0.5%), CMC (1-5%). The effect of all these three dependent parameters was studied on foam expansion, foam density and foam stability. The guava pulp was dried by using three methods such as sun drying (30-32 °C and RH 40%), tray drying (60 °C) and microwave drying (360 W).

From the drying data drying characteristics viz, drying time, moisture content, drying rate, moisture ratio were determined. To determine the most suitable drying equations, the experimental drying data were fitted in the four drying models. The coefficient of determination ( $R^2$ ) was the main criteria for deciding acceptability and goodness of fit was determined by various statistical parameters such as reduced mean square of the deviation  $\chi^2$  and root mean square error  $E_{RMS}$ , mean bias error (MBE).

The guava pulp powder was collected and stored in polythene bags and the quality parameters such as reducing sugar, total sugar and non-reducing sugar, ascorbic acid,  $\beta$ - carotene, water activity, colour were evaluated. Sensory evaluation was done by nine-point hedonic scale.

From the present study following conclusions were drawn:

1. The initial moisture content (wb) of foamed and non-foamed guava pulp was found to be 83.25% and 86.90% respectively.
2. The foam expansion, foam density and foam stability was obtained in the range from 7.9 - 14.9%, 0.89 - 0.95 g/cm<sup>3</sup> and 96 - 99% resp. for optimized condition 0.5% GMS, 3% CMC and 22.95 min whipping time.
3. The optimum solution was found to be foam expansion (14.83%), foam density (0.89 g/cm<sup>3</sup>) and foam stability (98.17%) were obtained at optimized 0.5% GMS, 3% CMC and 22.95 min whipping time.
4. The maximum final moisture content was found to be as 9.27% (db) for non-foamed sun drying and the minimum moisture content was observed to be 5.88% (db) for non-foamed tray drying.

5. The drying time was found maximum in non-foamed sun drying (570 min) and minimum in foamed microwave drying (64 min). The drying rate was found in maximum in non-foamed microwave drying (38.02 g/g.min) and minimum in non-foamed sun drying (2.46 g/g.min). EMC was found maximum in non-foamed sun drying (9.49%) and minimum in non-drying tray drying (5.88%).
6. Lewis model was found to be the most satisfactory among the models to represent the thin-layer drying of foamed and non-foamed guava pulp.
7. The maximum reducing, total and non-reducing sugar was to be found as 4.38%, 8.26% and 3.87% for foamed sun drying and minimum reducing, total and non reducing sugar was to be obtained as 4.18% in foamed microwave, 7.16% in non foamed microwave and 2.82% in non foamed tray drying.
8. The maximum ascorbic acid was found to be 202.03 mg/100g in foamed microwave drying and minimum was found to be 215.026 mg/100g in non foamed sun drying.
9. The maximum  $\beta$ - carotene was found to be 300.62 mg/100g in foamed microwave drying and minimum was found to be 292.33 mg/100g in foamed sun drying.
10. The maximum colour L-value was found to be 72.02 in foamed microwave and minimum was found to be 63.94 in non-foamed tray drying. The maximum water activity was found to be 0.388 in foamed tray drying and minimum was found to be 0.274 in non foamed microwave drying.
11. The optimum solution of drying methods and quality parameters for drying time (64.33 min), reducing sugar (4.19%), total sugar ( 7.38%) and non reducing sugar (3.22%), ascorbic acid (220.20 mg/100g),  $\beta$ - Carotene (299.07 mg/100g), Colour L-value (72.09), water activity (0.282), overall acceptability (7.96) with overall desirability 0.962 in foamed microwave drying.

12. The fresh guava pulp foamed by using GMS 0.5%, CMC 3% and whipping time 22.95 min dried in microwave drying gives quality powder with overall acceptability of 7.96.

## **SUGGESTIONS FOR FUTURE WORK**

1. Foam mat drying of guava pulp using different foaming agents such as soya protein isolate, methyl cellulose, egg albumen which gives maximum foam expansion, may be studied.
2. Drying of foamed guava pulp at different thickness, different drying methods and air velocity to evaluate their effect on drying characteristics may be conducted.

## CHAPTER VI

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**APPENDIX - A**

<b>Moisture content at temp. (105°C, 24 hrs.) in hot air oven</b>					
<b>A) Foamed Guava pulp</b>					
<b>SN</b>	<b>Replication (g)</b>	<b>Wt. of dish (g)</b>	<b>Wt. of samples(g)</b>	<b>Wt. loss (g)</b>	<b>Moisture content, wb (%)</b>
1	R1	22.52	20.78	3.52	83.06
2	R2	20.92	20.34	3.36	83.48
3	R3	22.52	20.54	3.45	83.20
4	Average	21.99	20.55	3.44	83.25
<b>B) Non-Foamed Guava pulp</b>					
<b>SN</b>	<b>Replication (g)</b>	<b>Wt. of dish (g)</b>	<b>Wt. of samples (g)</b>	<b>Wt. loss (g)</b>	<b>Moisture content, wb (%)</b>
1	R1	31.76	20.15	2.89	85.66
2	R2	37.53	20.32	2.38	88.29
3	R3	37.45	20.21	2.68	86.74
4	Average	35.58	20.23	2.65	86.90

## APPENDIX – B

### Details of foaming treatment combination

Sr. No.	Treatment combination			Initial vol. of pulp (cm <sup>3</sup> )	Final vol. of pulp (cm <sup>3</sup> )	Mass (g)	Foam responses		
	GMS (%)	CMC (%)	Whipping time (min)				Foam expansion (%)	Foam density (g/cm <sup>3</sup> )	Foam stability (%)
1	0.1	1	5	500	531	513.16	6.20	0.9664	99.00
2	0.1	1	15	500	546	513.16	9.20	0.9399	98.00
3	0.1	1	25	500	550	513.16	10.00	0.9330	97.00
4	0.1	3	5	500	540	513.16	8.00	0.9503	98.00
5	0.1	3	15	500	552	513.16	10.40	0.9296	97.00
6	0.1	3	25	500	560	513.16	12.00	0.9164	98.00
7	0.1	5	5	500	540	513.16	8.00	0.9503	99.00
8	0.1	5	15	500	563	513.16	12.60	0.9115	97.00
9	0.1	5	25	500	570	513.16	14.00	0.9003	98.00
10	0.3	1	5	500	539.5	513.16	7.90	0.9512	98.00
11	0.3	1	15	500	558	513.16	11.60	0.9196	97.00
12	0.3	1	25	500	570	513.16	14.00	0.9003	98.00
13	0.3	3	5	500	553	513.16	10.60	0.9280	99.00
14	0.3	3	15	500	560.1	513.16	12.3	0.9090	98.00
15	0.3	3	25	500	579	513.16	15.80	0.8863	98.00
16	0.3	5	5	500	551.6	513.16	10.30	0.9303	97.00
17	0.3	5	15	500	567	513.16	13.40	0.9050	98.00
18	0.3	5	25	500	572	513.16	14.40	0.8971	97.00
19	0.5	1	5	500	562	513.16	12.40	0.9131	99.00
0	0.5	1	15	500	564	513.16	12.80	0.9099	98.00
21	0.5	1	25	500	581	513.16	16.20	0.8832	97.00
22	0.5	3	5	500	551	513.16	10.20	0.9313	96.00
23	0.5	3	15	500	571	513.16	14.20	0.8987	96.00
24	0.5	3	25	500	574.5	513.16	14.90	0.8932	98.00
25	0.5	5	5	500	565	513.16	13.00	0.9082	99.00
26	0.5	5	15	500	570.6	513.16	14.12	0.8993	98.00
27	0.5	5	25	500	580	513.16	16.00	0.8848	97.00

## APPENDIX – C

EMC – 8.26%, IMC- 83.21%, DM- 16.79%, FMC – 7.42%

Foamed sun drying										
Sr. No.	Time (min)	R1 (g)	R2 (g)	R3 (g)	Average (g)	Moisture removed (g)	MC (wb %)	MC (db %)	Moisture ratio	Drying rate
1	0	100.02	100.2	100.2	100.14	0.00	83.21	495.59	1.0000	0
2	30	85.44	88.25	86.32	86.67	13.47	69.74	230.47	0.4560	2.6742
3	60	80.21	81.56	81.45	81.07	19.07	64.14	178.89	0.3501	1.8927
4	90	78.25	77.56	79.89	78.57	21.57	61.64	160.67	0.3127	1.4277
5	120	73.23	74.46	73.47	73.72	26.42	56.79	131.43	0.2527	1.3113
6	150	68.04	68.96	68.57	68.52	31.62	51.59	106.58	0.2018	1.2554
7	180	62.98	64.51	53.77	60.42	39.72	43.49	76.96	0.1410	1.3143
8	210	59.55	62.16	58.57	60.09	40.05	43.16	75.94	0.1389	1.1358
9	240	54.63	52.69	60.36	55.89	44.25	38.96	63.84	0.1140	1.0980
10	270	53.25	50.28	54.54	52.69	47.45	35.76	55.67	0.0973	1.0467
11	300	48.36	47.58	48.09	48.01	52.13	31.08	45.10	0.0756	1.0349
12	330	45.8	44.98	44.02	44.93	55.21	28.00	38.90	0.0629	0.9964
13	360	43.95	42.63	42.58	43.05	57.09	26.12	35.36	0.0556	0.9445
14	390	38.21	37.48	38.57	38.09	62.05	21.16	26.83	0.0381	0.9477
15	420	31.78	32.25	32.54	32.19	67.95	15.26	18.01	0.0200	0.9636
16	450	23.88	24.56	25.65	24.70	75.44	7.77	8.42	0.0003	0.9985
17	480	23.79	24.48	25.63	24.63	75.51	7.70	8.35	0.0002	0.9369
18	510	23.12	24.35	25.59	24.35	75.79	7.42	8.02	-0.0005	0.8851

## APPENDIX – D

EMC – 9.49, IMC- 86.90%, DM- 13.10%, FMC – 9.27%

Non foamed sun drying										
Sr. No	Time (min)	R1(g)	R2 (g)	R3 (g)	Average (g)	Moisture removed (g)	MC (wb %)	MC (db %)	Moisture ratio	Drying rate
1	0	100.3	100.06	100.02	100.13	0.00	86.9	663.36	1.0000	0
2	30	91.02	91.12	89.23	90.46	9.67	77.23	339.11	0.5041	2.4614
3	60	86.01	84.8	82.54	84.45	15.87	71.03	245.18	0.3605	2.0191
4	90	75.53	78.97	77.65	77.38	22.94	63.96	177.50	0.2569	1.9454
5	120	69.14	74.73	72.36	72.08	28.24	58.66	141.88	0.2025	1.7966
6	150	62.44	65.62	64.29	64.12	36.20	50.70	102.83	0.1427	1.8424
7	180	55.45	59.13	58.03	57.54	42.78	44.12	78.94	0.1062	1.8144
8	210	51.47	52.05	51.45	51.66	48.66	38.24	61.91	0.0802	1.7689
9	240	48.32	47.85	47.53	47.90	52.42	34.48	52.63	0.0660	1.6673
10	270	44.31	44.23	44.06	44.20	56.12	30.78	44.47	0.0535	1.5867
11	300	37.93	38.04	38.02	38.00	62.32	24.58	32.58	0.0353	1.5858
12	330	34.81	34.12	32.18	33.70	66.62	20.28	25.44	0.0244	1.5410
13	360	32.84	32.56	33.14	32.85	67.47	19.43	24.11	0.0224	1.4307
14	390	30.62	31.91	32.28	31.60	68.72	18.18	22.22	0.0195	1.3450
15	420	28.6	29.24	29.85	29.23	71.09	15.81	18.78	0.0142	1.2921
16	450	26.62	27.37	27.5	27.16	73.16	13.74	15.93	0.0098	1.2410
17	480	24.78	23.65	25.68	24.70	75.62	11.28	12.72	0.0049	1.2026
18	510	21.65	21.61	23.42	22.23	78.09	8.81	9.66	0.0002	1.1689
19	540	21.01	21.41	23.31	21.91	78.41	8.49	9.28	-0.0004	1.1084
20	570	21	21.4	23.3	21.90	78.42	8.48	9.27	-0.0003	1.0502

## APPENDIX – E

EMC – 6.36, IMC- 83.21%, DM- 16.79%, FMC – 6.07%

Foamed tray drying										
Sr. No .	Time (min)	R1 (g)	R2 (g)	R3 (g)	Average (g)	Moisture removed (g)	MC (wb %)	MC (db %)	Moisture ratio	Drying rate
1	0	100.06	100.18	100.44	100.23	0.00	83.21	495.59	1.0000	0
2	30	87.21	84.35	89.76	87.11	13.25	69.96	232.88	0.4631	2.63
3	60	74.64	76.86	76.74	76.08	24.15	59.06	144.25	0.2820	2.39
4	90	64.97	69.24	61.25	65.15	35.24	47.97	92.19	0.1756	2.33
5	120	51.22	52.29	52.78	52.10	48.13	35.07	54.02	0.0976	2.38
6	150	41.06	40.94	42.64	41.55	58.68	24.52	32.49	0.0536	2.33
7	180	37.45	38.54	36.75	37.58	62.65	20.56	25.88	0.0401	2.07
8	210	26.45	27.48	25.87	31.48	68.75	14.46	16.90	0.0217	1.94
9	240	23.84	22.98	22.64	23.15	77.08	6.13	6.53	0.0006	1.91
10	270	23.72	22.87	22.78	23.12	77.11	6.10	6.50	0.0005	1.70
11	300	23.62	22.09	22.53	22.75	77.48	5.72	6.07	-0.0003	1.53

## APPENDIX – F

EMC – 6.75, IMC- 86.90%, DM- 13.10%, FMC – 5.88%

<b>Non-Foamed Tray drying</b>										
<b>Sr. No.</b>	<b>Time (min)</b>	<b>R1</b>	<b>R2</b>	<b>R3</b>	<b>Average (g)</b>	<b>Moisture removed (g)</b>	<b>MC (wb %)</b>	<b>MC (db %)</b>	<b>Moisture ratio</b>	<b>Drying rate</b>
1	0	100.03	100.1	100.03	100.05	0.00	86.90	663.36	1.0000	0.0000
2	30	90.25	91.25	88.24	89.91	10.14	76.76	330.35	0.4928	2.5793
3	60	83.92	80.97	79.34	81.41	18.64	68.26	215.06	0.3172	2.3715
4	90	72.24	71.03	73.97	72.41	27.64	59.26	145.48	0.2113	2.3441
5	120	66.12	66.34	66.21	66.22	33.83	53.07	113.10	0.1620	2.1518
6	150	58.24	59.3	59.4	58.98	41.07	45.83	84.60	0.1186	2.0901
7	180	50.14	50.34	52.36	50.95	49.10	37.80	60.76	0.0822	2.0824
8	210	44.65	43.64	46.74	45.01	55.04	31.86	46.76	0.0609	2.0007
9	240	40.14	41.05	39.24	40.14	59.91	26.99	36.97	0.0460	1.9054
10	270	34.52	32.14	34.91	33.86	66.19	20.71	26.11	0.0295	1.8715
11	300	30.14	31.24	28.34	29.91	70.14	16.76	20.13	0.0204	1.7848
12	330	25.14	24.24	24.14	24.51	75.54	11.36	12.81	0.0092	1.7475
13	360	20.14	19.14	20.74	20.01	80.04	6.86	7.36	0.0009	1.6973
14	390	18.34	19.01	18.75	18.70	81.35	5.55	5.88	-0.0013	1.5923

**APPENDIX – G**

EMC – 8.38, IMC- 83.21%, DM- 16.79%, FMC – 8.45%

<b>Foamed microwave drying</b>										
<b>Sr. No.</b>	<b>Time (min)</b>	<b>180 watt</b>	<b>360 watt</b>	<b>540 watt</b>	<b>Average (g)</b>	<b>Moisture removed (g)</b>	<b>MC (wb %)</b>	<b>MC (db %)</b>	<b>Moisture ratio</b>	<b>Drying rate</b>
1	0	100.2	100.07	100.28	100.18	0.00	83.21	495.59	1.0000	0.00
2	0.5	97.57	98.06	97.83	97.82	2.36	80.85	422.19	0.8493	28.11
3	1	95.12	96.95	94.45	95.51	4.67	78.54	365.91	0.7338	27.83
4	1.5	94.59	93.86	93.22	93.89	6.29	76.92	333.28	0.6668	24.97
5	2	94.45	92.96	88.87	92.09	8.09	75.12	301.98	0.6026	24.08
6	2.5	94.8	88.41	87.85	90.35	9.83	73.38	275.70	0.5487	23.41
7	3	92.34	87.12	85.75	88.40	11.78	71.43	250.06	0.4960	23.38
8	3.5	90.62	85.71	83.1	86.48	13.70	69.51	227.94	0.4506	23.3189
9	4	89.65	83.71	80.37	84.58	15.60	67.61	208.71	0.4112	23.23
10	4.5	88.67	81.75	77.69	82.70	17.48	65.73	191.83	0.3765	23.13
11	5	87.34	79.67	75.2	80.74	19.44	63.77	175.99	0.3440	23.16
12	5.5	86.3	78.03	72.43	78.92	21.26	61.95	162.81	0.3170	23.02
13	6	85.1	76.27	70.22	77.20	22.98	60.23	151.42	0.2936	22.81
14	6.5	83.67	74.46	67.98	75.37	24.81	58.40	140.38	0.2709	22.73
15	7	82.45	73.01	65.96	73.81	26.37	56.84	131.68	0.2531	22.43
16	7.5	81.06	71.04	64.1	72.07	28.11	55.10	122.70	0.2346	22.32
17	8	80.04	69.1	62.3	70.48	29.70	53.51	115.10	0.2190	22.11
18	8.5	79.05	67.6	60.46	69.04	31.14	52.07	108.62	0.2057	21.82
19	9	77.93	65.89	58.02	67.28	32.90	50.31	101.25	0.1906	21.77
20	9.5	76.7	63.02	56.74	65.49	34.69	48.52	94.24	0.1762	21.75

21	10	75.1	60.34	54.17	63.20	36.98	46.23	85.99	0.1593	22.02
22	11	73.46	58.1	53.9	61.82	38.36	44.85	81.32	0.1497	20.76
23	12	71.46	55.78	51.76	59.67	40.51	42.70	74.51	0.1357	20.10
24	13	71.86	55.76	48.08	58.57	41.61	41.60	71.22	0.1290	19.06
25	14	69.8	53.5	45.32	56.21	43.97	39.24	64.57	0.1153	18.70
26	15	68.14	51.38	42.67	54.06	46.12	37.09	58.97	0.1038	18.31
27	16	66.3	49.38	40.35	52.01	48.17	35.04	53.94	0.0935	17.93
28	17	64.77	46.12	38.21	49.70	50.48	32.73	48.65	0.0827	17.68
29	18	63.2	42.73	34.7	46.88	53.30	29.91	42.67	0.0704	17.63
30	19	61.72	40.96	32.21	44.96	55.22	27.99	38.88	0.0626	17.30
31	20	60.26	37.45	29.23	42.31	57.87	25.34	33.95	0.0525	17.23
32	22	57.71	34.15	24.7	38.85	61.33	21.88	28.01	0.0403	16.60
33	24	54.71	32.55	23.09	36.78	63.40	19.81	24.71	0.0335	15.73
34	26	52.6	30.2		41.40	58.78	24.43	32.33	0.0491	13.46
35	28	48.19	28.47		38.33	61.85	21.36	27.16	0.0385	13.15
36	30	46.35	27.26		36.81	63.38	19.84	24.74	0.0336	12.58
37	32	44.35	26.7		35.53	64.66	18.56	22.78	0.0295	12.03
38	34	42.82	26.34		34.58	65.60	17.61	21.37	0.0267	11.49
39	36	40.41	25.97		33.19	66.99	16.22	19.36	0.0225	11.08
40	38	39.17	25.56		32.37	67.82	15.40	18.20	0.0201	10.62
41	40	36.16	25.23		30.70	69.49	13.73	15.91	0.0154	10.34
42	42	34.85			34.85	65.33	17.88	21.77	0.0275	9.26
43	44	32.852			32.85	67.33	15.88	18.88	0.0215	9.11
44	46	30.98			30.98	69.20	14.01	16.29	0.0162	8.95
45	48	30.98			30.98	69.20	14.01	16.29	0.0162	8.58
46	50	29.98			29.98	70.20	13.01	14.96	0.0135	8.36

47	52	27.92			27.92	72.26	10.95	12.30	0.0080	8.27
48	54	26.78			26.78	73.40	9.81	10.88	0.0051	8.09
49	56	24.98			24.98	75.20	8.01	8.71	0.0007	7.99
50	58	24.91			24.91	75.27	7.94	8.62	0.0005	7.72
51	60	24.88			24.88	75.30	7.91	8.59	0.0004	7.47
52	625	24.8			24.80	75.38	7.83	8.50	0.0002	7.24
53	64	24.76			24.76	75.42	7.79	8.45	0.0001	7.01

**APPENDIX – H**

EMC – 8.72, IMC- 86.90%, DM- 13.10%, FMC – 8.66%

<b>Non-Foamed Microwave drying</b>										
<b>Sr. No.</b>	<b>Time (min)</b>	<b>180 watt</b>	<b>360 watt</b>	<b>540 watt</b>	<b>Average (g)</b>	<b>Moisture removed (g)</b>	<b>mc (wb %)</b>	<b>mc ( db %)</b>	<b>Moisture ratio</b>	<b>Drying rate</b>
1	0	100.45	100.23	100.26	100.31	0.00	86.9	663.36	1.0000	0.00
2	0.5	97.57	98.06	97.83	97.82	2.49	84.41	541.44	0.8138	38.02
3	1	95.12	96.95	94.45	95.51	4.80	82.10	458.56	0.6871	36.67
4	1.5	94.59	93.86	93.22	93.89	6.42	80.48	412.30	0.6165	32.67
5	2	94.45	92.96	88.87	92.09	8.22	78.68	369.12	0.5505	31.36
6	2.5	94.8	88.41	87.91	90.37	9.94	76.96	334.09	0.4970	30.34
7	3	92.34	87.12	85.75	88.40	11.91	74.99	299.89	0.4448	30.30
8	3.5	90.62	85.71	83.1	86.48	13.83	73.07	271.29	0.4011	30.17
9	4	89.65	83.71	80.37	84.58	15.73	71.17	246.82	0.3637	30.03
10	4.5	88.67	81.75	77.69	82.70	17.61	69.29	225.66	0.3314	29.87
11	5	87.34	79.67	75.2	80.74	19.57	67.33	206.06	0.3014	29.88
12	5.5	86.3	78.03	72.43	78.92	21.39	65.51	189.94	0.2768	29.69
13	6	85.1	76.27	70.22	77.20	23.11	63.79	176.14	0.2557	29.41
14	6.5	83.67	74.46	67.98	75.37	24.94	61.96	162.88	0.2355	29.29
15	7	82.45	73.01	65.96	73.81	26.50	60.40	152.50	0.2196	28.90
16	7.5	81.06	71.04	64.1	72.07	28.24	58.66	141.88	0.2034	28.75
17	8	80.04	69.1	62.3	70.48	29.83	57.07	132.94	0.1897	28.46
18	8.5	79.05	66.98	60.46	68.83	31.48	55.42	124.32	0.1766	28.27
19	9	77.93	65.89	57.12	66.98	33.33	53.57	115.38	0.1629	28.27

20	9.5	76.7	62.12	56.89	65.24	35.07	51.83	107.58	0.1510	28.18
21	10	75.1	60.34	55.12	63.52	36.79	50.11	100.44	0.1401	28.08
22	11	73.46	58.1	53.9	61.82	38.49	48.41	93.84	0.1300	26.71
23	12	71.46	55.78	51.76	59.67	40.64	46.26	86.07	0.1181	25.85
24	13	71.86	55.76	48.08	58.57	41.74	45.16	82.34	0.1124	24.51
25	14	69.8	53.5	45.32	56.21	44.10	42.80	74.81	0.1010	24.05
26	15	68.14	51.38	42.67	54.06	46.25	40.65	68.50	0.0913	23.54
27	16	66.3	49.38	40.35	52.01	48.30	38.60	62.87	0.0827	23.04
28	17	64.77	46.12	38.21	49.70	50.61	36.29	56.96	0.0737	22.73
29	18	63.2	42.73	34.7	46.88	53.43	33.47	50.30	0.0635	22.66
30	19	61.72	40.96	32.21	44.96	55.35	31.55	46.10	0.0571	22.24
31	20	60.26	37.45	29.23	42.31	58.00	28.90	40.65	0.0488	22.14
32	22	57.71	34.15	24.7	38.85	61.46	25.44	34.13	0.0388	21.32
33	24	54.71	32.55	23.09	36.78	63.53	23.37	30.50	0.0333	20.21
34	26	52.6	30.2		41.40	58.91	27.99	38.87	0.0460	17.30
35	28	48.19	28.47		38.33	61.98	24.92	33.19	0.0374	16.90
36	30	46.35	27.26		36.81	63.51	23.40	30.54	0.0333	16.16
37	32	44.35	26.7		35.53	64.79	22.12	28.39	0.0300	15.45
38	34	42.82	26.34		34.58	65.73	21.17	26.86	0.0277	14.76
39	36	40.41	25.97		33.19	67.12	19.78	24.66	0.0243	14.23
40	38	39.17	25.56		32.37	67.95	18.96	23.39	0.0224	13.65
41	40	36.16	25.23		30.70	69.62	17.29	20.90	0.0186	13.29
42	42	34.85			34.85	65.46	21.44	27.29	0.0284	11.90
43	44	32.852			32.85	67.46	19.44	24.13	0.0235	11.70
44	46	30.98			30.98	69.33	17.57	21.32	0.0192	11.51

45	48	30.98			30.98	69.33	17.57	21.32	0.0192	11.03
46	50	29.98			29.98	70.33	16.57	19.86	0.0170	10.74
47	52	27.92			27.92	72.39	14.51	16.97	0.0126	10.63
48	54	26.78			26.78	73.53	13.37	15.43	0.0102	10.39
49	56	24.98			24.98	75.33	11.57	13.08	0.0067	10.27
50	58	24.91			24.91	75.40	11.50	12.99	0.0065	9.92
51	60	24.88			24.88	75.43	11.47	12.96	0.0065	9.60
52	62	24.88			24.88	75.43	11.47	12.96	0.0065	9.29
53	64	23.4			23.40	76.91	9.99	11.10	0.0036	9.17
54	66	22.75			22.75	77.56	9.34	10.30	0.0024	8.97
55	68	22.29			22.29	78.02	8.88	9.75	0.0016	8.76
56	70	21.84			21.84	78.47	8.43	9.21	0.0007	8.56
57	72	21.58			21.58	78.73	8.17	8.90	0.0003	8.35
58	74	21.35			21.35	78.96	7.94	8.62	-0.0002	8.15
59	76	21.38			21.38	78.93	7.97	8.66	-0.0001	7.93

## APPENDIX- I

### Modelling used in drying of foamed and non foamed guava pulp

Sr. No.	Drying method	Model	a	k	c	R <sup>2</sup>	$\chi^2$	MBE	RMSE
1	Foamed Sun	Lewis		0.0134		0.9532	0.0053	0.017	0.0215
2		Pages	0.2065	5.7257		0.6242	0.038	0.1287	0.0433
3		Logarithmic	0.8639	0.0149	0.0516	0.9718	0.0036	0.4963	0.013
4		Magee	0.4927	-0.0024		0.7995	0.0015	0.0107	0.0086
1	Non foamed sun	Lewis		0.0155		0.9866	0.217	0.0026	0.0018
2		Pages	0.0621	0.6897		0.9994	0.001	0.3052	0.0069
3		Logarithmic	0.9275	0.0159	0.0233	0.9912	0.0277	0.4197	0.3532
4		Magee	0.4349	-0.002		0.744	0.0018	0.3051	0.0035
1	Foamed tray	Lewis		0.0216		0.9967	0.0014	0.0036	0.007
2		Pages	0.1696	7.7751		0.7956	0.0368	0.1031	0.0529
3		Logarithmic	0.9715	0.0221	0.0122	0.9973	0.001	0.6725	0.0063
4		Magee	0.5605	-0.0048		0.7991	0.0311	0.0123	0.0525
1	Non foamed tray	Lewis		0.0179		0.9903	0.0036	0.0108	0.0097
2		Pages	0.1897	6.7425		0.74	0.1031	0.1106	0.0475
3		Logarithmic	0.9425	0.0193	0.0293	0.994	0.6725	0.1956	0.0076
4		Magee	0.5169	-0.0034		0.7856	0.0123	0.1411	0.0437
1	Foamed microwave	Lewis		0.2032		0.9887	0.0015	0.0103	0.0048
2		Pages	0.3125	0.7483		0.9991	0.0001	0.0036	0.0013
3		Logarithmic	0.8935	0.1982	0.0265	0.996	0.0006	0.9113	0.0029
4		Magee	0.3903	-0.0173		0.7133	0.0268	0.3828	0.0227
1	Non foamed microwave	Lewis		0.2340		0.9833	0.0103	0.0127	0.0051
2		Pages	0.3800	0.697		0.9988	0.0036	0.0044	0.0013
3		Logarithmic	0.8723	0.2226	0.0260	0.9937	0.9113	0.0932	0.0031
4		Magee	0.3306	-0.0124		0.6716	0.3828	0.054	0.2593

## APPENDIX-J

### Chemical analysis of foamed and non-foamed guava pulp

<b>A) Ascorbic acid (Vitamin C, mg/100g)</b>					
Sr. No.	Drying methods	R1	R2	R3	Average
1	Foamed sun	213.4	215.54	216.14	215.03
2	Non-Foamed sun	214.42	218.65	214.89	215.98
3	Foamed tray	213.94	217.84	218.54	216.77
4	Non-Foamed tray	214.56	213.69	220.58	216.27
5	Foamed Microwave d	224.71	221.23	214.67	220.21
6	Non-Foamed Microwave	221.36	220.06	211.42	217.61
<b>B) Reducing sugar (%)</b>					
1	Foamed sun drying	3.95	4.05	5.16	4.38
2	Non-Foamed sun	4.01	5.31	3.59	4.31
3	Foamed tray	4.48	3.87	4.21	4.18
4	Non-Foamed tray	4.56	4.51	3.79	4.28
5	Foamed Microwave	5.02	3.87	3.68	4.19
6	Non-Foamed Microwave	4.11	3.86	4.57	4.18
<b>C) Total sugar (%)</b>					
1	Foamed sun	7.85	8.41	8.52	8.26
2	Non-Foamed sun	7.45	8.02	7.84	7.77
3	Foamed tray	7.82	8.64	7.84	8.1
4	Non-Foamed tray	8.81	5.76	6.73	7.1
5	Foamed Microwave	6.84	6.75	7.9	7.16
6	Non-Foamed Microwave	7.15	6.79	8.23	7.39
<b>D) Non Reducing sugar (%)</b>					
1	Foamed sun	3.9	4.36	3.36	3.87
2	Non-Foamed sun	3.44	2.71	4.25	3.47
3	Foamed tray	3.34	4.77	3.63	3.91
4	Non-Foamed tray	4.25	1.25	2.94	2.81
5	Foamed Microwave	1.82	2.88	4.22	2.97
6	Non-Foamed Microwave	3.04	2.93	3.66	3.21
<b><math>\beta</math>- carotene (mg/100g)</b>					
1	Foamed sun	312.01	289.45	300.41	300.63
2	Non-Foamed sun	288.21	294.21	302.15	294.86
3	Foamed tray	301.25	287.21	289.88	292.78
4	Non-Foamed tray	295.51	288.54	287.12	290.39
5	Foamed Microwave	287.65	296.68	295.87	293.40
6	Non-Foamed Microwave	298.14	287.45	291.42	292.34

## APPENDIX – K

### Quality parameters of foamed and non-foamed guava pulp

Sr. No.	Drying methods	Water activity	Colour Value			Average
			L	a	b	
1	<b>Foamed Sun drying</b>					
	R1 (g)	0.312	70.58	2.64	19.94	31.05
	R2 (g)	0.314	68.96	2.76	20.36	30.69
	R3 (g)	0.313	70.62	2.73	20.14	31.16
	<b>Average (g)</b>	<b>0.313</b>	<b>70.05</b>	<b>2.71</b>	<b>20.15</b>	<b>30.97</b>
2	<b>Non-Foamed Sun drying</b>					
	R1 (g)	0.281	66.4	4.32	19.97	30.23
	R2 (g)	0.284	65.22	5.03	19.46	29.90
	R3 (g)	0.282	68.38	5.11	20.11	31.2
	<b>Average (g)</b>	<b>0.282</b>	<b>66.67</b>	<b>4.82</b>	<b>19.85</b>	<b>30.44</b>
3	<b>Foamed Tray drying</b>					
	R1 (g)	0.388	72.06	1.63	22.42	32.03
	R2 (g)	0.381	70.26	1.41	21.78	31.15
	R3 (g)	0.373	72.73	1.53	21.81	32.02
	<b>Average (g)</b>	<b>0.381</b>	<b>71.68</b>	<b>1.52</b>	<b>22.00</b>	<b>31.73</b>
4	<b>Non-Foamed Tray drying</b>					
	R1 (g)	0.282	63.18	3.52	22.17	29.62
	R2 (g)	0.285	62.18	3.51	23.25	29.64
	R3 (g)	0.287	61.94	3.66	22.4	29.33
	<b>Average (g)</b>	<b>0.285</b>	<b>62.43</b>	<b>3.56</b>	<b>22.61</b>	<b>29.53</b>
5	<b>Foamed Microwave drying</b>					
	R1 (g)	0.283	69.09	2.1	20.9	30.69
	R2 (g)	0.283	69.71	1.86	20.85	30.80
	R3 (g)	0.281	68.4	1.86	20.71	30.32
	<b>Average (g)</b>	<b>0.282</b>	<b>69.07</b>	<b>1.94</b>	<b>20.82</b>	<b>30.60</b>
6	<b>Non-Foamed Microwave drying</b>					
	R1 (g)	0.275	72.02	2.95	21.95	32.30
	R2 (g)	0.274	71.43	3.64	21.96	32.34
	R3 (g)	0.275	71.52	2.98	21.88	32.12
	<b>Average (g)</b>	<b>0.275</b>	<b>71.66</b>	<b>3.19</b>	<b>21.93</b>	<b>32.25</b>

## APPENDIX – L

### Sensory score card

Name of panelist:

Date: / /2018

Please evaluate the product for its quality by giving the marks according the score provided below:

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

Sr. No.	Sample no.	Colour	flavour	taste	appearance	Overall acceptability
1	Foamed Sun drying					
2	Non-Foamed Sun drying					
3	Foamed Tray drying					
4	Non-Foamed Tray drying					
5	Foamed Microwave drying					
6	Non-Foamed Microwave drying					

**APPENDIX – M**  
**Sensory evaluation of foamed and non-foamed guava pulp**

Sr. No.	Drying method	quality attributes	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J1 0	J1 1	J1 2	J1 3	J1 4	J1 5	J1 6	J1 7	J1 8	J1 9	J2 0	Average	
1	Foamed sun	Colour	6	7	5	8	9	8	7	8	6	7	8	7	8	6	6	7	5	8	9	6	7.10	
		flavour	6	7	7	8	7	6	8	7	7	6	6	8	7	7	6	7	7	8	7	7	7	6.94
		taste	6	8	7	8	8	6	7	8	8	5	6	7	8	8	6	8	7	8	8	8	8	7.21
		appearance	6	7	5	8	8	8	6	8	8	7	8	6	8	8	6	7	5	8	8	8	8	7.10
2	Non foamed sun	Colour	6	6	4	8	8	7	6	7	4	5	8	8	7	6	7	4	5	6	4	8	6.10	
		flavour	6	6	6	7	6	7	7	7	6	6	7	6	7	7	7	6	6	6	6	6	7	6.42
		taste	6	7	6	7	7	8	7	7	7	5	7	7	8	7	7	7	5	7	6	7	6	6.73
		appearance	6	6	4	8	9	7	8	8	7	5	8	9	7	8	8	7	5	6	4	8	8	6.84
3	Foamed tray	Colour	8	8	9	8	7	8	8	7	8	8	7	7	8	8	8	9	8	8	8	7	7.89	
		flavour	9	8	8	8	7	8	8	8	8	7	7	8	8	9	8	8	8	8	8	8	7	7.94
		taste	9	6	8	9	8	8	7	8	9	7	8	8	9	9	6	8	9	8	7	8	7	7.94
		appearance	8	7	9	8	7	7	8	7	9	6	7	7	9	8	7	9	8	7	8	7	8	7.68
4	Non foamed tray	Colour	7	7	4	9	6	6	6	8	7	8	7	4	9	6	8	7	8	4	8	8	6.78	
		flavour	6	7	8	7	8	7	5	7	7	8	7	8	7	8	7	7	8	6	7	6	7	7.10
		taste	6	7	7	8	7	7	7	8	6	7	7	7	8	7	8	6	7	6	7	7	7	7
		appearance	7	7	7	9	8	6	7	7	7	8	7	7	9	8	7	7	8	4	8	9	9	7.26
5	Foamed microwave	Colour	8	8	7	9	8	9	7	9	9	5	8	7	8	8	7	7	4	8	8	9	7.57	
		flavour	8	8	6	8	8	8	8	9	9	5	8	7	8	8	6	7	8	9	8	8	8	7.68
		taste	8	8	7	9	9	8	8	7	9	6	9	8	8	7	6	7	7	9	6	8	8	7.68
		appearance	8	8	7	9	9	9	7	8	8	5	8	7	7	8	7	7	7	8	7	9	9	7.57
6	Non foamed microwave	Colour	7	8	8	8	9	8	8	8	8	6	6	6	7	8	9	6	6	4	8	8	7.26	
		flavour	7	7	8	8	8	8	8	8	7	7	7	5	6	8	8	6	6	6	7	6	7	7.10
		taste	7	8	9	8	9	8	8	7	7	6	7	7	6	8	9	6	7	6	7	7	7	7.36
		appearance	7	8	9	8	7	8	9	9	7	7	6	7	7	8	7	6	6	4	8	9	9	7.26

## VITA

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6. Research papers : Nil  
published (if any)
7. Field of Interest (in which you desire to work) : Administrative services

**Place** : Akola

**Date** :

**Signature of Student**

**(Sapkal Arti Bhikaji)**