COMPARATIVE STUDY OF MICROWAVE PROCESSED MANGO LEATHER WITH TRADITIONALLY PROCESSED MANGO LEATHER

A THESIS SUBMITTED FOR THE PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN

FOOD TECHNOLOGY AND BIOCHEMICAL ENGINEERING

2017-19

BY

PRITHA NAYAK

Examination Roll No. M4FTB19004

Registration No. 123569 OF 2013-14

Under the Guidance of

DR. (Mrs.) RUNU CHAKRABORTY

Professor

Department of Food Technology and Biochemical Engineering

Faculty of Engineering and Technology

Jadavpur University

Kolkata - 700032

This thesis is dedicated to my beloved Father and all the persons who have helped me to reach here.

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DEPARTMENT OF FOOD TECHNOLOGY AND BIOCHEMICAL ENGINEERING

JADAVPUR UNIVERSITY

KOLKATA- 700032

Declaration of Originality and Compliance of Academic Ethics

I hereby declare that the thesis contains survey and original research work by the undersigned candidate, as part of her Master of Technology in Food Technology and Biochemical Engineering studies.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct. I have fully cited and referenced all materials and results that are not original to this work.

Name: **Pritha Nayak**

Examination Roll No: **M4FTB19004**

Thesis Title: **"Comparative Study of Microwave Processed Mango Leather with Traditionally Processed Mango Leather"**

Signature with date:

_____

(PRITHA NAYAK)

FACULTY OF ENGINEERING AND TECHNOLOGY

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JADAVPUR UNIVERSITY

KOLKATA- 700032

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I hereby recommend the thesis entitled, **"Comparative Study of Microwave Processed Mango Leather with Traditionally Processed Mango Leather"** prepared by Pritha Nayak (Examination Roll No. M4FTB19004 & Class Roll No. 001710902002), student of M.Tech 2nd year, under the guidance and supervision of **Dr. (Mrs.) Runu Chakraborty**. The thesis has been evaluated and thus found satisfactory. It is therefore accepted and submitted as a dissertation for the partial fulfilment for the requirement for awarding the degree of Masters of Technology in Food Technology and Biochemical Engineering.

Dr. Dipankar Halder	**Dr. Chiranjib Bhattacharjee**
Associate Professor and Head	**Dean**
Department of Food Technology and Biochemical Engineering	**Faculty of Engineering and Technology**
Jadavpur University	**Jadavpur University**
Kolkata- 700032	**Kolkata- 700032**

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DEPARTMENT OF FOOD TECHNOLOGY AND BIOCHEMICAL ENGINEERING

JADAVPUR UNIVERSITY

KOLKATA- 700032

Certificate of Approval

This is to certify that **Ms. Pritha Nayak** (Exam Roll No. M4FTB19004 and Class Roll No. 001710902002) has carried out her research work entitled **"Comparative Study of Microwave Processed Mango Leather with Traditionally Processed Mango Leather"** under my supervision, at Department of Food Technology and Biochemical Engineering, Jadavpur University. I am satisfied that she has carried out this work independently with proper care and confidence. I hereby recommend that this dissertation be accepted in the partial fulfilment of the requirement of the degree of Master of Technology in Food Technology and Biochemical Engineering.

I am very much pleased to forward this thesis for evaluation.

_____

Dr. (Mrs.) Runu Chakraborty

Professor

Department of Food Technology and Biochemical Engineering

Jadavpur University

Kolkata- 700032

Acknowledgement

This thesis entitled **"Comparative Study of Microwave Processed Mango Leather with Traditionally Processed Mango Leather"** is by far the most significant scientific accomplishment in my life and it would be impossible without people who supported me and believed in me.

To begin with, I express my deep regards, unbound gratitude with sincere thanks to my guide **Dr. (Mrs.) Runu Chakraborty**, Dept. of Food Technology and Biochemical Engineering, Jadavpur University, Kolkata, without her efficient and untiring guidance, my work on this practical would have remained incomplete. She has been very kind and affectionate and allowed me to exercise thoughtful and intelligent freedom to proceed with this project work and finally produce this thesis.

I would like to thank **Dr. Dipankar Halder** (HOD, Dept of Food Technology and Biochemical Engineering) for extending his constant encouragements and guidance which helped me to do the work and complete it within schedule time.

I am also thankful to research scholars and my lab mates, **Mr. Suman Kr. Saha, Ms. Najmun Nahar, Ms. Runni Mukherjee, Mrs. Debasmita Pathak** and last but not the least **Mr. Tanmay Sarkar** who has motivated and mentored me over the last one year.

I am also thankful to library staffs, laboratory staffs, all Research scholars, non-teaching staff and sub-staff of this department for their cooperation.

I must not forget to express my deep sense of gratitude to my father and almighty, for being there for me over the years.

May, 2019 Pritha Nayak

Contents

Abstract

Mango *(Mangifera indica)* is a very important food crop of India. It is one of the most savored fruits worldwide. Due to improper post harvesting management we cannot savor this fruit whole year. Therefore a lot of mango products can be prepared from the fruit with increased shelf stability than a raw mango/ ripe mango pulp so that it is available round the year. Mango leather is a very popular and traditional product prepared from sound ripe mango. Traditionally, sun drying is employed for preparing mango leather from ripe fruit pulp. But the sun-dried product is discolored and the process is unhygienic and lengthy. In this study entitled **"Comparative Study of Microwave Processed Mango Leather with Traditionally Processed Mango Leather"**, mango leather is prepared both in traditional sun drying technique along with a contemporary drying method (Microwave drying) and phytochemical property, physicochemical property, packaging and storage stability of the prepared mango leathers have been analysed.

Chapter 1 deals with review of Mango Leather (ML) preparation by different formulations and drying techniques. It also focusses on the physicochemical tests that have been done by researchers to ascertain desirable composition and nutrient characteristics of mango leather. Drying techniques such as Sun drying, hot air drying, vacuum drying, microwave oven drying and infra-red drying have been employed by researchers to dry the mango pulp and the dehydration behaviour in different dryers had been studied.

Chapter 2 deals with optimisation of texture and colour components of microwave dried mango leather by Response Surface Methodology (RSM) approach. Colour (L, a, b, Hue angle) and texture (hardness) are taken as responses for previously modelled microwave dried mango leather. The response surface plots are generated for different interactions. The numerical optimization of the drying process is aimed

at finding the levels of microwave power and drying time, which could maximize the overall colour (hue) and minimize hardness (as demanded from the consumers in traditional sun dried mango leather).

Chapter 3 deals with mango leather prepared in traditional way of processing along with modern technology (microwave drying). The proximate analysis shows that there is no significant difference within the mango leathers processed in two different methods. The Total phenolic content (TPC), Total flavonoid content (TFC), Carotenoid content and antioxidant activity have been studied for both types of mango leathers. Microwave dried product has been found to be nutritionally better from sun dried product where sun dried mango leather has been found with least amount of bioactive compounds like TPC (4.1 mg/g db), TFC (2.21 mg/g db), FRAP (5.34 mg/g db), HPLC (0.305 mg/kg).

Chapter 4 deals with storage study of mango leather under different packaging conditions for maintaining better nutritional characteristics. The purpose of this study is to analyse the composition of mango leather and observe the shelf life of the product under sustainable packaging circumstances. The mango leathers are stored under four different packaging condition (a) 200 gauge high density polyethylene (HDPE), (b) 260 gauge Metallised polyethylene terephthalate (MET PET) (c) 200 gauge Low density polyethylene (LDPE), (d) biodegradable paper pouch (PP). Processed mango leathers have been analysed for proximate composition and vitamin C and sensory attributes. MET PET has been found the best packaging material for mango leather to retain its quality characteristics for 6 month of storage at 30 ± 5^{0}C.

Chapter 1

1. Literature Review of Mango Leather Prepared by Different Drying Technologies

1.1 Introduction

Fruit leather, also called a fruit bar or a fruit slab, is a dehydrated fruit-based confectionery dietary product which is often eaten as snack or dessert (Raab and Oehler, 1976). It is chewy and flavorful, naturally low in fat and high in fiber and carbohydrates; it is also lightweight and easily stored and packed (Ayotte, 1980). Consuming fruit leather is an economic and convenient value-added substitute for natural fruits as a source of various nutritional elements. Furthermore, fruit leather has far fewer calories, less than 100 kcals per serving, than many other snacks (Huang and Hsieh, 2005). Fruit leathers are restructured fruit made from fresh fruit pulp or a mixture of fruit juice concentrates and other ingredients after a complex operation that involves a dehydration step (Huang and Hsieh, 2005; Maskan et al., 2002). Fruit pulp-based fruit leathers are nutritious and organoleptically acceptable to customers. They contain substantial quantities of dietary fibers, carbohydrates, minerals, vitamins, and antioxidants (which remain constituents of the finished product) (Ayotte, 1980; Gujral and Brar, 2003). Most fresh fruits have a short harvest season and are sensitive to deterioration and even when stored under refrigerated conditions; therefore, making fruit leather from fresh fruits is an effective way to preserve fruits. Fruit leathers are manufactured by dehydrating a fruit puree into a leather like sheet (Diamante et al., 2014).

The mango (Mangifera indica Linn.) belongs to the Anacardiaceae family and due to its flavour, taste and fragrance it is called the "King of fruits" (Nunes et al., 2007). Apart from sensory superiorities mango have significant amount of bioactive compounds with antioxidant activity. Ripe mango contains high gallic acid and total polyphenols (Danalache et al., 2014). The significant amount of vitamin C, β carotene and minerals in ripe mango are helpful in prevention of cardiovascular disease and cancer (Alothman et al., 2010; Liu, 2003; Sanchez-Robles et al., 2009).

More than 1000 varieties of mango are being cultivated over the world occupying the second position as a tropical crop in terms of production and coverage area of cultivation (Solís-Fuentes and Durán-de-Bazúa, 2011; Muchiri et al., 2012). India produces 66% of total world mango production (Shafique et al., 2006) and holds the first position (Jahurul et al., 2015). Improper post-harvest management and processing causes' more than 30% wastage (Carrillo-lopez et al., 2000; Rathore et al., 2007). As mango is a climacteric fruit, improper harvesting time, condition of ripening, and absence of suitable storage facilities affect the price and availability of mango. For the same reasons large portion of the produce is wasted (Lalel et al., 2003). Only about 2% of total mango produced is processed whereas 20-30% of total production is spoiled which costs about 480 million dollar (FAO, 2004).

Mango contains 81.7% of moisture, due to this high moisture content it is perishable in nature and consumed mostly as fresh (Hashmi et al., 2007). To obtain the taste and benefits of mangoes at off season a variety of processed mango products are produced like juice, mango bar, jam, jelly, mango powder, canned mango slices, mango purees and mango leather (Djantou et al., 2011; Ledeker et al., 2014, Liu et al., 2014, Sogi et al., 2015; Sriwimon and Boonsupthipet al., 2011; Hussain et al., 2003). Among all these mango products mango leather is most popular in India (Danalache et al., 2014).

Mango leather or mango bar can be produced by dehydration of fresh mango pulp or pulp accompanied by other ingredients (Raab and Oehler, 1976; Huang and Hsieh, 2005; Maskan et al., 2002; Diamante et al., 2014). Simultaneous moisture and heat transfer are the main characteristics of drying through which perishable ripe mango pulp can be transformed to mango leather and can be suitable for long term storage (FAO 2004). Researchers formulate it with different components like sugar, soy flour, skim milk powder, coconut powder, pectin, acid, gum, preservatives etc. along with mango pulp to meet desired sensory and textural property. The evaporation of moisture from pulp along with other ingredients gives the cohesive leathery texture of mango leather (Vatthanakul et al., 2010).

To ascertain the desired quality of the processed mango leather, researchers have done various physicochemical analysis on it like proximate analysis, total ascorbic acid content, determination of colour, textural analysis, sensory analysis etc. Subject to the aim of research the researchers optimise their formulation based on the test results found.

Sun drying being the most simplest and traditional drying method, used from the ancient period of mankind. Though it gives natural colour, good texture of final product the exposure to ambient environment and high time consumption are the problems associated with this kind of drying technique (Maskan et al., 2002). With progress in technology, more effective drying techniques are employed to produce mango leathers. The alternative drying methods are like microwave drying, microwave drying, vacuum drying, infra-red drying etc. Most of the industries use convective type microwave oven for drying. Direct and indirect drying processes may cause crystallisation, shrinkage, puffing and desired or undesired biochemical reaction which ultimately affects the sensory, textural and nutritional qualities of mango leather (Diamante et al., 2014). Researchers have proposed different mathematical models for different kind of drying operations to predict the dehydration behaviour of the mango pulp.

Sun drying is free and renewable source of energy suitable for small scale industry but not for medium and large scale industry (Tiwari, 2016). Convection dryers are not economically viable for medium and small scale industries in developing country like India (Ibrahim et al., 2009; Jayaraman and Gupta, 1995; Banout et al., 2010; Boughali et al., 2009). A substantial amount of thermal energy is lost in convective drying as well as inferior heat transfer quality is another disadvantage of microwave drying. Infra-red dryers provide rapid drying and low operational cost (Brooker et al., 1992; Strumillo, 1987; Nonhebel, 1973). Microwave drying is fastest mode of drying as electromagnetic energy converted directly to the kinetic energy during this process but cell damage is the constrain associated with whereas vacuum drying approach facilitates better quality of product (Krulis et al., 2005; Kompany, 1993; Jaya & Das, 2003; Zhang et al., 2006).

In this era of globalization, competitive market packaging and storage of mango leather to expand its shelf life with respect to moisture content, water activity, microbial stability, texture and acceptability are the prime concern for industries (Irwandi et al., 1998).

1.2. Preparation Method:

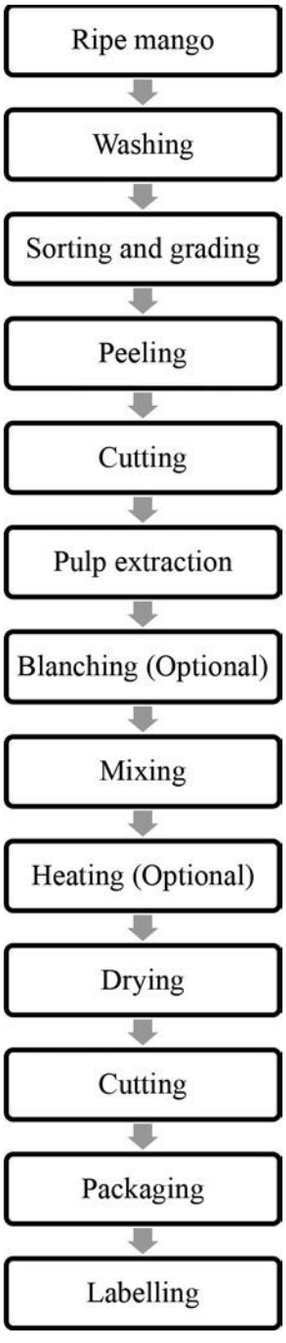

Fig. 1. Flow chart of mango leather preparation

Researchers have found different design to formulate mango leather in order to meet shortcomings from their point of view. Mir and Nath (1995) have prepared mango bar from mangoes of Langra cultivar. After washing, peeling and pulping it has been heated for 2 min at 91-93°C. They have increased the TSS to 30% by addition of powdered cane sugar, 0.6% of CA and 1734 ppm potassium metabisulphite (KMS) as preservative.

Gowda et al. (1995) have prepared mango fruit bar from Alphanso cultivar. 20% sugar, 0.2% CA and 700 ppm KMS are added to the pulp and dried to get good quality of mango bar. Similar kind of formulation is deliberated by Prasad and Nath (2002) where they use mangoes of Totapuri cultivar; after washing, peeling, pulping and it was heated for 2 min at 85°C. Total soluble solids of pulp was raised to 30% using powdered cane sugar, and 0.6% citric acid; whereas the preservative KMS is replaced by 1000 ppm SO2 (Prasad and Nath, 2002).

In a recent study Effah-Manu et al. (2013) have prepared mango-sweet potato leather. They have used mango of Keitt variety. The sweet potatoes have been baked in an oven at 150-220°C for 2 h, 2.5 h and 3 h to convert the starch to dextrin. Then it is cooled at 30°C and the edible portion of sweet potatoes is homogenized in a blender; thereafter it is mixed with mango pulp in 30:70, 20:80 and 10:90 ratios respectively. 0.1% sodium benzoate and 0.2% citric acid are

added to it. The final mixture is smeared on 7 mm × 7 mm aluminium trays coated with glycerol and dried. Though the overall acceptability of this leather is good but the amount of sweet potatoes incorporated is found insignificant by researchers (Effah-Manu et al., 2013).

The plain mango leather from mango pulp of cultivar Tommy Atkins is prepared by Azeredo et al. (2006) without addition of any preservative. The mango puree is passed through 1-mm sieve and the pulp is dried to obtain leather with moisture content 15-18% and optimise the time and temperature for production of the mango leather. The synergistic effect of pH and water activity inhibit microbial growth; thus, mango leathers with shelf-life for several months has been produced without the need of chemical preservatives.

A different kind of mango bar is formulated by Florina Danalache et al. (2014) where they have used mangoes of cultivar Palmer; after washing and cutting it is pureed at room temperature by blender. The pulp is heated at 88 ± 2°C in a water bath with addition of 1 gm of gellan powder per 100 gm of mango puree with continuous stirring at a rotation speed of 1640 g using a four-blade impeller. The mixture is poured in a rectangular silicone mould and kept at 22 ± 2°C temperature to set.

Gujral and Khanna (2002) prepared mango leather from Safaida variety, which is washed, peeled and pulped. The pulp with TSS 10.6% has been blanched at 80°C for 5 min, then cooled and 0.2% w/w of KMS has been added to it. The mango pulp has been mixed with soy protein concentrate (0%; 4.5%; 9%), skim milk powder (0%; 4.5%; 9%) and sucrose (0%; 4.5%; 9%). 250 g of this mixed pulp was poured on aluminium trays of dimension 25.5 cm × 13 cm × 2 cm. After drying it has been found that mango leather containing 4.5% skim milk powder and 4.5% sucrose is the most acceptable (Gujral and Khanna, 2002).

Mangoes of Langra cultivar have been washed, peeled and pulped by Gujral and Brar (2003). The pulp was blanched at 80°C temperature for 5 min, after cooling 0.2% of KMS has been added. 20% of sugar has been added to the pulp of total solid 14.3% to increase its sweetness and total solids. Then hydrocolloid has been incorporated to the mango pulp at concentrations of 1, 2, and 3% w/w respectively. 250 g of this

mixture has been spread over 25.5 cm × 13 cm × 2 cm aluminum trays. After drying it is found that incorporation of hydrocolloid significantly modified the texture of mango leather. They also found that with yellowness (b) and redness (a) of mango leather drop with increasing concentration of hydrocolloid whereas the concentration of hydrocolloid has been found insignificant in case of lightness value (L).

Gujral et al. (2013) produced mango leather by blanching of pulp at 80°C for 5 min to inactivate enzymes followed by addition of 1000 ppm of KMS as preservative, sucrose at concentration of 0, 5, and 10%, pectin at concentration of 0, 1, and 2%, maltodextrin in concentration of 0, 2.5 and 5% and has been kept overnight for hydration. Finally 300 g of this mixed pulp has been poured in aluminum trays measuring 0.3 m × 0.1 m × 0.03 m. They found that drying rate, drying rate constant and effective moisture diffusivity have been significantly affected by the additives like sucrose, pectin and maltodextrin.

G. Puspa et al. (2006) used Alphonso mango pulp with 16% TSS along with sugar (50 g), corn flour (5 g), and lime juice (2 g) at different specified level in mango leather preparation. Skim milk powder and roasted defatted soy flour with 51.8% of protein content is mixed together in the ratio of 1:1; this mixture has been finally mixed with mango pulp at concentration of 10, 15, 20 and 25%. After drying it has been found by the researchers that colour retention is higher for mango leather enriched with 20 and 25% soy flour. Whereas the mango leather enriched with 10 and 15% soy flour have significantly higher values of sensory attributes.

Mango bar has been prepared by Prasad (2009) from pulp of Totapuri cultivar. After washing, peeling and pulping it has been acidified to 0.3% CA and blanched at 85°C temperature for 5 min to inactivate enzymes.

Powdered cane sugar has been added in different extent to this pulp to increase the TSS to 20, 25 and 30%. To this mixture, roasted Bengal Gram flour and skim milk powder has been added in concentration of 0, 5 and 10%. Citric acid has been added in order to maintain acidity at 0.3, 0.45 and 0.6%. The final

mixture has been spread over stainless steel trays and dried. It has been found that roasted Bengal gram and skim milk powder at concentration of 5% respectively gave superior sensory qualities.

Parekh et al. (2014) prepared mango bar from Kesar cultivar fortified with DCP (Desiccated coconut powder). After washing and pulping of mango the pulp has been passed through stainless steel sieve of 1 mm mesh. The pulp has been blanched to destroy enzyme at 91-93 °C for 2 min and cane sugar has been incorporated to increase the TSS at 30° Brix. KMS has been added to the pulp at level of 0 and 1734 ppm, DCP has been added to pulp at concentration of 0, 1, 2 and 3%. The final mixture has been spread over trays smeared with glycerine followed by drying. Investigators have found that the mango bar with 2% DCP and 1734 ppm of KMS has best sensory attributes, whereas interaction effect of the treatment recipes has been found insignificant.

1.3. Methods of Drying

1.3.1. Sun Drying

When mango pulp is spread over metal tray for drying an uneven surface is created. When Sun rays of shorter wavelength fall on this rough surface, a part of it is reflected back and the rest get absorbed by pulp. The Sun rays of long wavelength cannot be absorbed by pulp. The colour of mango pulp is the prime factor for absorption of radiation wavelength from sun rays (Nowak and Lewicki, 2004). Temperature can be expressed as the average energy of molecular motion according to the kinetic theory. Water molecules having kinetic energy more than the escape energy and by overcoming the cohesive force that binds the water molecules in mango pulp will escape from the surface of the pulp. The rate of evaporation is much lower as it takes time for heat to migrate into the pulp from the surrounding air.

The mango pulp mixture has been poured on aluminium tray smeared with oil and exposed to open air. Sun rays are directly incident on the pulp and evaporate the moisture present within it. Due to the reflection

of the Sun rays on the shiny metal surface the drying temperature rise up and ultimately a leathery product can be obtained (Rameshwar, 1979).

1.3.2 Hot-air Drying

It is the conventional drying method where heat is transferred from the heated air to the pulp through the mechanism of conduction of heat. After the absorption of heat by the pulp the moisture diffuses from the pulp surface to the microwave as well as the moisture diffuses from the interior of pulp to the surface of the pulp. Both the diffusion processes continue simultaneously until the moisture content of pulp drops to a degree to achieve the drying purpose. The temperature difference is the driving force for the heat transfer while the driving force of mass transfer is the concentration difference of partial vapour pressure.

Mir and Nath (1995) produced mango leather in a cross-flow cabinet dryer at 63 ± 2°C for time 14-16 hours, where the tray load was 9.8 kg/m2 to get final moisture content of 22.9, 20.5 and 19.5% for plain mango bar, mango-desiccated coconut powder (DCP) bar and mango-soy protein concentrate (SPC) bar respectively. The values of R^2 for the BET model are 0.9067 and 0.4898 for plain mango bar and mango DCP respectively. In comparison to the Henderson model (R^2 values 0.8370-0.9800) and GAB model (R^2 values 0.9325-0.8005) for all the three types of mango bars it has been found that the Oswin model (R^2 values 0.9201-0.9731) and Smith model (R^2 values 0.93780.9493) were better. Therefore Oswin model is pertinent to drying all of the three types of mango bar whereas the GAB model fits to predict the sorption behaviour of plain mango bar only (Mohamad and Nath, 1995).

Microwave oven has been used by Gujral et al. (2013) at 103±2°C for 24 h to dry the mango pulp. The incorporation of sucrose and maltodextrin increases the drying as more water is bounded with increase of total soluble solid, whereas due to high water binding property drying time increases in case of pectin addition. Page's model describes the drying characteristics as well as the rate constant effectively with shape factor within the range of 0.799–0.996. The R^2 value has been found 0.86. The effective moisture

diffusivity calculated by Fick's second law of diffusion has been found in the range of 1.65 to 4.03 × 10−7 m2/sec. In regression analysis from the p-values it has been revealed that sucrose followed by pectin and maltodextrin affect the effective moisture diffusivity significantly (Gujral, 2013).

Cabinet dryer at temperature 60 ± 1°C and relative humidity of 15% has been used by Gujral and Brar (2003) to produce mango leather. The drying rate constant and shape factor have been investigated by them by using diffusion mechanism. The R^2 values lies in the range of 0.90-0.99. From the investigation it has been established that during early two hours of drying the rate of dehydration of mango leather is rapid; thereafter a significant drop in drying rate is observed. The incorporation of hydrocolloid significantly decreases the rate of drying for initial two hours whereas it has been found to have an insignificant effect on rate of dehydration for later period of drying.

Gujral and Khanna (2002) produced mango leather using microwave at a temperature of 60 ± 1°C and air velocity of 3.5 m/s in a cabinet dryer. From regression analysis, it has been found that increasing levels of sucrose lowered the drying time whereas drying time increases with increasing levels of skim milk powder and soy protein concentrate in mango pulp, because of water binding capacity of the protein molecules present in the skim milk powder and soy protein concentrate.

Azeredo et al. (2006) prepared mango leather using microwave oven to derive minimum drying time required to attain leather with moisture content of 15-18%. Drying temperature (60–80°C) and puree load (0.4–0.6 g/cm2) have been selected as two independent variables to conduct drying in accordance with central composite design. Both the factors significantly affect the drying time. The minimum drying time to produce mango leather has been found 120 min at 80°C and with a puree load of 0.5 g/cm2.

Prasad et al. (2002) studied the dehydration kinetics of mango leather which is dried at 70 ± 1°C for 26 hours with tray load 12.5 kg/m2 in cross flow cabinet dryer. During the first eight hours of drying rate of dehydration was higher. The incorporation of roasted Bengal gram (RBF) in mango pulp slowed down

the dehydration rate. Thereafter, less moisture loss was observed till 20 hours of drying time for both plain mango pulp and fortified mango pulp. Though after 14 hours and 16 hours of drying, the change in moisture content has been found insignificant for plain and fortified mango pulp respectively. Researchers found shape factor (A) 1.017 and 0.997 whereas drying constant (k) 0.318 and 0.255 for plain mango and mango-RBF leather respectively.

Parekha et al. (2014) conducted the quality evaluation of mango bar fortified with desiccated coconut powder using tray drier at 63 ± 2°C for 8-10 hours.

1.3.3. Microwave Drying

Microwave heating is one of the direct heating methods. Microwaves are basically a form of electromagnetic energy (300 MHz–300 GHz) which is generated by magnetrons due to the mutual force of electric and magnetic fields at right angle. The most common frequency used for drying of food material is 2450 MHz. When an oscillating electric field is incident on the polar molecules present in mango pulp (water), the permanently polarized dipolar molecules orient and reorient themselves according to the direction of the field at 2450 MHz, the orientation of the field changes 2450 million times per second. This consequences oscillatory migration of ions in the food and generates heat.

Pushpa et al. (2006) has produced mango leather through microwave drier of 750 W and 2450 MHz at power levels of 4, 8, 12, 16 and 20 W/g using 50 g of pulp with a power cycle of 30 sec on and 30 sec off respectively to achieve moisture content of 12-15%. Due to lower heat generation at lower power levels of microwave oven, the rate of drying is slow so the time required to dry the mango pulp is longer. They have found that increasing soy flour level from 15 to 25% is insignificant in variation of drying rates.

1.3.4. Infra-red Drying (IR Drying)

In IR drying without heating, radiation energy of the adjacent air is transferred from the heating element to the pulp surface. The radiation energy first impinges on the top-most surface of pulp, penetrates it and finally increases the sensible heat (Ginzburg, 1969). As thermal degradation of heat-labile phytochemical occurs at high temperature, the drying temperature should not be too high (Rieger and Šesták, 1993). During drying, as the moisture content decreases the transitivity and reflectivity increases while the absorptivity of the dried material decreases. The absorptivity, the skin depth and the transitivity are the functions of the density, wavelength of IR heating and properties of mango pulp. IR drying is preferred over microwave drying due to short drying time, high heat transfer coefficients and simple material temperature control system (Nowak and Lewicki, 2004). Because of these advantages IR drying in combination with convection or vacuum is more in practice in recent era (Mujumdar, 1995).

Effah-Manu et al. (2013) produced mango-sweet potato leather with 15.4% moisture content, through drying using flameless gas infrared catalytic heater at 45°C, 50°C and 55°C temperature. It has been found that the cabinet, oven and solar dried jackfruit leather had moisture contents of 18.85%, 14.79% and 18.5% respectively (Okilya et al., 2010). From these results of moisture content they concluded that in comparison with cabinet, oven and solar dryer infra-red dryer is more effective in.

1.3.5. Vacuum Drying

A vacuum dryer is an indirect type of heat dryer, that is, pulp is in contact with heated surface of dryer. Therefore drying is carried out by conduction mode. In this process materials are dried in a low pressure environment than normal atmospheric pressure and this results in a reduced temperature heating. Heated steam or hot water through hollow shelves is used as the heating medium. For the major part of the drying cycle, temperatures can be controlled with complete command and the mango pulp remains at the boiling point of water.

Jaya and Das (2003) have considered vacuum drying model for mango pulp. The ingredients

(maltodextrin, glycerol monostearate, and tri calcium phosphate at an amount of 0.62, 0.015 and 0.015 kg/kg dry mango solid respectively) have been mixed with mango pulp. In the process of mixing a planetary mixer having its mixing arm operated at 75 m/min peripheral speed for 15 to 20 min has been used; thereafter the pulp has been spread on aluminum trays coated with teflon. This mixture has been spread to 2, 3 and 4 mm thickness and dried at temperatures 65, 70 and 75°C in a vacuum drier. The absolute pressure has been maintained in the vacuum dryer at 30–50 mmHg. They have found that the product was leathery but non-sticky. They have also found that during first 900 and 1000 s of drying, the reduction in moisture content is high. Mango pulp with thickness 0.004 m dried at 65°C shows maximum drying time of 10800 seconds and the pulp with thickness 0.002 m dried at 75°C shows minimum drying time of 3500 seconds. The value of R^2 for actual and predicted moisture content using predicted effective diffusivity lies in the range of 0.991 to 0.997.

Drying methods	**Key features**	**References**
Sun Drying	▪ Energy extensive and most economical. ▪ Climate dependent and time consuming.	Rameshwar (1979)
Hot Air drying	▪ Process parameter like drying temperature and air flow rate can be controlled. ▪ Very low residual moisture level cannot be achieved. ▪ A possibility of thermal damage is there for material with high initial moisture content.	Mir and Nath (1995); Gujral et al (2013); Gujral and khanna (2002); Azeredo et al (2006); Prasad et al (2002); Parekha et al (2014)
Microwave drying	▪ Fastest drying process and high energy density. ▪ Rapid heat transfer along with inadequate homogeneity. ▪ A possibility of dark spot generation and plasma expulsion.	Puspa et al (2006)
Infra-red (IR) drying	▪ Process parameters can easily be controlled. Uniform temperature distribution can be achieved. ▪ Depending on food commodity the wavelength of radiation is selected.	Effah-Manu L (2013

	▪ In case of thin layer drying Far Infra-red radiation (3-1000 μm) is better whereas Near Infra-red radiation (0.78-1.4 μm) is efficient in drying of thick layers.	
Vacuum drying	▪ Comparatively less energy consuming process and environment friendly process. ▪ Ideal for hygroscopic and heat sensitive material.	Jaya and Das (2003)

Table.1. Comparison of different drying methods used in mango leather processing

1.4. Physicochemical Analysis

A series of physicochemical analysis has been done by researchers to determine the effect of formulation and processing technology on quality of mango leather.

1.4.1 Proximate Analysis

Researchers have analysed the moisture content, crude protein, fat, crude fibre, carbohydrate and ash content of mango leather according to AOAC methods (EffahManu, 2013; AOAC, 1990). The acidity, reducing and total sugars of samples have been analysed by Lane and Eynon method (Effah-Manu, 2013; Ranganna, 1986).

1.4.2 Determination of Total Soluble Solids (°Brix)

Effah-Manu et al. (2013) have determined the total soluble solids using the analogue hand-held refractometer. To calibrate the instrument distilled water and test solution of known sucrose concentration have been used. All the readings have been taken in duplicates and averaged before analysis of results.

1.4.3. Determination of Vitamin C (Total Ascorbic Acid) Content

Effah-Manu et al. (2013) have used the following procedure to determine the vitamin C in mango leather. 10 ml of sample extract was poured in a 100 ml volumetric flask and the volume made up by 0.4% oxalic acid solution. After filtration of this solution through Whatman No. 4 filter paper, 10 ml of the filtrate has been pipetted into a conical flask and 15 ml of 0.4% oxalic acid solution added to it. The solution has been

titrated against 0.04% aqueous sodium dichlorophenolindophenol solution; end point has been detected on appearance of first pink shade. 0.01 N sodium thiosulfate along with potassium iodide (50%) and 1 N HCl has been used to standardize sodium dichlorophenolindophenol solution using starch as indicator. The amount of total ascorbic acid has been determined through the following equation (Sharma et al., 2016):

$$\text{Ascorbic Acid } \left(\frac{mg}{100g\ sample}\right) = \frac{0.5\ mg}{V1} \times \frac{V2}{15\ ml} \times \frac{100\ ml}{weight\ of\ sample} \times 100$$

1.4.4. Total Carotenes

Prasad (2009) underwent through the following method to estimate total carotenes in mango leather. 100 mg of leather has been added with 10 ml of 80% acetone and grinded well in mortar-pestle. After centrifugation of the mixture at 3000 rpm for 10 min the supernatant has been taken and the volume is made up to 10 ml. The optical density values have been studied at 480 nm in ultra violet spectra. The following equation has been used to calculate the amount of carotenoids in mango leather (Harbone, 1973).

$$\text{Amount of carotenoids in 100 mg leather} = \frac{4 \times \text{optical density} \times \text{total volume of sample (10 ml)}}{\text{mass of leather (100mg)}}$$

1.4.5. Texture Analysis

Florina Danalache et al. (2014) have carried out texture analysis of mango bar in order to mimic the human biting action. They employ method used by texture analyser equipped with 50N load cess (Mandala et al., 2007). By using an aluminium plunger with 60 mm diameter a double compression cycle test has been performed, with a time gap of 5 s between the two compression cycles. To avoid friction a thin layer of paraffin oil has been applied between plates and the testing sample in order to avoid friction. Hardness has been measured as the maximum force during the first compression cycle. Springiness is the ratio of

the second and first compression distances. Cohesiveness has been defined as the ratio of the positive force area during the second and first cycle of compression.

1.4.6. Colour Measurement

The mango leather has been positioned underneath the optical sensor of Hunter Lab Calorimeter; the readings for mean value of L, a and b were considered from three measurements performed on each sample in terms of defining the colour of samples. Before initialization of experiment the colorimeter has been standardized by using standard white and black tiles (Effah-Manu et al., 2013; Pushpa et al., 2006).

1.4.7. Sensory Analysis

Most of the researchers employ nine-point Hedonic scale to evaluate mango leather samples for flavour, colour and texture where the sensory panel consisted of 20 trained members. (Prasad et al., 2002; Effah-Manu et al., 2013; Azeredo et al., 2006; Gujral et al., 2013; Pushpa et al., 2006; Prasad, 2009; Dina et al., 2015).

A preference–ranking test (ISO 8587:2006) has been performed by Florina Danalache et al. (2014). As texture is the determining factor in developing food products like bars, they have been considered only one sensory parameter that is the overall texture and each panellist had been requested to assess that particular attribute of samples by preference. According to ISO 8587:2006 the sensory evaluation of mango bars has been carried out in a sensory room with six analysis boxes. The 63 panelists aged between 20-65 years old and regular consumers of mango fruit have been chosen. The five different mango bars have been presented to the panelists in random order and labelled with randomly generated code of three digits at room temperature (20-22°C). The panelists rank the five samples in order of their preference: (1) the least, (2) slightly, (3) moderately, (4) neither like nor dislike and (5) the most preferred texture (Meilgaard et al., 1999). The panelists have been asked to validate their choices and the justifications have been used to determine whether each sample was significantly preferred over the others.

TSS (^{0}B)	Moisture (%)	ERH (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)	Water activity	Vitamin C (mg/100	Carotene (mg/100 g)	Reference
	15.0 ± 1.60		2.25 ± 0.92	0.55 ± 0.03	2.82 ± 0.04	2.06 ± 0.25	77.32 ± 0.62	0.61 ± 3.8a	17.49 ± 2.11		Effah-Manu et al. (2013)
81.24							65.57		25.93		Parekha et al. (2014)
	15.21		2.0			2.0	65.94				Prasad et al. (2002)
	17.2							0.621			Azeredo et al. (2006)
	10.0										Gujral et al. (2002)
	10.0	45.16									Gujral and Brar (2003)
75-80	10.0-15.0							0.667-0.529			Pushpa et al. (2006)
	13.2		2.0	0.3		2.0	82.5			12.2	Prasad (2009)
	22.9	69					61.40-7150				Mir and Nath (1995)
	11.17 – 17.94							0.46 – 0.72			Dina et al. (2015)

Table 2: Mango leather compositions

1.4.8. Packaging and Storage

As mango leather is a ready to eat food so food containment can be achieved best by food packaging. This is the best way to control and protect the food against physical, chemical, biological and environmental deterioration. Therefore packaging and storage of mango leather is one of the prime factors with respect to food safety as well as for marketing.

Rectangular pieces of mango bars have been packed in polyethylene bags and stored at room temperature for six months. The chemical and organoleptic assessment of mango bars during the storage period of 0, 1, 2, 3, 4, 5 and 6 months show progressively decline of taste score with storage period (Parekha et al., 2014). Up to six months of time mango leathers are consumable. The similar kind of result is also found by other researchers (Narayana et al., 2003).

In some case Al foil rolled mango leather is packed in cellophane film (Effah-Manu et al., 2013). In some other cases polyethylene pouch as packaging material and at room temperature storage is used (Gujral and Khanna, 2002; Gujral et al., 2013; Gujral and Brar, 2003). The use of poly propylene (PP) pouches as packaging material and refrigerated storage at 11±1°C temperature is also found in some studies (Prasad, 2009).

The microbiological safety of mango leather on storage at 25°C for six months packaged in polypropylene buckets with lids has been studied by Azeredo et al. (2006). It has been found that mesophilic aerobes remained less than 10 colony forming unit (CFU)/g, yeasts and mold count is less than 100 CFU/g throughout the storage period of six months. It has been concluded that the product is microbiologically safe for the storage period considered as there is no proof of presence of Salmonella and most probable numbers (MPN) of all coliforms (including E. coli) have been found to be lower than three organisms/gram.

Polyethylene pouch, wax paper and aluminium foil have also been used for packaging of mango bar purchased from market for two months of storage. During storage heavy load of Enterobacter and some other bacteria indicating spoilage have been found (Singh et al., 2003).

1.5. Conclusion

The “King of fruit” mango is not only superior with respect to sensory attributes but also has medicinal activity. But as it has high moisture content it is perishable in nature. Thus processing and preservation is required. Among the processed mango products mango leather is relished most. Texture and other sensory qualities of mango leather can vary with different formulations used and different drying techniques employed. These changes of qualities can be determined by a series of physicochemical analysis. The drying techniques used for mango leather preparation include sun drying, microwave drying, microwave drying, IR drying and vacuum drying. The total energy consumption of these dryers is investigated by researchers. There is lack of research in the field of process optimisation for mango leather production to get superior textural and nutritional quality. A vivid research is required in the area of packaging and storage of mango leather.

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Chapter 2

2. Response Surface Methodology (RSM) Approach for Optimisation of Texture and Colour Components of Microwave Dried Mango Leather

2.1. Introduction

Response surface methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes in which a response of interest is influenced by several variables and the objective is to optimize this response. RSM has important application in the design, development and formulation of new products, as well as in the improvement of existing product design. It defines the effect of the independent variables, alone or in combination, on the processes. In addition to analyzing the effects of the independent variables, this experimental methodology generates a mathematical model which describes the chemical or biochemical processes (Anjum et al., 1997; Myers & Montgomery, 1995). Before applying the RSM methodology, it is first necessary to choose an experimental design that will define which experiments should be carried out in the experimental region being studied. There are some experimental matrices for this purpose (Bezerra et al., 2008). Some examples of the RSM applications performed for optimization of food processes include optimization of fura production, processing parameter optimization for obtaining dry beans with reduced cooking time, optimization of edible oil extraction from ofada rice bran and optimization of microwave-assisted hot-air drying conditions of okra (Jideani et al., 2010; Akinoso & Adeyanju 2012; Schoeninger et al., 2014; Kumar et al., 2014).

2.2. Materials and methods

The drying experiment has been carried out in a domestic microwave oven (Samsung P70B17L-T8) with technical features of 220-240 V, 50 Hz and 700 W at the frequency of 2450 MHz. The dimensions of the microwave cavity are 262 × 452 × 335 mm equipped with a glass turn table of 320 mm diameter and a

control facility to monitor the microwave output and processing during drying operation (Ganesapillai et al., 2011; Silva et al., 2014).

Fig. 1. Microwave dried mango leather (at 200W)

2.2.1. Colour Determination

The surface colour of mango leather measured using a colorimeter (ColorFlex, HunterLab, USA). The colorimeter was calibrated with a standard white (L* = 93.71, a* = –0.84 and b* = 1.83) and black plate before each color measurement. The colours are expressed as L-value (lightness/darkness), a-value (redness/greenness) and b-value (yellowness/blueness). The overall color of the product is reported using hue angle (Thuwapanichayanan et al., 2011), which is calculated by the Equation 1:

$$\text{Hue} = \tan b/a \quad (1)$$

The measurements are performed in triplicate and the average values were reported.

2.2.2. Texture (hardness) Determination

Textural attributes of mango leather is measured using a texture analyzer TA.XT PLUS, Stable Micro Systems fitted with a 5-N load cell equipped with a 35 mm flat ended cylindrical aluminum body. The flat ended cylindrical aluminum body moved down vertically with a velocity of 2 mm/s and compressed the sample slice placed on the base. The maximum compression force in the force–deformation curve of each sample is considered as an indication of the hardness of the sample (Kotwaliwale et al., 2007; Kumar et al., 2014). The measurements are performed in triplicate and the average values (± SD) are reported.

2.2.3. Statistical Analysis

All the experimental procedures are carried out in triplicate and values recorded as mean ± standard deviation. Collected data are processed using a commercial statistical package, Design-Expert Version 8.0.1.0 (Statease Inc; Minneapolis USA, version). The software is used for analysis of variance (ANOVA), regression analysis, and optimization (Akinoso & Adeyanju, 2012). The response surface plots are generated for different interactions. The numerical optimization of the drying process is aimed at finding the levels of microwave power and drying time, which could maximize the overall colour (hue) and minimize hardness.

Levels of process variables and values of quality parameters for mango dried under microwave-drying conditions:

Sl No.	**Independent Variables**		**Response**				
	Power level (watt)	**Time (min)**	**L**	**a**	**b**	**Hue (^{0})**	**Hardness (N)**
1	300.00	12	43.47 ± 0.05	15.24 ± 0.25	31.44 ± 0.59	64.14 ± 0.05	6.36 ± 0.05
2	200	27	46.08 ± 0.06	14.49 ± 0.16	37.46 ± 0.50	68.85 ± 0.05	3.56 ± 0.05
3	300.00	42	43.53 ± 0.05	17.12 ± 0.28	32.45 ± 0.58	62.19 ± 0.05	2.77 ± 0.05
4	58.58	27	46.41 ± 0.02	13.47 ± 0.14	38.05 ± 0.58	70.48 ± 0.05	0.87 ± 0.05
5	100	42	44.81 ± 0.05	11.18 ± 0.07	33.42 ± 0.32	71.51± 0.05	0.45 ± 0.03

6	100.00	12	41.85 ± 0.08	11.41 ± 0.11	31 ± 0.40	69.79 ± 0.05	0.57 ± 0.05
7	200.00	5.79	49.13 ± 0.05	12.34 ± 0.06	39.18 ± 0.34	72.51 ± 0.05	0.73 ± 0.05
8	200.00	27	46.44 ± 0.32	14.19 ± 0.26	37.93 ± 0.74	69.49 ± 0.02	2.22 ± 0.05
9	341.42	27	46.77 ± 0.05	16.08 ± 0.15	34.45 ± 0.40	64.98 ± 0.05	6.35 ± 0.03
10	200.00	48.21	50.27 ± 0.05	15.79 ± 0.18	41.75 ± 0.52	69.27 ± 0.03	5.65 ± 0.03
11	200.00	27	46.44 ± 0.32	14.19 ± 0.26	37.93 ± 0.74	69.49 ± 0.02	2.22 ± 0.05
12	200.00	27	46.08 ± 0.06	14.49 ± 0.16	37.46 ± 0.50	68.85 ± 0.05	3.56 ± 0.05
13	200.00	27	46.38 ± 0.06	14.40 ± 0.16	37.53 ± 0.50	69.85 ± 0.05	3.76 ± 0.05

Table 1. Response under different variables

2.3. Results and discussions

2.3.1. Colour Characteristics of Mango Leather (ML) Under Microwave-Drying Process

The colour characteristics of the ML varied with microwave power and drying time. The range of L*, a *, and b* of ML were in the range of 40.29 to 50.27, 11.18 to 17.12, 29.15 to 41.75 (Table .1). These variations in the values of the colour parameters, at different drying conditions can be attributed to chemical changes in the colour pigment of the mango due to heat and oxidation during drying. The overall colour change of the dried mango slices was determined in terms of hue angle (Tables 1). A larger value of hue angle indicate a greater shift from red to yellow (Thuwapanichayanan et al., 2011). ANOVA of the effect of model parameters on colour characteristics of mango showed that linear effects of microwave power and drying time, interaction effects of microwave power and drying time, quadratic effects of microwave power and drying time, all had significant ($p < 0.05$) effects on the colour parameters L*, a*, b* and the hue of the mango varieties (Table 2). Regression models relating L*, a*, b* and hue to the independent variables, that is, microwave power and drying time for ML are shown in Tables 3 respectively. In terms of ML, quadratic, linear, reduced quadratic and quadratic models best explain the relationship between the processing variables and L*, a*, b* and hue respectively for ML (Table 3). A lack of fit test of the models was non-significant ($p > 0.05$). Non-significant lack of fit is good as this

strengthens the fitness of the models. Coefficient of determination (R^2) of models was relatively high. This guarantees a good fitness of the models when applied. The coefficients of the models parameters indicate the magnitude and significance of each model parameter with regards to their effects on the response variables, that is, the higher the coefficient of a model parameter, the higher the significance of such parameter (Jideani et al., 2010). In terms of ML, drying time (B) had the most quadratic, linear and quadratic effect on L*, a,* and hue respectively while the interactive effect of microwave power and drying time (AB) had the most significant on b* (Table 3).

Source	**L**		**a**		**b**		**Hue**		**Hardness**	
	F - value	**P- value**	**F - value**	**P- value**	**F - value**	**P- value**	**F - value**	**P- value**	**F - value**	**P- value**
Model	11.93	0.0045*	77.26	<0.0001*	12.98	0.0014*	43.43	<0.0001*	36.27	< 0.0001
A-Power	1.77	0.2315	82.48	<0.0001*	8.2	0.021*	126.09	<0.0001*	23.19	0.0007*
B-Time	1.13	0.3285	61.23	<0.0001*	4.99	0.0559	29.69	0.0006*	37.12	0.0001*
AB	36.17	0.001*	--	--	22.31	0.0015*	20.81	0.0018	--	--
A^2	0.59	0.473	--	--	23.84	0.0012*	13.18	0.0067	--	--
B^2	10.08	0.0192	--	--	--	--	13.36	0.0065*	--	--

Table. 2. ANOVA results of the effect of model parameters on colour characteristics and texture of MWD mango leather

Response variables	**Models**	**Residual lack of fit p - value**	**R^2 value**
L	+63.74882 - 0.063736*A - 0.83820*B + 2.96544E-003*A*B-2.92672E-005*A2 + 4.92963E-003*B2	0.7981	0.91
a*	+9.88953 + 0.012956*A + 0.074421*B	0.1242*	0.91
b*	+52.54853 - 0.036127*A - 0.69969*B + 3.84786E - 003*A*B - 2.03000E-004*A2	0.127*	0.87
˚Hue	+67.86640 + 0.042872*A - 0.020998*B - 1.19261E-003*A*B-7.71865E-005*A2 + 3.45282E-003*B2	0.8573*	0.97
Hardness	-1.81639 + 0.011451*A + 0.092879*B	0.3809*	0.88

Table. 3. Mathematical model for different responses

Response surface plots of the variability of L*, a*, b* and hue angle with change in microwave power levels, and drying time for ML are shown in Figures 2, 3, 4 & 5. Akinoso & Adeyanju (2012) reported that response surface plot helps to visualize the shape of the response surface and give useful information about model fitness. It is evident from the figures that there are differences in the shape of the response surface plots obtained for ML. These differences can be attributed to the effect of ML and processing conditions.

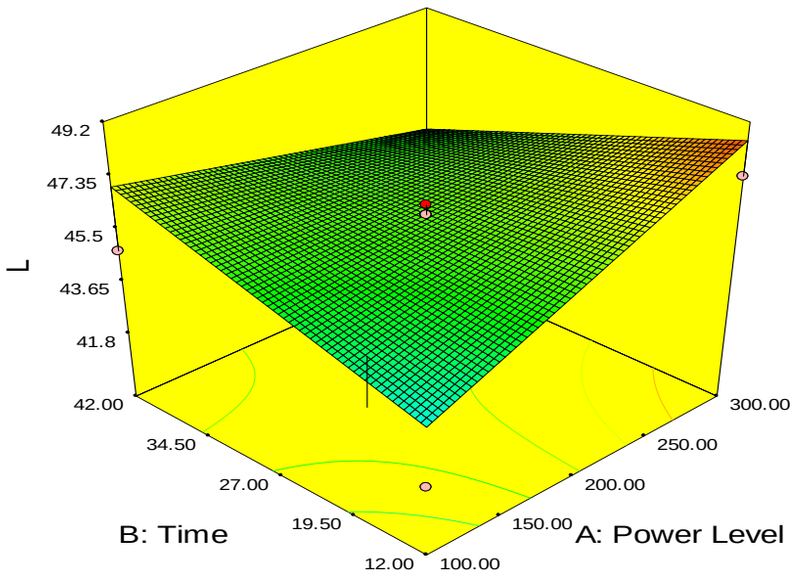

Fig. 2. Characteristics of response 'L' with respect to power level and Time

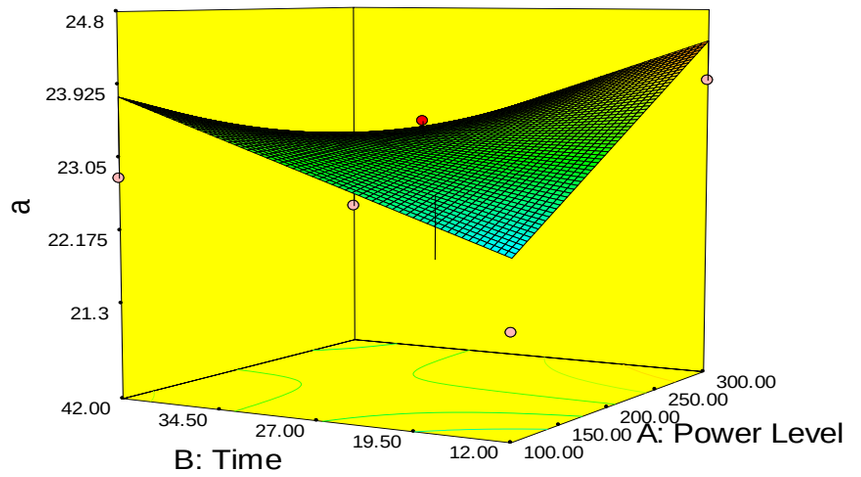

Fig. 3. Characteristics of response ‘a’ with respect to power level and Time

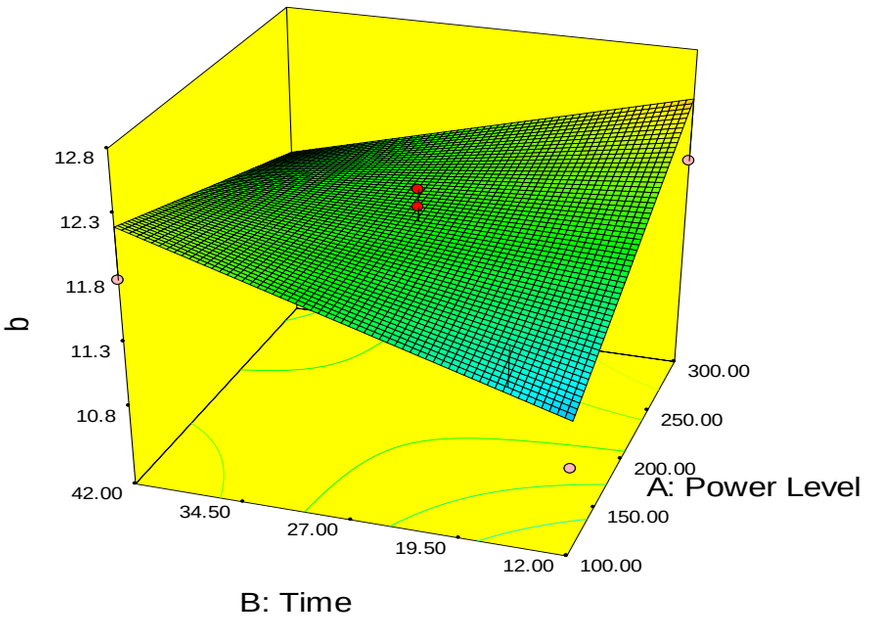

Fig. 4. Characteristics of response ‘b’ with respect to power level and Time

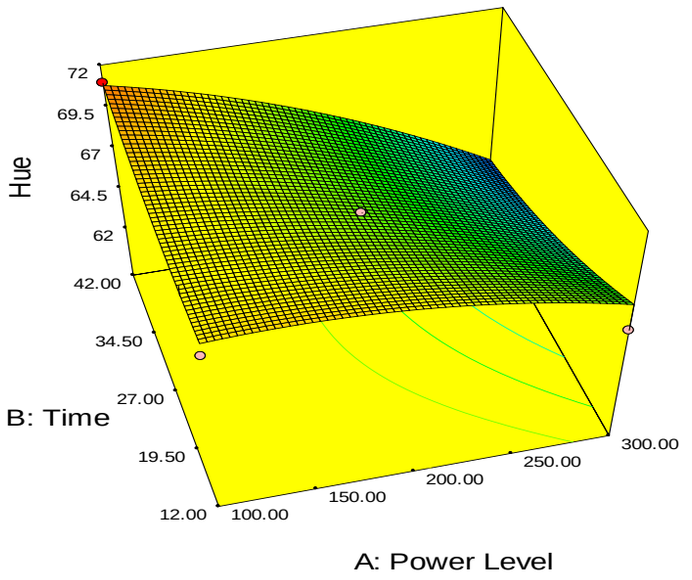

Fig. 5. Characteristics of response 'Hue' with respect to power level and Time

2.3.2. Hardness of ML under Microwave Drying Process

Hardness of ML dried under various drying conditions ranged between 1.29 to 14.28 N and 0.45 to 9.28 N. The highest value of hardness was obtained at 300 W microwave power 12 min drying time for ML (Table 1). ANOVA showed that microwave power, drying time, interaction of microwave power and drying time and quadratic effect of microwave power and drying time had significant effect on hardness of ML (Table 2). Regression models relating hardness to the independent variables obtained ML (Table 3) satisfied the lack of fit test ($p > 0.05$) with a coefficient of determination R^2 as high as 0.88 (ML), hence the models can be used to explain the functional relationship between microwave power, drying time and hardness. The Tables further showed that linear effect of drying time had the most significant effect on hardness ML (Table 3). The variability of microwave power level and drying time on hardness of ML (Fig. 6) showed that hardness increased with increase in microwave power for the two ML varieties. This might be due to crystallisation of cellulose, as a result of the high internal pressure development at high microwave power levels, (Fellows, 2009; Kotwaliwale et al., 2007).

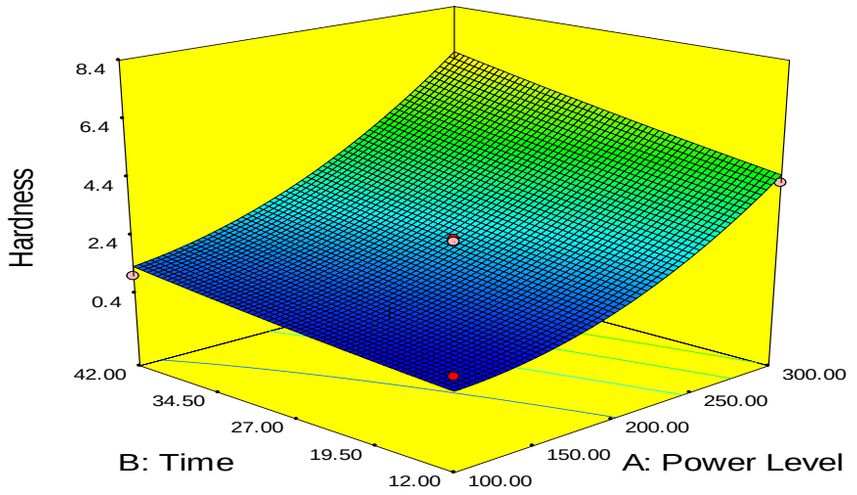

Fig. 6. Characteristics of response 'hardness' with respect to power level and Time

2.3.3. Optimization and Validation of Microwave Drying of ML

The results of optimization of drying conditions for 127.67 W microwave power, 12 min drying duration for Mango leather (ML). The predicted values of colour (hue) and hardness at the optimized conditions were 70° and 0.86 N were obtained for ML. Desirability of the obtained optimum conditions were 0.86 for ML respectively. The indication of this result is that drying of ML at the optimized drying conditions will increase energy savings and yield dried samples with good quality in terms of colour and hardness. Validation of the software generated optimum drying conditions for the ML varieties was achieved by experimentally subjecting the ML slices to the optimized drying conditions obtained by RSM. The experimental values of hue and hardness were 70.07° and 0.89 N for ML. These values are relatively close to the software generated values, hence confirming the validity of the optimized results and consistency of the regression models generated by the RSM software. Food processing industries can therefore use the optimized drying conditions as a standard or base line information for industrial processing of the ML varieties.

2.4. Conclusion

Regression models were developed to effectively predict quality parameters at any given microwave power and drying time. Good fit of the models were justified with the non-significant lack of fit ($p > 0.05$) and relatively high regression values. The drying conditions of 127.67 W microwave power, 12 min drying duration with a desirability of 0.86 was predicted for ML. Response surface methodology was effective in optimizing process parameters for microwave dried ML. Hence the optimum drying conditions obtained in this study could be used as a standard or base line information for processing of the mango leather.

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Chapter 3

3. Quality Assessment of Mango Leather Processed traditionally and by Microwave Drying Technique

3.1. Introduction

Mango (*Mangifera indica* L.), the 'king of fruits' belongs to the family Anarcardiaceae and is the national fruit of India. Mango has good nutritional value with 81.7% water, 16% carbohydrate, 0.7% protein, 0.4% fat and 0.1% fibre (per 100g mango pulp). It also contains a good amount of β-carotene, vitamin A, C, B-complex, minerals and several anti-oxidants. Being a perishable fruit, mango cannot be stored for longer time and usually consumed as fresh. In order to improve availability of mango round the year, mango pulp can be converted to many processed products like soft drinks, juice, nectar, squash, RTS beverages, jam, jelly, powder, mango bar, mango leather and canned mango slices (Parekh et al., 2014; Hashmi et al., 2007; Hussain et al., 2003). Among different processed products, mango leather, which is a dehydrated confectionery product, often eaten as snack or dessert is chewy and has mango flavor, naturally low in fat and high in fiber and carbohydrates. Therefore, consuming mango leather is an economic and convenient value-added substitute for natural mango as a source of various nutritional elements (Diamante et al., 2014).

The preparation of mango leather by dehydration may be considered as an alternate low cost preservation process (Prasad and Nath, 2002). However, conventional sun drying process is quite time consuming and also unhygienic in terms of exposure to dirt (Maskan et al., 2002). Mango leathers are now being produced with emerging drying technologies like microwave, microwave, freeze, infra-red, vacuum drying which are more effective in terms of time saving and therefore high throughput. However, a considerable amount of thermal energy is lost in convection drying and poor heat transfer ability is a disadvantage of microwave drying. Infra-red dryers used to prepare fruit leather gives the advantage of rapid drying in low operational cost and microwave drying has been observed as the fastest mode of drying due to conversion of electromagnetic energy to kinetic energy directly. However, cell damage of the product is a point of

concern in microwave drying whereas vacuum drying produces better quality product (Sarkar and Chakraborty, 2018).

In this present study, my objective was to determine and compare the quality of mango leather prepared by a contemporary drying technique (microwave drying) along with traditional sun drying method in terms of impact on nutrients, antioxidants and functional properties.

3.2. Materials and method

3.2.1. Materials used

Mangoes (*Mangifera indica*) of Langra cultivar have been purchased from Agri-Horticultural society of India, Kolkata, India. Puree from these mangoes has been used throughout the study.

3.2.2. Sample preparation

The mango puree has been dried in both microwave and traditional sun drying method. Fresh and ripe mangoes has been properly washed and pulped followed by aforementioned drying techniques to get the final product i.e. mango leather. The TSS content of the pulp for each of dried leathers has been made up to 25^0B by adding powdered cane sugar and the puree load chosen as to be 0.5g/cm^2 as per central composite design (CCD) (Azeredo et al., 2006). The leathers are then packed in air tight Polyethylene pouches and kept at 5-8^0C.

3.2.3. Microwave drying

Laboratory microwave dryer (Samsung, Combi CE1031LAT, Mumbai, India) has been employed for drying operation. The wattage applied for drying has been chosen as 200W keeping the puree load and TSS content constant and it took 87 minutes to prepare the leather.

3.2.4. Sun drying

The mango pulp has been poured on aluminium petri dishes previously smeared with oil and kept under the sunlight in open air condition. Sun rays directly incident on the pulp present in the metal surface to evaporate moisture by rising the temperature resulting in a leathery product (Sarkar & Chakraborty, 2018).

3.3. Proximate analysis

Analysis of carbohydrate, crude protein, crude fibre, moisture and ash content of the samples are carried out according to the method illustrated by Association of Official Analytical Chemists (AOAC) (Effah-Manu L et al., 2013; Prasad K, 2009)

3.4. FRAP

10 mL of sample extract [1g of mango leather is extracted in 30mL mixture (3:1 ratio) of isopropyl alcohol and deionized water by ultra-sonication (Trans-O-Sonic, Mumbai) for 30 minutes]were mixed with 3 mL of FRAP reagent [consisting of 300 mmol/L sodium acetate buffer (pH 3.6), 10 mmol/L 2,4,6tripyridyls-triazine solution and 20 mmol/L ferric chloride hexahydrate solution at a ratio of 10:1:1] and then incubated at 37^0C for 30 min before measuring the absorbance at 593 nm. The ability to reduce ferric ions of the mango leathers has been expressed as mM FeSO4 equivalents per 100 g sample (Benzie and Strain, 1996).

3.5. TPC

A modified version of the Folin Ciocalteu assay as described by Singleton and Rossi (1965) has been used to determine the total phenolic content. Independently, extract (20µL each), gallic acid and blank is prepared and mixed with 1.58 mL distilled water, then Folin Ciocalteu reagent (100 µL) and 300 µL of sodium carbonate were added to the mixture. The samples are vortexed immediately and incubated for 30 minutes at 40^0C.The absorbance is measured at 765 nm in UV-Vis spectrophotometer (UV-Vis Spectrophotometer, Thermo Fisher Scientific, India).

3.6. DPPH

2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging ability of mango leather extracts are evaluated according to Harakotr, Suriharn, Tangwongchai, Scott, and Lertrat (2014). 100 µL of extracts are taken and added to 1.4 mL DPPH radical methanolic solution (10^{-4} M). After 30 min of incubation at dark, absorbance was taken at 517 nm using spectrophotometer (UV-VIS Spectrophotometer, Thermo scientific, India). The percentage of radical-scavenging ability is calculated taking account of the formula below:

Radical scavenging acitivity (%) = $\{(A_0-A_s)/A_0\}\times100$

where, A_0 is absorbance of control and A_s was absorbance of sample extract.

3.7. TFC

Total flavonoids were measured using a colorimetric assay adapted from Kim et al., (2010). 150µL of 5% aqueous Sodium Nitrite ($NaNO_2$) was added to an aliquot (2.5 mL) of each extract and the mixture was stirred. A blank was prepared using 80% aqueous methanol instead of the sample. After keeping for5min at ambient temperature, 150 mL of 10% aqueous $AlCl_3$ and 1 mL of 1 M NaOH were added. The absorbance was measured against the blank at 510 nm. Total flavonoids were calculated with respect to quercetin standard (concentration range: 50-200 mg/mL). Results were expressed in mg of quercetin/g of the dried product.

3.8. HPLC Analysis

Phenolic compounds has been analyzed via reversed-phase high-performance liquid chromatography (Alliance 2695 HPLC system, Waters Corporation, Massachusetts, USA). Separations were achieved using Symmetry® C-18 reversed-phase column (250 mm × 4.6 mm length, 5 µm particle size) at 30 ^{0}C. Detection and quantification has been carried out with a binary pump, a dual λ absorbance UV detector 2487, inline degasser and Empower 2 software from Waters Corporation. The eluates has been detected

at 278 nm using dual λ absorbance UV detector 2487. Two solvents were used for the separation in a gradient system that ran for 40 mins. Solvent A consisted of 0.5% phosphoric acid in water while Solvent B was 90% methanol. For analysis, the samples were dissolved in methanol and 10 µL was injected into the column. The elution gradient applied at a flow rate of 1 mL/min was: 100% A/0%B for 0-8 min, 70%A/30%B in 8-15 min, 50%A/50%B in 15-20 min, 40%A/60%B in 20-25 min, 30%A/70%B in 25-35 min and 100 %B for 5 min until the end of the run.

Seventeen phenolic compounds has been considered as standard.These compounds are gallic acid, protocatechuic acid, (+)-catechin, p-coumaric acid, chlorogenic acid, caffeic acid, epicatechin, syringic acid, vanillic acid, ferulic acid, sinapinic acid, rutin, rosmarinic acid, trans-cinnamic acid, quercetin, kaempferol and apigenin. Identification and quantitative analysis has been done by comparison with standards. The amount of each phenolic compound has been expressed as mg/g of the extract.

3.9. Total Carotenoids

Total carotene in mango leather has been estimated by the method used by Sarkar and Chakraborty, 2018 with slight modification as follows, 10 ml of 80% acetone is added to 100 mg of leather and grinded well in mortar-pestle. The mixture is centrifuged at 3000 rpm for 10 min the supernatant has been collected and the volume is made up to 10 ml. The optical density values have been studied at 480 nm in ultra violet spectra. The following equation has been used to calculate the amount of carotenoids in mango leather as per AOAC standards:

$$\text{Amount of carotenoids in 100 mg leather} = \frac{4 \times \text{optical density} \times \text{total volume of sample (10 ml)}}{\text{mass of leather (100mg)}}$$

3.10. FTIR Spectroscopy/Assay

Spectral information of all type of mango leathers has been used to identify the formation of chemical bonds in all type of mango leathers and nature of chemical bonds (functional groups) present. FTIR spectra is recorded in duplicate at 25^0C using a Bruker FTIR spectrophotometer (Bruker Tensor 27, Bruker Corp, Massachusetts, USA) in the spectral range of 400– 4000cm^{-1} by accumulating 16 scans at 2 cm^{-1} resolution. After thorough mixing, approximately 1 g of the mango leather sample is positioned on the potassium bromide (KBr) plate. In between the determinations, the KBr plate being properly cleaned with acetone and also examined visually to ensure that no residue from the previous sampling is left on the plate surface. The FTIR spectra are smoothened and their baselines are corrected automatically using the built-in software of the spectrophotometer. Spectral data analysis has been carried out using BRUKER Software version 7.5 (1991) (Origin Lab Corporation, Northampton, MA, USA).

3.11. Statistical Analysis

The data has been expressed as the average of the independent experiments carried out in triplicate and analyzed using one-way analysis of variance (ANOVA). Student's t-test ($p < 0.05$) has been considered to be statistically significant.

3.12. Results and discussion

3.12.1. Proximate analysis

The carbohydrate, protein, fat, vitamin and mineral composition of both types of mango leathers are given below in the form of Table 1. There was no significant difference ($p> 0.05$) found in the proximate composition of different types of mango leathers prepared.

Macronutrient	Microwave (%)	Sun Dry (%)
Carbohydrate	77.76	78.43
Crude protein	2.05	2.19
Crude fat	0.565	0.58

Moisture	16.78	17.22
Ash	2	2

Table 1. Proximate analysis of mango leathers

3.12.2. FRAP

Ferric antioxidant reducing power is measured in terms of trolox equivalent. The ability of the mango leathers to reduce Fe^{3+} to Fe^{2+} was decreased in the following manner: Microwave > Sun Dried. The FRAP value was higher in microwave dried mango leather (7.03 mg/g db) comparable with sun dried mango leather (5.34 mg/g db). Statistical analysis showed a significant difference ($p< 0.05$) between FRAP values with mode of change of drying. The FRAP values reported by Aziz et. al. (2012) for ripe mango pulp flour was higher than what we found in this study, this may be due to the cultivar difference.

3.12.3. TPC

The total phenolic content (TPC) of mango leathers varied in different processing conditions having statistical significant effect ($p< 0.05$). Total phenolic content decreased in the following manner: Microwave > Sun Dried. The TPC value was significantly lower for sundried mango leather (4.1 mg/g db) due to heat damage for keeping the leather under sun for prolonged period. Microwave dried leather indicated a TPC value of 6.3 mg/g db. The values indicate degradation of total phenolics when exposed to increased temperature at atmospheric condition for longer residence time. Brat et al., (2006) and Luximon-Ramma et al., (2003) have found higher TPC may be due to difference in variety, post-harvest treatment and alteration in extraction procedure (Shofian et al., 2011).

3.12.4. DPPH

DPPH values (expressed in terms of %) indicated the radical scavenging activity of the mango leathers prepared. The free radical scavenging activity determined by DPPH method exhibited as 7.22% and 6.714% for microwave dried and sun dried mango leather respectively which means the microwave dried mango leather has the better free radical scavenging activity. The incorporation of thermal energy may

enhance the rate of oxidation of diphenol to quinone. Higher the rate of reaction superior will be the rate of degradation of phenolic compounds leading to inferior antioxidant activity (Shofian et al., 2011). Hunter and Fletcher, (2002) has observed similar degradation of free radical scavenging activity for spinach and pea.

3.12.5. TFC

Similar to FRAP and TPC, the total flavonoid content (TFC) exhibited the increasing order of flavonoid content: Microwave > Sun Dried. TFC of sun dried mango leather was the lower than microwave dried leather (2.75 mg/g db) being 2.21 mg/g db. This result can be comparable with FRAP and TPC, where the result indicates the damage of bioactive components with increased temperature exposure for a longer residence time.

3.12.6. Polyphenolic composition by HPLC

The composition of phenolic compounds present in the extract prepared from the mango leather was interpreted by the HPLC analysis. As the compounds present in the sample extract was more on the polar side, reversed phase HPLC was chosen to be performed. Out of the 17 standard phenolic compounds around 11-12 compounds were found in each type of mango leather, the predominant of which was gallic acid. The other phenolic compounds that were detected in the chromatogram was dihydroxy benzoic acid, catechin, vanillic acid, cholorogenic acid, dihydrocaffeic acid, rutin, trans cinnamic acid, ferulic acid, quercetin, kaemferol and apigenin. Gallic acid content was found higher in the microwave dried mango leather (Fig. 2) having a value of 43.53 mg/kg db and lowest in the sun dried leather (0.3 mg/g db) (Table 2). In case of microwave dried leather the retention of the phenolic compounds were better than sun dried leather provided the power settings of the microwave.

Polyphenol name	Sun dried (mg/kg)	Microwave dried (mg/kg)
Gallic acid	0.30512	43.53493
Dihydroxy benzoic acid	0.02829	18.41602

Catechin	0.03937	3.081904
Vanillic acid	0.06008	4.290943
Cholorogenic acid	0.0662	0.639502
Dihydroxy cinnamic acid	0.02353	1.14159
Rutin	0.00493	0.441012
Trans cinnamic acid	0.03667	0.41389
Ferulic acid	0.08310	12.89018
Quercetin	0.37471	9.310958
Kaempferol	0.21862	46.45688
Apigenin	0.21240	21.23985

Table 2. Amount of phenolics in sun and microwave dried mango leather

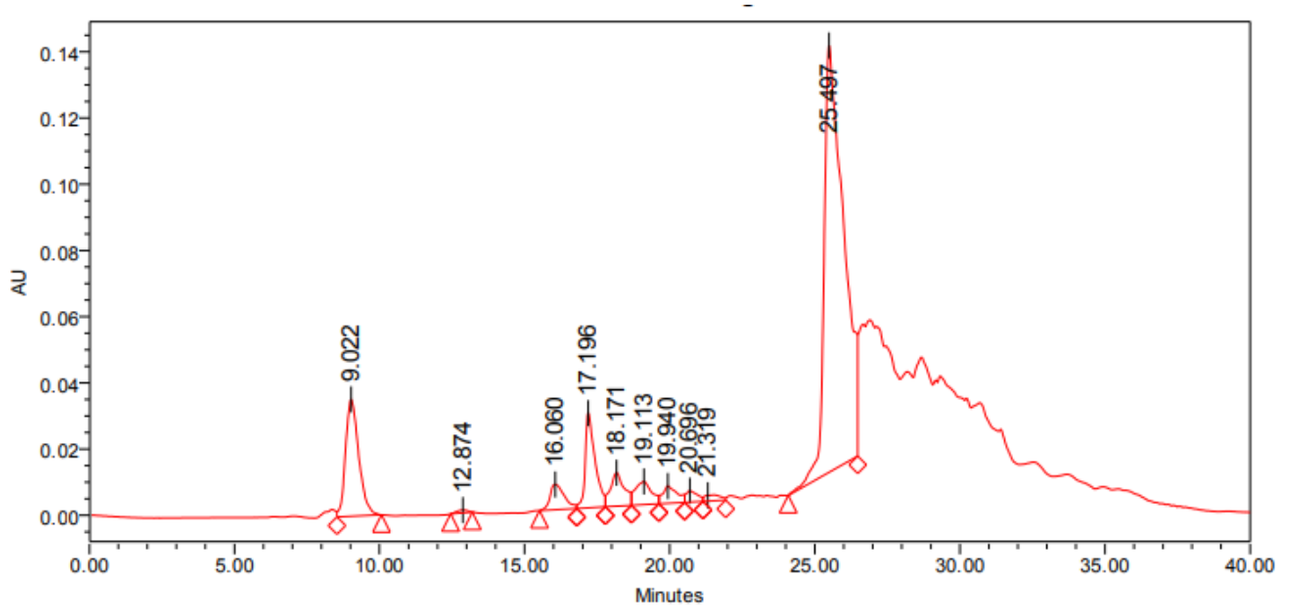

Fig. 2. Chromatogram of microwave dried mango leather

3.12.7. Total carotenoids

Fresh mangoes of langra cultivar have been found to contain 293.4 µg/g db of carotenoids. Mangoes of different cultivar contribute different contents of carotenoids as seen in the case of (Link et al., 2017). Carotenoids contain pigment that results in yellow to orange colour of fruits and vegetables stored in lipid membrane or within the plasma vacuoles (Maiani et al., 2009). These pigments are susceptible to oxidation provided increasing temperature. The total carotenoids content has been varied significantly ($p< 0.05$) with different drying condition. Sun dried mango leather contains 169.18 µg/g carotenoid and is followed by microwave dried leather (163.52 µg/g).

3.12.8. FTIR Analysis

Nature of spectral bands has been studied by FTIR analysis. FTIR spectra of mango leathers are shown in Fig.2. The O-H stretching frequency is observed between 3557-3377cm^{-1} for polyphenols namely gallic acid and also for ß-carotene. Asymmetric stretch of >CH_2 group has been found at wavenumber 2930-2932 cm^{-1} in both types of leathers for gallic acid and ß-carotene. Vijayalakshmi and Ravindhran, (2012) has observed absorbance for gallic acid in the similar range for Bakh (*Diospyrus ferrea*) root. C=O stretch of polyphenols, flavonoids and catechins are observed at a spectral range of 1629-1663 cm^{-1} in both types of prepared mango leather. C-H deformation of ß-carotene has been observed at 1336.69 cm^{-1}. Functional group –C-O alcohols of catechin and gallic acid is to be found is all types of samples at 1047.89 cm^{-1}.

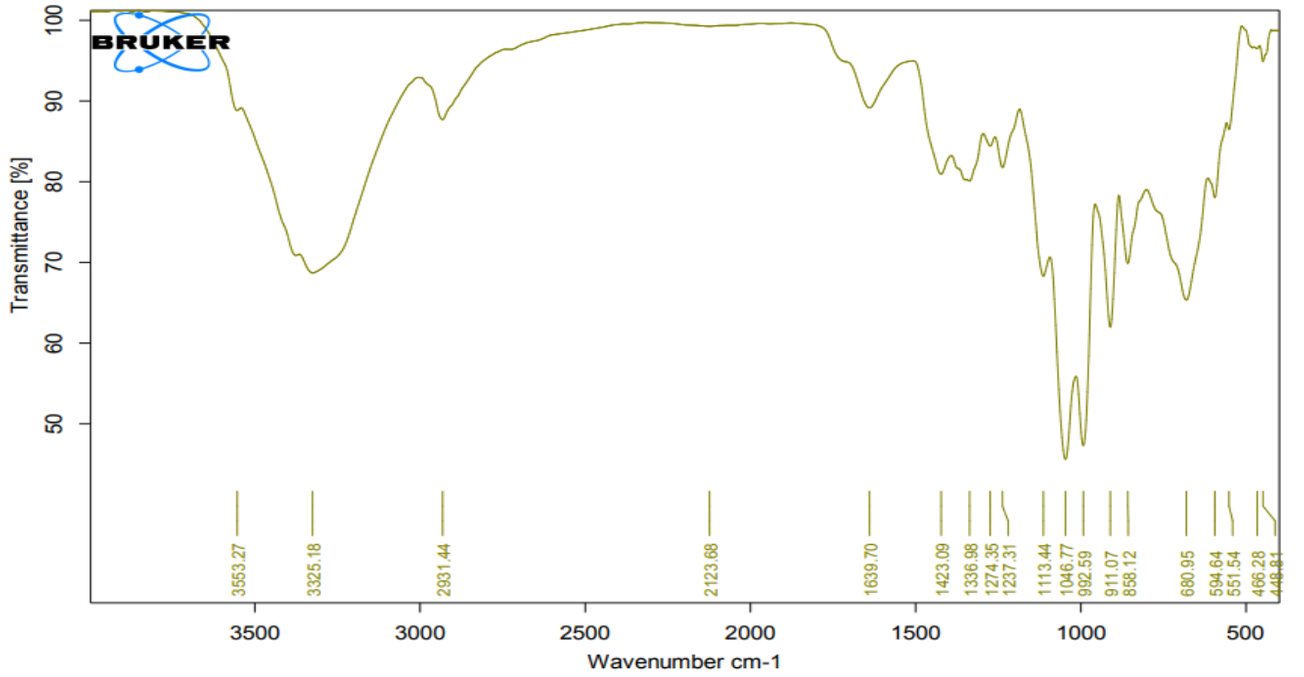

Fig. 3. FTIR spectra of microwave dried mango leather

3.13. Conclusion

Microwave dried mango leather has been found to be superior in terms of TPC (6.3 mg/g db), TFC (2.75 mg/g db) but slightly lower in carotenoid content (169.18 µg/g fresh weight). It has been also studied that the microwave dried mango leather hold higher antioxidant retention activity than traditional mango

leather and mango leather processed through sun drying method. Though, harder texture and natural colour of mango leather been appreciated by inhabitants. Sun dried mango leather has been found to be paramount with respect to exterior physiognomies. Statistical investigation clearly indicates the mango leather processed by means of traditional method has been significantly ghettoized from other contemporary methodology of preparation.

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Chapter 4

4. Storage study of mango leather in sustainable packaging condition

4.1. Introduction

Mango (*Mangifera indica*) belongs to the Anacardiaceae family. Due to its flavour, taste and fragrance it is called as "King of fruits" (Nunes et al., 2007). Apart from sensory superiorities, mango has significant amount of bioactive compounds with antioxidant activity. Ripe mango contains high gallic acid and total polyphenols (Danalache et al., 2014). The significant amount of vitamin C, β-carotene and minerals in ripe mango are helpful in prevention of cardiovascular disease and cancer (Alothman et al., 2010; Liu, 2003; Sanchez-Robles et al., 2009). More than 1000 varieties of mango are being cultivated all over the world, and it occupies the second position as a tropical crop in terms of amount of production and coverage area of cultivation (Solís-Fuenteset al., 2011; Muchiri et al., 2012). India produces 66% of total world mango production (Shafique et al., 2006), thus holding the first position (Jahurul et al., 2015). Despite this huge amount of production there is no such proper post-harvest management and processing which results more than 30% wastage of production (Carrillo-Lopez et al., 2000, Rathore et al., 2007) which costs about 480 million dollar (FAO, 2004). As mango is a climacteric fruit, conditions like improper harvesting time, condition of ripening, and absence of suitable storage facilities affect the price and availability of mango and mango products (Lalel et al., 2003). The high moisture content of mango (81.7%) makes it perishable in nature and so it is consumed mostly as fresh. (Hashmi et al., 2007). To obtain the taste and benefits of mangoes in off seasons a variety of processed mango products are produced like juice, mango bar, jam, jelly, mango powder, canned mango slices, mango purees and mango leather (Djantou et al., 2011; Ledeker et al., 2014; Liu et al., 2014; Hussain et al., 2003; Sogi et al., 2015; Sriwimon and Boonsupthip, 2011). Mango leather is a popular product in India (Danalache et al., 2014). The main objective of this present research is to select most appropriate flexible packaging material and proper storage condition for mango leather to enhance its shelf life and make it available round the year.

4.2. Material and method

Mangoes of cv. Langra are collected from Agri-Horticultural society of India, Kolkata, West Bengal, India. Sound, fresh and ripe mangoes has been washed with clean water and then fruits are peeled by knife. Pulp has been collected by squeezing the flesh of mangoes and further blended in an electric blender (Prestige Stylo, Serial no. 9B 4030, 2800 rpm). The total soluble solid (TSS) of mango pulp has been raised to 25^0B by addition of powdered cane sugar (8% (w/w)). It is stored in a deep freeze (New Brunswick Scientific, England, C340-86) at a temperature of -18^0C for future use (Sarkar and Chakraborty, 2018).

35g of this pulp have been poured in petri dish and dried in microwave oven (Samsung Combi CE1031LAT , Mumbai, India) to achieve a moisture content of 15-18%. After drying, sheet has been cut into (75 mm × 50 mm × 2.5 mm) bar form. Prepared mango leathers have been packed in packaging pouches [200 gauge high density polyethylene (HDPE), 260 gauge Metallised polyethylene terephthalate (MET PET), 200 gauge Low density polyethylene (LDPE) and biodegradable paper pouches (PP)] purchased from RKP Polybags Private Limited, Chennai, Tamilnadu, India. Packed samples are stored in room temperature (30 ± 5^0C). Samples have been withdrawn at one month intervals for analysis purpose.

The mango leather were analysed as follows. All the determinations were done in triplicate and the results were expressed as average value.

4.2.1. Nutritional analysis

The moisture content, crude protein, crude fibre, carbohydrate and ash content of mango leather was analysed according to AOAC methods (Effah-Manu et al., 2013; Prasad, 2009). The acidity, reducing sugar and total sugars of the samples have been analysed by Lane and Eynon method (Effah-Menu et al., 2013; Ranganna, 1986).

4.2.2. Determination of vitamin C (total ascorbic acid) content

The following procedure has been followed to determine the vitamin C in mango leather, 10 ml of sample extract has been poured in a 100 ml volumetric flask and the volume has been made up by 0.4% oxalic acid solution. After filtration of this solution through Whatman No. 4 filter paper, 10 ml of the filtrate has been pipetted into a conical flask, and 15 ml of 0.4% oxalic acid solution has been added to it. The solution has been titrated against 0.04% aqueous sodium dichlorophenolindophenol solution, the end point has been detected on appearance of first pink shade. 0.01 N sodium thiosulfate along with potassium iodide (50%) and 1 N HCl has been used to standardize sodium dichlorophenolindophenol solution using starch as indicator (Effah-Menu et al., 2013; Sharma et al., 2016) The amount of total ascorbic acid has been determined through the following equation (Sharma et al., 2016):

$$\text{Ascorbic Acid } \left(\frac{mg}{100g\ sample}\right) = \frac{0.5\ mg}{V1} \times \frac{V2}{15\ ml} \times \frac{100\ ml}{weight\ of\ sample} \times 100$$

4.2.3. Sensory analysis

A semi-trained panel of 30 staff and research scholar (19 male and 11 female) from Jadavpur University, aged between 25 to 55 years, evaluated the mango leather sample for overall acceptability. The nine point hedonic scale, ranging from 1 to 9 as dislike extremely to like extremely has been used for ranking of mango leather samples. Randomly generated three digit codes have been assigned to all the samples. All the samples have been presented to the panelist at room temperature (30 ± 5^0C) and in normal light. After evaluations of each sample, panelists rinse their mouth with potable water and to neutralise the taste with puffed rice (AlJahani and Cheikhousman, 2017).

4.2.4. Statistical analysis

All the data obtained has been assessed by one way analysis of variance (ANOVA) and samples are segregated using Fisher's least square difference (LSD). At $p \leqslant 0.05$ the results have been considered statistically significant.

4.3. Results and discussion

The ash, reducing sugar, total sugar, carbohydrate, total acidity and crude protein content are 2%, 21%, 66%, 82.5%, 1.23% and 2% respectively; ash, reducing sugar, total sugar, carbohydrate, total acidity and crude protein these parameters are found to be constant throughout the storage period of six months and irrespective of packaging materials.

From Fig. 1 it is evident that moisture gain for the mango leather packed in PP is highest (20%) over the storage period followed by LDPE, HDPE and MET PET. This may be due to the lower Water Vapor Transmission Rate (WVTR) of MET PET (19 g μm/m^2 Day) in comparison to HDPE (125 g μm/m^2 Day), LDPE (375-500 g μm/m^2 Day) and PP has the highest WVTR (Maganraj et al., 2009; Ayvaz et al.,2012). Results show choice of packaging material significantly affects the moisture gain of mango leather and MET PET has been preferred over the other packaging material with respect to the moisture absorption of mango leather.

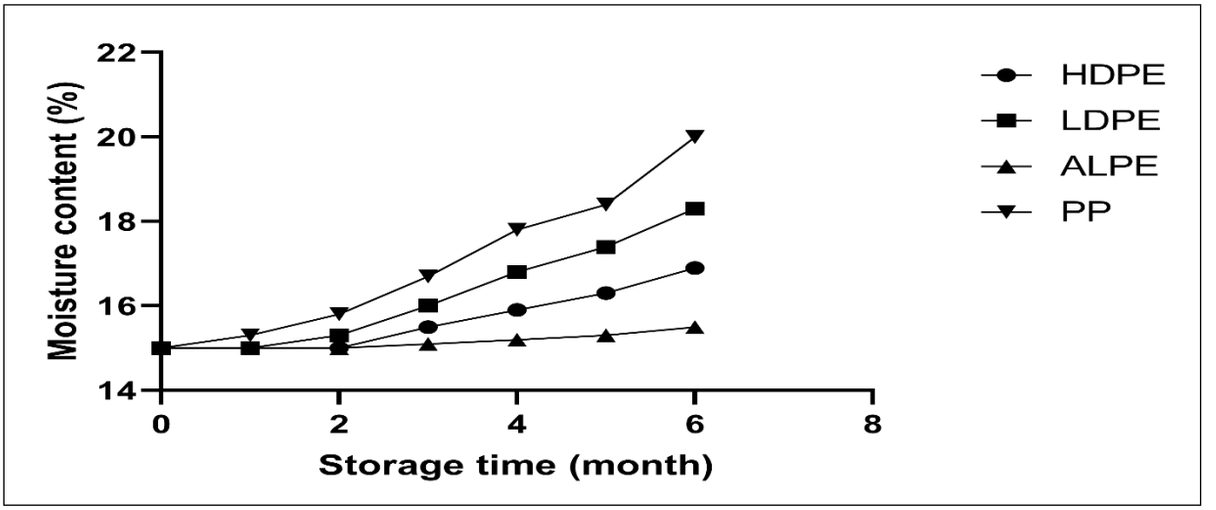

Fig. 1. Moisture content vs Storage period of Mango leather in different packaging material

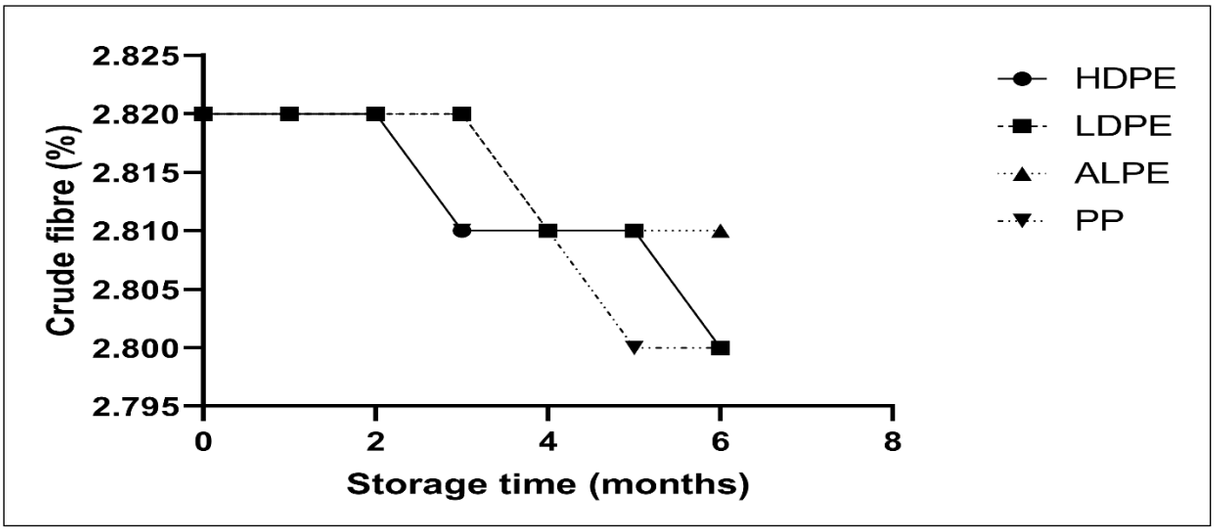

Fig. 2. Crude Fibre vs Storage period of Mango leather in different packaging material

From Fig. 2 it can be established that, mango leather packed in all the four packaging material having the initial crude fibre (CF) 2.82%, after 6 months of storage the product packed in MET PET shows the lowest change in CF value (2.81%) and for the mango leather packed in HDPE, LDPE and PP the CF value is found identical (2.80%). During the storage of 6 months the choice of packaging material is found to be insignificant ($p<0.05$) in terms of CF content of mango leather.

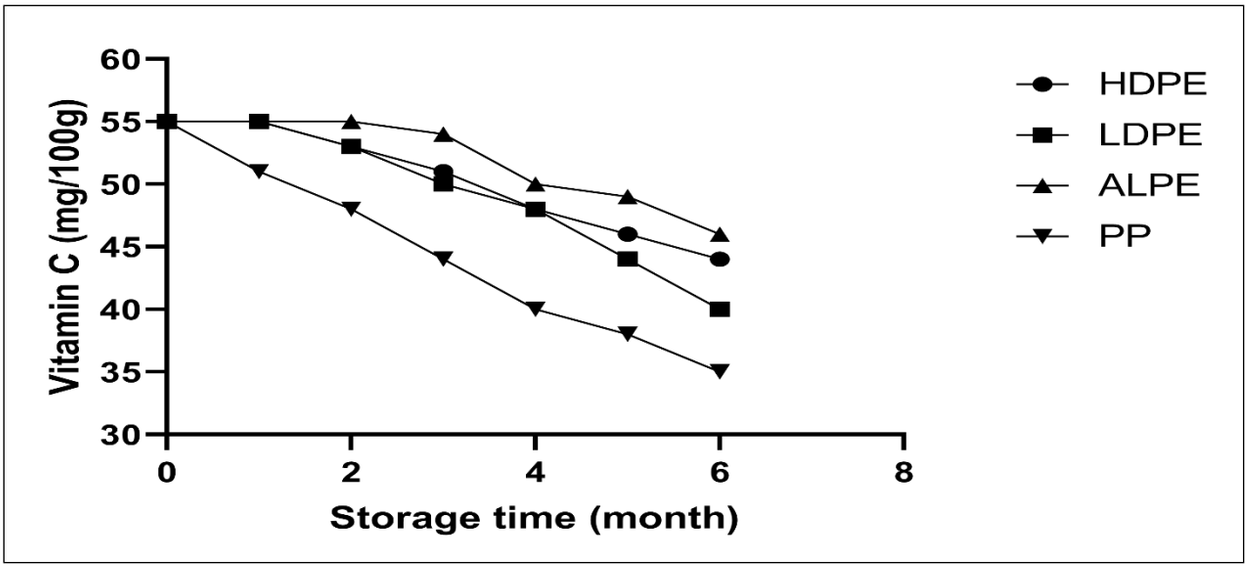

Fig. 3. Vitamin C vs Storage period of Mango leather in different packaging material

Fig. 3 explains the denaturation of vitamin C with storage time in different packaging materials. At the beginning of the experiment vitamin C content of the mango leather is 55 mg/100g. But with increase in storage time, the vitamin C content of mango leather packaged in PP decreases drastically. The vitamin C content of mango leather packed under HDPE and LDPE decrease similarly up to 3 months of storage but thereafter the reduction rate of vitamin C for mango leather packed in LDPE increases and after 6 month it comes down to 35 mg/100g. After 6 months of storage the vitamin C content for mango leather packed in HDPE is 44 mg/100g. Mango leather packed in MET PET shows minimum loss in vitamin C content. The Oxygen Transmission Rate (OTR) value for MET PET is (1.33±0.04 cc/m^2/day) lowest among the packaging material chosen in this experiment, followed by OTR value for HDPE (1666-30141cc/m^2/day), LDPE (6600-8750 cc/m^2/day) and PP has the highest OTR value (AlJahani et al., 2017). The higher the OTR value, higher amount of oxygen will be transmitted into the packet so the mango leather get oxidised. This may be the cause of decrease in the vitamin C content of mango leather. Thus, packaging material significantly affected the vitamin C content over 6 months of storage.

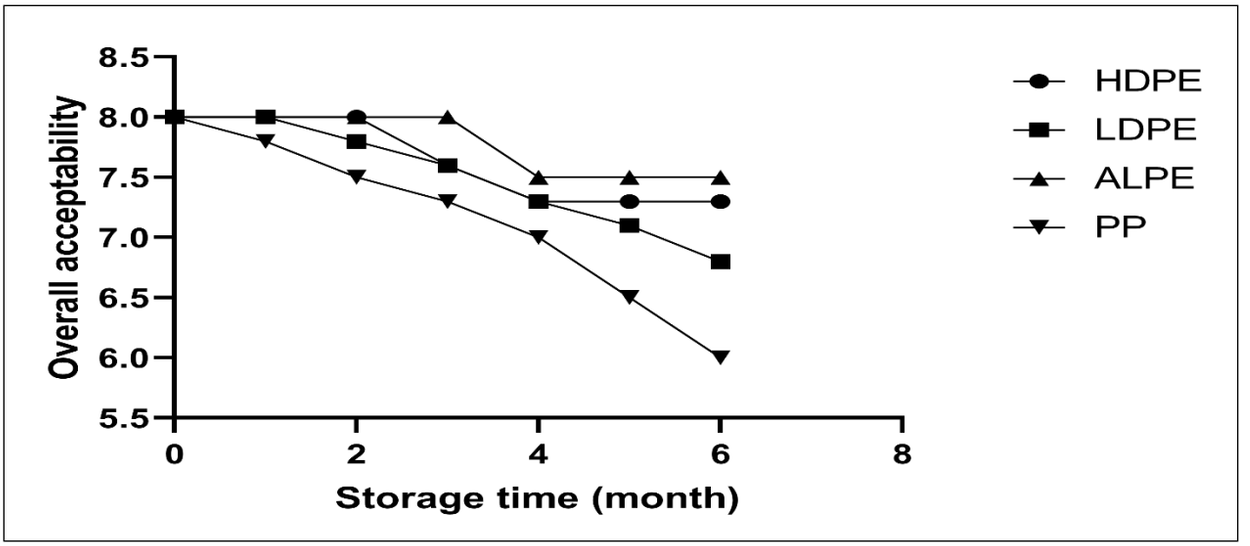

Fig. 4. Overall Acceptability vs Storage period of Mango leather in different packaging material

From Fig. 4 it is obvious that overall acceptability of mango leather enveloped in MET PET for first three months of storage is stagnant, whereas the stipulated parameter for mango leather packaged in HDPE is persistent for first two months of storage but for mango leather packed in LDPE it is deteriorating after one month of storage. The rate of declining of overall acceptability is highest for mango leather packed in PP and a sharp deteriorating rate is observed from fourth month of storage. Selection of packaging material is found to be insignificant in degeneration of overall acceptability over 6 months of storage.

4.4. Conclusion

The maximum moisture gain is observed for mango leather packed in PP (20% moisture) whereas only 15.5% moisture content is found for the mango leather packed in MET PET at the end of 6 months, which is lowest among the mango leather packed in four different packaging films. The miscellany of packaging film is found insignificant in case of CF during the storage period of 6 months. The initial vitamin C content of mango leather (55 mg/100g) decreases down over the storage period. The vitamin C content of mango leather packed in MET PET after 6 month of storage is highest (46 mg/100g) followed by mango leather packed in HDPE (44 mg/100g), LDPE (35 mg/100g) and PP (23 mg/100g). The preliminary value

of total carotenoid is 12.2% for fresh mango leather. After 6 months of storage it has been found to be 11% for the mango leather packed in MET PET, 10.8% for the mango leather packed in HDPE, 10.3% for the product packed in LDPE and the lowest value of 9% for the mango leather packed in PP. Initially the overall acceptability for mango leather is 8 in nine points hedonic scale. After 6 months of storage the overall acceptability for mango leather packed in MET PET has been found highest (7.5) followed by the product packed in HDPE (7.3), LDPE (6.8) and PP (6). Mango leather packed in MET PET has been found best among the product packed in HDPE, LDPE and PP. So it can be concluded over the storage period of 6 months at temperature of 30 ± 5^0C, MET PET is the best packaging material for mango leather.

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5. Future Scope

In the present comparative study, mango leather prepared by microwave drying and sun drying has been characterized.

- In future, to continue this work further, mango leather can be prepared by some other contemporary techniques (for eg. Freeze Drying, Infra-Red Drying, Hot Air Drying to name a few) and therefore can be compared with the traditional sun dried mango leather.

- To increase the shelf stability of the product several other packaging (Modified Atmosphere Packaging, Active Packaging) atmosphere might be explored.

- Flavor profiling (GC-MS), Quantitative & Consumer centric sensory analysis options of the samples might be discovered to get a better idea of consumer acceptability of the mango leathers produced.