ASSESSMENT OF BIOACTIVE COMPOUNDS AND PRODUCT DEVELOPMENT FROM MAJOR *GARCINIA* SPP. OF KERALA

by

APARNA G. S.

(2017-22-004)

THESIS

Submitted in partial fulfillment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POSTHARVEST MANAGEMENT

COLLEGE OF AGRICULTURE

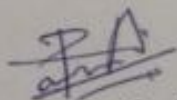**VELLAYANI, THIRUVANANTHAPURAM-695522**

2023

DECLARATION

I, hereby declare that this thesis entitled **"ASSESSMENT OF BIOACTIVE COMPOUNDS AND PRODUCT DEVELOPMENT FROM MAJOR *GARCINIA* SPP. OF KERALA"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani

Date: 23.06.2023
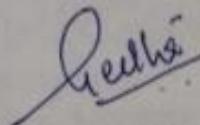
Aparna G. S.

(2017-22-004)

CERTIFICATE

Certified that this thesis entitled **"ASSESSMENT OF BIOACTIVE COMPOUNDS AND PRODUCT DEVELOPMENT FROM MAJOR *GARCINIA* SPP. OF KERALA"** is a record of research work done independently by Ms Aparna G. S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani

Date: 23|6|2023

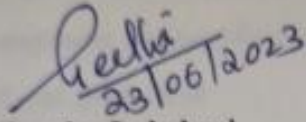**Dr. P. R. Geetha Lekshmi**

(Major Advisor, Advisory Committee)

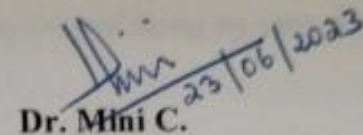Assistant Professor

Department of Postharvest Management
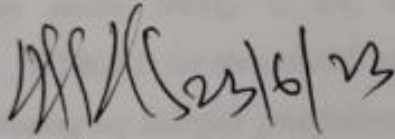
College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Aparna G. S. a candidate for the degree of **Doctor of Philosophy in Horticulture** with major in Postharvest Management agree that the thesis entitled **"ASSESSMENT OF BIOACTIVE COMPOUNDS AND PRODUCT DEVELOPMENT FROM MAJOR *GARCINIA* SPP. OF KERALA"** may be submitted by Ms Aparna G. S., in partial fulfillment of the requirement for the degree.
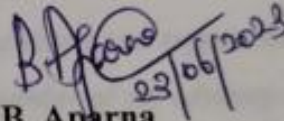
Dr. P. R. Geetha Lekshmi
(Chairman, Advisory Committee)
Assistant Professor
Department of Postharvest Management
College of Agriculture, Vellayani
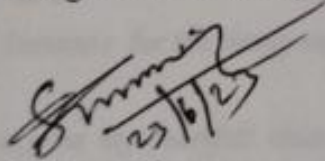
Dr. Mini C.
(Member, Advisory Committee)
Professor and Head
Department of Postharvest Management
College of Agriculture, Vellayani
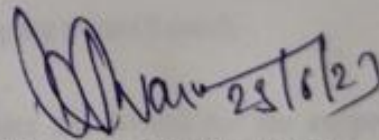
Dr. Anith. K. N.
(Member, Advisory Committee)
Professor and Head
Department of Microbiology
College of Agriculture, Vellayani

Dr. B. Aparna
(Member, Advisory Committee)
Professor & Head
Department of Organic Agriculture
College of Agriculture, Vellayani

Dr. K. B. Rameshkumar
(Member, Advisory Committee)
Scientist
Phytochemistry and Phytopharmacology
Jawaharlal Nehru Tropical Botanic
Garden and Research Institute, Palode

EXTERNAL EXAMINER
Dr. K.R.Vasudeva
Professor and Head
Department of Post Harvest Management
College of Horticulture
UHS Campus, GKVK post,
Bengaluru-560 065

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Sl. No.	Title	Appendix No.
1	Score card for assessing organoleptic qualities of *Garcinia* nectar	I
2	Score card for assessing organoleptic qualities of osmodehyrated *G.gummi-gutta* rind	II
3	Score card for assessing organoleptic qualities of ready to cook paste from *G.gummi-gutta* rind	III
4	Score card for assessing organoleptic qualities of sweet and sour *G.gummi-gutta* pickles	IV

LIST OF ABBREVATIONS

^{0}C	Degree Celsius
%	Per cent
Min	Minutes
Ml	Milli litre
CD	Critical difference
CFU	Colony forming unit
et al.	And co-workers
g	Gram
Mm	Milli molar
H	Hour
µg g^{-1}	Micro gram per gram
Mg	Milligram
mL^{-1}	Per millilitre
NS	Non significant
viz.,	Namely
TSS	Total Soluble Solids
SG	Solid Gain
WL	Weight Loss
WR	Weight reduction
TPC	Total Phenol Content
HCA	Hydroxy Cirtic Acid
TFC	Total Flavonoid Content

Introduction

1. INTRODUCTION

Garcinia is an important genus of the family Clusiaceae, distributed widely in tropical Asia, and Africa.   *Garcinia* plants are rich source of secondary metabolites including phenolic compounds, xanthones, flavonoids, benzophenones, organic acids, and lactones, with immense potential to use as a food supplement (Patil and Appaiha, 2015; Rameshkumar, 2016). *Garcinia* spp. received significant attention in the prevention and treatment of chronic diseases as the extracts of different plant parts had chemical compounds with potential effectiveness (Santo *et al.,*2020).

Garcinia gummi-gutta, G. mangostana and G. xanthochymus are the major fruit yielding *Garcinia* species of Kerala with economic importance. *G. gummi-gutta* popularly known as Kudampuli or Malabar tamarind is grown in homesteads of Kerala for the acidic fruit rind which is used as a condiment (Abraham *et al., 2006*).

Garcinia fruits are of high commercial importance as it is a rich source of hydroxycitric acid, an anti obesity phytochemical and several industries of pharmaceutical, food, and nutraceutical concentrated on their potential benefits (Hemshekhar, *et al*., 2011, Magadula and Mbwambo, 2014).

Mangosteen (*Garcinia mangostana* L.), is famous for its nutritious edible aril. Mangosteen pericarp showed significantly higher flavonoid, phenols, and anthocyanin pigment than of other coloured plants (Azima *et al.,* 2017). The fruit had been shown to have many pharmacological activities such as antioxidant, antidiabetic, antibacterial, anti-inflammatory, antifungal, antimalarial, and anticancerous properties (Kalick *et al.,* 2022).

Garcinia fruits are rich sources of bioactive compounds and have great potential in development of functional food products with health benefits. Even though there is a huge potential for commercialization of products from *Garcinia,* they remain under exploited. *Garcinia* fruits are available during specific seasons,

therefore it is essential to preserve the fruits, so that they could be made available throughout the year. To avoid wastage during the surplus season, fruits have to be processed into several value added products using different methods of preservation. The Malabar tamarind rind could be processed to spice paste, pickles and osmodehydrated products with nutraceutical properties and consumer acceptability.

Hence the present study was undertaken with the objective to assess the bioactive compounds in major *Garcinia* species of Kerala *viz. G. gummi-gutta* (Malabar tamarind), *G. mangostana* (mangosteen)*, G. xanthochymus* (yellow mangosteen) and development of value added products with nutraceutical importance.

Review of Literature

2. REVIEW OF LITERATURE

The chemical structures that plant produce had wide range of applications in a number of industries, including medical, cosmetics, food, and nutraceuticals. There is a growing global knowledge on the plant-derived products and use of phytochemicals, despite the availability to substitute with synthetic alternatives (Croteau *et al*., 2000). *Garcinia* is the largest genus in the family Clusiaceae (formerly Guttiferae) which is dioecious and comprises of more than 395 species all over the world. The *Garcinia* fruits are rich source of nutrients, dietary fibers, minerals, and vitamins, and are well known for resins, essential oils, fats, and pigments (Hemashekhar *et al.,* 2011).

The present study was focused on to assess the bioactive compounds in major *Garcinia* spp. of Kerala *viz. G. gummi-gutta* (Malabar tamarind), *G. mangostana* (mangosteen),*G. xanthochymus* (yellow mangosteen)and development of value added products with nutraceutical importance. This chapter describes the review of research findings on *Garcinia* spp. for its composition, bioactive compounds and value addition.

2.1 MAJOR *GARCINIA* SPECIES OF KERALA

The genus *Garcinia* is distributed in the tropics, mainly Asia, with approximately 200 species of which 30 species are under cultivation (Hammer, 2001). Numerous *Garcinia* species produce fruits with edible arils that are consumed regionally. Exocarp from fresh as well as dried *Garcinia* fruit is used as a spice, condiment, and garnish in many different cultures to give food an acidic flavour and lengthen the shelf life (Parthasarathy *et al*., 2013). *Garcinia gummi-gutta, G. mangostana , G. indica , G. dulcis , G. cowa , G. atroviridis ,* and *G. xanthochymus* are the important *Garcinia* spp. of western Ghats of India. Among these *G. indica, G. gummi-gutta and G. mangostana* are exploited as fruit crop.

Gamboge, the yellow colouring pigment, is a widely known product from *Garcinia* species and some species are rich source of red pigments also. *Garcinia* fruits are good source for an anti-obesity compound (-) hydroxycitric acid (HCA) which has industrial importance (Hemshekhar *et al*., 2011; Parthasarathy *et al.*,2013).

The *Garcinia* species selected in the present study are described below

2.1.1 *Garcinia gummi-gutta* (L.) Roxb.

Garcinia gummi-gutta trees are widely known as Malabar tamarind or kudampuli which is an evergreen, small or medium-sized dioecious tree. The bark is smooth and dark, leaves are opposite, petiolate, dark green and shiny. The fruit is ovoid berry, 5 cm in diameter, yellow or red when ripe, with 6-8 grooves, large smooth seeds 6 to 8.5 cm long and 2 cm width surrounded by a succulent aril. The fruits may vary in size weighing from 50 to 180 g (Benny, 2003). *Garcinia gummi-gutta* (L.) Roxb. (Syn.: *Garcinia cambogia* (Gaertn.) Desr;) is an indigenous tropical under exploited semi-domesticated crop. *Garcinia cambogia* trees are economically important fruit crop and a crucial component of the forest flora of the Western Ghats and three varieties of the species were reported from India (Shameer *et al.,* 2016).

Garcinia gummi-gutta fruits are valued as a condiment in South India due to its acidic flavour of rinds, used instead of tamarind or lemon, for flavouring curries, especially seaood cuisine. The extract additionally serves as a completely unique flavour enhancer in beverages, gourmet spice and as a post-prandial carminative (Sergio, 1988).

Malabar tamarind fruits are considered as an exceptional source of antioxidants, polyphenols, vitamins C, E and carotenoids (Vinson *et al.* 2001). Rheumatism and bowel issues were treated in traditional medicine with the malabar

tamarind juice or powdered rind and also the preparations are utilized as an emetic, purgative, hydragogue, and antihelminthic (Abraham *et al*., 2006).

The crude extract (constituents) from the various plant part of *G. gummi gutt*a exhibitted hypolipidaemic, antidiabetic, anti-inflammatory, anticancer, anthelmintic, anticholinesterase and hepatoprotective activities. Phytochemical studies confirmed the occurrence of xanthones (eg. carbogiol) and benzophenones (eg. garcinol) together with organic acids (Hydroxy Citric Acid) and amino acids (eg. gamma aminobutyric acid) contribute the properties (Semwal *et al.,* 2015).

Two morphotypes of malabar tamarind were subjected to a comparative morphological and physicochemical analysis, which revealed significant differences in fruit and leaf morphology (Bohra and Waman,2019). The *G. gummi-gutta* seeds are a rich source of edible fat with stearic acid as the major constituent and could be used for confectionary products and chocolates (Rani *et al.,* 2022)

2.1.2 *Garcinia mangostana* Linn.

Mangosteen (*Garcinia mangostana*) fruits are round, red to purplish in colour, soft, juicy with pleasant flavour and aroma. It is also known as "Queen of the fruits". It is commonly cultivated in tropical countries throughout Asia, such as Thailand, India, Malaysia, Vietnam, Indonesia and the Philippines. Fruits are composed of 17% outer pericarp, 48% inner pericarp, 31% flesh and 4% cap (calyx). To create a new market, a variety of processing techniques, such as juice processing, concentrating, and drying, are utilized to extend the fruit's shelf life. Products like mangosteen juice and nutritional supplements had recently became widely available worldwide. For many years, traditional Thai medicine used mangosteen pericarp to treat diarrhea, wound infections, and skin infections. (Mahabusarakam *et al*., 1987; Moongkarndi *et al*., 2004).

Colour of the mangosteen pericarp contributed by the major anthocyanin pigment cyanidin-3-sophoroside, and the minor pigment is cyanidin-3-glucoside (Du

and Francis, 1977). Total anthocyanin content of mangosteen pericarp increased continuously during maturation and reached a maximum value at fully ripe stage (Ratanamarno *et al.*, 1999).

The mangosteen pericarp usually discarded as waste due to its unpleasant taste of bitterness, is a good source polyphenols and consumption of mangosteen pericarp had increased as dietary supplement due to their potential pharmacological properties (Pedraza-Chaverri *et al.,* 2008). Major active ingredients in nutritional supplements made from mangosteen *(G. mangostana)* fruits was found to be the xanthones, α-mangostin, which has antioxidant and anticarcinogenic properties (Gutierrez-Orozco and Failla, 2013). The extracts from fresh and frozen peel and pulp of mangosteen fruits using ultrasound extraction method indicated a higher antioxidant activity and highest TPC in fresh peel extracts (Muzykiewicz *et al.,* 2020).

2.1.3 *Garcinia xanthochymus* Hook.

Garcinia xanthochymus is commonly known False Mangosteen, Gamboge Tree, Himalayan Garcinia, Mysore Gamboge, Sour mangosteen, Yellow Mangosteen with synonyms as *Garcinia pictoria (Roxb.) Engl., Garcinia tinctoria (DC.) Dunn, Xanthochymus pictorius Roxb., Garcinia tinctoria W. Wight,* and *Xanthochymus tinctorius DC.* The Yellow mangosteen is believed to have originated in India, Myanmar and south Thailand and had become semi naturalised in many Southeast Asian countries. It is a medium-sized, branched, evergreen tree or shrub from a botany point of view. Its fruits are berries with a fleshy rind and thin skin that contains 2 to 8 large, pulpy seeds. It is a prolific bearer, producing two crops per year. As they ripened, the fruit became a deep to orange-yellow color (Lim , 2012).

In India *G. xanthochymus* is distributed in southern states, Goa, Maharashtra, Assam, Odisha, Bihar, Sikkim, Tripura, and Meghalaya (Rema and Krishnamoorthy,

2000). The yellow mangosteen fruits are used as condiment and also in folk medicine against diarrhoea, dysentery etc. (Pedraza- chaverry *et al.,* 2008).

Both the fruit rind and the stem of the *G. xanthochymus* plant can yield a significant amount of inferior gamboge, which widely used for dyeing cotton in Assam (Aral and Rameshkumar, 2016). As a fruit crop and avenue tree, these Western Ghats plants became popular, and many tribal populations in Odisha rely on fruits for food and income (Shameer *et al.,* 2016).

2.2 BIOCHEMICAL COMPOSITION OF MAJOR *GARCINIA* SPP.

2.2.1 Primary Metabolite Composition of *Garcinia* Fruits

Primary metabolites serve as source of energy during the growth and development of plants. Parthasarthy and Nandakishore (2014) reported that carbohydrates were the major metabolites present in *Garcinia* fruits followed by proteins. Carbohydrate content showed a great variation from 3.75 % to 15.12 % in various *Garcinia* species and total protein content ranged from 1.82 % to 4.93 %. The fruit's organic acids outweighed the reducing sugar content, which resulted in a sour flavor even as it ripened. *G. mangostana* fruits had the highest reducing sugar content (1.28 percent), while *G. indica* fruits had a higher total protein content (4.78 percent) and crude fat content. *Garcinia mangostana* had the highest concentration of ascorbic acid (61 mg 100 g-1), followed by *Garcinia pedunculata* (36 mg 100 g-1).

Bohra and Waman (2019) compared pulp and rind of two *G. gummi-gutta* morphotypes for biochemical parameters. Fruit pulp recorded higher Total Soluble Solids (TSS) of 9.67 to 10.11 ^{0}Brix where as ascorbic acid content of the rind was higher than fruit pulp for both samples. Morphotype GG-02 recorded an ascorbic acid content of 25.09 ± 3.58 for rind and 16.13 ± 3.106 mg/100g for pulp.

Yellow mangosteen pulp from Brazil recorded a TSS of 11.73 °Brix, 4.19% titratable acidity and vitamin C content of 31.21 to 46.82 mg 100g^{-1} for fresh fruit (Cavalcante *et al.,* 2006). Virgolin *et al.* (2017) evaluated nutritional composition of six fruits including two *Garcinia* spp. such as *G.xanthochymus* (Yellow mangosteen) and *G.humilis* (Achachairu.). Total soluble solid content, total and reducing sugar contents, titratable acidity, and protein of the yellow mangosteen fruits were reported as 9.00±0.01, 6.47±0.20, 8.15±0.30 g glucose 100 mL^{-1} pulp, 1.39±0.0 g citric acid 100 g-1 pulp and 1.70±0.01% respectively .

Suwardi *et al.* (2020) analyzed the nutritional composition of eight *Garcinia sp*. and reported that *G. xanthochymus* had higher total carbohydrate (25.1±0.32%) and crude fiber (8.4±1.67%) content. *Garcinia mangostana* was superior in flavour and colour, and recorded a crude protein of 1.8±0.13%, crude fat of 1.2±0.004% and crude fibre of 5.1±0.03%.

Prakash *et al.* (2022) characterized phytochemicals present in different part of *G.xanthochymus* fruits. Lyophilized peel and pulp of fruit recorded a fat content 6.29 ± 0.10, and 6.08 ± 0.11% respectively whereas, crude fiber was the highest for lyophilized peel (16.31 ± 0.35%) and pulp recorded a value of 7.11 ± 0.16%. The highest total sugar recorded was 33.42 ± 0.18% in pulp followed by the peel (20.13 ± 0.27%). Reducing sugar content was found to be higher in peel (18.13 ± 0.27%) followed by the pulp (16.55 ± 0.29%) . The total acidity was the highest in pulp (25.00 ± 0.3%) whereas the peel recorded an acidity of 20.65 ± 0.09%.

Joseph *et al.* (2017) evaluated African mangosteen (*Garcinia livingstonei* T. Anderson) fruits for the chemical compositions and nutritive value. Proximate composition of fruit parts varied for epicarp, mesocarp, endocarp and seed. Carbohydrate and crude protein were the major component in all the fruit portions. The moisture content, crude fat (1.23–19.55%), crude fiber (2.93–21.13%) and ash (1.76–5.44%) content varied in different fruit portions.

Garcinia buchananii an underutilized indigenous fruit tree of tropical Africa was evaluated for its physical and chemical characteristics by Omujal *et al.*(2021). The results indicated that titratable acidity of the pulp ranged from 6.1±0.8 to 7.1±0.1 %, dietary fibre, vitamin C, iron and zinc ranged from 20.0±0.4 to 22.6±1.8 g/100g, 32.8±3.2 to 42.0±3.3 mg/100g, 4.8±0.2 to 6.5±0.8 mg/100g and 1.1±0.0 to 2.5±0.1 mg $100g^{-1}$, respectively.

Mineral profiling of *Garcinia* sp. by Parthasarathy and Nandakishore (2014) revealed *G. mangostana* (163.6 mg $100g^{-1}$) as the rich source of total minerals followed by *G. indica*. Potassium, calcium and magnesium of *Garcinia* spp. showed a variations, unlike the minerals phosphorus, sodium, and iron. Magnesium and potassium were the predominant minerals in *Garcinia* fruits and *G. mangostana* recorded the highest phosphorus (7.45 mg/kg), potassium (78.3 mg/ kg), and magnesium (60.43 mg/ kg. Joseph *et al.* (2017) reported that Nitrogen and Potassium were the most abundant minerals in *G. livingstonei* followed by calcium and magnesium.

2.2.1.1 Organic Acid Composition

The primary soluble components of ripe fruits are sugars and organic acids, which are both responsible for the sourness and flavour of the fruit. Malic and citric acids are the organic acids found most frequently in many fruits (Famiani *et al.,* 2015).

Different environmental factors (temperature, light intensity) and cultivation practices (cultivar, rootstock, mineral nutrition, water availability, fruit load/ pruning etc. affect organic acid content of fruits (Etienne *et al.,* 2002).

Hydroxycitric acid (HCA), a potential antiobesity and hypocholesterolaemic component present in fruits and leaves of *Garcinia* species is used as an ingredient in popular dietary supplements for weight loss (Jena *et al.*, 2002). HCA in free form is reported to possess potent biological activities (Louter-van de Haar *et al.*, 2005).

Plants from *Garcinia* species and *Hibiscus sabdariffa* are the only abundant natural sources of HCA (Yamada *et al.*, 2007).

A process for large-scale isolation of HCA was demonstrated by Ibnusaud *et al.* (2000) from the rinds of *Garcinia indica* and *Garcinia cambogia*. A thermal process of obtaining concentrated HCA using osmotic membrane distillation was employed by Ramakrishnan *et al.* (2008) from *Garcinia* fruit rinds with deionized water.

Jena *et al.* (2002) quantified organic acids in fresh leaves, fruits, and dried rinds of *Garcinia cowa* by high-performance liquid chromatography (HPLC). HCA was quantified as the major acid in leaves, fruits, and rinds with 1.7, 2.3, and 12.7%, respectively. Oxalic and citric acids were also present in lesser quantity.

HPLC estimation of HCA result showed that *G. indica* contains 4.1 to 4.6% (-)-HCA in leaves and 10.3 to 12.7% in fruits (Jayaprakasha and Sakariah, 2002). Gogoi *et al.* (2016) validated less expensive and faster analysis time for extraction and estimation of (-) HCA from the fruit rinds of *Garcinia lanceaefolia*.

Parthasarathy and Nandakishore (2014) evaluated major *Garcinia* fruits for quantifying total acidity (%) and organic acid present in the fruits. The acid content of the fruits varied notably from 4.39% (*G. mangostana*) to 27.3% (*G. kydia*) as the most acidic followed by *G. gummi-gutta* (23.81%). HCA was reported as major acids and *G. gummi-gutta* had 15.48% followed by *G. kydia* (8.97%). Hydroxy citric acid was absent in *G. xanthochymus* and citric acid was reported as the major acid and very low acidity and low HCA content was reported in *G. mangostana*.

Organic acid content of leaf extract of various *Garcinia* sp. varied from 95.0 mg g^{-1} to 0.99 mg g^{-1} (Pandey *et al.*, 2015). Organic acids from dried leaves of *Garcinia cambogia, Garcinia indica, Garcinia xanthochymus, and Garcinia morella* were extracted and analyzed by HPLC. The amount of (-)-HCA, lactone, and citric

acid in dry leaves of *G. cambogia* was estimated as 7.95%w/w, 3.25%w/w, and 0.13%w/w respectively and it was 0.02%w/w, 0.06%w/w, and 0.18%w/w in dried leaves of *G. xanthochymus*. Dried leaves *G. cambogia and G. indica* showed higher amount of (-)-HCA and lactone (Bheemaiah and Kushalappa, 2019).

The HPLC profiling of *G.xanthochymus* fruit was done for quantify various organic acids and succinic acid (413.14 ± 52.95 g/100 g) was found the highest in the pulp, while peel was rich in ascorbic acid (74.23 ± 0.05 g 100 g^{-1}) (Prakash *et al.,* 2022).

2.2.2 Secondary Metabolite Composition of *Garcinia* Fruits

2.2.2.1 Phenolic compounds and antioxidant properties

Phenols with one carboxylic acid group virtually derived from benzoic and cinnamic acids are known as phenolic acid group. Hydroxybenzoic acids have the carboxylic acid group directly attached to the ring while hydroxycinnamic acids have a three carbon side chain (Robbins, 2003). The caffeic, p-coumaric and ferulic acid are common hydroxycinnamic acids that occur in foods as simple esters with quinic acid or glucose (Mattila and Hellström 2007).

Phenolics are compounds possessing one or more aromatic rings with one or more hydroxyl groups. They are broadly distributed in the plant kingdom and are the most abundant secondary metabolites ranging from simple phenolic acids to highly polymerized substances such as tannins. Phenolics are widespread constituents of plant foods, beverages and responsible for the overall organoleptic properties food products (Dai and Mumper, 2010).

Phenols contribute to the high antioxidant activity of the plant parts (Amin and Lee, 2005). Antioxidant compounds play an important role in reducing the risk of many chronic diseases such as cancer, coronary heart disease, and immune system

decline had been well documented. Several studies demonstrated a relationship between consumption of fruits and a lower incidence of degenerative diseases such as heart disease, arthritis and ageing (Kaur and Kapoor, 2001; Abas *et al.,*2006*;* Patras, *et al.,* 2009).

Flavonoids, phenolic acids, bioflavonoids and triterpenoids in *Garcinia* fruits are responsible for various pharmacological activities of the plant parts (Hemshekhar, 2011; Ritthiwigrom *et al*., 2013). Pandey *et al.* (2015) quantified phenolic acids such as protocatechulic acid, caffeic acid, ferulic acid and vanillic acid from the leaves of *G. gummi gutta*.

Sulaiman and Balachandran (2017) identified phenolic compounds viz., p-coumarylquinic acid, luteolin 7-O-glucuronide, dicaffeoylquinic acid, kaempferol 3-O-(6-O-acetyl) glycoside, and apigenein-6-C-pentosyl-8-C-hexoside though LC/MS characterisation of malabar tamarind fruit.

Sudharani *et al*. (2018) conducted study to determine bioactive components and antioxidant activity of dry and wet rinds of *G.gummi-gutta*. The bioactive components of fresh rind recorded higher values than dried rinds *viz*, total flavonoids 2.48 %, total tannins 2.76 % and total poly phenols 1.1% whereas dry rind recorded the values as 0.20%,0.10% and 0.04% respectively. The antioxidant activity of fresh rind at various concentrations 20mg, 40mg and 60mg were 66.30 %, 73.65 % and 81.44% respectively.

Ngawhirunpat *et al.* (2010) studied antioxidative, skin protective activities, and cytotoxicity of three extracts (water, methanol, and hexane) of mangosteen hull and their phenolic constituents such as α-mangostin, epicatechin, and tannin. Water extract exhibited the highest total flavonoid content (12.1 g epicatechin equivalents $100\,g^{-1}$ extract) and total tannin content (59.6 g tannic acid equivalents $100\,g^{-1}$ extract). The DPPH radical scavenging activity of the water extract

(IC_{50} 11 µg mL^{-1}) and methanol extract (IC_{50} 14.7 µg mL^{-1}) were more efficient than that of the hexane extract (IC_{50} 41.2 µg mL^{-1}).

Phenolic acid present in various parts of mangosteen fruits (*Garcinia mangostana*) were determined by GC–MS (Gas Chromatography-Mass Spectrometry). The total phenolic acids content identified by GC-FID (Gas Chromatography with flame ionization detection) ranged from 265.7 ± 12.7 mg kg^{-1} in aril to 5027.7 ± 188.0 mg kg^{-1} of dry matter in peel. Among the identified ten phenolic acids, protocatechuic acid was reported to be in higher quantity in pericarp and rind whereas *p*-hydroxybenzoic acid was the predominant phenolic acid in the aril (Zadernowski *et al.,* 2009).

Zarena and Shankar (2011) used HPLC technique for quantifying phenolic acids and flavonoids in mangosteen fruit pericarp and reported caffeic acid (1.51 mg g^{-1}), t-cinnamic acid (0.73 mg g^{-1}), vanillic acid (0.71 mg g^{-1}), sinapic acid (0.71 mg g^{-1}) and syringic acid (0.63 mg g^{-1}) as the predominant phenolic acids. The phenolic content (294.4 2.3 mg g^{-1} GAE) of the fraction was higher than that of the free phenolic acid fraction (209.1 2.04 mg g^{-1} GAE) and acid-hydrolyzed phenolic acid fraction (18.6 0.04 mg g^{-1} GAE). Apart from phenols, two flavonoids *viz*., catechin and quercetin were also identified. Mangosteen peels recorded 10 times more phenolic compounds and 20 times more antioxidant activity when compared to mangosteen pulp (Yoshimura *et al.,* 2015).

Antioxidant activity of pulp and peel of the yellow mangosteen fruit revealed that ethanolic extract of fruit peel had the major antioxidant activity with the highest content of total phenolics in comparison to the pulp. The FRAP assay revealed that the peel extract showed the strongest reductor power compared to pulp extacts (Arazo *et al.* 2011). Eleven bioactive benzophenones isolated from *G. xanthochymus* fruits were aristophenone-A, alloathyriol, amentoflavone, 3,8″-biapigenin, cyclo-xanthochymol, fukugetin, fukugiside, guttiferone-E, isoxanthochymol,

volkensiflavone, and xanthochymol (Baggett *et al,.* 2005a). The yellow mangosteen fruits are rich source of starch and carbohydrate and phytochemical studies revealed that the fruits are good source of bioactive compounds such as saponin, tannins, alkaloid, terpenoid and phenolic compounds (Murmu *et al., 2016*).

Garcinia atroviridis fruit extract at 60°C for 6 hours showed the highest total phenolic content (16.23 ± 0.18 mg GAE mg^{-1}) compared with fruit extracted at 40°C for 12 hour and 100°C for15 hours. The antioxidant activity (DPPH-radical-scavenging activity and ferric reducing power assay) was positively correlated with the total phenols. Fruit extract contain 0.46% ± 0.08, 8.64% ± 0.06 and 0.15% ± 0.06 proteins, carbohydrate and ash contents respectively (Nursakinah *et al., 2012*).

Proximate composition of different parts of African mangosteen (*Garcinia livingstonei* T.) were evaluated and Phenolics (174.02 to 10.73 mg GAE g^{-1}), flavonoid (19.25 to 99.98 µg QE g^{-1}) and alkaloid (1.56 to 9.49 mg kg^{-1}) content of each part of fruits varied (Joseph *et al.,* 2017). The total phenolic compounds and antioxidant activity of *Garcinia buchananii* fruits ranged from 996.7±50.5 to 1147.5±47.4 mg g^{-1} GAE and 8.0±0.2 to 8.4±0.1 mg 100 g^{-1} as IC50, respectively. Crude oil content of seed was 6 to 24% and major fatty acids were palmitic, stearic, oleic and linoleic whereas total unsaturated fatty acids was in the range of 58.4 to 59.5% (Omujal *et al.*, 2021).

G. xanthochymus is a rich source of polyphenols and fruits recorded epicatechin and catechin with high stability and bioavailability which could be effectively used as source of epicatechin and catechin substituting green and black berry (Janhavi *et al.*, 2020).

Fruit peel of *G. xanthochymus* recorded highest amount of the total polyphenols (1552.62 ± 6.48 mg 100 g^{-1}) and total flavonoids (5943.96 ± 286.59 µg 100 g^{-1}). The peel extract contain epicatechin (575.26 ± 2.93 mg 100 g^{-1}), gallic acid

(149.67 $\pm$ 2.26 mg 100 g^{-1}), chlorogenic acid and syringic acid. Pulp extract had epicatechin (113.01 $\pm$ 0.68 mg 100 g^{-1}), catechin (25.25 $\pm$ 0.6 mg 100 g^{-1}), coumaric acid (6.15 $\pm$ 0.09 mg 100 g^{-1}), cinnamic acid, chlorogenic acid (5.77 $\pm$ 0.23 mg 100 g^{-1}), and syringic acid (Prakash *et al.,*2022).

2.2.2.2 Benzophenone

The genus Garcinia and Clusia are the main sources of natural benzophenones in plants. Natural benzophenones are a class of compounds with a phenol-carbonyl-phenol framework. Several polyisoprenylated benzophenones have been reported from the fruits of Garcinia species. The floral resins and latex of some Clusiaceae plants are the main source benzophenones (Cuesta-Rubio *et al*., 2001).

Aravind *et al.* (2016) reviewed 120 garcinia species for phytochemical investigation of which 50 species reported benzophenones. The benzophenones are classified generally into simple polyisoprenylated benzophenones and complex bicyclo-[3.3.1]-nonane derivative and the major benzophenones reported from the genus *Garcinia* are polyisoprenylated bezophenones .

Camboginol (garcinol) and cambogin (isogarcinol) are the major benzophenones isolated in large quantities (37.0% and 5.5% respectively) from the latex of *G. gummi-gutta* in (Rao *et al.,* 1980). Xanthochymol and isoxanthochymol belong to the prenylated benzophenone class of compounds and had been isolated from *G. xanthochymus, G. mannii, G. stauditi, G. subeilliptica, and G. pyrifera* (Matsumoto *et al*., 2003). Baggett *et al.* (2005b) isolated 13 compounds from the fruits of *G.xanthochymus* which included two benzophenones guttiferone H (1) and gambogenone.

Kokum fruits possessed garcinol, xanthochymol and isoxanthochymol compounds (Chattopadhyay and Kumar, 2006) whereas garcinol, isogarcinol guttiferones (I, J, K, M and N) were isolated from fruits of *G.gummi gutta* (Masullo

et al., 2008). Yu *et al.* (2007) isolated Garcimangosone D, kolanone, and maclurin from mangosteen fruits.

Kokum fruit contains 1.5% of polyisoprenylated benzophenone derivative called Garcinol ($C_{38}H_{50}O_6$, melting point 122°C), yellow colour fat soluble pigment which was crystallized out from the hexane extract of the fruit rinds The benzophenones from mangosteen, malabar tamarind and kokum fruits reported to strong biological activities and garcinol had high pharmacological properties (Yamaguchi *et al.,* 2000). High yields of garcinol could be obtained from dried kokum (*Garcinia indica*) and garcinol could be easily converted to isogarcinol under acidic conditions (Kaur *et al.,* 2012)

The garcinol was found effective in prevention of tumour in human colorectal cancer cell line HT-29 as reported by Liao *et al.* (2005). Garcinol also had antioxidant, anti-inflammatory, anticancer and antimicrobial activity as reported by Pasha and Ramachandran (2014).

Chattopadhyay and Kumar (2007) developed liquid chromatography–mass spectrometry (LC-MS/MS) method for the determination of camboginol in the extract of fruit rinds of *Garcinia cambogia*. Separation was achieved isocratically on an RP C18 column using a solvent system consisting of a mixture of acetonitrile–water (9:1) and methanol–acetic acid (99.5:0.5) in the ratio of 30:70 as mobile phase. *G.cambogia* rind extract recorded a camboginol content of 48.34 ± 3.58 ng mL^{-1}.

Kumar *et al.* (2009) developed rapid, sensitive and simple reverse-phase HPLC–electrospray ionization MS method for the identification and quantification of isoxanthochymol and camboginol, from the extracts of of *Garcinia indica* and in fruit rinds of *Garcinia cambogia*. The separation of isoxanthochymol and camboginol was achieved on a Perkin Elmer RP8 column using a solvent system consisting of a mixture of acetonitrile–water (80:20, v/v) and methanol–acetic acid (99.0:1.0, v/v) as

a mobile phase in a gradient elution mode. Isoxanthochymol and camboginol in methanol extracts of *G. cambogia* rind was quantified as 16.6 and 88.2 mg g^{-1} respectively.

Bharate *et al.* (2014) developed easier method to quantify garcinol and isogarcinol from different extracts of *Garcinia indica* fruits. Air-dried powdered fruits of *G. indica* were extracted with dichloromethane–methanol at room temperature and yielded two major pure fractions using silica gel column chromatography. Fractions A and B obtained were washed using hexane and pure compounds 1 (49.2 g, yellow solid) and 2 (8.1 g, white solid) were identified as garcinol (1) and isogarcinol (2).

Garcinol content of *Garcinia indica* and Tryodashang Guggul and Slimmerz commercial capsules was determined by HPTLC and found that dried *Garcinia indica* rind recorded 2.5% garcinol, 0.701% in Tryodashang Guggul and Slimmerz capsules with 0.760 % garcinol (Patel *et al.,* 2015).

2.2.2.3 Xanthones

Xanthones are secondary metabolites with two aromatic rings through carbonyl and ether linkages, originated biosynthetically by condensation of acetate and shikimate derived moieties. *Garcinia* species are important sources of xanthones and 74 *Garcinia* species, comprising more than half of all the *Garcinia* species studied so far, were reported to contain xanthones. *G. mangostana* has been extensively studied and contain the highest number of xanthones (Aravindh *et al*., 2016)

Xanthones derived from mangosteen fruits recorded remarkable pharmacological effects such as anti-allergic (Nakatani *et al.,* 2002), anti-oxidant (Jung *et al*., 2006), anti-cancer (Akao *et al.,* 2008; Aisha *et al*., 2016), analgesic (Cui *et al.,* 2010) , anti-inflammatory (Tewtrakul *et al.,* 2009), anti-fungal (Kaomongkolgit *et al*., 2009),) and enhancement of the immune system (Tang *et al*., 2009). The most

common xanthone compound in the mangosteen fruit peel is α-mangostin which is reported to have antioxidant, anti-inflammatory, anticancer, and antimicrobial activities (Shan *et al.,* 2011).

Parthasarathy *et al.* (2014) estimated xanthone content of various *Garcinia spp.* and the highest content was recorded in *G. xanthochymus* (2.66%) and the lowest was in *G. indica* (0.9%).

The average total content of mangostin in mangosteen pericarp powder and ethanol extract were $9.94 \pm 0.88\%$ and $36.25 \pm 4.66\%$ respectively (Pothitirat and Gritsanapa, 2009). The levels of α-mangostin in young fruit peel extract, ripe rind and the bark of *Garcinia mangostana* by TLC-Densitometry method were 4.19%, 15.85% and 3.88% respectively (Agustina *et al*., 2014).

Mayefis *et al.* (2019) validated UV-Visible spectrophotometry for estimation of total xanthones content from three market samples of mangosteen rind with maximum absorption wavelength obtained at 243 nm . Total xanthone content in the mangosteen pericarp capsules were reported as 100,8 μg mg^{-1}, 197 μg mg^{-1} and 50 μg mg^{-1} .

2.3 COLOUR EXTRACTION FROM MANGOSTEEN RIND

Anthocyanins are a group of natural plant pigments yielding red, blue and purple color from various fruits, vegetables and flowers. Unlike chlorophylls and carotenoids, anthocyanins are water soluble. These pigments are considered to be potential replacements for synthetic coloring agent because of their bright attractive colour and water solubility (Kong *et al*., 2003). Anthocyanin has high potential to use as natural food colorant in the production of confectionery, jellies, jams, health beverages and squash-like products, red wine, and desserts as reported by Nayak *et al* (2010).Addition of anthocyanin to the food systems not only improves the color intensity but also the medicinal and therapeutic values of the foods (Maran *et al.,* 2015).

Chaovanalikit and Mingmuang (2007) reported that mangosteen rind as a rich sources of anthocyanin and external pericarp had the highest amount of pigment. A number of therapeutic benefits have been reported from the antioxidants and anthocyanin that are extracted from mangosteen, including cardioprotective, anti-inflammatory, anticarcinogenic (Zafra-Stone *et al., 2007)* and antimicrobial properties (Lacombe *et al*., 2010).

Lourith and Kanalayavattankul (2011) evaluated mangosteen pericarp as a source of potent natural colour which could be used in pharmaceutical products. The study conducted by Hiranrangsee *et al*.(2016) suggested utilization of pericarp as a potent source of natural antioxidants that could be used in food industries. Mangosteen pericarp showed significantly higher total phenolic, flavonoid, and anthocyanin content than that of other colored plant samples, such as *Syzygium cumini* (Java plum) fruit, *Clitoria ternatea* (butterfly pea) flower, and *Ardisia colorata* var. elliptica (chicken's eye) fruit (Azima *et al., 2017*).

Mangosteen fruits are generally harvested when pericarp is light greenish yellow scattering with pinkish spots (Tongdee and Suwanagul, 1989). Temperature and light were environmental factors that are important for red pigment development in the fruit (Saure, 1990). Total anthocyanin content increases continuously during maturation and reaches a maximum value at fully ripe stage (Ratanamarno *et al*., 1999). The effect of storage temperature on anthocyanin content and phenylalanine ammonia-lyase activity of harvested mangosteen fruits were evaluated from stage 1 to stage 6. The anthocyanin content increased accordingly at all temperature levels and the highest at stage 6 (red colour) (Ratanamarno *et al., 2005*).

Fugal *et al*. (2006) studied different solvent extraction methods for colour extraction from mangosteen rind and the ethanol extracted colour recorded the highest antioxidant activity which was supplemented to different fruit juices for the preparation of nutraceutical beverages. Mai and Tan (2013) optimized condition for

colour extraction from mangosteen rind as extraction at 40° C ethanol with HCl 1.5% at 1:10 rind and solvent ratio at a temperature of 60°C for 40 minutes.

Sothornvit (2010) investigated the effect of different drying methods (hot air drying and drum drying) on the quality of mangosteen rind powder and effect of addition of different polymers and reported that incorporation of whey protein isolate into mangosteen rind powder increased the xanthone content (15.20 mg kg^{-1}) as compared to maltodextrin addition.

Cheok *et al. (*2013) investigated anthocyanin recovery from mangosteen pericarp using an aqueous methanol solvent acidified by Mexican lime (*Citrus aurantifolia* Swingle.) The addition of lime juice to aqueous methanol solvent yielded maximum total anthocyanin recovery of 4.742 ± 0.590 mg cy-3-glu g^{-1} hull whereas 2.950 ± 0.265 mg cy-3-glu g^{-1} for HCl acidified extraction and suggested natural lime as a good source of acidifying agent for anthocyanin extraction.

Ortega and Beltran (2014) studied the effect of average particle size, type of solvent, and extraction time on the physiochemical and phytochemical properties in *Hibiscus sabdariffa* (Roselle) calyces. All extractions were performed at 50 °C and reported no significant difference in moisture content, pH, and titratable acidity. Fine powder of hibiscus calyces (0.55 mm) exhibited lower water activity (0.37±0.01) and higher TSS (5.53±0.05%) than the 0.97 mm ground powder. Fine powder 50% ethanol and extraction time of 30 minutes recorded the highest anthocyanins (451.4±28.1 mg 100 g^{-1}) and total phenols (2016.2±159.8 mg 100 g^{-1}).

Maran *et al.* (2015) optimized extraction conditions for maximizing the yield of anthocyanin and colour from jamun and recorded the highest amount of total anthocyanin (10.58 mg 100 g^{-1}) and colour at an extraction temperature of 44 °C, for 93 minutes at a solid–liquid ratio of 1:15 g mL^{-1}.

Hosseini *et al.* (2016) extracted anthocyanins from barberry, eggplant peel and red cabbage using different organic solvents. Different concentration of hydrochloric, citric and acetic acids was dissolved in a mixture of water and ethanol to prepare acidified aqueous solution. Results indicated that citric acid solution is one of the best solvents for phenolic and anthocyanin extraction which showed the best scavenging activity of DPPH radical and confirmed that stability of anthocyanins in the solution depended on temperature and extraction medium.

Anthocyanin from fresh and dried pericarp of mangosteen were extracted by three different method of extraction viz., maceration, shaking water bath extraction, ultrasonic assisted extraction with the extraction time of 6, 4 h and 5 min, respectively. Shaking water bath extraction recorded the highest total phenolic content . The anthocyanin content extracted by ultrasonic assisted extraction for fresh and dried mangosteen pericarp was 23.54 ± 0.31 and 20.83 ± 0.96 mg Cyn-3-Glu 100 g^{-1}, respectively (Hiranrangsee *et al.,* 2016).

Garcinia indica is a potential source of anthocyanin. Concentration of anthocyanins (2.4 g 100 g^{-1} of fruit) was high in kokum fruits as compared to other natural colour sources and the major pigments characterize were cyanidin-3-glucoside and cyanidin-3-sambubioside usually present in the ratio of 4:1 (Nayak *et al.*, 2010). When kokum rinds were treated with pectinase and cellulose overall increase in anthocyanin recovery was reported by Ranveer *et al.*(2020).

2.3.1 Food Supplementation with Natural Anthocyanin Extract

Mangosteen rind tea obtained by dissolving mangosteen rind powder-whey protein in hot water had a pH of 5.36, the solubility in water was 0.83 g water/g DM solubility time at 90°C in hot water for 23 seconds (Sothornvit, 2010).

Afifah and Niwat (2015) evaluated stability of polyphenols in green tea drink with mangosteen pericarp extract with citric acid. The mixture of green tea drink with

0.4% mangosteen pericarp extract and 0.2% citric acid showed the lowest pH (2.79), the highest total phenols(25.48±0.38 mg GAE ml^{-1}), DPPH (57.86±1.25(mmol Trolox 100 ml-1), and FRAP (5.68±0.33 mM ml^{-1}asorbic acid).

The functional mangosteen ice-cream developed by the addition of pericarp extract showed higher TPC and DPPH inhibition when compared to the ice-cream without pericarp extract (Hiranrangsee *et al.,* 2016). Mangosteen juice adjusted to 18° Brix and added with 0.2% mangosteen pericarp obtained the highest sensory scores and quality attributes. Mangosteen juice was pasteurized at 90ºC for 5 min and stored at 4º C for 5 weeks. Colour parameters (L*, a*, b*), pH, ascorbic acid, anthocyanin, total phenolic compounds and antioxidant capacity of the mangosteen juice decreased whereas an increase in titratable acidity was observed during the storage (Manurakchinakorn *et al.,* 2016).

Mangosteen pericarp powder could be used as low cost polyphenol source to enhance the bioactive and flavour profile of chocolates was reported by Sim *et al.* (2016). Mangosteen pericarp powder was added at different concentration (1%, 2% and 3% w/w) to dark and compound chocolates during the mixing stage. The 3% pericarp powder concentration significantly increased the bioactive profile and total phenolic content (13% in dark chocolates and 50% in compound chocolates) when compared to control without affecting sensory qualities.

Hanafi *et al.* (2017) formulated a functional drink using mangosteen peel extract by adding mangosteen peel extract for about 10%, 20%, 30%, and 40%. Mangosteen peel extract drink had higher anthocyanin and antioxidant levels when added to 1% gelatin. Anthocyanin was relatively stable at storage temperature 50 ^{0}C and 25^{0}C.

Addition of mangosteen rind juice as a natural colorant to sugar palm fruit jam (Kolang-kaling) improved red color, texture, and flavour, high moisture content,

water activity, total dissolved solids, crude fiber and enhanced various organoleptic properties of jam (Sayuti *et al.,* 2020). Yoghurt supplemented with mangosteen rind showed increased total phenolics and high antioxidant potential (Shori *et al.,* 2018;Wibawanti *et al.,* 2019).

Mangosteen rind extract was prepared by maceration with 95% ethanol for 24 hour was stable at temperature of 10–50°C and also showed stability for pH, and colour during storage. They also studied lip colour formulations with various concentrations of mangosteen rind (10, 15, and 20%) and the addition of 20% mangosteen to lip colour mixture was the most preferred concentration (Mustarichie and Gozali, 2019).

Solvent mixture of water and ethanol (1:1) improved the biomass yield, antioxidant activity and phenolic content of mangosteen peel extract and this was incorporated in mangosteen pulp beverage. The sensory evaluation did not show significant differences between the treatments applied to the beverages, for which a high-cost antioxidant agent such as ascorbic acid can be replaced by mangosteen extract (Machado *et al.,* 2022).

2.3.2 Colour Stability Studies of Food Supplemented with Natural Anthocyanin Extract

Anthocyanins are highly unstable and are more susceptible to degradation. The colour stability of anthocyanins is controlled by several factors such as pH, chemical structure, concentration, storage temperature, copigmentation, light, proteins, oxygen, moisture content, and the presence of enzymes, ascorbic acid, flavonoids, and metal ions (Hellstrom *et al.,* 2013; Enaru *et al.,* 2021).

The most dynamic loss of anthocyanin occurs when the pigments are exposed to fluorescent light. Protection toward light could be obtained by selecting packaging material with proper light barriers. Light induced degradation depends on

the concentration of molecular oxygen present in the product (Giusti and Wallace, 2009).

Colour of the anthocyanin also varied with pH, at pH 1 and below, the anthocyanin pigment gave an intense red but became colourless or purple when the pH was increased (between 4 and 6). The anthocyanin turned a deep blue when the pH is between 7 and 8 and further increase in pH turned the colour from blue to green and then to yellow (Lee *et al., 2002*).

Sari *et al,* (2015) evaluated stability of natural anthocyanin from jambolan fruits (*Syzygium cumini*) and reported that storage temperature as an important parameter for color stability of naturally colored beverages. The disaccharides from jamun fruits showed greater stability at low and room storage temperatures and stabilization of anthocyanins through copigmentation was done using different acids such as sinapic, caffeic, and ferulic acids as well as rosemary polyphenolic extracts.

High temperature short time processing is recommended for maximum anthocyanin retention of foods containing anthocyanins. (Flamini *et al*., 2013). Arabic gum had been shown to improve the stability of purple carrot anthocyanins in beverage model solutions (Chung *et al*., 2016). The use of edible nanoparticles of chitosan could be a strategy to increase anthocyanin stability in beverages and delayed gastrointestinal degradation (Hu *et al*., 2017).

Naresh (2016) standardized anthocyanin extraction method from jamun and evaluated stability to pH, light, temperature, storage conditions in products such as jam and beverages. Among the different extraction methods ethanol solvent (20%) acidified with 0.5% citric acid recorded the highest anthocyanin (61.07 mg $100g^{-1}$), recovery per cent (13.75), colour hue (1.30) and colour intensity (1.13). One hour of heating at 90 ^{0}C decreased the anthocyanin content from 61.25 mg $100g^{-1}$to

50.24 mg 100g^{-1} and increase in pH also decreased the anthocyanin content and the least decrease was found at a pH of 2.5.

Swer *et al.,* (2019) studied the incorporation of anthocyanin pigment from Sohiong (*Prunus nepalensis* L.) in products *viz.,* yoghurt, syrup and hard boiled candy. The stability of anthocyanin of products during storage at 4°C for yoghurt (14 days) and 27^0 C for syrup (90 days) and hard boiled candy (90 days), was studied. Concentration of pigment and time of storage had a significant effect on the colour stability and the products with higher pigment concentrations were found high acceptability.

2.4 PRODUCT DVELOPMENT FROM *GARCINIA*

Garcinia fruits are rich in bioactive compounds and have great potential in developing food products with health benefits. Even though there is a huge potential for commercialization of products from *Garcinia,* they remain under exploited. *Garcinia* fruits are seasonal and therefore it is essential to preserve the fruits, so that they can be made available throughout the year. To avoid the wastage during surplus production, fruits should be be processed into valued added products viz., juice, pulp, squash, jam etc.

Kokum (*G. indica*) based cool drinks were prepared during summer periods with addition of sugar and cardamom. Repeated soaking and drying of kokum rind in juice of the kokum pulp resulted as unsalted kokum of commerce (Sampathu and Krishnamurthy, 1982). Kokum rinds was also used in some vegetable dishes and to prepare chutneys and pickles. As kokum is a highly under-utilized fruit, it can be preserved by making it as a processed food to use it during off season (Krishnamurthy *et al.,* 1982).

Biswas *et al.* (2017) formulated a variety of products from *Garcinia pedunculata* fruit by blending modern processing techniques with traditional knowledge viz., jam, squash, fruit juice, juice powder, spicy and sweet pickles. The

highest antioxidant property was recorded in sweet pickles (1394.7μg mg^{-1}) and lowest in dry powder (764.8μg mg^{-1}) and the highest vitamin C content was observed in fruit juice (67.52 mg 100g^{-1}) and crude fibre (2.03%) for dry fruit powder.

To take advantage of health promoting properties of kokum (*G. indica*), five different value added products namely, kokum pickle, kokum sauce, kokum sambar mix, kokum spice candy, kokum popsicles were standardized and sensory evaluation of the products indicated that, kokum popsicles were highly acceptable among the kokum products (Sowmya *et al.,*2019).

2.4.1 Formulation of Fruit Beverages from *Garcinia* spp.

Beverages made from fruits and vegetables are important in human diet as they are excellent medium for the supplementation of nutraceutical components for enrichment (Sheela and Sruthi, 2014). To develop fruit-based beverages with potential health benefits, fruits rich in bioactive compounds with good sensory qualities and stable physical properties should be utilized (Wickramasinghe *et al.,* 2020).

Waskar and Garande (2003) reported that the blending of pomegranate and kokum juice in 80 ; 20 had good TSS, acidity and anthocyanins. It was also observed that with the addition of kokum juice in pomegranate juice, the TSS of resultant blend was found to be decreased with an increase in acidity wheras the color of pomegranate juice improved by blending with kokum juice which increased the anthocyanin content of the blended juice.

Functional beverages containing *G. cambogia* was found effective in reducing body fat (Kim *et al.,* 2003). Gopakumar and Kavitha (2014) evaluated ready to serve *Garcinia* blended beverage were prepared with watermelon (1:1) whereas Blended squashes were prepared from *Garcinia* juice (100 %) with oranges (50 per cent) and pineapple (50 per cent) and sharbath was prepared by using *Garcinia* juice, lime juice and ginger. *Garcinia* incorporated beverages exhibited a shelf life of 3

month at room temperature and refrigerated condition except for *Garcinia* - watermelon blend.

Bensi (2017) developed ready to serve panakam from *G.cambogia* fruit which recorded initial acidity as 0.32% and 15^0Brix TSS, both parameters increased slightly during storage. At the time of storage antioxidant activity and total sugar content of the beverage were 44.81% and 16.12% respectively. Ascorbic acid content and antioxidant activity of the samples were decreased while total sugar content was increased during storage.

Bhagavathi *et al*. (2017) developed *Garcinia cambogia* blended squash with pineapple juice in three different proportions (75%, 50% and 25%). The sensory evaluation revealed that treatment with 75:25(pineapple juice : fresh *Garcinia* cambogia) and 75:25 (pineapple juice : dried *Garcinia* cambogia) were highly acceptable.

Several food processing methods such as juice processing, concentration and drying could add value for mangosteen to create a new market. Nowadays mangosteen juices or dietary supplements had good demand around the world. The edible part of mangosteen contain comparable amount of phenolics as grape, plum, and cherries. The use of pectinase enzyme for juice clarification was found to increase the total phenolics of mangosteen juice concentrate (Chaovanalikit *et al.,* 2012).

Studies on preparation of functional fermented beverages from *G. xanthochymus* yielded beverage with high bioactive compounds and acceptable sensory quality (Rai *et al*., 2010). Wickramasinghe *et al*. (2020) demonstrated the potential of processed *G. xanthochymus* fruit as a functional beverage ingredient. The pH, colour and DPPH scavenging activities of freeze dried samples recorded the highest quantity of 2,4,6,3′,4′ pentahydroxybenzophenone-2-O-ß-D-glucopyranoside.

Xess *et al.* (2021) formulated various nectar formulations from ripe jack fruit pulp. Nectar prepared from 20% pulp + 18% TSS + 0.4% acidity recorded highest organoleptic score with respect to colour and appearance, aroma, taste and overall acceptability. Blended nectar beverage were prepared from custard apple pulp with lime juice, kinnow mandarin juice, Nagpur mandarin juice and strawberry pulp and prepared nectars had low microbial load at the time of preparation and increased upon storage (Gautam *et al.,* 2021).

Salaria and Reddy (2022) developed Ready-to-Serve beverage (RTS) nectar from *Cucumis melo* L. (muskmelon) nectar prepared with the formulation of 15% pulp and 10°Brix total soluble solids was rated superior for overall acceptability during storage. During the storage period of muskmelon RTS (nectar) there was an increasing trend in pH, total soluble solids, total sugars and reducing sugars while there was a declining trend in acidity, ascorbic acid and non-reducing sugars.

Mongkontanawat *et al.* (2022) formulated mangosteen beverage with thai herbal plant with high anti-inflammatory activities. Mangosteen juice supplemented with 0.20%w/v Sappan wood extract was chosen in term of high nutritional value. Results revealed that the formula contained mangosteen juice 55% w/v and 0.20%w/v Sappan wood extracted, had potential antioxidant activity of 91.15 + 0.47 DPPH %, total phenolic compound of 5.34+ 0.34 mg gallic acid/ml sample, tannin content 6.92+ 0.27 mg/ml, anthocyanin content of 4.59+ 0.53 mg/l and study confirmed development of healthy functional beverage from mangosteen.

Jayashree and Susanna (2023) standardized three RTS beverages from kokum fruit and conducted storage studies. Parameters such as total soluble solids, titratable acidity, reducing sugars and total sugars were increased during storage whereas, a decrease in pH was noticed. Kokum RTS blended with roasted powdered cumin seeds stored in PET bottles under refrigerated condition recorded highest acceptability of 8.16.

2.4.2 Value Added Products from *Garcinia gummi-gutta*

Market for spices paste has increased significantly mainly because of the success of fast food industries (Ahmed, *et al.*, 2004). Promjiam *et al.* (2013) compared quality changes, total phenolic compound and antioxidant properties of the Keang-hleung soup pastes as affected by the addition of *Garcinia* fruits during storage. Results shows that, the total phenolic content of normal paste without *Garcinia*, garcinia- Keang-hleung paste and garcinia Keang-hleung paste without salt decreased during storage. Salt and *Garcinia* in the paste helped to prolong the shelf life of the paste in term of microbiological quality.

Bensi (2017) studied the preparation of paste from dried rind of *Garcinia cambogia* with addition of different levels of salt. Paste added with 7 % salt with 20.12°Brix TSS was selected for storage studies based on sensory evaluation in two different packaging material such as polypropylene (PP) and metalized poly propylene (MPP). During storage, moisture content of the paste decreased from 55.60% per cent to 50.82% in polypropylene and 51.67 % in MPP packaging materials. Total antioxidant activity of the paste was recorded as 38.09 and 40.29 % at the end of 120 days of storage. A considerable reduction in TSS, protein, fat and ascorbic acid content was exhibited during storage and there was increase in the sugars and acidity and non- enzymatic browning were also observed during the storage of paste.

Physico-chemical changes in pH, titratable acidity, color change, and microbial changes of ready-to-use sambar paste was determined at two different storage conditions. Colour analysis showed significant decrease in the lightness (L) and yellowness (b*), where as redness (a*) of the paste increased during storage. Sensory evaluation showed that there was no significant difference in most of the sensory attributes during storage except for colour (Maity and Raju., 2014).

Anantawan and Petchler (2018) studied antioxidant properties of six type Tai instant sour curry pastes. Sour curry and yellow sour curry pastes showed strong antioxidant capacity with various flavonoids from their ingredients mixed together. Yellow sour curry pastes (Kanokwan and Lobo) which were added with turmeric (*Curcuma longa* L.) and finger root (*Boesecnergia pandurata* (Roxb) exhibited more antioxidant activity than typical sour curry pastes.

Arefin *et al.* (2019) developed ready to use onion paste and effect of preservatives on chemical, sensory and microbial parameters were analyzed under two storage conditions. Preservatives used were, potassium metabisulphites, sodium benzoate and citric acid at two concentrations 750 and 1000 ppm respectively. Onion paste with preservatives showed acceptance for colour, flavour and texture up to 60 and 120 days of storage at ambient temperature and room temperature respectively

Francis *et al*. (2019) evaluated the sensory characteristics of the ready-to-use bharwa spice-mix paste. Bharwa spice-mix paste was treated with different levels of vinegar (0.1%, 0.2%, 0.3%), citric acid (0.1%, 0.2%, 0.3%) and oil (3%, 5%, 7%) and all the treatments were evaluated for its taste, colour, texture, flavour, appearance and overall acceptability during 45 days of storage. Considering all the parameters such as the change in sensory parameters, safety of food and nutritional quality, bharwa spice-mix paste treated with oil reported with the best acceptability and storage stability of 45 days under refrigerated condition.

Zhang *et al.,* (2020*)* studied the effects of sodium chloride (0, 17, 42.5, 85 mmol/L) on pH, total soluble solids, phenolics, anthocyanins and DPPH activity of grape juice stored at different temperature (7, 20, and 30ºC). At 6th day of storage all the juice samples added with NaCl delayed the decrease of total anthocyanins and DPPH effectively at storage temperatures. Sodium chloride treated samples recorded higher levels of total phenolics than control during storage and the results confirmed

the potential effect of NaCl on maintaining the quality and extending shelf life of grape juice without preservatives.

2.4.2.1 Development of Dehydrated Products

Dehydration is considered as one of the oldest form of preservation known to man which resulted in production of food with long durability (Nastaj and Witkiewicz, 2004). Osmodehydration is considered as an effective method for preservation of fruits and vegetables, a simple process, which facilitated processing of fruits and vegetables such as banana, sapota, fig, guava, pineapple, apple mango, grapes, carrots, pumpkins, etc. with retention of initial fruit characteristics like colour, aroma, texture and nutritional composition (Chavan, 2012).

Osmodehydrated aonla fruits showed better retention of ascorbic acid and sugars and with reduced acidity (Pragati *et al.*, 2003). Mauro *et al.* (2004) reported that when banana and apple slices dipped in 70º and 50ºBrix respectively at an osmotic solution temperature of 50ºC for 3 hour immersion time recorded optimum water loss and sugar gain. Geetha *et al.* (2005) conducted a study on osmotic concentration kinetics on aonla preserve and reported that total sugar and TSS increased with the increase in sugar syrup concentration and temperature, while the content of moisture and ascorbic acid decreased.

Rittirut and Siripatana (2006) developed most suitable drying conditions for *Garcinia atroviridis* material in a tray dryer based on the final moisture content. It was found that for the material thickness of 2, 4 and 6 mm, a temperature of 55 °C and air velocity of 1.2 m/s were found suitable for drying. Gopakumar and Kavitha (2014) explored processing of Malabar tamarind using sugar and salt which employed the technique of osmotic pressure preservation to develop products such as jam, preserve and pickles. Using dehydration techniques wet and dry chutney powders were also developed from malabar tamarind fruits.

Hande *et al.* (2016) studied open sun drying characteristics of *G. indica* (kokum) rind. Acidity of kokum rind increased from 0.85 ± 0.19 to 4.363 ± 0.098 % and reducing sugar content in the dried rind increased from 1.32 to 3.491% after drying process. Other parameters such as total calorific value, protein and ash were also increased after drying process whereas anthocyanin (%) was decreased from 2.79 ± 0.08 to 2.5 ± 0.002% .

Bensi (2017) investigated development of dried and encapsulated powder from *G. gummi-gutta* rind and recorded an initial moisture content of 3.82 which was increased to 5.10% in polypropylene and 4.56% in metalized polypropylene (MPP) during storage. Ascorbic acid and fat content were also decreased during storage. The retention of Hydroxy Citric Acid (HCA) in *Garcinia* extract was 210 mg g^{-1} where as in encapsulated powder it ranged between 320 and 312 mg g^{-1}.

Lim *et al*. (2020) compared the kinetic drying characteristics and quality of the *G. cambogia* through sun drying and superheated steam drying method. The optimal conditions for superheated steam drying of *G. cambogia* fruit rinds were identified as 46.60 minutes at 150°C which resulted in faster drying process and better quality of dried rind than conventional sun drying technique

Garcinia pedunculata slices were pretreated with sucrose (10%), fructose (10%), and brine solution (2%) for 10 minutes at three different temperatures. Sucrose pretreated samples helped to retain more ascorbic acid (115.25 ± 0.19 mg 100 g^{-1}), antioxidant activity (33.25 ± 0.07%) whereas fructose pretreated samples dried at 45 °C exhibited maximum value for B vitamins, total phenolic content (15.78 ± 0.15 mg GAE 100 g^{-1}), total flavonoid content (11.11 ± 0.08 mg QE100 g^{-1}). The brine pretreated sample showed minimum microbial growth. Fructose pretreated sample was selected as the best method for preserving the quality of dried *Garcinia pedunculata* (Hossain *et al.,* 2021).

2.4.2.2 Development of Pickle

Pickling is one of the oldest and most successful methods of food preservation by fermentation. Pickles have a long history as the cucumber was taken to Middle East from India about 4000 years ago. In India, use of pickle in meals has a long history where Ibn Battuta (A.D.1336-1357) described pickles of 'Pepper, green ginger, or lemon and mangoes. Pickles are known as good appetizers which are preserved and flavoured in solution of common salt and vinegar along with spices and oil (Sharma, 2010). Pickle is a traditional fermented food made mainly from vegetables and during pickling process sugars will be converted to acid by lactic acid bacteria (Nurul and Asmah, 2012).

Fermentation of fruits and vegetables is mainly by the natural flora Lactic Acid Bacteria (LAB) present in the surface of sample, such as *Lactobacillu*s spp., *Leuconostoc* spp., and *Pediococcus* spp. (Karovicova *et al*., 1999) that lead to production of pickle. Lactic acid bacteria fermented vegetables helped to enhance human nutrition by providing vitamins, minerals, and carbohydrates (Yamano *et al*., 2006). Pickled products by lactic acid bacteria fermentation had unique flavour and great healthful effects (Choi *et al*., 2013).

Depending on the individual preferences, Pickles are usually made from salt reserves of raw fruit and vegetable prepared during the season for consumption between 5 and 25 g. pickle is believed to be an indispensable food ingredient in many parts of India but with the prevalence of hypertension, people are unable to add pickle into their usual eating habits because of large salt content found in pickle (Drenjancevic-Peric *et al*., 2011).

According to Sayin and Alkan (2015) pickling improved the levels of bioactive components and antioxidant capacities of vegetables even after 30th day of

fermentation. The study confirmed that domestically prepared pickles were not only a delicious vegetable product, but also a good source of antioxidants.

Effect of salt concentration and fermentation time on pH value, total acidity and microbial characteristic of pickled ginger (*Zingiber officinale* Rosc.) was studied by Susilowati, *et al*. (2018). Two factors namely salt (NaCl) concentrations (2.5, 5.0 and 7.5 % w/w) and fermentation time (5 and 10 days) were taken for the experiment. The total acidity and total lactic acid bacteria count were found to decrease with increase in salt concentrations and longer fermentation time.

Malabar tamarind fruits were processed into spicy and sweet pickles using salt as a preservative agent and for the preparation of sweet pickle fruits were incorporated with good quality dates. The Products got a shelf life of 2 months at room temperature and 3 months at refrigerated condition. Calorie and carbohydrate content was higher in sweet pickle compared to spicky pickle were13.06 Kcal and 1.45 g respectively in 5 g servings. Vitamin C retention and protein retention was also more in sweet pickle 1.03 mg and 0.54 g compared to spicy pickles (Gopakumar and Kavitha, 2014).

Other acidic fruits from *Garcinia* sp such as *Garcinia lancifolia* and *Garcinia binucao (Blanco) Choocy* were also used for preparation of pickles (Policegoudra *et al.,* 2012 ; Bainto *et al.,* 2018). Sowmya *et al.,* (2019) standardized protocol for development of pickle from kokum fruit with addition of salt and spices, and the product recorded good sensory characters.

Thakur *et al.* (2017) evaluated the development and storage quality of seedling mango (*Mangifera indica L.)* pickle of Himachal Pradesh. Pickles showed a storage life of 6 months under ambient condition in glass bottles. All the biochemical parameters tested such as acidity, ascorbic acid, total phenols, chlorophyll content, starch and crude fiber showed a decreasing trend with increase in storage period.

Lee *et al.* (2015) studied the changes in quality characteristics and antioxidant activity during ageing of bitter melon pickle (*Momordica charantia* L.). During the aging process pH, salinity soluble solids, and reducing sugars of pickle were decreased, whereas acidity increased. Total viable, lactic acid bacteria, and yeast viable cell numbers greatly increased during aging upto 1 week, then they slightly decreased. Levels of soluble phenolics and antioxidant activity increased during ageing.

Attri and Sharma (2016) evaluated peach fruits (cv July Elberta) for the preparation of sweet pickle in order to see their suitability and consumer acceptability. For standardization procedure various combinations of sugar, salt along with fixed quantity of citric acid, acetic acid and spice extracts were tried. Among various treatments sweet peach pickle prepared with 5.50 % salt and 60°Brix TSS of syrup combination was found to be the best and also recorded the highest sensory score at the end of 90 days of storage.

Materials and Methods

3. MATERIALS AND METHODS

The materials used and the methodologies adopted during the present investigation "Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala" conducted with the objective to assess the bioactive compounds in major *Garcinia* spp.of Kerala *viz. G. gummi-gutta* (Malabar tamarind), *G. mangostana* (mangosteen), *G. xanthochymus* (yellow mangosteen) and development of value added products with nutraceutical importance are described in this chapter. The study was conducted as four separate experiments.

3.1 Assessment of bioactive compounds

3.2 Standardization of colour extraction from mangosteen pericarp

3.3 Development of nectar from *Garcinia* spp.

3.4 Value added products from *G. gummi-gutta*

The experiment was conducted at Department of Postharvest Management, College of Agriculture, Vellayani, Kerala Agricultural University, during the year 2017-2021.

3.1 ASSESSMENT OF BIOACTIVE COMPOUNDS

Fully ripe and uniform sized fruits of *G. gummi-gutta* var. *gummi-gutta* (Malabar tamarind) and *G.xanthochymus* (yellow mangosteen) were collected from Instructional Farm, College of Agriculture, Vellayani and *G. mangostana* fruits were collected from selected orchards of Pathanamthitta district. The bioactive compounds in both pulp and pericarp were assessed separately for the three species of Garcinia (Plate 1.). Primary and secondary metabolites present in pulp and pericarp of all the three species were analysed and described as T_1 - *G. gummi-gutta*, T_2 -*G. mangostana*, T_3 - *G. xanthochymus* and pulp (P_1) and pericarp (P_2) (Plate 2).
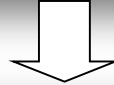
Garcinia gummi-gutta   **_Garcinia mangostana_**   **_Garcinia xanthochymus_**

Plate 1. Selected _Garcinia_ spp.
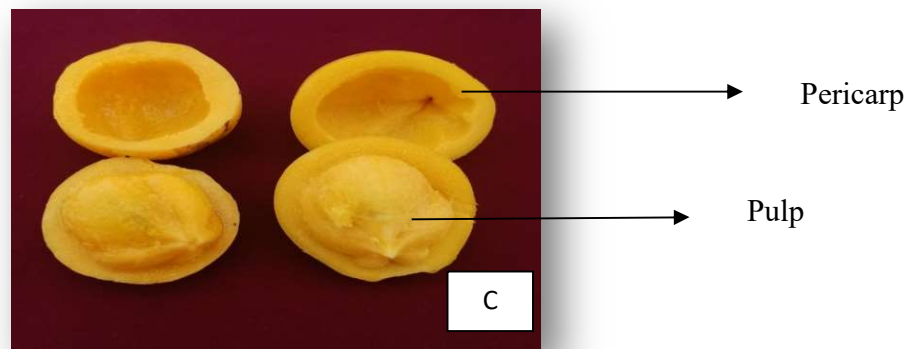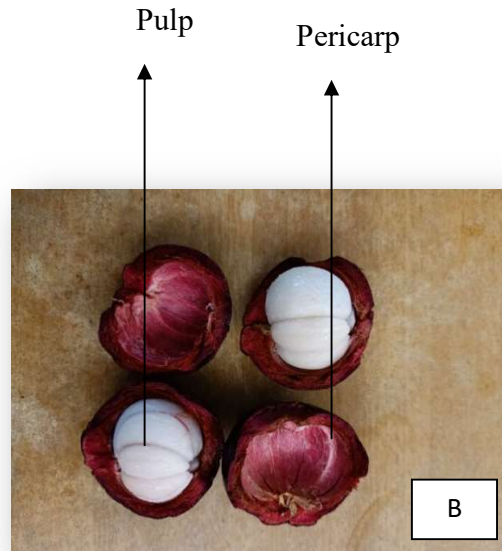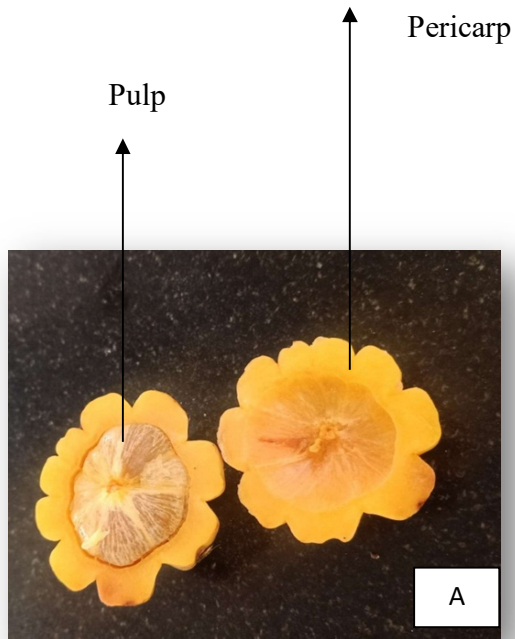
Plate 2. Pulp and pericarp of Gracinia fruits (A: *G. gummi-gutta* **: B-** *G. mangostana* **;C-** *G.xanthochymus***)**

Treatments   : 6 (2x3)

Replications   : 3

Design   : CRD

3.1.1 Biochemical Parameters

Biochemical parameters *viz.,* TSS (^{0}Brix),Total acidity(%), Hydroxy Citric Acid (HCA (%), Vitamin C (mg 100g^{-1}), Total and reducing sugar (%), Protein (g 100g^{-1}), Fat (mg 100g^{-1}), Crude Fibre(%),Total Flavonoids (μg QE g^{-1}), Total phenols (mg GAE 100g^{-1}), Antioxidant activity (DPPH(%)), Carotenoid (mg 100g^{-1}) and minerals *viz.,* Potasium (K), Calcium (Ca) and Iron (Fe) were analysed.

3.1.1.1 Total Soluble Solids ($^{o}Brix$)

Total Soluble Solids (TSS) was recorded by using digital refractometer (Atago - 0 to 85 $^{o}Brix$) and expressed in ⁰ Brix.

3.1.1.2 Total Acidity (%)

The titrimetric method of Cox and Person as described by Ranganna (1986) was adopted for the estimation of total acidity. The titratable acidity was expressed in terms of per cent citric acid equivalent using following formula:

$$\text{Acidity} = \frac{\text{Titre value x Normality of NaOH (0.1N) x Volume made up (100 mL) x}}{\text{Equivalent weight of citric acid (0.064)} \quad \text{x 100}} \\ \text{Volume of aliquot (25 mL) x Weight / volume of the sample}$$

3.1.1.3 Hydroxy Citric Acid (HCA) (%)

Percentages of HCA in pulp and pericarp were analyzed by the procedure described by Patel and Buch (2019). The method is based on colour complex formation by HCA in presence of metavanadate. The acid from the samples were

extracted in a total volume of 200 mL 0.05 N H_2SO_4 and to one mL of the extract, 1 mL of NaOH (1 N) and 0.4 mL of sodium metavanadate (2.5%) were added . After incubation of the mixture for 30 minutes at room temperature coloured HCA-metavandate complex was formed and absorbance recorded at 485 nm using spectrophotometer. Standard curve was plotted with freshly extracted Ca salt of HCA at laboratory and the amount of HCA was calculated.

3.1.1.4 Vitamin C (mg 100g^{-1})

The titrimetric method described by Ranganna (1986) was adopted using 2, 6 dichloro phenol Indophenol method.

$$\text{Vitamin C (mg 100g-1)} = \frac{\text{Titre value X Dye Factor X Volume made up(mL) X 100}}{\text{Aliquat. of extract taken (mL) X Wt. of sample (g)}}$$

3.1.1.5 Total Sugar (%)

The total sugar content was expressed as per cent (Ranganna, 1986) according to the following formula

Total sugar (%) =

$$\frac{\text{Glucose Eq. (0.05) x Total vol. made up (mL) x Vol. made up after inversion (mL) x 100}}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (mL)}}$$

3.1.1.6 Reducing Sugar (%)

The titrimetric method of Lane and Eynon as described by Ranganna (1986) was adopted for the estimation of reducing sugar. Percentage of reducing sugar was calculated according to the following formula

Reducing sugar (%) = $\dfrac{\text{Glucose Eq. (0.05) x Total volume made up (mL)}}{\text{Titre value x Weight of the pulp (g)}} \times 100$

3.1.1.7 Protein (g 100 g^{-1})

Protein content in *Garcinia* samples was estimated using Bradford's colorimetric method (Sadashivam and Manickam, 1992) and a standard curve was plotted and protein content estimated.

3. 1.1.8 Fat (mg 100g^{-1})

The fat content of the sample was determined following the Twisselman method using petroleum ether as solvent (AOAC, 1990). Five gram of the sample (W) was introduced into an ether-extracting thimble and placed on a soxhlet reflux flask connected to a round bottomed flask of known weight (W$_1$). The amount of fat was determined by gravimetric method and expressed as percentage.

$$\text{Fat (\%)} = \frac{W2 - W1 \times 100}{W}$$

W$_2$ – Weight of flask with fat

W$_1$ – Weight of empty flask

 W – Weight of sample taken

3. 1.1.9 Crude Fibre (%)

Crude fibre was determined using the method described by Sadasivam and Manickam (1992). Percentage of crude fibre content of the samples was calculated using the formula

$$\text{Crude Fibre(\%)} = \frac{\text{Loss in weight in ignition} \times \{(W2 - W1) - (W3 - W1)\} \times 100}{\text{Weight of the sample}}$$

W$_1$ - Weight of crucible

W_2–Weight of sample and crucible after two hours

W_3 - Weight of the sample taken

3.1.1.10 Total Flavonoids (μg QE g^{-1})

Total flavonoid content in fruits were assessed according to the colorimetric assay described by Quettier-Deleu *et al.* (2000). The results were expressed in μg Quercetin equivalent per gram in sample by comparison with the quercetin standard curve.

3. 1.1.11 Total Phenols (mg GAE 100g^{-1})

Total phenol content (TPC) of the fruits were determined by method described by Sadasivam and Manickam (1992). Standard curve using different concentrations of Gallic acid was prepared and phenol content of the test sample was expressed as mg phenols 100g^{-1} sample.

3.1.1.12 Antioxidant Activity (%)

Total antioxidant activity of fruits was determined using 2, 2- diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The scavenging effect on DPPH free radical was measured according to the procedure described by Sharma and Bhat (2009).

3. 1.1.13 Carotenoids (mg 100g^{-1})

Carotenoids were estimated as per the procedures of Saini *et al.* (2001) and expressed as mg 100g^{-1} of fruit.

3.1.1.14 Mineral Analysis (Calcium, Potassium and Iron)

3.1.1.1.a Calcium

The calcium content was estimated using Ethylene Di-amine Tetra Acetic Acid (EDTA) titration method, after wet digestion of the samples using di – acid mixture (Jackson, 1973). The digestion of the sample was done by taking 5 mL of the sample in a 100mL standard flask. In the sample 10mL of di-acid digestion mixture (HNO_3 : $HClO_4$ – 9:4) was added and made up the volume to 100mL using distilled water. From this digestion mixture, 10 mL of the sample was pipetted out and to the sample 5 mL of distilled water, 5 mL of NaOH, 10 drops of hydroxylamine hydrochloride and tri ethanol amine and 1 mL of calcon (indicator) were added. The resultant solution was pink in color and the sample solution was titrated with EDTA to get the blue end point.

$$\% \text{ Ca in the sample} = \frac{\text{Titre value x Normality of EDTA (0.01N) x 0.02 x100 x 100}}{10 \text{ x volume of the sample taken}}$$

3.1.1.14.b Potassium (ppm)

Potassium content in the samples were determined by flame photometric method described by Jackson (1973).

3.1.1.14.c Iron (ppm)

The iron content of sample was estimated using the the di-acid digestion and estimation using Atomic Absorption Spectrophotometry (AAS) by Jackson (1973). For the digestion of the sample, 1mL of the sample was taken in a 100 mL conical flask and added 10 mL of digestion mixture, (HNO_3 : $HClO_4$ – 9:4) shaken gently to mix it. For measuring the iron content instrument was set with zero using the blank

(blank digest) and was loaded with standard of iron to standardize it. Then the absorbance/concentration of element in the digested sample was recorded.

Iron (ppm) = AAS reading (mg/L) x dilution

 Volume of sample taken

3.1.2 Profiling of Sugars, Organic Acids, Phenols and Flavonoids Using LC-MS/MS Techniques

Oven dried economic important parts (rind/pulp) of the fruits of three species were subjected to phytochemical profiling using LCMS/MS (Waters UPLCH class system fitted with TQD MS/MS system).

3.1.2.1 Sugar Profiling

Sugars were extracted by following the methods described by Steppuhn and Wackers, (2004). Fruit sample (0.1 g) was diluted 20 times with mobile phase (Solvent A: 80:20-Acetonitrile: Water; Solvent B: 30:70-Acetonitrile: Water + 0.1% Ammonium hydroxide) and out of the filtered 1 mL sample, 2µl sample was injected to LCMS/MS (Waters UPLC H class system fitted with TQD MS/MS system) for analysis.

LC and MS-MS condition

The initial gradient was composed of 100 per cent solvent A, held for 1 minute. At 8th minute, the gradient was changed to 88% of solvent A and 12 per cent of solvent B, held for 1 minutes and a linear gradient was followed by 98 per cent of solvent A and 2 per cent of solvent B at 15 mins, held for 0.5 minute. The system was then returned to the initial conditions at 19th minute and equilibrated for 1 minute before the next injection. The flow rate was 0.1 mL/minute and the analytical column was 2.1 X 100 mm UPLC BEH-Amide column (Waters, USA) with 1.7 µm particles,

protected by a vanguard BEH-Amide with 1.7μm. Guard column (Waters, USA) was used with column temperature at 25°C. The elution was monitored using a PDA detector and the UPLC column effluent pumped directly without any split into the TQD-MS/MS (Waters, USA) system, optimized for the sugars analysis.

Mobile phase

Solvent A: 80:20-Acetonitrile: Water

Solvent B: 30:70-Acetonitrile: Water + 0.1% Ammonium hydroxide

3.1.2.2 Organic Acids Profiling

The extraction procedure for organic acids was carried out as per Ribeiro *et al*. (2007). Sample (1g) was diluted 20 times with mobile phase and 1mL was filtered and 2μl sample was injected to LCMS/MS (Waters UPLC H class system fitted with TQD MS/MS system) for analysis.

LC and MS-MS conditions

The initial gradient composed of 100% aqueous phase (A) and 0% organic phase (B) was held for 30 seconds. At 5th minute, the gradient was changed to 95% aqueous phase and 5% organic phase, held for 0.5 min. System was then returned to the initial conditions at 6th minutes and this condition was held for 1 min to equilibrate before the next injection. The flow rate was maintained at 0.1 mL/min. The analytical column used was 2.1 X 50mm UPLC BEH- Amide column (Waters) with 1.7μm particles, protected by a Vanguard 2.1 X 5mm BEH-Amide with 1.7μm particle size guard column (Waters) was used and the column temperature was maintained at 25°C. The sample injection volume was 4μL. The elute organic acids were monitored using a PDA detector and the UPLC column effluent was pumped

directly without any split into the TQD-MS/MS (Waters, USA) system, which was optimized for the identification and quantification of organic acids analysis.

Mobile Phase

Solvent - A: 10mM Ammonium Acetate: Acetonitrile (50:50), pH: 8.5 (pH adjusted with Ammonia)

Solvent - B: Acetonitrile with 0.05% formic acid

3.1.2.3 Phenolic Acids and Flavonoids Profiling

The individual phenolic acids and flavonoids for LC-MS/MS analysis were isolated from 80% methanol extract as per Weidner *et al*. (1999) and Chen *et al*. (2001) with slight modifications. Sample (1g) was homogenized in methanol (80%), subjected to centrifugation and the final volume was made up to 50 mL. Extract (10 mL) was taken and evaporated near to dryness under vacuum at 45°C and then diluted to 5 mL with water. Later extracted thrice with 40 mL of ethyl acetate and aqueous layer formed was discarded; ethyl acetate extract was evaporated to dryness under vacuum at room temperature. To the dry residue, 4 mL of 2N NaOH was added and allowed for hydrolyzing overnight. Extract was acidified to pH 2 by using 5 mL 2N HCl extracted with 50 mL ethyl acetate. Ethyl acetate layer was again re-extracted twice with 25 mL of 0.1N NaHCO$_3$. The ethyl acetate layer which carries the flavonoids/phenols was allowed to evaporate for complete dryness under vacuum, the residue was dissolved in 2 mL MS grade methanol and filtered through 0.2 μm nylon filter prior to injection into HPLC-MSMS system for flavonoids estimation. The aqueous layer was further acidified to pH 2 with 5 mL 2N HCl and extracted thrice with 25 mL ethyl acetate, the ethyl acetate layer was dried completely in rotary evaporator and the residue was dissolved in 2 mL MS grade methanol, filtered through 0.2 μm nylon filter prior to injection into HPLC-MSMS system for phenolic acid estimation.

LC and MS-MS conditions

The phenolic acids and flavonoids were resolved on the analytical column BEH-C18 (2.1 x 50 mm, 1.7 μm) from waters India Ltd., protected by a Vanguard BEH C-18 (Waters, USA) with the gradient flow of organic and aqueous phase with the flow rate of 0.3 mL minute[-1]. The column temperature was maintained at 25°C during analysis and the sample injection volume was 2μL. The eluted phenolic acids and flavonoids were monitored by a PDA detector and the UPLC column effluent pumped directly without any split into the TQD-MS/MS (Waters, USA) system optimized for the phenolic acids and flavonoids analysis.

Mobile phase

Solvent - A: 0.1 per cent formic acid in water

Solvent - B: 0.2 per cent formic acid in methanol

3.1.3 Isolation of Major Benzophenones Garcinol and Isogarcinol from *Garcina indica* Fruits

3.1.3.1 Extraction

Fruits of *G. gummi-gutta* and *G. xanthochymus* free from pest and diseases were collected from Instructional Farm of College of Agriculture, Vellayani, ,Kerala, India. *Garcinia indica* fruits were collected from Udupi district of Karnataka and *G. mangostan*a fruits from farmers' field of Pathanamthitta, Kerala. All the fruits samples were oven dried at 50 °C and powdered samples were packed in airtight container and stored at 20 °C until analysis.

3.1.3.2 Column Chromatographic Separation of Hexane Extract

Isolation of compound I and II

The dried fruits (*Garcinia indica*) weighted 500g were powdered and were extracted with hexane (3 L) using Soxhlet extractor for 4 hours. The removal of solvent at 40°C under reduced pressure in a rotary evaporator yielded 30 g of crude hexane extract. Column chromatography was done using 100-200 mesh silica gel and 20 g hexane extract was loaded on the top of the column. The column was eluted successively with varying polarities of hexane-ethyl acetate mixtures (100:0–0:100). First compound was isolated on elution with 15% ethyl acetate in hexane (15:85) as yellow colour, which on crystallization at 4 ^{0}C yielded needle like yellow crystals. Second compound was isolated on elution with 20% ethyl acetate in hexane (20:80) as colour less lustrous crystals (Plate 3.) .

Isolation of compound III

The dried fruits (*Garcinia xanthochymus*) 200 g were coarsely powdered using a blender and extracted with hexane (2 L) using soxhlet extractor for 4 hours. The removal of solvent at 40°C under reduced pressure in a rotary evaporator yielded 20 g of crude hexane extract. This extract was subjected to gradient elution with 100–200 mesh silica gel column chromatography using the solvents hexane–ethyl acetate (100:0–70:30) to give fractions. Compound was isolated on elution with 5% ethyl acetate in hexane (5:95) as yellow colored crystals (Plate 3.) .

The structures of all isolated compounds were identified by the interpretation of their spectral data viz., UV, ^{1}H NMR and ^{13}C NMR, as well as by comparison of their spectral data with those reported in the literature.

3.1.3.3 Quantification of Benzophenones in the Fruits through HPTLC Estimation

The oven dried samples of *Garcina* species (2 g) were extracted with 100 mL of hexane for 2 hours by using soxhlet extraction. The hexane extracts were transferred in conical flask and were concentrated and re-dissolved in 50 mL of hexane.

G. indica

G.xanthochymus

Crystallization

Crystallization

Garcinol

Isogarcinol

Xanthochymol

Plate 3. Coloumn chromatography of *G. indica* (a)and *G. xanthochymus* (b)

Sample preparation

Stock solutions of garcinol, isogarcinol, and xanthochymol (1 mg mL^{-1}) were prepared by dissolving garcinol and isogarcinol in hexane and chloroform respectively, and different amounts (1,5,10 µl) of these were loaded to a TLC plate.

Instrumentation

A HPTLC documentation system (AETRON 5.01 model Easy Doc) equipped with an automatic automatic sample applicator, and integrated software ISHAAN version: 5.01 was used for the analysis. The stationary phase was pre-coated silica gel TLC 60F$_{254}$ (20 cm × 20 cm) plate used for the quantification of benzophenones in *Garcinia* species. The plant samples and the standards were loaded with the help of Spraline IV automatic sample applicator on the TLC plate. The TLC plates were developed in a twin trough chamber (20 cm × 20 cm), which was pre-saturated with 25 mL mobile phase with hexane :ethylacetate (7; 3) for 30 min, at room temperature (28 ± 2 °C) and 55 ± 5% relative humidity. Quantitative evaluation of the plate was performed in the absorption–reflection mode at 268 nm. Each analysis was carried out in triplicate.

3.1.4 Quantification of Major Xanthone α-- Mangostin in Mangosteen Pericarp by HPLC Technique

HPLC analysis was done using the instrument CKL/ANL/E-027 – Agilent Technologies 1200 Infinity Series. HPLC grade standard of α- mangostin was purchased from Sigma Aldrich . Ten grams of the dried mangosteen rind powder was extracted in 400 mL of methanol in a soxhlet apparatus for 15 h. The filtrate was concentrated at 50ºC and was transferred to 10 mL volumetric flask using methanol. The solution was filtered through 0.22 µm filters and injected to the HPLC system. The standard was prepared by weighing 5 mg α- Mangostin standard in a 5mL

standard flask and volume made with methanol to get 1000ppm. From this 50,100,200,300 ppm were prepared by diluting with methanol.

Mobile phase : Acetonitrile : 0.1% Orthophosphoric acid in Water (70: 30)

Chromatographic conditions

Column   : C_{18} 4.6×250mm×3μm

Flow rate   : 1.0mL/minute

Inj.Volume   : 10μL

Wave length   : 320nm

Run time   : 30 minutes

3.2 COLOUR EXTRACTION FROM MANGOSTEEN PERICARP

3.2.1 Anthocyanin Extraction

Mangosteen fruits of optimum commercial maturity stage were collected from orchards of the Pathanamthitta district of Kerala, India.The harvested fruits free from physical damage, pests, diseases, and physiological disorders were washed thoroughly using distilled water. The pulp and pericarp were separated manually and the pericarp was dried at $50^{0}C$ till it attained a constant weight with moisture content. The powdered pericarp samples were extracted using solid- liquid extraction method with distilled water (aqueous extraction) and ethanol (50% V/V) as solvent, acidified using citric acid (0.1% and 0.2%) and acetic acid (1 and 2%). Experiment treatments were T_1- Ethanol with 0.1%, Citric acid, T_2- Ethanol with 0.2% Citric acid, T_3- Ethanol with 1 % Acetic acid, T_4- Ethanol with 2% Acetic acid, T_5- Aqueous extraction (distilled water) with 0.1% Citric acid, T_6- Aqueous extraction with 0.2% Citric acid, T_7- Aqueous extraction with 1% Acetic acid, T_8- Aqueous extraction with 2% Acetic acid, T_9-Ethanol (50% V/V), T_{10}-Aqueous extraction (distilled water). The Ratio of solid to solvent was maintained at 1:10 done at $50^{0}C$ for 1 hour. After

the extraction process filtrate was concentrated to dryness using rotary vacuum evaporator (Heidolph) at 60°C. The extracts were stored under refrigeration at 5- 7°C for further analysis.

Treatments   : 10
Replications   : 3
Design   : CRD

3.2.2. Analysis of Colour Extract

3.2.2.1 pH

pH of the extracted anthocyanin was measured by using pocket pH tester (Hanna instruments, pHep Tester).

3.2.2.2 Yield (%)

The extraction yield was calculated as percentage using following formula (Ho *et al.*, 2011)

Extraction Yield (%) = Weight of concentrated extract (g) x 100

$\overline{\hspace{4cm}}$

Weight of pericarp powder taken for extraction (g)

3.2.2.3 Total Flavonoids (µg QE g⁻¹)

Total flavonoids was calculated as described in *3.1.1.10*

3.2.2.4 Total Phenol (mg GAE 100g⁻¹)

Total phenol was calculated as described in *3.1.1.11*

3.2.2.5 DPPH(%)

DPPH (%) was calculated as described in *3.1.1.1 3*

3.2.2.6 Colour Analysis

Colorimetric data were recorded with HunterLab Color Flex EZ (USA). Instrument was standardized using different coloured tiles and the samples were placed in a transparent quartz container. Colour values were noted in triplicates. The colour parameters were expressed as CIE Lab* coordinates where L* represents Lightness (L*), redness (a*, ±red-green), and yellowness (b*, ±yellow-blue). Chroma and hue angle were calculated from CIE a * and b * (Stintzing *et al.*,2005)

$$Chroma* = (a^2 + b^2)^{\frac{1}{2}}$$

$$H° = arctan\ b*/a*$$

3.2.2.7 Total Anthocyanin Content (mg 100g^{-1})

Total anthocyanin content in the samples were calculated with the method described by Ranganna (1997). Anthocyaninn was extracted with ethanolic HCl and measurement of colour at a wavelength of 535 nm against blank of ethanolic-HCl using a UV spectrophotometer.

$$Total\ OD/100g = \frac{OD\ x\ volume\ made\ up\ x\ 100\ x\ Dilution\ factor}{Weight\ of\ sample}$$

$$Total\ anthocyanin\ (mg\ 100g^{-1}) = \frac{(Total\ OD/100\ g)}{98.2}$$

3.3 DEVELOPMENT OF NECTAR FROM *GARCINIA* SPP.

3.3.1. Preparation of Nectar from *Garcinia* spp.

Pulp extracted from the rind of *G. gummi-gutta* (G_1,) mangosteen aril (G_2) and fruits of *G.xanthochymus* (G_3) was used for the preparation of nectar with different fruit pulp concentration as per FSSAI standards. Both *G.gummi-gutta* and *G. xanthochymus* fruits were water blanched prior to the pulp extraction. Nectar formulations were.

F_1 –Fruit (15%): TSS (15^0Brix)

F_2 –Fruit (20%): TSS (15^0Brix)

F_3 –Fruit (15%): TSS (20^0Brix)

F_4 –Fruit (20%): TSS (20^0Brix)

F_5 –Fruit (20%): TSS (25^0Brix)

F_6 –Fruit (20%): TSS (30^0Brix).

Biochemical and sensory parameters of the nectar formulations were analysed and the best formulation selected from each *Garcinia sp.* was used for the colour addition and storage stability studies .

Treatments   : 6
Replications   : 3
Design   : CRD

3.3.1.1. Biochemical Analysis of Nectar

Biochemical parameters of the nectar formulation *viz.,* TSS, total acidity, vitamin C, reducing sugar, total sugar,total anthocyanin content, total flavonoids, total phenols , antioxidant activity and HCA were analyzed for each *Garcinia* sp.

3.3.1.1 .a Total Soluble Solids (^oBrix)

Total Soluble Solids (TSS) was calculated as described in 3.1.1.1

3.3.1.1.b Total acidity (%)

Total acidity was calculated as described in 3.1.1.2

3.3.1.1.c Vitamin C (mg 100g^{-1})

Vitamin C content was calculated as described in 3.1.1.4

3.3.1.1.d Reducing Sugar (%)

The reducing sugar was calculated as described in 3.1.1.6

3.3.1.1.e Total Sugar (%)

The total sugar content was calculated as described in 3.1.1.5

3.3.1.1.f Total anthocyanin content (mg 100g^{-1})

Total anthocyanin content was calculated as described in *3.2.2.7*

3.3.1.1.g Total Flavonoids (µg QE g^{-1})

Total flavonoids was calculated as described in 3.1.1.1*0*

3.3.1.1.h Total phenol (mg 100g^{-1})

Total phenol was calculated as described in3.1.1.11

3.3.1.1.i Antioxidant Activity (%)

Total antioxidant activity of nectar was calculated as described in 3.1.1.13

3.3.1.1.j HCA(%)

HCA was calculated as described in 3.1.1.3

3.3.1. 1.k Sensory Analysis

The nectar formulations prepared were evaluated for sensory characteristics *viz*., appearance, colour, flavour, taste, texture and overall acceptability by 30 semi trained members. Each character was given a score from 1 to 9 according to Hedonic rating (Ranganna, 1986). The sensory analysis was carried out to obtain one best treatment from each fruit species. The score was statistically analysed using Kruskall-Wallis test (chi-square value) (Shamrez *et al*., 2013).

3.3.2. Colour Addition to Nectar Formulations

The best nectar formulation from each *Garcinia* spp. selected based on biochemical and sensory evaluation and treatments were used for colour addition studies.

F_4G_1 - *G. gummi gutta* nectar prepared with 20 % fruit and 20 ^{0}Brix

F_2G_2 -- *G. mangostana* nectar prepared with 20 % fruit and 15 ^{0}Brix

F_3G_3 - *G. xanthochymus* nectar prepared with 15 % fruit and 20 ^{0}Brix

Colour extracted from the previous experiment (Part II) of the study was incorporated in the selected nectar formulations at different concentration (0.5%, 0.3% and 0.5%) to develop an acceptable colour for the product. The formulations with and without addition of colour extract was stored in glass bottles at room temperature for three months and biochemical and sensory parameters were analysed at monthly interval .

Treatments were,

G_1W- *G.gummi-gutta* nectar without mangosteen colour, G_1 C- *G.gummi-gutta* nectar supplemented with 0.5% colour, G_2W- *G. mangostana* nectar Without mangosteen colour, G_2C- *G. mangostana* nectar supplemented with 0.3% colour,

G₃W- *G.xanthochymus* nectar without mangosteen colour and G₃C- *G.xanthochymus* nectar supplemented with 0.5% colour

3.3.2.1 Biochemical Changes During Storage

3.3.2.1 .a *Total Soluble Solids (^oBrix)*

Total Soluble Solids (TSS) was calculated as described in 3.1.1.1

3.3.2.1.b *Total Acidity (%)*

Total acidity was calculated as described in 3.1.1.2

3.3.2.1.c *Vitamin C (mg 100g^{-1})*

Vitamin C content was calculated as described in 3.1.1.4

3.3.2.1.d *Reducing Sugar (%)*

The reducing sugar was calculated as described in 3.1.1.6

3.3.2.1.e *Total Sugar (%)*

The total sugar content was calculated as described in 3.1.1.5

3.3.2.1.f *Total Anthocyanin Content (mg 100g^{-1})*

Total anthocyanin content was calculated as described in 3.2.2.7

3.3.2.1.g *Total Flavonoids (µg quercetin equivalent g^{-1})*

Total flavonoids was calculated as described in 3.1.1.10

3.3.2.1.h *Total Phenol (mg 100g^{-1})*

Total phenol was calculated as described in 3.1.1.1*1*

3.3.2.1. e *Antioxidant Activity (%)*

Total antioxidant activity of nectar was calculated as described in 3.1.1.13

3.3.2.1. f HCA(%)

HCA was calculated as described in 3.1.1.3

3.3.4 Colour Stability Studies

3.3.4.1 Effect of Light on Colour Stability

Nectar formulations were stored in two different storage containers, (i) T-Transparent ii) A- amber. Anthocyanin was measured at monthly interval for three months.

3.3.4.2 Effect of Temparature on Colour Stability

Nectar formulations were kept at two temperatures (70 ^{0}C and 90 ^{0}C) and anthocyanin was measured at initially, after 30 minutes and one hour.

3.4 VALUE ADDED PRODUCTS FROM *GARCINIA GUMMI-GUTTA*

Fully ripe *G. gummi gutta* fruits were harvested and rind was used for making different value-added products viz., osmodehydrated product, culinary paste and pickles.

3.4.1   Development of Osmodehydrated Product

Two-centimeter-long fruit rind slices were made out of steam blanched fruit rind and subjected to osmotic dehydration with sucrose as osmotic medium. Rind slices were immersed in 50°Brix (C_1) and 70°Brix (C_2) osmotic solution (sucrose) for an immersion time of 24 hour (T_1) 36 hour (T_2) and 48 hour (T_3) with three replications. The ratio of fruits to osmotic solution was maintained at 1:2.

After osmotic treatments, the samples were removed from the solution, drained and analysed for mass transfer characters. The osmosed *G. gummi-gutta*

rinds was further dehydrated using cabinet drier at 50°C till the product attain a moisture of 15-18% and were analysed for biochemical and sensory parameters.

Treatments   : 6(2x3)

Replications   : 3

Design   : CRD

3.4.1.1 Mass Transfer Characters

3.4.1.1.a Solid Gain (%)

Solid gain (%) was determined using the procedure followed by (Kowalski and Mierzwa, 2011).

$$SG(\%) = \frac{St - Si}{mi} \times 100$$

Where, S_t = dry mass at time t, S_i = Initial dry mass (of fresh) and m_i= initial mass of wet sample.

3.4.1.1.b Water Loss (%)

Weight of fresh fruit and weight after osmosis was recorded in electronic balance (Cyber Lab-0.01mg to 1000mg). Dry mass of fresh fruit and dry mass after osmosis were recorded and water loss in terms of percentage was calculated by the method described by Sridevi and Genitha (2012) using following formula

$$WL(\%) = \frac{(Wo - Wt) + (St - So)}{Wo} \times 100$$

W_o = Initial weight of rind

W_t = Weight of rind after osmotic dehydration

S_0 = Initial dry mass of rind

S_t = Dry mass of rind after osmotic dehydration

3.4.1.1. c Weight Reduction (%)

Weight reduction in terms of percentage was calculated using the method described by Yadav *et al.* (2012).

$$WR(\%) = \frac{Mo-M}{Mo} \times 100$$

Mo = Initial mass of rind prior to osmosis (g)

M = Mass of rind after osmosis (g)

3.4.1.2 Biochemical Analysis of Osmodehydrated Product

3.4.1.2.a Total Soluble Solids (^oBrix)

Total Soluble Solids (TSS) was calculated as described in 3.1.1.1

3.4.1.2.b Total Acidity (%)

Total acidity was calculated as described in 3.1.1.2

3.4.1.2.c Reducing Sugar(%)

The reducing sugar was calculated as described in 3.1.1.6

3.4.1.2.d Total Sugar(%)

The total sugar content was calculated as described in 3.1.1.5

3.4.1.2.e Vitamin C(mg 100g^{-1})

Vitamin C content was calculated as described in 3.1.1.4

3.4.1.2.f Antioxidant Activity (%)

Total antioxidant activity of nectar was calculated as described in 3.1.1.13

3.4.1.2.g HCA (%)

HCA was calculated as described in 3.1.1.3

3.4.1.2.h Sensory Analysis

Sensory analysis was conducted as described in *3.3.1. 1.k*

3.4.1.3 Storage Studies of Osmodehydrated *G.gummi-gutta* rind

Osmodehydrated product obtained from all the six treatments were packed and stored for a period of 3 months and microbial sensory and biochemical analysises were conducted at monthly interval.

3.4.1.3.a Total Soluble Solids (^oBrix)

Total Soluble Solids (TSS) was calculated as described in 3.1.1.1

3.4.1.3 .b Total Acidity (%)

Total acidity was calculated as described in 3.1.3.1

3.4.1.3.c Reducing Sugar(%)
Reducing sugar during storage was calculated as described in 3.1.3.3
3.4.1.3.d Total Sugar(%)

Total sugar during storage was calculated as described in 3.1.3.5

3.4.1.3.e Vitamin C(mg 100g^{-1})
Vitamin C during storage was calculated as described in 3.1.3.3

3.4.1.3.f Antioxidant Activity (%)

Antioxidant activity during storage was calculated as described in 3.1.3.6

3.4.1.3 .g Sensory Analysis

Sensory analysis was conducted as described in 3.3.1.1.k

3.4.1.3.h Enumeration of microbial load(log CFU ml^{-1})

The quantitative assay of the micro flora in stored samples was carried out by serial dilution spread plate techniques. Nutrient agar and Rose Bengal agar medium were used for the enumeration of bacterial and fungal population of the nectar beverages respectively.

$$\text{No. of colony forming units per mL of samples} = \frac{\text{Total no. of colony formed X dilution factor}}{\text{Aliquot taken}}$$

3.4.2 Development of Paste

Rind of the *G.gummi gutta* was made in to pulp and subjected to thermal processing (80 ^{0}C, 15 minutes) with addition of different concentration of salt in order to prepare culinary paste as per FSSAI specifications.

T_1- 100g paste + 3% salt

T_2-100g paste + 5%salt

T_3 -100g paste + 7% salt

T_4- 100 g paste+9 %salt

T_5- 100g paste (control)

All the samples were packed in glass bottle and biochemical, microbial and sensory analysis were conducted at monthly interval for a period of three months.

Treatments : 5

Replications : 3

Design : CRD

3.4.2.1 Biochemical Analysis

Biochemical parameters were analysed at monthly interval for three months

3.4.2.1.a Moisture Content

Moisture content of one gram paste was estimated using moisture analyser (Essae, AND MAX 50) which dries the sample using a halogen lamp and gives the moisture content in percentage based on the principle of thermo gravimetric analysis.

3.4.2.1.b Total Soluble Solids (^oBrix)

Total Soluble Solids (TSS) was calculated as described in 3.1.1.1

3.4.2.1.c Total Acidity (%)

Total acidity was calculated as described in 3.1.3.2

3.4.2.1.d Reducing Sugar(%)

Reducing sugar during storage was calculated as described in 3.1.3.4

3.4.2.1.e Total Flavonoids ($\mu g\ QE\ g^{-1}$)

Total flavonoids was calculated as described in 3.1.4.1

3.4.2.1.f Antioxidant Activity (%)

Total antioxidant activity was calculated as described in 3.1.3.6

3.4.2.1.g Crude Fibre(%)

Crude fibre was calculated as describide in 3. 1.3.11

3.4.2.1.h HCA(%)

HCA was calculated as describide in 3. 1.3.11

3.4.2.i Colour Analysis and Browning index

CIE Lab* coordinates were calculated by the method as described in **3.2.2.6**.

Browning index (BI) of paste during storage calculated using the following equation

$$BI = \frac{100(x-0.31)}{0.17}$$

where,

$$x = \frac{a^* + 1.75L^*}{5.645L^* + a^* - 3.012b^*}$$

3.4.2.j Sensory Analysis

Sensory analysis was conducted as described in *3.3.1. 1.k*

3.4.2.k Enumeration of Microbial Load

Microbial analysis was done at monthly interval for three months.Enumeration of microbial load was calculated by procedures as described in**3.3.2.1.h**

3.4.3 Development of Pickle

Sour (P_1) and sweet pickles (P_2) were prepared from osmo dehydrated (best treatment from Part 3.4.1) slices and fresh *G.gummi-gutta* slices respectively. Pickles were prepared as per FSSAI specifications and other pickle ingredients used for pickle were finalized based on preliminary trials.

Treatments : 2
Replications : 7
Design : CRD

3.4.3.1 Biochemical Analysis

Biochemical parameters were analyzed during aging (14 days) at weekly interval. After aging biochemical, microbial and sensory analysis was conducted at fortnight interval for 2 months.

3.4.3.1.a Total Soluble Solids (^oBrix)

Total Soluble Solids (TSS) was calculated as described in 3.1.3.3

3.4.3.1.b Total Dissolved Solid (TDS)(mg L^{-1})

Total Soluble Solids (TDS) was calculated from formula described Rani *et al.* (2012)

TDS (g/L) = 0.6 x Electrical conductivity (EC) (dS/m)

3.4.3.1.c pH

pH was calculated as described in *3.2.2.1*

3.4.3.1.d Total Acidity (%)

Total acidity was calculated as described in *3.1.3.2*

3.4.3.1.e Vitamin C(mg 100g^{-1})

Vitamin C was calculated as described in *3.1.3.3*

3.4.3.1.f Reducing Sugar(%)

Reducing sugar was calculated as described in 3.1.3.4

3.4.3.1.g Total Sugar(%)

Total sugar was calculated as described in 3.1.3.5

3.4.3.1.h Antioxidant Activity (%)

Antioxidant activity during storage was calculated as described in 3.1.3.6.

3.4.3.1.i sensory analysis

Sensory analysis of pickle was done as described in 3.3.1. 1.k

3.4.3.1.j Enuumeration of microbial load

Microbial analysis of pickle was done as described in 3.3.2.1.h

Results

4. RESULTS

Results of the present investigation entitled "Assessment of bioactive compounds and product development from major *Garcinia* spp.of Kerala" are presented in this chapter under the following heads.

4.1 ASSESSMENT OF BIOACTIVE COMPOUNDS

4.2 COLOUR EXTRACTION FROM MANGOSTEEN PERICARP

4.3 DEVELOPMENT OF NECTAR FROM *GARCINIA* SPP.

4.4 VALUE ADDED PRODUCTS FROM *GARCINIA GUMMI-GUTTA*

4.1 ASSESSMENT OF BIOACTIVE COMPOUNDS

The pulp and pericarp of fruits of *G.gummi-gutta, G.mangostana* and *G.xanthochymus* were analysed for primary and secondary metabolites through biochemical, spectrophotometric, HPTLC and LC-MS/MS methods and are depicted in Table 1 to Table 7.

4.1.1 Proximate Composition of *Garcinia* Fruits

Biochemical parameters *viz.,* Total Soluble Solids (TSS), total acidity, Hydroxy Citric Acid (HCA), vitamin C, total and reducing sugars, protein, fat, crude fibre, total flavonoids, total phenols, antioxidant activity and carotenoid contentin pulp (P_1)and pericarp (P_2) of three *Garcinia* spp such as *G.gummi-gutta* (T_1), *G.mangostana* (T_2), *G.xanthochymus* (T_3)were assessed and the results are presented in Table 1a, Table1b, Table 1c and Table 1d.

The Total Soluble Solids (TSS) present in the pulp and pericarp of all fruits varied significantly (Table 1a). The highest TSS of 27.93^0Brix (T_2P_2) was recorded for the pericarp of *G.mangostana* and the lowest TSS of 11.13^0Brix (T_1P_2) was observed for *G.gummi-gutta* pericarp. Among the pulp of the fruits, *G.mangostana*

Table 1a. Proximate composition of *Garcinia* fruits

Treatments (T)	TSS (^{0}Brix)		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	14.30^c	11.13^e	12.72^b
T$_2$ (*G. mangostana*)	20.83^b	27.93^a	24.38^a
T$_3$ (*G. xanthochymus*)	14.80^c	12.47^d	13.63^b
Mean (P)	16.64	17.18	
CD (0.05)	T- 0.726 P-NS TXP- 1.026		
SE(±m)	T- 0.233 P-.190 TXP- 0.329		
Treatments (T)	Total acidity (%)		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	1.91^d	5.08^c	3.50^b
T$_2$ (*G. mangostana*)	1.03^e	0.38^f	0.707^c
T$_3$ (*G. xanthochymus*)	6.18^b	6.54^a	6.36^a
Mean (P)	3.04^b	4.00^a	
CD (0.05)	T- 0.128 P-0.104 TXP- 0.181		
SE(±m)	T- 0.041 P-0.033 TXP- 0.058		
Treatments (T)	Vitamin C(mg 100g^{-1})		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$ (*G. gummi-gutta*)	13.18^d	20.37^c	16.78^b
T$_2$ (*G. mangostana*)	33.80^a	5.96^e	14.24^c
T$_3$ (*G. xanthochymus*)	22.52^c	27.03^b	30.42^a
Mean (P)	23.17^a	17.78^b	
CD (0.05)	T- 1.826 P 1.491 TXP- 2.582		
SE(±m)	T- 0.586 P-0.478 TXP- 0.829		
Treatments (T)	Reducing sugar (%		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	7.17^b	3.69^d	5.43^b
T$_2$ (*G. mangostana*)	11.96^a	0.88^e	6.42^a
T$_3$ (*G. xanthochymus*)	7.10^b	6.26^c	6.68^a
Mean (P)	8.74^a	3.61^b	
CD (0.05)	T-0. 527 P -0.430 TXP- 0.745		
SE(±m)	T- 0.169 P-0.138 TXP- 0.239		

pulp recorded the highest TSS of 20.83^0Brix (T_2P_1) and *G.xanthochymus* fruit pulp recorded 14.80 ^{0}Brix which did not differ statistically significant from *G. gummi-gutta* fruit pulp (14.30 ^{0}Brix).

Garcinia xanthochymus fruit recorded the highest acidity (T_3P_2) for pericarp (6.54%) and fruit pulp (6.18%) (T_3P_1) followed by *G.gummi-gutta* pericarp (T_1P_2) with 5.08% acidity. Thelowest acidity (0.38 %) was observed in mangosteen pericarp (T_2P_2) and it was 1.03% for mangosteen pulp. Hydroxy Citric Acid (HCA) was highest (4.31%) in pericarp of Malabar tamarind (T_1P_2) followed by its pulp (0.92%). The HCA content in mangosteen pulp (T_2P_2) was 0.31% and it was not detected in *G.mangostana* pericarp and *G.xanthochymus* (Yellow mangosteen) pulp and pericarp (Table 1b).

Mangosteen fruit pulp (T_2P_1) noticed the highest ascorbic acid content of 33.80 mg $100g^{-1}$followed by the yellow mangosteen fruit pulp (T_3P_1) with a content of 27.03mg $100g^{-1}$. Malabar tamarind fruit pericarp (T_1P_2) recorded a vitamin C content of 20.37 mg $100g^{-1}$ whereas the lowest ascorbic acid content (5.96 mg $100g^{-1}$) was exhibited by mangosteen fruit rind (T_2P_2).

The highest reducing sugar (11.96 %) and total sugar content (13.31%) were recorded for mangosteen fruit pulp (T_2P_1) rind (T_2P_2) (Table 1a and Table 1c) recorded a lower value (1.96 %). The Malabar tamarind pulp recorded a reducing sugar of 7.17%which was statistically on par with yellow mangosteen fruit pulp (7.10 %), and the lowest reducing sugar was reported in mangosteen pericarp (T_2P_2). Malabar tamarind fruit pulp (T_1P_1) recorded a total sugar of 8.69%, and yellow mangosteen fruit pulp (T_3P_1) recorded 8.42 % which were statistically on par.

The protein content of fruits differed significantly as mentioned in Table 1c. *G.xanthochymus* (yellow mangosteen) (T_3P_1) noticed the highest protein of 5.24g $100g^{-1}$ and lowest protein (0.36g $100g^{-1}$) was recorded in Malabar tamarind pulp

Table 1b. HCA (%) of *Garcinia* fruits

Treatments	HCA (%)
T_1P_1	0.92^b
T_1P_2	4.31^a
T_2P_1	0.31^c
T_2P_2	ND
T_3P_1	ND
T_3P_2	ND
CD(0.05)	0.471

T_1 – *G. gummi-gutta*, T_2 – *G. mangostana* ,T_3 – *G. xanthochymus* ;
   P_1 – Fuit pulp , P_2 – Fruit pericarp

Table 1c. Proximate composition of *Garcinia* fruits

Treatments (T)	Total sugar (%)		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	8.69^b	5.11^d	6.90
T$_2$ (*G. mangostana*)	13.31^a	1.96^e	7.63
T$_3$ *G. (xanthochymus)*	8.42^b	7.37^c	7.90
Mean (P)	10.14^a	4.82^b	
CD (0.05)	T- NS P- 0.675 TXP- 1.169		
SE(±m)	T- 0.265 P-0.217 TXP- 0.375		
Treatments (T)	Protein(g 100g^{-1})		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	0.36^e	2.86^c	1.61^c
T$_2$ (*G. mangostana*)	1.74^d	5.18^a	3.46^b
T$_3$ (*G. xanthochymus*)	5.24^a	4.32^b	5.58^a
Mean (P)	3.11^b	4.12^a	
CD (0.05)	T- 0.451 P- 0.369 TXP- 0.639		
SE(±m)	T- 0.145 P-0.118 TXP- 0.205		
Treatments (T)	Crude Fibre (%)		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	1.44^d	5.10^c	3.27^b
T$_2$ (*G. mangostana*)	1.73^d	12.37^a	7.05^a
T$_3$ (*G. xanthochymus*)	6.50^b	7.03^b	6.77^a
Mean (P)	3.22^b	8.12^a	
CD (0.05)	T- 0.483 P- 0.394 TXP- 0.683		
SE(±m)	T- 0.155 P-0.127 TXP- 0.219		
Treatments (T)	Fat(mg 100g^{-1})		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	0.14^d	0.36^c	0.25^b
T$_2$ (*G. mangostana*)	0.51^b	1.35^a	0.93^a
T$_3$ (*G. xanthochymus*)	0.39^c	0.20^d	0.30^b
Mean (P)	0.34^b	0.64^b	
CD (0.05)	T- 0.048 P- 0.039 TXP- 0.068		
SE(±m)	T- 0.015 P-0.013 TXP- 0.022		

(T_1P_1). Mangosteen pericarp recorded protein content of 5.18 g 100g^{-1} followed by yellow mangosteen fruit rind (T_3P_2) of 4.32 g 100g.$^{-1}$

The highest crude fibre content of 12.37 % was observed for the pericarp of mangosteen fruits (T_2P_2) and malabar tamarind pulp (T_1P_1) recorded a lower value of 1.44%which was on par with mangosteen fruit pulp (1.73%). Crude fibre content of pulp and pericarp of yellow mangosteen (T_3P_1 and T_3P_2) fruits were statistically on par and exhibited values as 6.50 and 7.03 % respectively.

The fat content present in pulp and pericarp of the all fruits varied significantly (Table 1b). The highest fat content of 1.35mg 100g^{-1} was recorded by pericarp of *G.mangostana* (T_2P_2) followed by mangosteen pulp (0.51mg 100g^{-1}. *G.gummi-gutta* pericarp (T_1P_2) recorded a fat content of 0.36 mg 100g^{-1}which was on par with *G.xanthochymus* fruit pulp (T_3P_1) (0.39 mg 100g^{-1}) and *G. gummi-gutta* fruit pulp (T_1P_1) recorded a fat content of 0.14 mg 100g^{-1}.

The highest total phenols (Table 1d) was observed in mangosteen pericarp (T_2P_2) was (2603.68 mg GAE 100g^{-1}) followed by yellow mangosteen pericarp (T_3P_2) (1937.73 mg GAE 100g^{-1}).The lowest total phenols was observed for mangosteen fruit pulp (T_2P_1) (164.14 mg GAE 100g^{-1}) whereas malabar tamarind fruit pulp recorded a phenol content of 382.25 mg GAE 100 g^{-1}.

Total flavonoid content (TFC) of mangosteen pericarp (T_2P_2) was recorded as 61.55mg QE g^{-1} which was the highest among other samples (Table 1d). Total flavonoid content of *G.xanthochymus* pulp (T_3P_1) and pericarp (T_3P_2) were statistically on par and the values were 24.73 and 27.37 mg QE g^{-1}respectively.The lowest flavonoid content (3.11 mg QE g^{-1}) was observed in pulp of mangosteen fruits (T_2P_1). The pericarp of *G.mangostana* (T_2P_2) showed the highest antioxidant activity of 92.27 % which was on par with pericarp of *G.xanthochymus* (91.46%) and *G. gummi-gutta* fruit pericarp (89.83%). The lowest antioxidant activity of 83.02 %was observed   for   mangosteen   fruit   pulp   (T_2P_1).

Table 1d. Proximate composition of *Garcinia* fruits

Treatments (T)	Total Phenol (mg GAE g^{-1})		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	382.25^d	1827.50^b	1104.87^c
T$_2$ (*G. mangostana*)	164.14^e	2603.68^a	1383.90^b
T$_3$ (*G. xanthochymus*)	1443.78^c	1937.73^b	1690.76^a
Mean (P)	663.39^b	2122.97^a	
CD (0.05)	T- 130.71 P- 106.73 TXP- 184.87		
SE(±m)	T- 41.96 P-34.26 TXP- 59.37		
Treatments (T)	Total Flavanoids (mg QE g^{-1})		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	6.58^d	20.19^c	13.38^c
T$_2$ (*G. mangostana*)	3.11^e	61.55^a	32.33^a
T$_3$ (*G. xanthochymus*)	24.73^b	27.37^b	26.05^b
Mean (P)	11.47^b	36.37^a	
CD (0.05)	T- 2.063 P- 1.684 TXP- 2.918		
SE(±m)	T- 0.662 P-0.541 TXP- 0.936		
Treatments (T)	Antioxidant activity (%)		
	Fruit pulp (P$_1$)	Fruit pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	87.32^c	89.83^{abc}	88.58
T$_2$ (*G. mangostana*)	83.02^d	92.27^a	90.14
T$_3$ (*G. xanthochymus*)	88.31^{bc}	91.46^{ab}	89.89
Mean (P)	87.88^b	91.19^a	
CD (0.05)	T- NS P- 1.633 TXP- NS		
SE(±m)	T- 0.642 P-0.524 TXP- 0.908		
Treatments (T)	Carotenoids (mg 100g^{-1})		
	Pulp (P$_1$)	Pericarp (P$_2$)	Mean (T)
T$_1$(*G. gummi-gutta*)	0.08^e	2.22^d	1.15^c
T$_2$ (*G. mangostana*)	ND	5.36^c	2.68^b
T$_3$ (*G. xanthochymus*)	9.00^a	8.51^b	8.75^a
Mean (P)	3.03^b	5.36^a	
CD (0.05)	T- 0.282 P- 0.230 TXP- 0.339		
SE(±m)	T- 0.090 P-0.074 TXP- 0.128		

The carotenoid content in pericarp and pulp of *Garcinia* fruits differed significantly (Table 1d). The fruit pulp of yellow mangosteen (*G. xanthochymus*) fruits recorded the highest carotenoid content of 9.00 mg 100g^{-1} followed by its pericarp (8.51 mg 100g^{-1}). Carotenoid was not detectable in mangosteen pulp and carotenoid content of 0.08 mg 100g^{-1} was observed for pulp of malabar tamarind fruit pulp (T$_1$P$_1$).

Proximate composition evaluation the *Garcinia* fruits revealed that other than sugar constituents, acidity, protein,fat, fibre, phenols,flavonoids and antioxidant activity were significantly higher for pericarp than pulp. Among the pericarp of the three species, mangosteen rind exhibited higher activity and proximate composition.

4.1.2 Mineral Composition of *Garcinia* Fruits

Major minerals such as Calcium (Ca), Potassium (K) and Iron (Fe) present in the pulp and pericarp of selected *Garcinia* fruits are presented in Table 2. The pericarp of *G.mangostana* (T$_2$P$_2$) recorded the highest values for Ca (1910.00 ppm), K (3323.33 ppm) and Fe (9.235 ppm). Calcium content in the pulp of *G. xanthochymus* was 920 ppm and all other *Garcinia* fruit parts showed no significant difference in calcium content. The yellow mangosteen fruit pulp (T$_3$P$_1$) recorded a potassium content of 2233.33ppm, followed by *G.gummi-gutta* pericarp (T$_1$P$_2$). With a value of 1430.0 ppm.The iron content (Fe) of mangosteen pulp (8.59 ppm) and pericarp (9.24 ppm) were statistically on par and the lowest value (2.76 ppm) was recorded for *G. xanthochymus* pericarp (T$_3$P$_2$).

4.1.3 Sugar Profiling of *Garcinia* Fruits

The major sugars quantified through LC-MS/MS from the economic parts of fruits of selected three *Garcinia* spp. are depicted in Table 3. The major sugar in *G.gummi-gutta* fruit rind (pericarp) was fructose (8.850±0.028mg g^{-1} DW) in highest quantity followed by ribose (4.87±0.019 mg g^{-1} DW), glucose (3.141±0.033mg g^{-1}

Table 2. Mineral composition of *Garcinia* fruits

Treatments	Ca (ppm)	K (ppm)	Fe (ppm)
T_1P_1	756.67 (27.517)^c	649.52 (25.274)^e	4.19^{bc}
T_1P_2	776.67 (27.844)^c	1430.00 (37.77)^c	6.33^{ab}
T_2P_1	746.67 (27.251)^c	1112.67 (33.36)^{cd}	8.52^a
T_2P_2	1,910.00 (43.623)^a	3323.33 (57.61)^a	9.24^a
T_3P_1	920.00 (30.337)^b	2233.33 (47.17)^b	6.60^{ab}
T_3P_2	743.33 (27.27)^c	1033.33 (32.141)^d	2.76^c
CD(0.05)	3.73	1.65	3.01
SE (±m)	1.198	134.87	0.966

Square root Transformed data

T_1 – *G. gummi-gutta*, T_2 – *G. mangostana* ,T_3 – *G. xanthochymus* ;
P_1 – Fuit pulp , P_2 – Fruit pericarp

DW), mannose (0.760 ± 0.008mg g^{-1} DW) and arabinose (0.488 ± 0.005mg g^{-1} DW).Fructose (28.163 ± 0.813mg g^{-1} DW) and glucose (26.700 ± 0.436mg g^{-1} DW) were the major sugars in fruit pulp *G. mangostana* and *G. xanthochymus* recorded 25.842 ± 0.151 mg g^{-1} DW of fructose and 24.281 ± 0.187 mg g^{-1} DW glucose. Mannose and ribose were the other important sugars quantified from these fruits.

4.1.4 Organic Acid Profiling of *Garcinia* Fruits

A total of eleven different organic acids was fractioned and quantified from from the economic parts of of *Garcinia* fruits as depicted in Table 4. Hydroxy citric acid was found as the major organic acid in *G. gummi-gutta* fruits and quantified as 547.458 ± 4.185mg g^{-1} DW flowed by citric acid (144.01 ± 1.383mg g^{-1} DW).Whereas in other two species, *G. mangostana* and *G.xanthochymus,* HCA was detected in lower quantity as 4.30 ± 0.475mg g^{-1} DW and 6.789 ± 0.089 mg g^{-1} DW respectively. Citric acid was the most abundant organic acid in *G. mangostana* (674.17 ± 0.485 mg g^{-1} DW) and *G.xanthochymus* fruit (680.361 ± 0.863mg g^{-1} DW) whereas it was the second most abundant acid in *G. gummi-gutta* fruits. Malic acid, succinic acid, pyruvic acid, malonic acid, and shikimic acid were the other acids present in fruits of all the three *Garcinia*s pecies.

4.1.5 Phenolic Acid Profiling of Garcinia Fruits

The phenolic pattern was studied for the *Garcinia* fruits and the results are mentioned in Table 5. The *G.gummi-gutta* fruit rind and fruit pulp of mangosteen and yellow mangosteen had the highest levels for p-coumaric acid which was quantified as 104.81 ± 4.409µgg^{-1} DW, 335.70 ± 1.801µgg^{-1} DW and 353.155 ± 4.277 µgg^{-1} DW respectively.   Gallic   acid   (56.129 ± 2.845 µgg^{-1} DW),   2,4-dihydroxybenzoic acid(41.290 ± 0.755 µgg^{-1} DW), caffeic acid (18.983 ± 4.917 µgg^{-1} DW) t-Cinnamic acid (18.390 ± 2.422 µgg^{-1} DW) were the other important phenoilc acids found in *G.gummi-gutta* rind. P-coumaric acid ($335.7039.64$ µgg^{-1} DW) was the major phenol detected in mangosteen fruit followed by t-Cinnamic acid (39.64 µgg^{-1} DW). Ferulic

Table 3. Sugar profiling of *Garcinia* fruits

Sugars (mg g^{-1})			
Sugars	*G.gummi-gutta*	*G. mangostana*	*G.xanthochymus*
Ribose	4.87±0.019	1.904±0.020	1.907±0.014
Arabinose	0.488±0.005	0.436±0.377	0.495±0.002
Xylose	0.234±0.000	0.005±0.001	0.007±0.000
Rhamnose	0.017±0.003	0.007±0.001	0.012±0.001
Fucose	0.099±0.004	0.007±0.000	0.013±0.000
Fructose	8.850±0.028	28.163±0.813	25.842±0.151
Glucose	3.141±0.033	26.700±0.436	24.281±0.187
Mannose	0.760±0.008	6.296±0.059	1.270±0.023
Galactose	0.145±0.003	0.069±0.004	0.065±0.001
Inositol	0.009±0.000	0.021±0.000	0.112±0.001
Sorbitol	0.031±0.001	0.038±0.003	0.152±0.002
Sucrose	0.002±0.000	0.165±0.003	0.144±0.001

Values are expressed as mean±SD (n=3)

Table 4. Organic acid profiling of *Garcinia* fruits

Organic acids (mg g^{-1})			
Organic acid	*G.gummi-gutta*	*G. mangostana*	*G.xanthochymus*
Lactic acid	0.013±0.002	0.020±0.001	0.027±0.001
Pyruvic acid	2.401±0.110	1.420±0.048	8.331±0.720
Malonic acid	1.455±0.144	1.520±0.078	2.763±0.178
Maleic acid	0.057±0.003	0.090±0.004	0.113±0.003
Fumaric acid	0.089±0.004	0.050±0.003	0.108±0.002
Succinic acid	3.557±0.271	2.930±0.071	4.800±0.057
Malic acid	3.004±0.145	3.740±0.176	7.092±0.234
Tartaric acid	0.405±0.036	0.130±0.003	0.283±0.016
Shikimic acid	0.788±0.078	0.700±0.038	0.943±0.030
Citric acid	144.01±1.383	674.17±0.485	680.361±0.863
Hydroxycitric acid	547.458±4.185	4.30±0.475	6.789±0.089

Values are expressed as mean±SD (n=3).

Table 5. Phenolic acid profiling of *Garcinia* fruits

Phenolic acid content (µg g^{-1})			
	G.gummi-gutta	*G. mangostana*	*G.xanthochymus*
Benzoic acid	3.739±0.032	3.70±0.597	0.705±0.007
p-hydroxy benzoic acid	1.597±0.005	2.01±0.017	6.029±0.069
Salicylic acid	35.885±0.615	4.51±0.147	11.135±0.351
3-Hydroxy benzoic acid	1.742±0.011	2.73±0.093	6.797±0.015
t-Cinnamic acid	18.390±2.422	39.63±6.781	21.991±0.859
2,4-dihydroxybenzoic acid	41.290±0.755	0.87±0.012	87.705±0.094
Gentisic acid	10.495±1.287	31.50±3.857	19.806±1.538
Protocatechuic acid	5.604±0.597	10.95±2.243	50.242±0.773
p-Coumaric acid	104.810±4.409	335.70±1.801	353.155±4.277
o-Coumaric acid	6.225±0.634	1.40±0.187	7.272±0.987
Vanillic acid	3.290±0.419	0.64±0.075	2.930±0.105
Gallic acid	56.129±2.845	9.10±0.575	39.197±2.505
Caffeic acid	18.983±4.917	27.23±3.852	17.117±0.733
Ferulic acid	7.851±0.621	27.33±0.095	114.703±0.636
Syringic acid	0.849±0.007	0.07±0.017	0.971±0.001
Sinapic acid	0.166±0.007	1.46±0.043	0.150±0.009
Ellagic acid	0.416±0.030	0.12±0.009	0.102±0.007
Chlorogenic acid	0.003±0.000	0.07±0.029	0.003±0.000

Values are expressed as mean±SD (n=3).

acid (114.703±0.636 μgg^{-1} DW),), protocatechuic acid (50.242±0.773 μgg^{-1} DW), gallic acid (39.197±2.505μgg^{-1} DW), 2,4-dihydroxybenzoic acid(87.705±0.094] μgg^{-1} DW) , t-Cinnamic acid(21.991±0.859μgg^{-1} DW) were the other important phenolic acids quantified from *G.xanthoxhymus* fruits.

4.1.6 Flavonoids Profiling of *Garcinia* Fruits

Total thirteen individual flavonoids were identified and quantified from the fruits of selected *Garcinia* spp. (Table 6).The epicatechin (18.699±0.211 μgg^{-1}DW), luteolin (8.814±0.791 μgg^{-1} DW, and catechin (6.688±0.492 μgg^{-1} DW) were the most predominant flavonoids in *G.gummi-gutt*a whereas epicatechin and catechin were not detected in *G. mangostana*. Individual flavonoid hesperetin was the major flavonoid (36.980±4.487μg g^{-1}DW) in *G. mangostana* fruits. Other important flavonoids present in mangosteen were naringenin (9.774±1.943μgg^{-1}DW) and quercetin (5.798±0.855μgg^{-1}DW) and *G.xanthochymus* fruits were rich in naringenin (44.424±0.363μgg^{-1}DW) followed by luteolin (3.289±0.037μgg^{-1}DW).

4.1.7 Extraction and Quantification of Major Benzophenones from *Garcinia*

4.1.7.1 *Spectral Analysis of Isolated Benzophenones*

Natural polyisoprenylated benzophenones such as garcinol and isogarcinol were isolated by column chromatography followed by crystallization from the hexane extract of *G. indica* fruits. Another benzophenone, xanthochymol was isolated by column chromatography from the hexane extract of *G.xanthochymus* fruits. The structures of the compounds (Plate 4), were identified by spectroscopic methods like UV-Vis $_1$H NMR and 13C NMR (Fig 1 and 2). The benzophenones were characterized and identified as below.

Garcinol, Yellow needle crystals; yield 330 mg; TLC : Hexane-ethyl acetate (15:85),single spot.Rf=0.346; UV (CH$_3$OH) λmax/nm:291.^{1}H NMR (400 MHz, CDCl$_3$): δ 6.96 (1H, dd, *J*= 8.0 and 2.0 Hz), 6.92 (1H, d, *J* = 2 Hz), 6.68 (1H, d, *J* = 8
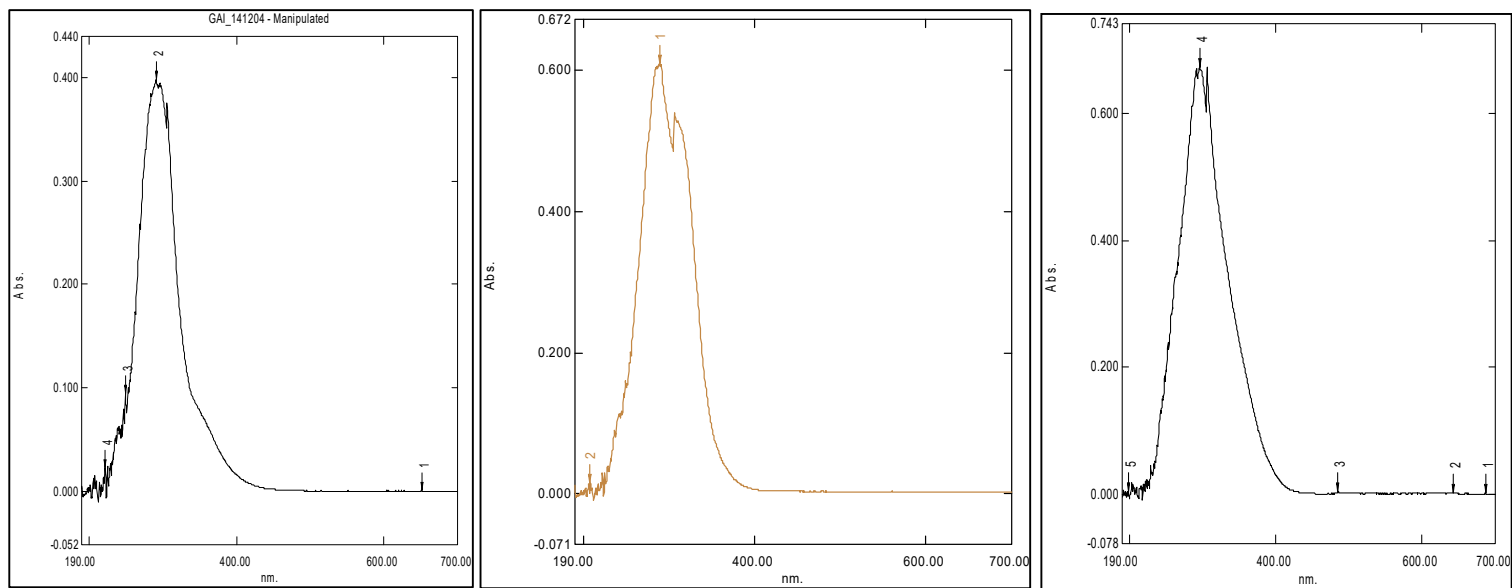
Fig. 1. UV spectrums of benzophenone compounds (I,II and III)
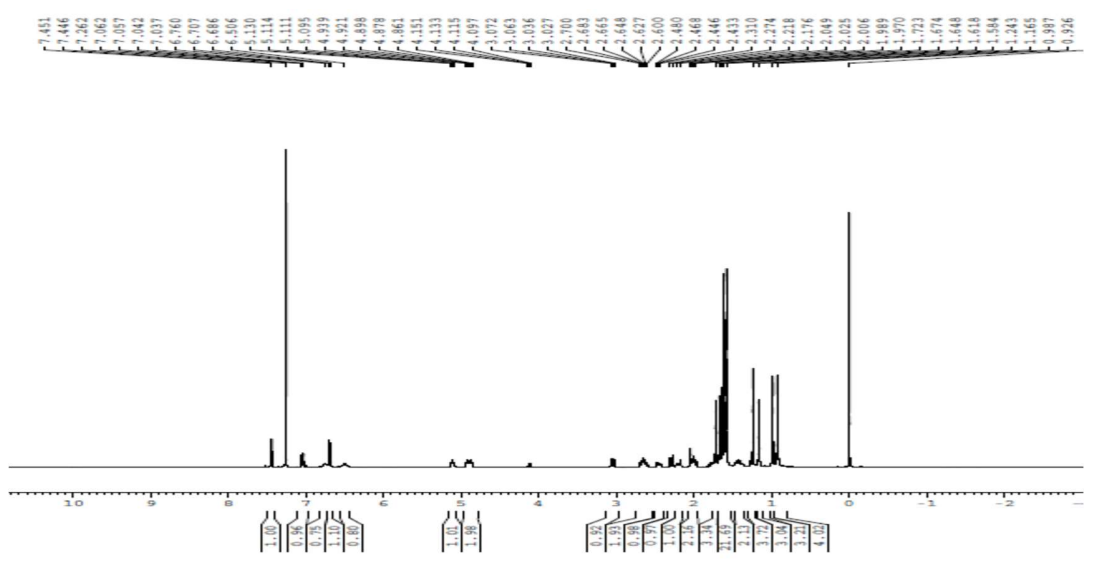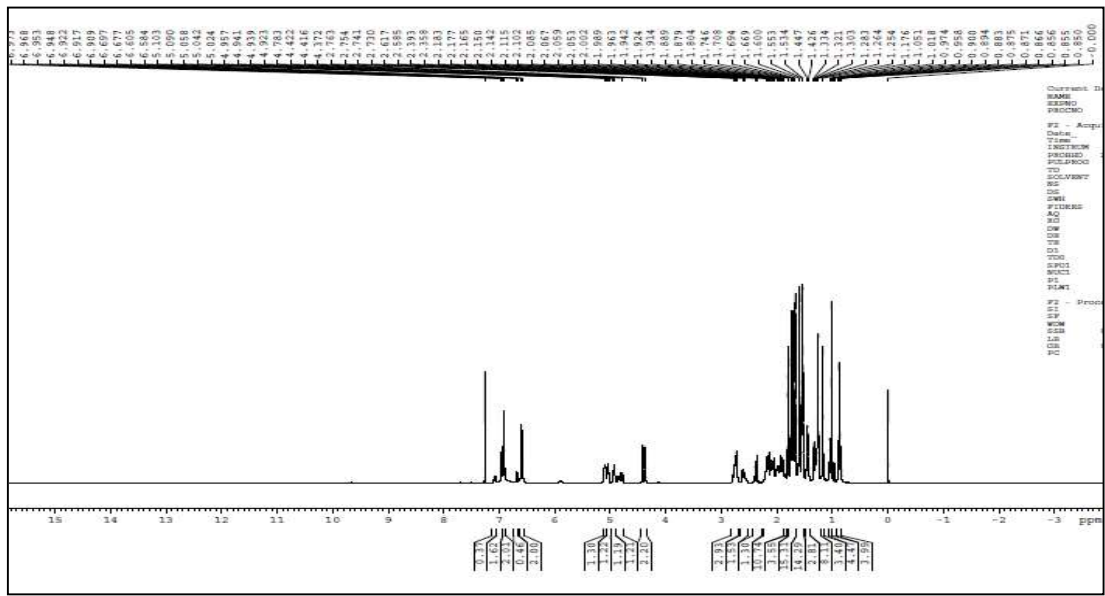
Fig. 2. ¹H NMR of compound I and II

A

Garcinol

B

Isogarcinol

C
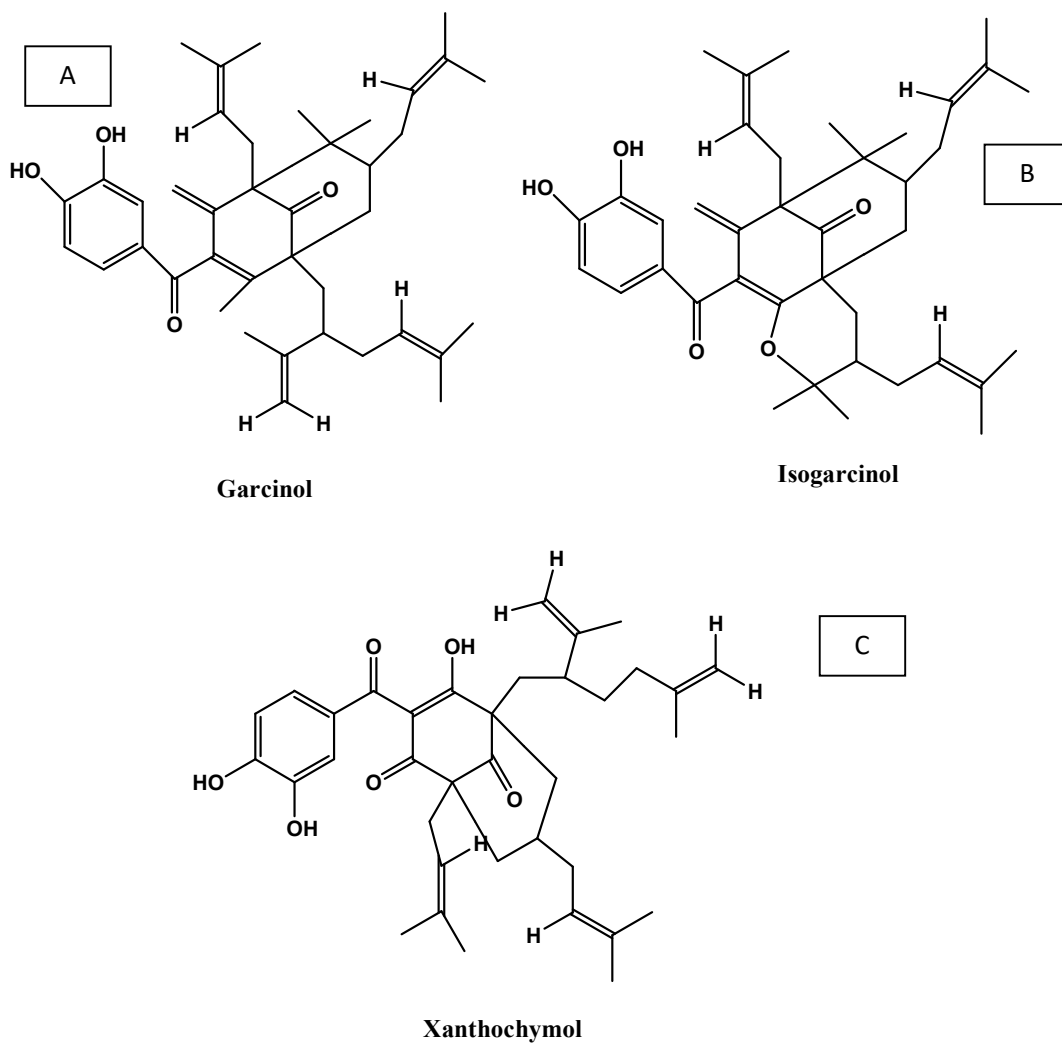
Xanthochymol

Plate 4 . Structure of Garcinol (A), Isogarcinol(B) and xanthochymol (C)

Table 6. Flavonoids profiling of *Garcinia* fruits

Flavonoids (µg g^{-1})			
Flavonoids	*G.gummi-gutta*	*G. mangostana*	*G.xanthochymus*
Umbelliferone	0.003±0.000	0.007±0.001	0.003±0.00
Apigenin	0.036±0.001	0.062±0.001	0.054±0.002
galangin	0.004±0.001	0.001±0.000	0.002±0.000
Naringenin	5.876±0.165	9.774±1.943	44.424±0.363
Kaemperol	0.192±0.005	0.521±0.031	0.068±0.002
Luteolin	8.814±0.791	6.633±0.627	3.289±0.037
Catechin	6.688±0.492	ND	1.207±0.078
Epicatechin	18.699±0.211	ND	1.208±0.067
Hesperetin	0.148±0.018	36.980±4.487	0.121±0.006
Quercetin	0.758±0.052	5.798±0.855	0.280±0.018
Epigallocatechin	0.198±0.031	0.087±0.004	0.327±0.016
Myricetin	0.374±0.045	0.626±0.061	0.915±0.021
Rutin	0.405±0.056	1.934±0.376	0.192±.010

Values are expressed as mean±SD (n=3).

Hz), 4.73 (3H, t, J = 1.2 Hz), 4.42 (2H, d, 2.4 Hz), 1.80 (3H, s), 1.75 (3H, s), 1.67 (3H, s), 1.60 (3H, s), 1.60 (3H, s), 1.55 (6H, s), 1.05 (3H, s), 0.97 ppm (3H, s); ^{13}C NMR (100 MHz, CDCl3): δ 208.2, 197.4, 195.4, 194.0, 149.7, 149.4, 143.6, 135.3, 133.1, 132.9, 127.8, 124.1, 123.8, 122.6, 120.1, 118.4, 116.5, 114.9, 112.7, 69.8, 57.9, 49.6, 46.8, 43.8, 42.6, 36.2, 32.6, 29.1, 27.0, 26.4, 26.1, 25.9, 24.3, 23.1,18.5, 18.2, 17.9, 17.6 ppm.

Isogarcinol, Colour less lustrous crystals; yield 180 mg; TLC: Hexane-ethyl acetate (20:80),singlespot.Rf=0.204; UV (CH3OH) λmax/nm:288.^{1}H NMR (400 MHz, CDCl3): δ 7.45 (1H, d, J = 2.0 Hz), 7.01 (1H, dd, J = 8 and 2 Hz), 6.69 (1H, d, J = 5 Hz), 5.13 (3H, t, J = 4 Hz), 4.92 (1H, d, 6.8 Hz), 4.37 (1H, t, 4.4 Hz), 3.10 (dd, 1H, J = 14.4 and 3.6 Hz), 2.70-2.60 (2H, m), 2.46 (dd, 1H, J = 14 and 4.8 Hz), 2.29 (d, 1H, J = 16.8 Hz), 2.05-1.97 (2H), 1.72 (m, 1H), 1.67 (s, 3H), 1.65 (s, 3H), 1.62 (s, 3H), 1.58 (s, 9H), 1.24–1.17 (m, 6H), 0.99 (s, 6H), 0.93 ppm (s, 3H); ^{13}C NMR (100 MHz, CDCl3): δ207.5, 194.3, 192.7, 171.8, 149.6, 143.7, 134.5, 133.7, 133.2,130.4, 125.1, 124.8, 124.3, 121.4, 119.8, 114.8, 114.4, 86.7, 68.4, 51.3, 46.4, 42.9, 42.8, 39.8, 29.6, 29.4, 28.7, 28.3, 26.8, 26.2, 25.9, 25.8, 25.6, 22.5, 21.3, 18.2, 18.1, 17.8 ppm.

Xanthochymol, Yellow crystals; yield 70 mg; TLC: Hexane-ethyl acetate (5:95),singlespot.Rf=0.532; UV (CH3Cl) λmax/nm:296.^{1}H NMR (400 MHz, CDCl3): δ 7.25 (1H, d, J = 2.0 Hz), 7.03 (1H, dd, J = 8.1 and 2.2 Hz), 6.67 (1H, d, J = 7.9 Hz), 5.32-5.38 (2H, m), 4.81 (1H, s), 4.68-4.63 (2H, m), 4.51 (1H, s), 2.79 (1H, dd, J= 20.0 and 6 Hz), 2.35-2.33 (2H, t, J-7.4 Hz), 2.99-1.99 (3H, m), 1.69-1.57 (4H, m), 1.31 (1H, s), 1.25 (16H, s), 0.99-0.95 (1H, m), 0.91 (1H, s), 0.91-0.85 (1H, m); ^{13}C NMR (100 MHz, CDCl3): δ209.6, 196.1, 195.3, 193.6, 154.3, 147.1, 146.9, 145.1, 137.5, 130.9, 129.2, 128.9, 128.8,127.3, 127.2, 127.0, 126.8, 126.7, 126.1, 67.3, 64.0, 48.7, 45.7, 33.1, 33.0, 30.5, 28.7, 28.5, 28.0, 26.2, 26.1, 25.9,25.1, 24.8, 23.9, 23.6, 21.7, 21.5.

4.1.7.2 HPTLC Profiling of Garcinol, Isogarcinol and Xanthochymol

Preliminary TLC evaluation revealed hexane extracts contained remarkable quantities of compounds and extraction solvent was confirmed as hexane. HPTLC densitometry (Plate 5) method was used to compare and quantify the benzophenones in three major *Garcinia* species. Results showed (Table 7) that garcinol was the major benzophenone in *G.gummi-gutta* (7.53±0.17%) and *G. xanthochymus* (8.26± 0.61 %) whereas *G.mangostana* fruits were rich in isogarcinol (8.10± 0.34%) followed by xanthochymol (4.75±0.27%).

4.1.8 HPLC Profiling of α-Mangostin

The λ max of α-mangostin was set as 320 nm for HPLC analysis. Retention time for the standard and sample were 19.988 minute and both of them in one range. From the standard curve obtained for the standard α-mangostin of the sample was calculated as 3.62 % on dry weight basis.

Table 7. Benzophenones (%) in *Garcinia* fruits

	G.gummi gutta	*G. mangostana*	*G.xanthochymus*
Garcinol	7.53±0.17	1.31±0.12	8.26±0.61
Isogarcinol	2.47±0.41	8.10±0.34	1.39±0.07
Xanthochymol	1.11±0.23	4.75±0.27	2.16±0.27

Values are expressed as mean ± SD (n=3).
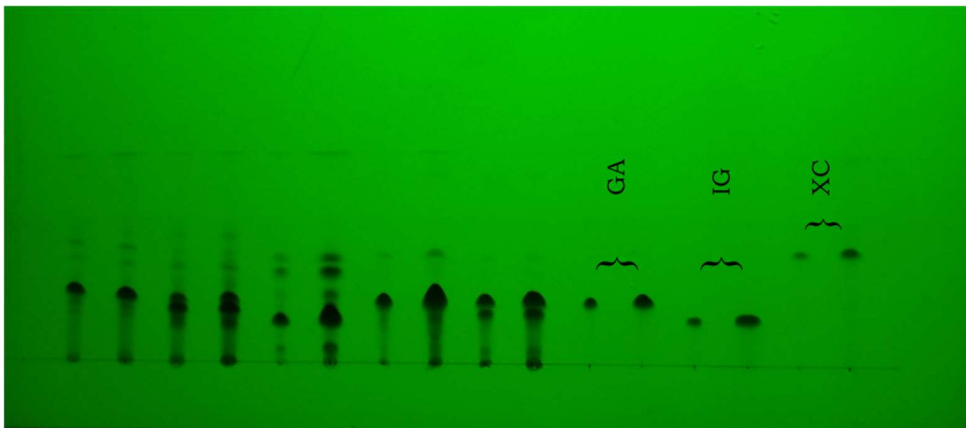
Plate 5. TLC profile of *Grcinia* fruits along with extracted standards (GA-garcinol; IG-isogarcinol;XC-xanthpchymol)

4.2 COLOUR EXTRACTION FROM MANGOSTEEN PERICARP

The effect of different acidified solvent system on extraction yield, quality parameters and colour parameters of extracts were analyzed statistically and results are tabulated and described as below in Table 8 and Table 9.

4.2.1 Effect of Treatments on Biochemical Parameters of Anthocyanin Extracts

4.2.1.1 pH

The pH values of treatments ranged from 5.10 to 3.60 among the different anthocyanin extracts. The data revealed that the highest pH was observed by the anthocyanin extracted with ethanol (T_9) which was followed by colour extracted with water (4.71) (T_{10}). Anthocyanin extracted from other treatments with addition of acids were statistically on par for the pH value.

4.2.1.2 Extraction Yield (%)

The data revealed that the extraction yield varied significantly among the treatments. The highest yield (28.57 %) was observed for the treatment T_4 (Ethanol with 2 % acetic acid) followed by treatment ethanol with 0.2 % citric acid (T_2) (26.58 %). Treatment T_1 (24.23 %) and T_3 (24.72%) were statistically on par. The lowest (13.94 %) yield was observed in the control treatment (T_{10}) were water as solvent.

4.2.1.3 Total Anthocyanin Content (mg 100g^{-1})

The effect of different solvent and acids on total anthocyanin content of mangosteen rind extracts were analyzed statistically and presented in Table 8. From the data, it was observed that the total anthocyanin content of extracts found to be in the range of 132.43 to 294.73 mg 100g^{-1}. In case of different extraction treatments, ethanol with 2% acetic acid (T_4) showed significantly higher total anthocyanin content of 294.73 mg 100g^{-1} and was followed by the treatment T_2 (ethanol+ 0.2%

citric acid) which had total anthocyanin content of 277.77mg $100g^{-1}$. In case of extracts with water as solvent medium showed significantly lower total anthocyanin content compared to ethanol.

4.2.1.4 Total Phenolic Content (TPC) (mg GAE $100g^{-1}$)

Total Phenolic content in extracts varied significantly among the treatments. Colour extracted in ethanol exhibited higher content than water extracts. Ethanol with 2% acetic acid recorded highest (T_4) TPC of 1549.55 mg GAE $100g^{-1}$ which was on par with treatment T_3(ethanol +acetic acid 1%). Treatment T_3 was also on par with the treatment T_2 (ethanol +0.2% Citric acid). Lowest phenol content of 1241 mg GAE $100g^{-1}$ was observed for the anthocyanin extracted in water (T_{10}).

4.2.1.5 Total Flavonoid Content (TFC) (mg QE g^{-1})

The results for the TFC showed that all the extract were rich in flavonoid content. Colour extracted with ethanol had the highest TFC when compared to water extracts. The highest TFC was recorded as 38.46 mg QE g^{-1} for the treatment T_4 (ethanol+ 2% acetic acid) which was followed by T_2 (ethanol+ 0.2% citric acid) (36.302 mg QE g^{-1}) and T_3 (ethanol+ 1% acetic acid). Anthocyanin extracted with water (T_{10}) recorded the lowest TFC of 22.35 mg QE g^{-1}.

4.2.1.6 Antioxidant Activity (%)

Colour extracted with ethanol as solvent recorded the highest antioxidant activity than water extracts. Anthocyanin extracted with ethanol + 2% acetic acid (T_4) showed highest antioxidant activity of 82.68 % which was on par with the treatments T_2 (Ethanol + Citric acid (0.2%)) and T_3 (Ethanol + Acetic acid (1%)). Whereas anthocyanin extracted with ethanol + 0.1% citric acid showed 80.10 % activity which was on par with T_2 and T_3. Anthocyanin extracted with distilled water (T_{10}) exhibited lowest antioxidant activity of 72.42 % and T_5 had an activity of 73.47 % was on par with treatments T_{10} and T_7 (water + 1 %acetic acid).

Table 8. Effect of solvents and acidification on quality of anthocyanin extracts from mangosteen pericarp

Treatments	pH	Yield (%)	Total anthocyanin content (mg 100g^{-1})	Total phenols (mg GAE 100g^{-1})	Total flavonoids (mg QE g^{-1})	Antioxidant activity (%)
T$_1$(Ethanol + 0.1% Citric acid)	3.78^d	24.23^c	253.30^c	1500.49^c	34.11^d	80.10^{bc}
T$_2$ (Ethanol + 0.2%Citric acid)	3.71^d	26.58^b	277.77^b	1538.23^b	36.30^b	80.57^{ac}
T$_3$ (Ethanol + 1% Acetic acid)	3.74^d	24.72^c	260.20^c	1540.94^{ab}	35.40^c	81.13^{ab}
T$_4$ (Ethanol + 2%Acetic acid)	3.60^d	28.57^a	294.73^a	1549.55^a	38.46^a	82.68^a
T$_5$ (Distilled Water + 0.1%Citric acid)	4.05^c	15.16^h	146.57^g	1316.45^h	23.56^h	73.47^{ef}
T$_6$ (Distilled Water + 0.2%Citric acid)	3.78^d	16.33^g	158.33^f	1357.34^g	25.82^g	75.85^d
T$_7$ (Distilled Water + 1%Acetic acid)	3.75^d	18.30^f	175.03^e	1388.68^f	25.16^g	75.15^{de}
T$_8$ (Distilled Water + 2%Acetic acid)	3.71^d	20.76^d	199.57^d	1401.01^e	29.05^f	76.67^d
T$_9$ (Ethanol)	5.10^a	19.19^e	194.94^d	1443.43^d	32.08^e	78.78^c
T$_{10}$ (Distilled Water)	4.71^b	13.94^i	132.43^h	1241.12^i	22.35^i	72.42^f
CD(0.05)	0.098	0.722	7.22	9.89	0.759	2.12
SE (±m)	0.003	0 .179	17.99	33.75	0.256	0.714

Values with the same letter in each column are not significantly diferent (p < 0.05), as separated by Duncan multiple range test

4.2.2 Colour Values of Anthocyanin Extracts from Mangosteen Pericarp

CIEL, a*b* method was used to measure colour properties of anthocyanin extracts. L*, a* and b* attributes were directly determined by Hunter Lab colorimeter and C* (Chroma) and H° (hue angle) were subsequently calculated (Table 9). The anthocyanin pigment extracted with ethanol were in darker colour and recorded lower Lightness (L*) values as compared to water extracts. The highest L*value was observed for the control treatment T_{10} (distilled water) as 25.44 which was followed by ethanol extract (T_9).

Hue° values of the anthocyanin extracts using different solvent system ranged from 24.16 to 37.74 and all falls under the red region. Chroma values of mangosteen peel extracts varied from 17.06 to 34.30 in different solvent systems where the treatment T_4 (Ethanol with 2% Acetic acid) recorded a chroma value of 34.30 which was on par with treatment T_1 (ethanol+ 0.1% citric acid).

Based on yield, anthocyanin content, TPC, TFC, DPPH activity and colour values of the extracts, anthocyanin extracted with ethanol acidified using 2% acetic acid (T4) was recorded as the best solvent system and was further utilized as natural food colorant (Plate 6.).

4.3 DEVELOPMENT OF NECTAR FROM *GARCINIA* SPP.

Pulp made out of *G. gummi-gutta* (G_1) rind, mangosteen aril (G_2) and fruits of *G.xanthochyms* (G_3), and were used for the preparation of nectar with different fruit pulp concentration and Total Soluble Solids (Plate 7.). Biochemical quality parameters such as total acidity, vitamin C, total sugar, reducing sugar, antioxidant activity, Total phenol content, total flavonoids and HCA were analyzed for all nectar formulations and analyzed for sensorial attributes for their acceptance was analysed by using 9 point hedonic scale.

Fresh mangosteen fruits

Cleaning and separation

Mangosteen pericarp

Using cabinet dryer at 60⁰C

Pericarp powder

Hot maceration

Acidified alcohol

Filtered extract

Using rotary evaporator

Concentrated anthocyanin extract
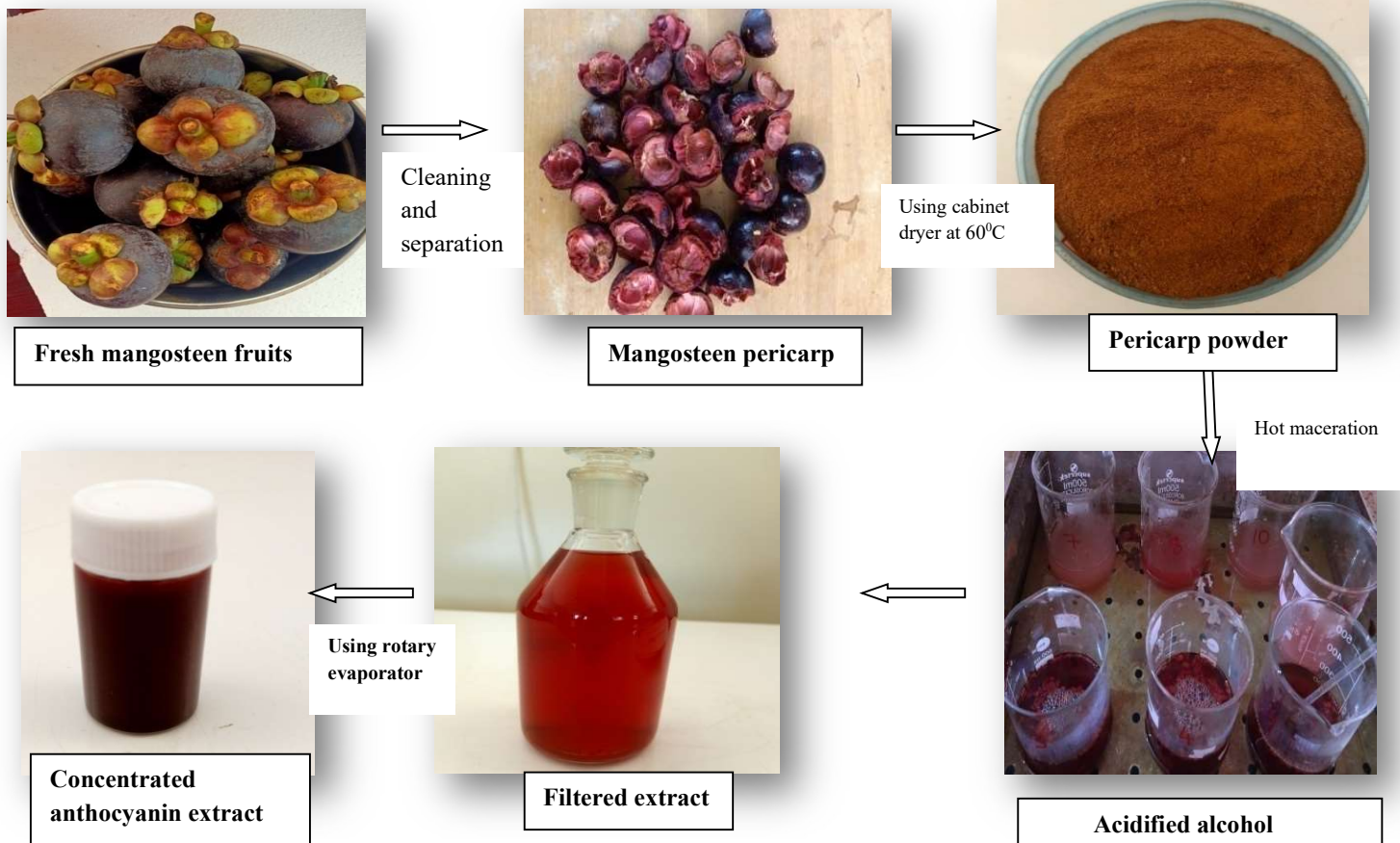
Plate 6. Standardization of anthocyanin extraction from mangosteen pericarp

Table 9. Colour values of mangosteen pericarp extract

Treatments	Lightness(L*)	Choma*	Hue^0
T_1(Ethanol + 0.1% Citric acid)	16.42 ±1.04 ^{de}	33.08±1.91^{ab}	27.59±2.04^d
T_2 (Ethanol + 0.2%Citric acid)	12.02 ±2.60^f	30.54±2.60^c	25.63±1.37^{ef}
T_3 (Ethanol + 1% Acetic acid)	10.65 ±0.92^{fg}	22.23±1.10^e	26.16±0.99^{de}
T_4 (Ethanol + 2%Acetic acid)	9.53±1.01 ^{g}	22.72±1.52^e	24.16±0.85^f
T_5 (Distilled Water + 0.1%Citric acid)	19.42±1.58 ^{c}	34.30±1.28^a	37.74±1.04^b
T_6 (Distilled Water + 0.2%Citric acid)	18.02 ±0.92^{cd}	11.01±1.52^h	36.47±0.60^b
T_7 (Distilled Water + 1%Acetic acid)	19.58±2.19 ^{c}	17.06±1.43^g	37.19±0.62^b
T_8 (Distilled Water + 2%Acetic acid)	15.74±0.93 ^{e}	19.39±2.06^f	33.35±1.00^c
T_9 (Ethanol)	23.01 ±0.89^b	31.62±1.31^{bc}	34.69±2.19^c
T_{10} (Distilled Water)	25.44 ±1.10^a	28.44±3.02^d	40.67±1.02^a
CD(0.05)	1.612	2.198	1.715
SE (±m)	0.543	0.740	0.577

Values with the same letter in each column are not significantly different (p < 0.05), as separated by Duncan multiple range test

4.3.1 Biochemical Qualities of *G. gummi- gutta* Nectar

The nutritional qualities of nectar varied with different formulation (Table 10). *Garcinia gummi- gutta* nectar formulated with 20 % fruit with 15^0Brix (F_2G_1) recorded the highest total acidity of 1.77% followed by F_4G_1 (20 % fruit, 20^0Brix) of 1.61% and F_5G_1 (20 % fruit, 25^0Brix) with1.52%. Among the formulations the lowest acidity of 1.35 % was observed by the treatment with highest TSS (30^0Brix).

Vitamin C content of the nectar formulations ranged from 3.71 to 4.80 mg 100g among the treatments. Nectar formulated with 20 % fruit and 20^0Brix recorded the Vitamin C content of 4.80 mg $100g^{-1}$. The highest total sugar and reducing sugar content of 15.86 % and 17.64 % was observed for the formulation prepared with highest TSS content (F_6G_2- 20 % fruit, 30^0Brix). Nectar formulated with 20 % fruit with 20^0Brix (F_4G_1) recorded a total and reducing sugar content of 14.89% and 4.68 % respectively. Antioxidant activity of the formulations was not significantly different and ranged from 65.87 % to 71.95 %. Total phenols in nectar formulations ranged from 130.17 to 161.93 mg GAE g^{-1}. Nectar formulated with 20 % fruit and 20^0Brix (F_4G_1) recorded a total phenol content of 158.44 mg GAE g^{-1}. Total flavonoids of nectars ranged from 3.09 to 4.21 mg QE g^{-1} and treatment F_4G_1 exhibited a value of 4.17 mg QE g^{-1}. HCA content of the formulations ranged from 1.06 to 1.45 % and nectar prepared with 20 % fruit and 20 ^{0}Brix recorded an HCA content of 1.41 %.

4.3.2 Sensory Qualities of *G. gummi-gutta* Nectar

Nectar formulations from the rind of *G. gummi gutta* were analyzed for various sensorial attributes (Table 11). Appearance scores for all six formulations were not significantly different from each other and scores ranged from 8.47 to 8.70. Nectar prepared with 20 % fruit pulp and 20^0 Brix TSS (F_4G_1) recorded the highest mean score for flavour (8.40) followed by nectar with 20 % fruit pulp and 25^0Brix
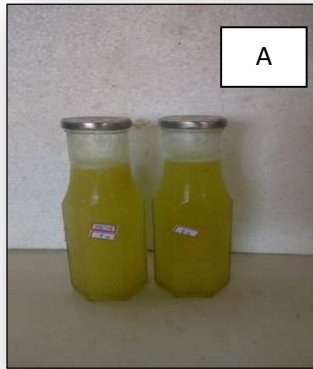
Plate 7. Nectar formulations from *Garcinia* (A: *G. gummi-gutta;* B-*G. mangostana;* C-*G. xanthochymus*)

Table 10. Biochemical qualities of *G. gummi-gutta* nectar

Nectar formulations	Total acidity (%)	Vitamin C (mg 100g^{-1})	Total sugar (%)	Reducing sugar (%)	Antioxidant activity (%)	Total phenol content (mg GAE g^{-1})	Total Flavanoids (mg QE g^{-1})	HCA (%)
F$_1$G$_3$(15%, 15^{0}Brix)	1.50^{bc}	3.71^d	13.19de	11.70^d	66.45 ^{ab}	135.31 ^{bc}	3.09^b	1.10 ^{b}
F$_2$G$_3$(20%, 15^{0}Brix)	1.77^a	4.43^{abc}	13.66^d	12.12^d	71.87 ^{a}	155.10 ^{ab}	4.21^a	1.45 ^{a}
F$_3$G$_3$(15%, 20^{0}Brix)	1.39^{cd}	3.75^d	14.53^{cd}	13.03^{cd}	65.87 ^{ab}	130.17^{bc}	3.15^b	1.06 ^{b}
F$_4$G$_3$(20%, 20^{0}Brix)	1.61^{ab}	4.80^a	14.89^c	13.38^c	71.09 ^{a}	158.44^a	4.17^a	1.41 ^{a}
F$_5$G$_3$(20%, 25^{0}Brix)	1.52^{bc}	4.65^{ab}	16.04^b	14.42^b	71.95 ^{a}	161.93 ^{a}	4.17a	1.45 ^{a}
F$_6$G$_3$(20%, 30^{0}Brix)	1.35^{cd}	4.68^a	17.64^a	15.86^a	70.60^a	159.05 ^{a}	4.17^a	1.41 ^{a}
CD(0.05)	0.063	0.336	0.160	0.144	4.28	7.25	0.203	0.205
SE (±m)	0.020	0.108	0.051	0.046	1.376	2.327	0.156	0.066

Table 11. Sensory qualities of *G. gummi gutta* nectar

Treatments	Appearance	Flavour	Taste	Overall acceptability
F$_1$G$_3$(15%, 15^{0}Brix)	8.47	7.43	7.20	7.03
F$_2$G$_3$(20%, 15^{0}Brix)	8.53	7.27	7.03	6.97
F$_3$G$_3$(15%, 20^{0}Brix)	8.43	8.03	7.70	8.13
F$_4$G$_3$(20%, 20^{0}Brix)	8.67	8.40	8.37	8.37
F$_5$G$_3$(20%, 25^{0}Brix)	8.70	8.07	8.13	8.10
F$_6$G$_3$(20%, 30^{0}Brix)	8.67	7.80	8.03	8.03
KW value	4.58	11.45	32.51	42.21
χ^2 (0.05)	11.071			

TSS (F_5G_1) (8.07) and nectar with 15 % fruit pulp and TSS fixed to 20^0Brix (F_3G_1) (8.03).

Among the nectar formulations, F_4G_1 (20 % fruit pulp and 20^0 Brix TSS) recorded the highest mean score for taste (8.37) followed by F_5G_1 (8.13) and F_6G_1 (8.03). *Garcinia gummi-gutta* nectar formulation F_4G_1 (20 % fruit pulp with TSS 15^0 Brix) recorded the lowest mean score for taste (7.03). Overall acceptability of the formulations revealed that nectar prepared with 20 % fruit and TSS of 20 ^{0}Brix recorded the highest mean score (8.37) followed by nectar with 15% pulp and 20^0Brix (8.13).

Based on sensory mean scores of the formulation of *G.gummi-gutta* nectar prepared with 20 % fruit and TSS of 20 ^{0}Brix (F_4G_1) was selected as the best formulation for further colour addition studies.

4.3.3 Biochemical Qualities of *G. mangostana* Nectar

Biochemical quality evaluation of *G. mangostana* nectar formulations are shown in Table 12. Total acidity of mangosteen nectar formulations ranged from 0.253 to 0.307 %. The vitamin C, antioxidant activity, total phenols and total flavonoids of the nectar prepared with higher fruit percentage recorded comparatively higher values.

The highest vitamin C content of 9.51 mg $100g^{-1}$ was observed by the formulation with 20 % fruit and 25 ^{0}Brix TSS (F_5G_3). Nectar formulated with 15 % fruit pulp and 20 ^{0}Brix recorded a vitamin C content of 7.15 mg $100g^{-1}$. The highest total sugar and reducing sugar content of 19.32 % and 16.12% was observed for the formulation prepared with highest TSS content (F_6G_2- 20 % fruit, 30^0Brix). Nectar formulated with 20 % fruit with 15^0Brix (F_2G_2) recorded a total and reducing sugar content of 14.48% and 11.28 % respectively.

Antioxidant activities of the all formulations with 20% fruit were on par with each other. The nectar formulated with 20 % fruit with 15^0Brix (F_2G_2) recorded an antioxidant activity of 60.91 %. Total phenols of formulations with 20 % fruit pulp

ranged from 49.64 to 53.13 mg GAE g^{-1}. Nectar formulated with 15 % fruit and 20^0Brix (F_3G_2) recorded lowest total phenol content of 21.37 mg GAE g^{-1}. Total flavonoids of formulation F_2G_2 (20% fruit and 15^0Brix) was recorded as 1.21 mg QE g^{-1}.

4.3.4 Sensory Qualities of *G. mangostana* Nectar

The sensory attributes apperance of the mangosteen nectar formulations were not significantly different for scores and ranged from 8.17 to 8.33 (Table 13). The nectar formulations with 20 % mangosteen fruit pulp and TSS of 15^0 Brix (F_2G_2) recorded the highest mean score for flavour (8.67) followed by nectar with 15 % fruit pulp and TSS of 15 ^{0}Brix (F_1G_2) (8.57) and nectar with 20 % fruit pulp and TSS of 30 ^{0}Brix recorded the lowest mean value (7.43). Among the nectar formulations, formulation F_2G_2 (20 % fruit pulp and TSS of 15^0 Brix) recorded the highest mean score for taste (8.57) followed by F_1G_2 (8.30) and F_4G_2 (8.27).

Garcinia mangostana nectar formulation F_2G_2 (20 % fruit pulp with TSS 15^0 Brix) recorded the highest mean score for overall acceptability (8.57) followed by F_1G_2 (8.27). Based on sensory mean scores of the formulation nectar prepared with 20 % fruit and TSS of 15 ^{0}Brix (F_2G_2) was selected as the best formulation for further studies

4.3.5 Biochemical Qualities of *G. xanthochymus* Nectar

Biochemical quality evaluation of *G.xanthoxhymus* nectar formulations are described in Table 14. Nectar formulation F_2G_3 (20 % fruit, 15^0Brix) recorded the highest total acidity of 2.10% followed by F_4G_3 (20 % fruit, 20^0Brix) with 2.06%. Among the formulations the lowest acidity of 1.60 % was observed for the nectar with 15 % fruit and 20 ^{0}Brix (F_3G_3).

Nectar formulated with 20 % fruit and 15^0Brix recorded the Vitamin C content of 6.17 mg $100g^{-1}$. The highest total sugar and reducing sugar content of 17.28 % and 15.56% was observed for the formulation prepared with highest TSS

Table 12. Biochemical qualities of *G. mangostana* nectar

Nectar formulations	Total acidity (%)	Vitamin C (mg 100g-1)	Total sugar (%)	Reducing sugar (%)	Antioxidant activity (%)	Total phenol content (mg GAE g^{-1})	Total Flavanoids (mg QE g^{-1})
F_1G_3(15%, 15^{0}Brix)	0.253^{ab}	6.98^d	13.55^{cd}	10.35^{bc}	54.17^b	26.51^{cd}	0.88^b
F_2G_3(20%, 15^{0}Brix)	0.307^a	9.31^b	14.48^c	11.28^{bc}	60.91^a	46.30^{ab}	1.21^a
F_3G_3(15%, 20^{0}Brix)	0.223^{ab}	7.15^c	14.70^c	11.50^{bc}	52.86^b	21.37^d	0.88^b
F_4G_3(20%, 20^{0}Brix)	0.293^{ab}	9.35^b	16.78^{bc}	13.38^{abc}	62.35^a	49.64^a	1.18^a
F_5G_3(20%, 25^{0}Brix)	0.253^{ab}	9.51^a	18.11^{ab}	14.91^{ab}	63.16^a	53.13^a	1.21^a
F_6G_3(20%, 30^{0}Brix)	0.253^{ab}	9.26^b	19.32^a	16.12^a	59.53^a	50.25^a	1.23^a
CD(0.05)	0.042	0.090	2.251	2.334	4.152	7.251	0.057
SE (±m)	0.013	0.029	0.723	0.749	1.333	2.327	0.012

Table 13. Sensory qualities of *G. mangostana* nectar

Nectar formulations	Appearance	Flavour	Taste	Overall acceptability
F_1G_3(15%, 15^{0}Brix)	8.17	8.57	8.30	8.27
F_2G_3(20%, 15^{0}Brix)	8.20	8.67	8.57	8.57
F_3G_3(15%, 20^{0}Brix)	8.23	8.17	7.73	7.70
F_4G_3(20%, 20^{0}Brix)	8.23	8.03	8.27	8.23
F_5G_3(20%, 25^{0}Brix)	8.33	7.67	7.87	7.90
F_6G_3(20%, 30^{0}Brix)	8.30	7.43	7.70	7.67
KW value	2.01	14.53	24.10	11.93
χ^2(0.05)	11.071			

content (F_6G_2- 20 % fruit, 30^0Brix). The nectar formulated with 15 % fruit with 20 ^{0}Brix (F_3G_3) recorded a total and reducing sugar content of 14.14% and 12.73 % respectively. Among the nectar formulations highest antioxidant activity of 74.01 % was observed by the formulation F_4G_3 (20 % fruit, 20^0Brix) and the lowest for the formulations with 15 % fruit pulp. The nectar formulated from 15% pulp with TSS of 20^oBrix recorded an antioxidant activity of 69.56 %. Highest total phenols were exhibited by the formulations with 20 % fruit pulp and the nectar formulation F_3G_3 recorded a total phenol content of 139.72 mg GAE g^{-1}.

4.3.6 Sensory Qualities of G. *xanthochymus* Nectar

The sensory score obtained with respect to appearance, flavour, taste, overall acceptability are presented in Table 15. The mean score of appearance score of the formulations ranged from 8.37 to 8.53 and for 15% fruit pulp and TSS of 20^0 Brix (F_3G_3) recorded the highest mean score for flavour (8.47), taste (8.33) and overall acceptability (8.53) whereas, nectar with 20 % fruit and TSS of 15^0Brix showed the lowest mean score for the Taste (7.17) and overall acceptability (7.43).

Based on the sensory mean scores the formulation of *Garcinia xanthochymus* nectar prepared with 15 % fruit and TSS of 20 ^{0}Brix (F_3G_3) was selected as best formulation.

4.3.2 Storage Stability Studies of Garcinia Nectar Supplemented with Colour Extract from Mangosteen Pericarp

Based on biochemical quality and sensory mean scores of the formulations, *G. gummi-gutta* nectar prepared with 20 % pulp and 20^0 Brix, *Garcinia mangostana* nectar formulation with 20% fruit pulp with TSS 15^0 Brix and for *G. xanthochymus,* nectar prepared with 15% fruit and 20^0 Brix were selected as the best formulation for addition of natural colour extracted from mangosteen pericarp.

The selected nectar formulation of *G. gummi- gutta* and *G. xanthochymus* was added with 0.5% mangosteen pericarp colour extract whereas 0.3 % was added to *G.*

Table 14. Biochemical qualities of *G. xanthochymus* nectar

Nectar formulations	Total acidity (%)	Vitamin C(mg 100g^{-1})	Total sugar (%)	Reducing sugar (%)	Antioxidant activity (%)	Total phenol , (mg GAE g^{-1})	Total Flavanoids (mg QE g^{-1})
F$_1$G$_3$(15%, 15^{0}Brix)	1.66^d	4.25^b	12.76^e	11.49	69.96^c	144.86^c	3.69^b
F$_2$G$_3$(20%, 15^{0}Brix)	2.10^a	6.12^a	13.23^e	11.91	73.23^b	163.91^b	4.98^a
F$_3$G$_3$(15%, 20^{0}Brix)	1.60^e	4.22	14.14^d	12.73	69.56^c	139.72^c	3.62^b
F$_4$G$_3$(20%, 20^{0}Brix)	2.06^b	6.08^a	14.53^c	13.08	74.01^a	167.33^{ab}	4.97^a
F$_5$G$_3$(20%, 25^{0}Brix)	1.86^c	6.17^a	15.68^b	14.11	73.35^b	168.60^{ab}	4.96^a
F$_6$G$_3$(20%, 30^{0}Brix)	1.65^d	6.16^a	17.28^a	15.56	73.46^b	171.69^a	5.00^a
CD(0.05)	0.027	0.160	0.160	0.143	0.377	6.87	0.197
SE (±m)	0.009	0.051	0.051	0.046	0.133	2.23	

Table 15. Sensory qualities of *G. xanthochymus* nectar

Nectar formulations	Appearance	Flavour	Taste	Overall acceptability
F$_1$G$_3$(15%, 15^{0}Brix)	8.53	7.13	7.17	7.43
F$_2$G$_3$(20%, 15^{0}Brix)	8.40	6.97	7.03	7.30
F$_3$G$_3$(15%, 20^{0}Brix)	8.53	8.47	8.33	8.53
F$_4$G$_3$(20%, 20^{0}Brix)	8.47	8.20	8.23	8.33
F$_5$G$_3$(20%, 25^{0}Brix)	8.37	8.17	8.20	8.17
F$_6$G$_3$(20%, 30^{0}Brix)	8.40	8.07	8.07	8.03
KW value	0.51	24.76	27.83	17.24
χ^2(0.05)	11.071			

mangostana nectar. Storage stability studies of the nectar formulations were conducted under room temperature along with control (formulation without addition of natural colour) (Plate 8.).

4.3.2.1 Biochemical Qualities of Stored Nectar Formulations

4.3.2.1.a TSS (^{0}Brix)

Addition of natural colour extract from mangosteen pericarp colour extract to the *Garcinia* nectar significantly increased the TSS content of the nectars (Table 16). At the time of storage *G. gummi-gutta* nectar with addition of colour (G_1C) recorded a TSS of 20.53 ^{0}Brix, *G. mangostana* nectar with addition of colour (G_2C) recorded 15.33 ^{0} Brix and *G. xanthochymus* nectar with colour (G_2C) recorded 20.47 ^{0}Brix. During storage, there was no significant difference among the interaction effects between treatments and storage. With respect to storage months TSS of the nectar were increased and the highest TSS content of 19.36 ^{O}Brix was observed after third month of storage and the lowest value (18.56 ^{O}Brix) at the time of storage.

4.3.2.1.b Titratable acidity (%)

Total acidity of Garcinia nectar during storage is depicted in Table 17. Addition of colour extract to nectars slightly increased the acidity of nectar. At the time of storage, acidity of colour added nectars were 1.62, 0.32 and 1.61 % respectively for *G. gummi gutta, G. mangostana and G.xanthochymus* sp respectively. The acidity of all the formulations was significantly increased during storage.

4.3.2.1.c Vitamin C (mg 100g^{-1})

Vitamin C content of Garcinia nectar during storage is depicted in Table 18. The colour supplimentation to beverages increased the vitamin C of nectar and the highest quantity (7.53 mg 100g^{-1}) was reported in *G. mangostana* nectar added with colour extract (G_2C). At storage vitamin C content was recorded as 5.10 and 6.44 mg 100g^{-1}respectively for *G. gummi-gutta* nectar added with colour (G_1C) and *G. mangostana* nectar added with colour (G_2 C). During storage vitamin C content

Plate 8. Garcinia nectar formulations with mangosteen colour extract

Table 16. Effect of storage on TSS (^{0}Brix) of *Garcinia* nectar

Treatments (T)	TSS (^{0}Brix)				
	Months after storage (M)				
	At the time of storage	1	2	3	Mean (T)
G$_1$W (*G.gummi-gutta*, without colour)	20.00	20.37	20.50	20.70	20.39[b]
G$_1$C (*G.gummi-gutta*, with colour)	20.53	20.89	21.14	21.31	20.97[a]
G$_2$W (*G.mangostana*, without colour)	15.00	15.29	15.43	15.60	15.33[d]
G$_2$C (*G.mangostana*, with colour)	15.33	15.62	16.43	16.60	15.99[c]
G$_3$W (*G.xanthochymus*, without colour)	20.00	20.38	20.52	20.69	20.40[b]
G$_3$C (*G.xanthochymus*, with colour)	20.47	20.82	21.09	21.26	20.91[a]
Mean M	18.56[b]	18.90[b]	19.18[a]	19.36[a]	
CD(0.05)	T- 0.282 M- 0.230 TX M- NS				
SE (±m)	T-0.099 M- 0.81 TXM- 0.198				

Table 17. Effect of storage on total acidity (%) of *Garcinia* nectar

Treatments (T)	Total acidity (%)				
	Months after storage (M)				
	At the time of storage	1	2	3	Mean (T)
G$_1$W (*G.gummi-gutta*, without colour)	1.61	1.68	1.75	1.82	1.71[a]
G$_1$C (*G.gummi-gutta*, with colour)	1.62	1.69	1.76	1.83	1.73[a]
G$_2$W (*G.mangostana*, without colour)	0.31	0.37	0.44	0.51	0.41[b]
G$_2$C (*G.mangostana*, with colour)	0.320	0.383	0.457	0.523	0.42[a]
G$_3$W (*G.xanthochymus*, without colour)	1.60	1.68	1.75	1.82	1.71[a]
G$_3$C (*G.xanthochymus*, with colour)	1.61	1.69	1.76	1.83	1.73[a]
Mean M	1.17[b]	1.24[b]	1.32[a]	1.38[a]	
CD(0.05)	T- 0.018 M- 0.015 TXM- NS				
SE (±m)	T-0.009 M- 0.0.005 TXM- 0.013				

showed a decreasing trend. *G. gummi- gutta* nectar without colour (G$_1$W) recorded lowest quantity of 4.93, 4.82 and 4.75 mg 100g^{-1} respectively for 1st, 2nd and 3rd month of storage.

4.3.2.1.d Total sugar(%)

Total sugar content of *Garcinia* nectar with and without addition of colour varied from 14.14 to 14.99 among the treatments at the time of storage (Table 19). Addition of mangosteen colour to beverages significantly increased total sugar content of the nectar formulations. During storage total sugar content increased, and the lowest total sugar of 14.55 % was noticed at the time of storage whereas the highest total sugar of 15.08 % was observed after third month of storage.

4.3.2.1.e Reducing sugar

Reducing sugar of *Garcinia* nectar during storage is depicted in Table 20. Garcinia gummi- gutta nectar added with mangosteen colour recorded (G$_1$C) recorded the reducing sugar of 13.80 % where as *G. gummi-gutta* beverage without colour recorded 13.70 %. Addition of mangosteen colour to the nectar slightly increased reducing sugar content of the nectar formulations. Reducing sugar content of the mangosteen nectar with the colour increased from 11.35 % to 12.02 at the end of storage. With respect to storage days, the highest reducing sugar content of 13.18 % was observed after third month of storage and lowest value (12.51%) at the time of storage.

4.3.2.1.f Total phenols (mg GAE g^{-1})

Total phenols of *Garcinia* nectars with and without addition of colour extract during storage are depicted in Table 21. Incorporation of mangosteen colour to nectar significantly increased total phenols of the beverages. Total phenols of *G.gummi-gutta* nectar increased from 158.44 to 168.55 mg GAE g^{-1}, mangosteen nectar from

Table 18. Effect of storage on vitamin C (mg 100g^{-1}) of *Garcinia* nectar

Treatments (T)	Vitamin C (mg 100g^{-1})				
	Months after storage (M)				
	At the time of storage	1	2	3	Mean (T)
G$_1$W (*G.gummi-gutta,* without colour)	4.80	4.62	4.52	4.44	4.60^e
G$_1$C (*G.gummi-gutta,* with colour)	5.10	4.93	4.82	4.75	4.90^e
G$_2$W (*G.mangostana,* without colour)	7.15	6.92	6.87	6.74	6.92^a
G$_2$C (*G.mangostana,* with colour)	7.53	7.30	7.23	7.12	7.30^a
G$_3$W (*G.xanthochymus,* without colour)	6.12	5.92	5.84	5.74	5.90^d
G$_3$C (*G.xanthochymus,* with colour)	6.44	6.24	6.16	6.06	6.23^c
Mean M	6.19^a	5.99b	5.91^{bc}	5.81^c	
CD(0.05)	T- 0.094 M - 0.0.077 TXM- NS				
SE (±m)	T-0.033 M- 0.27 TXM - 0.066				

Table 19. Effect of storage on total sugar (%) of *Garcinia* nectar

Treatments (T)	Total sugar (%)				
	Months after storage (M)				
	At the time of storage	1	2	3	Mean (T)
G$_1$W (*G.gummi-gutta,* without colour)	14.89	15.13	15.21	15.42	15.17a
G$_1$C (*G.gummi-gutta,* with colour)	14.99	15.23	15.32	15.52	15.26^a
G$_2$W (*G.mangostana,* without colour)	14.48	14.74	14.80	15.03	14.76^b
G$_2$C (*G.mangostana,* with colour)	14.55	14.81	14.87	15.10	14.84^b
G$_3$W (*G.xanthochymus,* without colour)	14.14	14.38	14.46	14.67	14.42^c
G$_3$C (*G.xanthochymus,* with colour)	14.22	14.46	14.54	14.75	14.49^c
Mean M	14.55^c	14.79^b	14.87^a	15.08^a	
CD(0.05)	T - 0.430 M - 0.351 TXM- 0.860				
SE (±m)	T- 0.151 M - 0.123 TXM- 0.301				

Table 20. Effect of storage on reducing sugar (%) of *Garcinia* nectar

Treatments (T)	Reducing sugar (%)				
	Months after storage (M)				
	At the time of storage	1	2	3	Mean (T)
G₁W (*G.gummi-gutta,* without colour)	13.38	13.55	13.83	14.05	13.70^a
G₁C (*G.gummi-gutta,* with colour)	13.48	13.65	13.93	14.15	13.80^a
G₂ W (*G.mangostana,* without colour)	11.28	11.45	11.73	11.95	11.60^b
G₂ C (*G.mangostana,* with colour)	11.35	11.52	11.80	12.02	11.68^b
G₃ W (*G.xanthochymus,* without colour)	12.73	12.90	13.18	13.40	13.05^a
G₃C (*G.xanthochymus,* with colour)	12.83	13.00	13.28	13.50	13.15^a
Mean M	12.51^b	12.68^{ab}	12.96^a	13.18^a	
CD(0.05)	T- 0.431 M- 0.352 TXM- 0.863				
±SE (m)	T-0.151 M - 0.123 TXM- 0.302				

Table 21. Effect of storage on total phenols (mg GAE g^{-1}) of *Garcinia* nectar

Treatments (T)	Total phenol content (mg GAE g^{-1})				
	Months after storage (M)				
	At the time of storage	1	2	3	Mean (T)
G₁W (*G.gummi-gutta,* without colour)	158.44	154.44	150.43	146.23	152.39^b
G₁C (*G.gummi-gutta,* with colour)	168.55	164.28	160.54	156.34	162.43^a
G₂ W (*G.mangostana,* without colour)	46.30	43.10	40.90	38.00	42.07^f
G₂ C (*G.mangostana,* with colour)	53.97	50.76	48.56	45.66	49.74^e
G₃ W (*G.xanthochymus,* without colour)	139.72	134.62	131.56	127.51	133.36^d
G₃C (*G.xanthochymus,* with colour)	148.06	142.83	139.90	135.85	141.66^c
Mean M	119.18^a	115.01^b	111.98^c	108.27^d	
CD(0.05)	T-3.07 M- 2.508 TXM- NS				
SE (±m)	T-1.077 M- 0.879 TXM- 2.154				

46.30 to 53.97 mg GAE g^{-1} and *G.xanthochymus* nectar from 139.72 to 148.06 mg GAE g^{-1} with addition of colour extract. There was no significant difference among the interaction effects between treatments and storage. During storage total phenols of all the nectar formulation showed a decreasing trend and the lowest TPC (108.27 mg GAE g^{-1}) was observed in mangosteen nectar without colour extract after 3 months of storage.

4.3.2.1.g Antioxidant activity(%)

The supplementation of colour extract significantly increased the antioxidant activity of all *Garcinia nectar* (Table 22.). Initial antioxidant activity was recorded as 75.94, 64.15 and 74.98 % respectively for *G.gummi-gutta* nectar with colour extract (G$_1$C), mangosteen nectar with colour extract (G$_2$C), and *G.xanthochymus* nectar with mangosteen colour extract (G$_3$C). *G.gummi-gutta* nectar with addd colour (G$_1$C) recorded an antioxidant activity of 73.53 % after one month of storage, 71.40 % after second month and 68.29 % after third month of storage Mangosteen nectar without colour (G$_2$W) recorded the lowest antioxidant activity of 59.63, 57.62, and 56.59 % respectively for 1st, 2nd and 3rd month of storage.

4.3.2.2 Effect of Storage on Bacterial Load of Garcinia Nectar

Nectar from each *Garcinia* species with and without incorporation of colour extract was separately analysed for bacterial population for 3 months and were found to be microbiologically safe (Table 23). Result showed that the microbial load for all the samples increased with storage time and was within the permissible limit as per FSSAI. Beverages prepared with addition of colour extract recorded relatively lower bacterial population during storage.

4.3.2.3 Sensory Qualities of Stored Garcinia Nectar

Nectar from each *Garcinia* species with and without incorporation of colour extract was separately analysed for various sensory attributed *viz.*, colour, flavour, taste and overall acceptability for their acceptance using 9 point hedonic scale.

Table 22. Effect of storage on antioxidant activity (%) of *Garcinia* nectar

Treatments (T)	Antioxidant activity (%)				
	Months after storage (M)				
	At the time of storage	1	2	3	Mean (T)
G₁W (*G.gummi-gutta*, without colour)	71.09	68.68	66.55	63.44	67.44[b]
G₁C (*G.gummi-gutta*, with colour)	75.94	73.53	71.40	68.29	72.29a
G₂ W (*G.mangostana*, without colour)	60.91	59.63	57.62	56.59	58.68[e]
G₂ C (*G.mangostana*, with colour)	64.15	62.87	60.86	59.83	61.92[d]
G₃ W (*G.xanthochymus,* without colour)	69.56	67.53	64.89	61.91	65.97[c]
G₃C (*G.xanthochymus,* with colour)	74.98	72.95	70.31	67.33	71.39[a]
Mean M	69.44[a]	67.53[b]	65.27[c]	62.90[d]	
CD(0.05)	T-1.278 M - 1.043 TXM- NS				
SE (±m)	T-0.448 M- 0.366 TXM- 0.896				

Table 23. Effect of storage on bacterial load of *Garcinia* nectar

Treatments (T)	Bacterial count (log cfu ml⁻¹)			
	Months after storage (M)			
	At the time of storage	1	2	3
G₁W (*G.gummi-gutta*, without colour)	-	-	0.76±0.68	1.25±0.23
G₁C (*G.gummi-gutta*, with colour)	-	-	0.41± 0.75	1.20±0.17
G₂ W (*G.mangostana*, without colour)	-	0.67±0.58	1.41± 0.09	1.66±0.05
G₂ C (*G.mangostana*, with colour)	-	0.33±0.57	1.35± 0.10	1.55±0.07
G₃ W (*G.xanthochymus,* without colour)	-	-	0.92±0.80	1.40±0.17
G₃C (*G.xanthochymus,* with colour)	-	-	0.82±0.17	1.20±0.17

Values are expressed as mean±SD (n=3)

The sensory mean score obtained for *G.gummi-gutta* nectars are presented in Table 24 a. Addition of colour extract to *G.gummi-gutta* nectar improved the colour parameter of the nectar. *G.gummi-gutta* nectar with mangosteen colour (G_1C) recorded the highest score for colour at storage (8.56) and the end of third month (8.39). Flavour and taste of the nectar were not significantly influenced by the addition of mangosteen colour extract. At the time of storage highest mean score for overall acceptability (8.65) was for *G.gummi-gutta* nectar with mangosteen colour (G_1C) where as *G.gummi-gutta* nectar without mangosteen colour (G_1W) recorded a score of 7.74. Score of all the parameters showed a decreasing trend with increase in the storage period.

The sensory mean score of *G. mangostana* nectar with and without addition of mangosteen colour extracts are depicted in Table 24 b. Mangosteen nectar with colour (G_2C) recorded the highest mean score for colour (8.60) whereas mangosteen nectar without colour (G_2W) recorded a score of 7.73. Mangosteen nectar colour was improved from white to light orange colour with the addition. At the end of third month Mangosteen nectar with colour (G_2C) recorded the highest mean score of 8.48. Flavour and taste parameters of the nectars were not significantly influenced by the colour addition. Mean score of mangosteen nectar with colour (G_2C) decreased from 8.40 to 8.18 during storage. At the time of storage mangosteen nectar with colour (G_2C) recorded highest mean score (8.51) for overall acceptability whereas mangosteen nectar without colour (G_2W) recorded a score of 7.70. During three month storage all the sensory qualities of the nectar showed a decreasing score but acceptable by the members.

The mean score for sensory attributes for *G.xanthochymus* nectars are presented in Table 24 c. The nectar without colour supplementation (G_3W) recorded the highest score for colour at storage (8.54) and the end of 3rd month (8.43) of storage. *Garcinia xanthochymus* nectar showed a characteristic deep yellow colour with good acceptability whereas flavour and taste of the nectar were not significantly

Table 24 a. Effect of storage on sensory qualities of *G.gummi- gutta* nectar

Treatments	Colour			
	Months after storage			
	At storage	1	2	3
G$_1$W (*G.gummi-gutta,* without colour)	7.63	7.60	7.54	7.49
G$_1$C (*G.gummi-gutta,* with colour)	8.56	8.51	8.46	8.39
KW value	4.12	4.15	4.20	4.72
χ^2 (0.05)	3.841			
Treatments	Flavour			
	Months after storage			
	At storage	1	2	3
G$_1$W (*G.gummi-gutta,* without colour)	8.17	8.12	8.08	8.03
G$_1$C (*G.gummi-gutta,* with colour)	8.25	8.21	8.17	8.07
KW value	0.311	0.287	0.138	0.098
χ^2 (0.05)	3.841			
Treatments	Taste			
	Months after storage			
	At storage	1	2	3
G$_1$W (*G.gummi-gutta,* without colour)	8.40	8.37	8.32	8.26
G$_1$C (*G.gummi-gutta,* with colour)	8.45	8.40	8.38	8.30
KW value	0.042	0.115	0.134	0.262
χ^2 (0.05)	3.841			
Treatments	Overall acceptability			
	Months after storage			
	At storage	1	2	3
G$_1$W (*G.gummi-gutta,* without colour)	7.74	7.71	7.65	7.60
G$_1$C (*G.gummi-gutta,* with colour)	8.65	8.6	8.55	8.48
KW value	4.83	4.92	5.11	4.74
χ^2 (0.05)	3.841			

Table 24 b. Effect of storage on sensory qualities of *G.mangostana* nectar

Treatments	Colour			
	Months after storage			
	At storage	1	2	3
G$_2$ W (*G.mangostana*, without colour)	7.73	7.67	7.60	7.50
G$_2$ C (*G.mangostana*, with colour)	8.60	8.57	8.53	8.48
KW value	4.19	4.16	4.10	4.56
χ^2 (0.05)	3.841			
Treatments	Flavour			
	Months after storage			
	At storage	1	2	3
G$_2$ W (*G.mangostana*, without colour)	8.28	8.27	8.23	8.14
G$_2$ C (*G.mangostana*, with colour)	8.32	8.30	8.27	8.18
KW value	0.026	0.093	0.029	0.034
χ^2 (0.05)	3.84			
Treatments	Taste			
	Months after storage			
	At storage	1	2	3
G$_2$ W (*G.mangostana*, without colour)	8.36	8.28	8.23	8.14
G$_2$ C (*G.mangostana*, with colour)	8.40	8.32	8.27	8.18
KW value	0.083	0.112	0.027	0.024
χ^2 (0.05)	3.841			
Treatments	Overallacceptability			
	Months after storage			
	At storage	1	2	3
G$_2$ W (*G.mangostana*, without colour)	7.70	7.68	7.62	7.58
G$_2$ C (*G.mangostana*, with colour)	8.51	8.45	8.39	8.35
KW value	4.14	4.27	4.32	4.56
χ^2 (0.05)	3.841			

Table 24 c. Effect of storage on sensory qualities of *G. xanthochymus* nectar

Treatments	Colour			
	Months after storage			
	At storage	1	2	3
G$_3$ W (*G.xanthochymus,* without colour)	8.54	8.50	8.48	8.43
G$_3$C (*G.xanthochymus,* with colour)	7.73	7.67	7.60	7.50
KW value	4.19	4.16	4.10	4.56
χ^2 (0.05)	3.841			
Treatments	Flavour			
	Months after storage			
	At storage	1	2	3
G$_3$ W (*G.xanthochymus,* without colour)	8.20	8.18	8.15	8.06
G$_3$C (*G.xanthochymus,* with colour)	8.18	8.16	8.13	8.04
KW value	0.014	0.011	0.011	0.013
χ^2 (0.05)	3.841			
Treatments	Taste			
	Months after storage			
	At storage	1	2	3
G$_3$ W (*G.xanthochymus,* without colour)	8.25	8.20	8.15	8.07
G$_3$C (*G.xanthochymus,* with colour)	8.20	8.18	8.10	8.03
KW value	0.028	0.019	0.014	0.013
χ^2 (0.05)	3.841			
Treatments	Overall acceptability			
	Months after storage			
	At storage	1	2	3
G$_3$ W (*G.xanthochymus,* without colour)	8.54	8.50	8.48	8.43
G$_3$C (*G.xanthochymus,* with colour)	7.73	7.67	7.60	7.50
KW value	4.19	4.16	4.10	4.56
χ^2 (0.05)	3.841			

influenced by the addition of colour extract. At the time of storage, the highest mean score for overall acceptability (8.54) was for *G.xanthochymus* nectar without mangosteen colour (G$_1$W) where as *G.xanthochymus* nectar with mangosteen colour (G$_1$C) recorded a score of 7.73.

4.3.3 Colour Stability of Anthocyanin in Nectar Formulations

Anthocyanin stability of nectars was studied by measuring total anthocyanin content. The effect of light on colour stability of nectar and effect of temperature on stability was observed

4.3.3.1 Effect of Light on Colour Stability of Garcinia nectar

Effect of light on colour stability of nectar formulations was studied by beverages in two different storage containers in transparent and amber coloured bottles and anthocyanin was measured at monthly interval for three months (Table 25). The initial anthocyanin content of the nectars was 4.23, 16.85, 10.97, 3.48 and 14.65 mg 100g^{-1} for *G. gummi-gutta* nectar supplemented with 0.5% colour, *G. mangostana* nectar supplemented with 0.3% colour, *G.xanthochymus* nectar without colour and *G.xanthochymus* nectar supplemented with 0.5% colour respectively.

The anthocyanin content of the nectars showed a decreasing trend during storage and lowest decrease was for the samples stored in amber colour bottles. *G.gummi-gutta* nectar stored in amber bottles (G$_1$WA) recorded an anthocyanin content of 3.94 mg 100g^{-1} after third months of storage whereas it was 3.64 mg 100g^{-1} for the nectar store in transparent bottle (G$_1$WT) which showed no significant difference statistically. *G. gummi-gutta* nectar supplemented with colour (G$_1$ C), exhibited a total anthocyanin content of 10.53 and 11.52 mg 100g^{-1} respectively for transparent (G$_1$CT) and amber (G$_1$CA) containers at the end of storage of 3 months at room temperature.

The mangosteen nectar from mangosteen fruit alone does not contain anthocyanin pigment. Total anthocyanin content of the mangosteen nectar added with colour in transparent bottle (G$_2$ CT) was 9.67, 9.10 and 7.44 after 1st, 2nd and 3rd

month after storage. Whereas anthocyanin content of nectar stored in amber bottles (G_2 CA) was observed as 10.01, 9.30 and 8.74 after first, second and third months of storage which were higher than the nectar stored in transparent bottles.

Anthocyanin of *G.xanthochymus* nectar stored in amber bottles (G_3WA) was 2.85 mg 100g^{-1} after third months of storage whereas, 2.67 mg 100g^{-1} for the nectar store in transparent bottle (G_1WT). The yellow mangosteen nectar supplemented with colour exhibited total anthocyanin content of 9.87 and 11.19 mg 100g^{-1} respectively for transparent (G_3CT) and amber (G_3CA) containers at the end of 3 month torage

4.3.3.2 Effect of Temperature Colour Stability of Garcinia Nectar

The effect of high temperatures (70 ^{0}C and 90 ^{0}C) on anthocyanin stability was measured at 30 minutes and 1 hour and results are depicted in Table 26. It was observed that with increase in temperature and incubation time anthocyanin content of the nectars reduced were significantly. The initial anthocyanin content of *G. gummi-gutta* nectar (G_1W) was 4.23 mg 100g^{-1} , which reduced to 3.58 and 3.40 mg 100g^{-1} at 70 and 90 ^{0}C after heating for 1 hour. The initial anthocyanin content of *G. gummi-gutta* nectar with colour (G_1C) was 16.85 mg 100g^{-1} which was reduced to 16.25 and 15.48 mg 100g^{-1} at 70 and 90 ^{0}C after 30 minutes of incubation, which was further reduced to 15.59 and 14.49 mg 100g^{-1} after 1 hour of heating.

Anthocyanin content of *G.mangostana* nectar with colour (G_2C) was 10.97 mg 100g^{-1} which was reduced to 10.42 and 9.71 mg 100g^{-1} at 70 and 90 ^{0}C after 30 minutes of incubation, which was further reduced to 9.71 and 9.35 after 1 hour of heating. Total anthocyanin content of *G.xanthochymus* nectar (G_3W) was reduced from 3.48 mg 100g^{-1} to 3.06 and 2.89 mg 100g^{-1} at 70 and 90 ^{0}C after heating for 1 hour. *G.xanthochymus* nectar with colour (G_3C) recorded anthocyanin content of 14.65 mg 100g^{-1} which was reduced to 14.43and 13.66 mg 100g^{-1} at 70 and 90 ^{0}C after 30 minutes of incubation, which was further reduced to 13.37 and 12.62 after 1 hour of heating respectively. During storage, TSS, titratable acidity, total sugar and reducing sugar parameters of the nectars were increased whereas vitamin C, total

Table 25 . Effect of light on colour stability of *Garcinia* nectar

Nectar formulations	Total anthocyanin content (mg 100g⁻¹)			
	Months after storage			
	At the time of storage	1	2	3
G₁WT(*G.gummi-gutta,* without colour)	4.23^d	3.95^{ef}	3.78^e	3.64^g
G₁WA(*G.gummi-gutta,* without colour)		4.13^e	4.03^e	3.94^g
G₁CT(*G.gummi-gutta,* with colour)	16.85^a	15.41^a	13.44^a	10.53^c
G₁CA (*G.mangostana,* with colour)		15.75^a	13.92^a	11.52^a
G₂ CT(*G.mangostana,* with colour)	10.97^c	9.67^d	9.10^d	7.44^f
G₂CA(*G.mangostana,* with colour)		10.01^d	9.30^d	8.74^e
G₃WT(*G.xanthochymus,* without colour)	3.48^e	3.22^f	2.99	2.67^h
G₃WA(*G.xanthochymus,* with colour)		3.30f	3.16^f	2.85^h
G₃CT(*G.xanthochymus,* with colour)	14.65^b	12.66^c	11.54^c	9.87^d
G₃CA(*G.xanthochymus,* withcolour)		13.55^b	12.50^b	11.19^b
CD (0.05)	0.540	0.813	0.566	0.319
SE (±m)	0.169	0.274	0.190	0.107

Table 26. Effect of temperature on colour stability (anthocyanin content) of *Garcinia* nectar

Treatments (T)	Total anthocyanin content (mg 100g⁻¹)				
	Temperature				
	70⁰C			90⁰C	
	At the time of storage	30 minutes	1 hour	30 minutes	1 hour
G₁W (*G.gummi-gutta,* without colour)	4.23^d	4.01^d	3.58^d	3.88^d	3.40^d
G₁C (*G.gummi-gutta,* with colour)	16.85^a	16.25^a	15.59^a	15.48^a	14.49^a
G₂ C (*G.mangostana,* with colour)	10.97^c	10.42^c	9.94^c	9.71^c	9.35^c
G₃ W (*G.xanthochymus,* without colour)	3.48^e	3.42^d	3.063^d	3.19^d	2.89^d
G₃C (*G.xanthochymus,* with colour)	14.65^b	14.43^b	13.37^b	13.66^b	12.62^b
CD(0.05)	0.540	0.652	0.540	0.897	0.782
SE (±m)	0.169	0.204	0.169	0.281	0.245

phenols and antioxidant activity were shown decreased. Effect of light on colour stability of the nectars was studied and nectar stored in amber bottles retained more anthocyanin than in transparent glass bottles. The temperature stability studies revealed that with increase in temperature and time, total anthocyanin content of the beverages decreased.

4.4 DEVELOPMENT OF VALUE ADDED PRODUCTS FROM G.GUMMI-GUTTA

4.4.1 Development of Osmodehydrated Product

The effect of different osmotic concentration (50^0Brix and 70^0Brix) and immersion time (24 h, 36 h and 48 h) on mass transfer characters, and quality parameters of osmodehydrated *G.gummi-gutta* (Malabar tamarind) slices were analyzed statistically and results are tabulated and described as below (Plate 9.).

4.4.1.1 Mass Transfer Characters

Mass transfer characters *viz.,* solid gain, water loss, weight reduction were analysed and tabulated in Table 27.

4.4.1.1.a Solid Gain (%)

Solid gain of osmodehydrated rind slices in different osmotic concentration and immersion time is shown in Table 27. Osmodehydrated slices at 50^0Brix (C_1) showed the lowest solid gain of 23.34 % and the highest solid gain (27.46 %) was observed for 70^0Brix (C_2). Among immersion time, T_3 (48 h) recorded the highest solid gain of 28.11 % followed by T_2 (36 h) with 25.79 % and the lowest solid gain (22.31 %) was recorded for T_1 (24 h).

Among the interaction effects, C_2T_3 (70 ^{0}Brix, 48 h) recorded the highest solid gain of 29.55 % followed by 27.51 % for C_2T_2 (70^0Brix, 36 h) and the lowest solid gain of 19.30 % was observed in C_1T_1 (50^0Brix, 24 h).

Ripe *G.gummi-gutta* fruits   Blanched fruits

Dehydration at 60⁰C

Osmodehydrated rind   Drained rind slices   Osmotic treatmnent

Plate 9. Development of osmodehydrated *G.gummi-gutta* rind

4.4.1.1.b Water Loss (%)

Water loss of osmodehydrated *G. gummi-gutta* slices were influenced significantly by osmotic concentrations and immersion time. The highest water loss of 44.99 % was observed for the osmotic concentration C_2 (70 ^{0}Brix) and the lowest water loss of 25.40 % was recorded for C_1 (50 ^{0}Brix). The immersion time, 48 h (T_3) recorded the highest water loss of 45.95 %; whereas 36 h (T_2) recorded the water loss of 40.44 % and lowest water loss (37.66 %) was observed for 24 h immersion time (T_1).

Among the interactions, maximum water loss (49.10 %) was observed in C_2T_3 (70^{0}Brix, 48 h), while minimum water loss (22.31 %) was in treatment with osmotic concentration of 50^{0}Brix for immersion time of 24 h (C_1T_1).

4.4.1.1.c Weight Reduction(%)

Percentage weight reduction of osmodehydrated rind slices at different osmotic concentration and immersion time is given in Table 27. Osmosed rind at 70^{0}Brix (C_2) recorded the highest weight loss of 26.50 % followed by C_1 (50^{0}Brix). When the effect of immersion time was considered T_1 (24 h) showed the lowest weight loss of 20.94 % where as T_3 (48 h) recorded the highest weight reduction (26.45 %) and T_2 (36 h) showed a weight reduction of 24.75 %.

When interaction effects were studied C_2T_3 (70^{0}Brix, 48 h) recorded maximum weight reduction of 29.00 % and the minimum weight reduction of 18.93 % was observed for C_1T_1 (50 ^{0} Brix, 24 h)

4.4.1.2 Biochemical Parameters of osmodehydrated G.gummi-gutta Rind

The osmodehydrated *G.gummi-gutta* rind obtained from all the six treatments were packed in PP cover and stored for a period of 3 months and biochemical, sensory and microbial analysis were done at monthly interval.

Table 27. Effect of osmotic concentrations and immersion time on mass transfer charcters of osmodehydrated *G.gummi-gutta* rind

Osmotic concentrations	Solid gain (%)			
	Immersion time (hours)			
	T_1 (24)	T_1 (36)	T_1 (48)	Mean (C)
C_1 (50^0 Brix)	19.30	24.06	26.67	23.34[a]
C_2 (70^0 Brix)	25.32	27.51	29.55	27.46[a]
Mean (T)	22.31[c]	25.79[b]	28.11[a]	
CD (0.05)	C- 0.712 T- 0.873 C X T-1.234			
SE (± m)	C - 0.229 T - 0.280 C X T-0.396			
	Water loss (%)			
	Immersion time (hours)			
	T_1 (24)	T_2 (36)	T_3 (48)	Mean (C)
C_1 (50^0 Brix)	22.31	25.79	28.11	25.40[b]
C_2 (70^0 Brix)	41.32	44.55	49.10	44.99[a]
Mean (T)	37.66[c]	40.44[b]	45.95[a]	
CD (0.05)	C- 0.597 T- 0.73 C X T-1.034			
SE(±m)	C- 0.192 T- 0.235 C X T- 0.332			
	Weight reduction (%)			
	Immersion time (hours)			
	T_1 (24)	T_2 (36)	T_3 (48)	Mean (C)
C_1 (50^0 Brix)	18.93	21.93	23.90	21.59[b]
C_2 (70^0 Brix)	22.94	27.56	29.00	26.50[a]
Mean (T)	20.94[c]	24.75[b]	26.45[a]	
CD (0.05)	C-0.808 T -0.989 C X T- NS			
SE(±m)	C -0.259 T -0.318 C X T - 0.449			

Biochemical parameters of osmodehydrated rind slices as influenced by storage are described below.

4.4.1.2. a Acidity(%)

Total acidity of osmodehydrated *G.gummi-gutta* slices during storage is depicted in Table 28. At the time of storage the highest acidity of 3.14 % was observed for the treatment C_1T_1 (50 ^{0} Brix, 24 h) followed by C_1T_2 (50 ^{0} Brix, 36 h) and C_2T_1(70 ^{0} Brix, 24 h). With increase in immersion time and concentration of sugar syrup acidity was decreased and lowest acidity of 1.54 was observed for the treatment C_2T_3 (70 ^{0} Brix, 48 h).

During storage there was no significant difference among the interaction effect between treatments and storage period. The acidity of the samples were significantly increased during storage. Osmodehydrated malabar tamarind sample C_1T_1 (50^{0}B, 24 h) recorded acidity of 3.18 % after 1 month, 3.22 % after 2 months and 3.25 % after 3 months of storage. Acidity of osmodehydrated slices in 70^{0}Brix for 36 (C_2T_2) hours was observed as 1.72, 1.75 and 1.79 % at 1st, 2nd and 3rd month of storage respectively.

4.4.1.2. b TSS (^{O}Brix)

The TSS of osmodehydrated slices during storage is depicted in Table 29. At the time of storage TSS of 46.93^{0}Brix was observed for the treatment C_2T_3 (70 ^{0} Brix, 48 h) followed by C_2T_2 (70 ^{0} Brix, 36 h and C_1T_3 (50 ^{0} Brix, 48 h). During storage, there was no significant difference among the interaction effects between treatments and storage. Among the treatments highest TSS of 47.88 ^{0}Brix was observed for the treatment osmodehydrated in 70^0 Brix for 48 hours (C_2T_3) followed by C_2T_2 (70^0 Brix, 36 h) recorded 40.46 %. With respect to storage months TSS of the osmodehyrated samples with storage increased and the highest TSS content of 39.23 ^{0}Brix were observed after three months of storage.

Table 28. Effect of storage on acidity (%) of osmodehydrated G. *gummi-gutta* rind

Osmotic treatments (A)	Acidity (%)				
	Months after storage (M)				
	At storage	1	2	3	Mean (A)
C_1T_1 (50ºBrix, 24 h)	3.14	3.18	3.22	3.25	3.20[a]
C_1T_2 (50ºBrix,36 h)	2.26	2.29	2.48	2.55	2.40[b]
C_1T_3(50ºBrix, 48 h)	1.78	1.82	1.85	1.90	1.84[c]
C_2T_1(70ºBrix, 24 h)	1.83	1.86	1.90	1.94	1.88[c]
C_2T_2(70ºBrix, 36 h)	1.67	1.72	1.75	1.79	1.73[cd]
C_2T_3(70ºBrix, 48 h)	1.54	1.57	1.60	1.63	1.58[d]
Mean (M)	2.04[b]	2.07[b]	2.13[a]	2.18[a]	
SE(±m)	A- 0.017		M-0.014	A X M-0.034	
CD (0.05)	A 0.048		M- 0.039	A X M- NS	

Table 29. Effect of storage on TSS (^{0}Brix) of osmodehydrated *G.gummi-gutta* rind

Osmotic treatments (A)	TSS (^{0}Brix)				
	Months after storage (M)				
	At storage	1	2	3	Mean (A)
C_1T_1 (50ºBrix, 24 h)	28.95	29.77	30.20	30.50	29.86[e]
C_1T_2 (50ºBrix,36 h)	34.73	35.17	35.80	36.23	35.48[d]
C_1T_3(50ºBrix, 48 h)	38.59	39.40	39.90	40.33	38.56[c]
C_2T_1(70ºBrix, 24 h)	36.34	37.22	37.77	38.17	37.38c
C_2T_2(70ºBrix, 36 h)	39.63	40.20	40.67	41.33	40.46[b]
C_2T_3(70ºBrix, 48 h)	46.93	47.73	48.03	48.83	47.88[a]
Mean (M)	37.53	38.25	38.73	39.23[a]	
SE(±m)	A- 0.1120		M- 0.092	A X M-0.225	
CD (0.05)	A- 0.320		M- 0.262	A X M-NS	

4.4.1.2.c Total Sugar (%)

Among the osmodehydrated treatments, the highest total sugar of 48.04 % was recorded for C_2T_3 (70^0 Brix for 48 h) followed by C_2T_2 (70^0 Brix for 36 h) with 45.04 % and the lowest total sugar of 36.21 % was observed for C_1T_1 (50^0B for 24 h) on storage (Table 30). During storage total sugar content increased, and the lowest total sugar of 42.26 % which increased to 45.29 % after third month of storage.

4.4.1.2. d Reducing Sugar (%)

The reducing sugar content of osmodehydrated rind slices during storage is depicted in Table 31. The fruit rind osmodehydrated in 70^0 Brix for 48 h (C_2T_3) recorded a reducing sugar of 17.48 %, C_2T_2 (70^0 Brix, 36 h) recorded 16.82 % and 15.83% for malabar tamarind in C_1T_3 (50^0 Brix, 48 h) at the time of storage. During storage, there was no significant difference among the interaction effects between treatments and storage. Among the treatments osmodehydrated malabar tamarind in 70^0 Brix for 48 hours recorded the highest reducing sugar content of 18.34 % whereas lowest value (12.65%) was for C_1T_1 (50^0 Brix for 24 h). With respect to storage days, the highest reducing sugar content of 17.10 % was observed after third month of storage and lowest value (15.13%) at the time of storage.

4.4.1.2.e Antioxidant Activity (%)

Antioxidant activity of osmodehydrated fruits during storage is depicted in Table 32. Initial antioxidant activity was recorded as 78.38, 76.22 and 75.05 % respectively for treatments C_1T_1 (50^0 Brix for 24 h), C_1T_2 (50^0 Brix for 36 h) and C_2T_1 (70^0 Brix for 24 h). Osmodehydrated sample in 70^0 Brix for 36 hours recorded an antioxidant activity of 70.61 % after one month of storage, 70.20 % after second month and 68.63 % after third month of storage. Fruit rind osmosed in 70^0 Brix for 48 h recorded lowest antioxidant activity of 65.32, 64.91 and 63.43 % respectively for

Table 30. Effect of storage on total sugar (%) of osmodehydrated *G.gummi-gutta* rind

Osmotic treatments (A)	Total sugar (%)				
	Months after storage (M)				
	At storage	1	2	3	Mean (A)
C_1T_1 (50ºBrix, 24 h)	36.21	36.99	37.96	39.24	37.60[e]
C_1T_2 (50ºBrix,36 h)	40.38	41.41	42.13	43.41	41.83[e]
C_1T_3 (50ºBrix, 48 h)	42.63	43.54	44.38	45.66	44.05[c]
C_2T_1 (70ºBrix, 24 h)	41.25	42.16	43.00	44.28	42.67[d]
C_2T_2 (70ºBrix, 36 h)	45.04	45.95	46.79	48.07	46.46[b]
C_2T_3 (70ºBrix, 48 h)	48.04	48.95	49.79	51.07	49.46[a]
Mean (M)	42.26[bc]	43.17[ab]	44.01[a]	45.29[a]	
SE(±m)	A- 0.143 M-0.117 A X M-0.287				
CD (0.05)	A- 0.409 M- 0.334 A X M- NS				

Table 31 . Effect of storage on reducing sugar (%) of osmodehydrated *G.gummi-gutta* rind

Osmotic treatments (A)	Reducing sugar (%)				
	Months after storage (M)				
	At storage	1	2	3	Mean (A)
C_1T_1 (50ºBrix, 24 h)	11.77	12.21	12.89	13.74	12.65[e]
C_1T_2 (50ºBrix,36 h)	13.84	14.28	14.96	15.81	14.72[d]
C_1T_3 (50ºBrix, 48 h)	15.83	16.27	16.95	17.80	16.71[bc]
C_2T_1 (70ºBrix, 24 h)	15.03	15.47	16.15	17.01	15.92[cd]
C_2T_2 (70ºBrix, 36 h)	16.82	17.26	17.94	18.79	17.70[b]
C_2T_3 (70ºBrix, 48 h)	17.48	17.92	18.60	19.45	18.36[a]
Mean (M)	15.13[bc]	15.57[bc]	16.25[ab]	17.10[a]	
SE(±m)	A- 0.077 M-0.063 A X M-0.154				
CD (0.05)	A- 0.220 M- 0.179 A X M- NS				

1st, 2nd and 3rd month of storage. With respect to storage, the highest antioxidant activity of 73.87 % was recorded at the time of storage and it reduced to 70.09 % at the end of three month of storage.

4.4.1.2. f HCA (%)

Hydroxy Citric Acid (HCA) content of osmdehydrated malabar tamarind fruit rind showed significant difference among the treatments and storage period (Table 33). Rind osmodehydrated in 50^0 Brix for 24 h (C_1T_1) recorded highest HCA content of 2.90% followed by C_1T_2 (50^0 Brix, 36 h) of 2.20 % at the time of storage. During storage, HCA of the osmodehydrated treatment 70^0 Brix for 36 h (C_2T_2) was observed as 1.40, 1.37 and 1.32 % after 1st, 2nd and 3rd month of storage respectively. Among the treatments lowest value (1.23) was for C_2T_3 (70^0 Brix for 48 h). With respect to storage months, the highest HCA content of 1.83% was observed at the time of storage which reduced to 1.69% at the end of storage of third month.

4.4.1. 3 Sensory Analysis of Osmodehydrated Malabar tamarind during Storage

Sensory parameters *viz.,* taste, colour (golden yellow to brown), flavour, texture and overall acceptability for stored osmodehydrated malabar tamarind rind were analysed using 9 point hedonic scale at monthly interval.

Effect of storage on taste of osmodehydrated rind is depicted in Table 34. The highest mean score (8.60) was recorded for osmodehydrated sample C_2T_2 (70^0 Brix, 36 h) followed by C_2T_3 (70^0 Brix, 48 h) with 8.47 and C_1T_3 (70^0 Brix, 48 h) recorded a mean score of 8.17 at the time of storage. After one month of storage the osmo dehydrated rind at 70^0 Brix, 36 hours (C_2T_2) recorded the highest mean score of 8.53 for taste and highest mean score of 8.33, and 8.07 after 2nd, and 3rd months of storage at room temperature.

Table 32. Effect of storage on antioxidant activity (%) of osmodehydrated
G.gummi-gutta rind

Osmotic treatments (A)	Antioxidant activity (%)				
	Months after storage (M)				
	At storage	1	2	3	Mean (A)
C_1T_1 (50ºBrix, 24 h)	78.38	76.58	76.17	74.60	76.43[a]
C_1T_2 (50ºBrix,36 h)	76.22	74.42	74.01	72.44	74.28[b]
C_1T_3(50ºBrix, 48 h)	74.02	72.22	71.81	70.24	72.07[bc]
C_2T_1 (70ºBrix, 24 h)	75.05	72.84	71.27	73.10	72.84[c]
C_2T_2(70ºBrix, 36 h)	72.41	70.61	70.20	68.63	70.46d
C_2T_3(70ºBrix, 48 h)	67.12	65.32	64.91	63.34	65.17
Mean (M)	73.87[a]	72.07[ab]	71.66[bc]	70.09[c]	
SE(±m)	A- 0.310		M-0.254	A X M-0.621	
CD (0.05)	A- 0.886		M- 0.0723	A X M- NS	

Table 33 . Effect of storage on Hydroxy Citric Acid (HCA (%) of osmodehydrated
G.gummi-gutta rind

Osmotic treatments (A)	HCA (%)				
	Months after storage (M)				
	At storage	1	2	3	Mean (A)
C_1T_1 (50ºBrix, 24 h)	2.90	2.87	2.83	2.79	2.85[a]
C_1T_2 (50ºBrix,36 h)	2.20	2.13	1.94	1.91	2.05[b]
C_1T_3(50ºBrix, 48 h)	1.55	1.50	1.47	1.43	1.49[cd]
C_2T_1(70ºBrix, 24 h)	1.59	1.55	1.51	1.48	1.53[c]
C_2T_2(70ºBrix, 36 h)	1.44	1.40	1.37	1.32	1.38[d]
C_2T_3(70ºBrix, 48 h)	1.28	1.25	1.22	1.19	1.23[e]
Mean (M)	1.83[a]	1.78[ab]	1.72[bc]	1.69[c]	
SE(±m)	A- 0.017 M-0. 0.014			A X M-0.034	
CD (0.05)	A- 0.048		M- 0.039	A X M- NS	

On analyzing colour of the osmodehydrated products (Table 35) highest mean score (8.53) was for rind osmosed in 70^0 Brix for 48 h at the time of storage. Malabar tamarind fruit osmodehydrated in 70^0 Brix for 36 hours recorded a mean score of 8.33 after first month, 7.97 after second month and 7.73 after third month of storage. Golden yellow colour of the osmodehydrated rind samples were further changed to darker colour upon storage which showed a decrease in colour mean score.

Sensory analysis of flavour of osmodehydrated malabar tamarind fruits at the time of storage (Table 36) revealed that the highest mean score (8.60) was recorded by C_2T_2 (70^0 Brix, 36 h) followed by C_2T_3 (70^0 Brix for 48 h) with 8.47 mean score value and 8.37 for rind osmodehydrated in 50^0 Brix for 48 h (C_1T_3). After three months of storage, the highest mean score for flavour was recorded by C_2T_2 (70^0 Brix, 36 h) (8.13) followed by C_2T_3 with a mean score of (8.00).

On analyzing the texture of the osmo dehydrated rind (Table 37) mean scores were not significantly different up to 1 month of storage. Fruit rind osmodehydrated in 70^0Brix for 48 h (C_2T_3) recorded the highest mean score of 8.03 after first month, 7.87 after second and 7.60 after third months of storage. All osmodehydrated combination recorded acceptable scores up to third month of storage.

Effect of storage on overall acceptability of osmo dehydrated *G.gummi guta* fruit rind is depicted in Table 38. The highest mean score (8.63) was recorded for osmodehydrated treatment C_2T_2 (70^0 Brix, 36 h) followed by C_2T_3 (70^0 Brix, 48 h) with 8.40 and C_1T_3 (50^0 Brix, 48 h) recorded 8.10 at the time of storage. After one month of storage the osmodehydrated rind at 70^0 Brix, 36 h (C_2T_2) recorded the highest mean score of 8.43 for overall acceptability and highest mean score of 8.20, 8.03 after 2nd, and 3rd months of storage at room temperature.

Table 34. Effect of storage on taste of osmodehydrated *G.gummi-gutta* rind slices

Osmotic treatments	Months after storage			
	At storage	1	2	3
C_1T_1 (50ºBrix, 24 h)	6.07	5.97	5.73	5.53
C_1T_2 (50ºBrix,36 h)	7.00	6.90	6.73	6.47
C_1T_3(50ºBrix, 48 h)	8.17	8.03	7.87	7.67
C_2T_1(70ºBrix, 24 h)	7.77	7.73	7.60	7.20
C_2T_2(70ºBrix, 36 h)	8.60	8.53	8.33	8.07
C_2T_3(70ºBrix, 48 h)	8.47	8.40	8.17	7.90
KW value	92.41	92.164	69.96	55.23
χ^2 (0.05)	11.071			

Table 35. Effect of storage on colour of osmodehydrated *G.gummi-gutta* rind

Osmotic treatments	Months after storage			
	At storage	1	2	3
C_1T_1 (50ºBrix, 24 h)	7.13	7.03	6.87	6.20
C_1T_2 (50ºBrix,36 h)	7.23	7.10	6.83	6.30
C_1T_3(50ºBrix, 48 h)	8.10	7.97	7.83	7.17
C_2T_1(70ºBrix, 24 h)	7.97	7.83	7.67	7.07
C_2T_2(70ºBrix, 36 h)	8.47	8.33	7.97	7.73
C_2T_3(70ºBrix, 48 h)	8.53	8.43	8.27	7.77
KW value	50.49	47.11	36.85	31.249
χ^2 (0.05)	11.071			

Table 36. Effect of storage on flavour of osmodehydrated *G.gummi-gutta* rind slices

Osmotic treatments	Months after storage			
	Initial	1	2	3
C_1T_1 (50ºBrix, 24 h)	6.80	6.70	6.53	6.37
C_1T_2 (50ºBrix,36 h)	7.10	7.00	6.87	6.63
C_1T_3(50ºBrix, 48 h)	8.37	8.23	8.07	7.93
C_2T_1(70ºBrix, 24 h)	8.03	7.93	7.73	7.63
C_2T_2(70ºBrix, 36 h)	8.60	8.33	8.37	8.13
C_2T_3(70ºBrix, 48 h)	8.47	8.37	8.20	8.00
KW value	75.28	65.208	57.47	54.52
χ^2 (0.05)	11.071			

Table. 37. Effect of storage on texture of osmodehydrated *G.gummi-gutta* rind slices

Osmotic treatments	Months after storage			
	At storage	1	2	3
C_1T_1 (50ºBrix, 24 h)	7.83	7.43	7.03	6.47
C_1T_2 (50ºBrix,36 h)	7.93	7.67	7.11	6.67
C_1T_3(50ºBrix, 48 h)	8.10	8.00	7.67	7.37
C_2T_1(70ºBrix, 24 h)	8.27	8.03	7.80	7.10
C_2T_2(70ºBrix, 36 h)	8.17	8.00	7.83	7.47
C_2T_3(70ºBrix, 48 h)	8.10	8.03	7.87	7.60
KW value	5.09	9.028	11.11	14.60
χ^2 (0.05)	11.071			

Table 38. Effect of storage on overall acceptability of osmodehydrated *G.gummi-gutta* rind slices

Osmotic treatments	Months after storage			
	At storage	1	2	3
C_1T_1 (50ºBrix, 24 h)	7.30	7.17	6.50	6.33
C_1T_2 (50ºBrix,36 h)	7.57	7.47	6.90	6.77
C_1T_3(50ºBrix, 48 h)	8.10	7.97	7.20	7.00
C_2T_1(70ºBrix, 24 h)	7.87	7.70	7.10	6.90
C_2T_2(70ºBrix, 36 h)	8.63	8.43	8.20	8.03
C_2T_3(70ºBrix, 48 h)	8.40	8.30	8.00	7.83
KW value	28.73	25.43	63.76	22.23
χ^2 (0.05)	11.071			

4.4.1. 4 Enumeration Microbial Load

The osmo dehydrated malabar tamarind fruit rinds on storage for 3 months were microbiologically found safe (Table 39). For microbial stability, total plate count method was conducted on the samples at monthly intervals and the result showed that the microbial load for all the samples increased with storage time and was within the permitted limit. All the treatment recorded lowest microbial population at one month after storage. The lowest fungal load from 0.33 to 1.69 log CFU g^{-1} bacterial load from 1.10 to 1.93 log CFU $g^-$was observed for the treatment 70^0B for 48 hours from the first month of storage to the end of storage. The bacterial load for 50^0B for 24 hours recorded as the highest which ranged from 2.28 to 3.50 log CFU g^{-1} during three months of storage.

The storage study revealed that all the six treatments were microbiologically safe and acceptable up to three months of storage and the treatment 70^0Brix for 36 hours was selected as the best treatment which exhibited highest acceptability and was selected for further pickle development studies.

4.4.2 Development of Paste

The effect of salt concentration (3%, 5%,7%, 9% and control) on quality parameters of the *G. gummi- gutta* (malabar tamarind) culinary paste for a storage period of three months were statistically analyzed and described as below. All the paste formulations were packed in glass bottles for storage stability studies. Biochemical, microbial and sensory analysis were done at monthly interval for a period of 3 months.

4.4.2. 1 Biochemical Parameters

Biochemical parameters *viz.,* moisture content, TSS, acidity, HCA, reducing sugar, TFC, antioxidant activity (%) and   fibre content in different formulations of

Table 39. Enumeration of microbial load during storage of osmodehydrated *G.gummi-gutta* rind

Osmotic treatments	Microbial count (log cfu g^{-1})					
	Bacteria			Fungi		
	Months after storage			Months after storage		
	1	2	3	1	2	3
C_1T_1 (50ºBrix, 24 h)	2.28	2.99	3.50	1.67	2.09	2.98
C_1T_2 (50ºBrix,36 h)	2.13	2.84	3.33	1.72	1.98	2.76
C_1T_3(50ºBrix, 48 h)	1.59	2.13	2.47	1.00	1.54	2.26
C_2T_1(70ºBrix, 24 h)	1.95	2.35	2.73	1.36	1.66	2.20
C_2T_2(70ºBrix, 36 h)	1.26	1.86	2.36	0.67	1.00	1.66
C_2T_3(70ºBrix, 48 h)	1.10	1.66	1.93	0.33	1.10	1.69
CD (0.05%)	0.260	0.143	0.209	0.606	0.202	0.255
SE(±m)	0.084	0.046	0.067	0.195	0.065	0.082

culinary paste were assessed and 100g paste (control) (T_5) were assessed during storage and results are presented (Plate 10.).

4.4.2. 1.a Moisture Content (%)

Moisture content of the culinary pastes from *G. gummi-gutta* rinds are given in Table 40. Salt concentrations of the culinary paste significantly affected the moisture content and the highest moisture content of 84.69 % was reported for the paste prepared without addition of salt (T_5).

At the time of storage highest moisture content of 85.14 % was observed for the treatment T_5 (control) followed by T_1 (salt 3%) and T_2 (5%salt). With increase in salt concentration moisture content was decreased and lowest of 78.55% was observed for the treatment T_4 (9 % salt) and it was 78.47, 78.29, 78.00 % at 1st, 2nd and 3rd month of storage respectively. During storage there was no significant difference among the interaction effect between treatments and storage period.

4.4.2. 1. b TSS (^{O}Brix)

The TSS of culinary paste from *G. gummi- gutta* paste during storage is depicted in Table 41. Salt addition to paste significantly increased TSS content of the paste. At the time of storage highest TSS of 22.60^0 Brix was observed for the treatment T_4 (9% salt) followed by T_3 (7% salt) and T_2 (5% salt).

Among the treatments highest TSS of 23.08 ºBrix was observed for the treatment with 9% salt (T_4) followed by T_3 (7%) with 20.90 ºBrix. The lowest TSS of 12.49 ºBrix was recorded for the paste without salt (T_5). With respect to storage months TSS of the paste samples were increased and the highest TSS content of 18.76 ^{O}Brix was observed after third month of. Garcinia paste prepared with addition of 9% salt recorded highest TSS content of 22.90, 23.20 and 23.64 ^{O}Brix after 1st, 2nd and 3rd months of storage respectively.

Blanched rind

Extracted pulp

Salt traetments

At the end of storage

Bottled and stored

Heat treatment

Plate 10. Development of culinary paste from *G.gummi-gutta* fruit rind

Table 40. Effect of storage on moisture content (%) of *G. gummi-gutta* past

Treatments (T)	Moisture content (%)				
	Months of storage (M)				
	At storage	1	2	3	Mean (T)
T$_1$ (3% salt)	84.48	84.26	84.04	83.72	84.13^{ab}
T$_2$ (5% salt)	83.16	83.09	82.87	82.55	82.92^{bc}
T$_3$ (7% salt)	79.57	79.53	79.35	79.06	79.38^{c}
T$_4$ (9% salt)	78.55	78.47	78.29	78.00	78.33^{d}
T$_5$ (Control)	85.14	85.02	84.57	84.04	84.69^{a}
Mean (M)	82.18^{a}	82.08^{a}	81.83^{b}	81.48^{c}	
CD (0.05)	T-0.351		M-0.314		TXM- NS
SE(±m)	T-0.122		M-0.109		TXM-0.244

Table 41. Effect of storage on TSS (^{O}Brix) of *G. gummi-gutta* paste

Treatments (T)	TSS (^{O}Brix)				
	Months of storage (M)				
	At storage	1	2	3	Mean (T)
T$_1$ (3% salt)	16.17	16.30	16.47	16.83	16.44^{d}
T$_2$ (5% salt)	17.80	18.03	18.37	18.42	18.16^{c}
T$_3$ (7% salt)	20.10	20.50	21.47	21.53	20.90^{b}
T$_4$ (9% salt)	22.60	22.90	23.20	23.64	23.08^{a}
T$_5$ (Control)	11.70	12.23	12.66	13.37	12.49^{e}
Mean (M)	17.67^{d}	17.99^{c}	18.43^{ab}	18.76^{a}	
CD (0.05	T- 0.234		M-0.209		T XM- 0.46
SE(±m)	T- 0.081		M- 0.073		TXM- 0.163

4.4.2. 1 c Total Acidity (%)

Total acidity of malabar tamarind paste showed significant difference among the treatments with the storage period (Table 42). Paste prepared without addition of salt (T5) recorded the highest acidity of 5% followed by T_1 (3% salt) of 4.97% at the time of storage. Which showed no statistical significant between the treatments.

Addition of salt to the culinary paste slightly decreased acidity of the samples and the lowest acidity of 4.86 % was reported by the treatment T_4 (9% salt) and the highest acidity of 5.19 % was observed in control treatment (T_5) followed by T_1 (5.12) and T2 (5.05%). During storage total acidity of paste prepared with 9% salt addition (T_4) was observed as 4.83, 4.87 and 4.95 % after 1st, 2nd and 3^{rd}month of storage respectively. With respect to storage months, the highest acidity of 5.18% was observed at the end of storage and lowest value of 4.90% was recorded at the time of storage.

4.4.2. 1.d HCA (%)

Hydroxy Citric Acid of *Garcinia* paste during storage is depicted in Table 43. HCA content of paste prepared without addition of salt (T_5) recorded the highest HCA of 4.72 % whereas 4.40% was recorded for T_4 (9% salt). With respect to storage days, the highest HCA content of 4.61 % was observed at the time of storage and lowest value (4.35%) at the end of third month. During storage, HCA content of paste samples were significantly decreased.

4.4.2. 1.e Reducing Sugar (%)

Reducing sugar content of *Garcinia* paste during storage is depicted in Table 44. Reducing sugar content of paste treatments at the time of storage varied from 3.66 to 3.69%. Among the treatments paste prepared without addition of salt (T_5) recorded the highest reducing sugar content of 4.45 % whereas lowest value (4.06%) was for T_4 (9% salt). With respect to storage days, the highest reducing sugar content of 4.79

Table 42. Effect of storage on total acidity (%) of *G. gummi-gutta* paste

Treatments (T)	Total acidity (%)				
	Months of storage (M)				
	At storage	1	2	3	Mean (T)
T$_1$ (3% salt)	4.97	5.04	5.19	5.28	5.12^a
T$_2$ (5% salt)	4.91	4.97	5.13	5.20	5.05a
T$_3$ (7% salt)	4.84	4.88	5.03	5.12	4.97^{ab}
T$_4$ (9% salt)	4.80	4.83	4.87	4.95	4.86^b
T$_5$ (Control)	5.00	5.17	5.25	5.38	5.19^a
Mean (M)	4.90^{bc}	4.98^{bc}	5.09^{ab}	5.18^a	
CD (0.05	T- 0.124 M- 0.111 TXM NS				
±SE(m)	T- 0.043 M- 0.039 TXM- 0.086				

Table 43. Effect of storage on HCA (%) of *Garcinia gummi-gutta*

Treatments (T)	Months after storage (M)				
	At storage	1	2	3	Mean (T)
T$_1$ (3% salt)	4.71	4.64	4.49	4.42	4.57^a
T$_2$ (5% salt)	4.65	4.58	4.42	4.36	4.50^{ab}
T$_3$ (7% salt)	4.57	4.48	4.33	4.29	4.42^{bc}
T$_4$ (9% salt)	4.4	4.32	4.28	4.25	4.31^c
T$_5$ (Control)	4.72	4.7	4.62	4.45	4.62^a
Mean M	4.61^a	4.54^a	4.43^b	4.35^b	
CD (0.05)	T- 0.131 M- 0.122 TXM- NS				
±SE(m)	T-0.051 M - 0.023 TXM- 0.0302				

% was observed after third month of storage and lowest value (3.67%) at the time of storage.

4.4.2. 1.f Total Flavonoids Content (TFC) (mg QE g⁻¹)

Total Flavonoid Content of culinary paste from *G.gummi gutta* paste during storage is depicted in Table 45. Salt addition to paste had no significant effect on TFC content of paste and it ranged from 20.14 to 20.97 *mg QE g⁻*1 at the time of storage. With respect to storage months TFC of the paste samples were increased and the highest TFC content of 23.82 *mg QE g⁻*1 was observed after third month of storage .

4.4.2. 1.g Antioxidant Activity (%)

Antioxidant activity of *Garcinia* paste during storage is depicted in Table 46. Initial antioxidant activity of the samples ranged from 90.21 to 90.64 among the paste treatments and salt addition increased antioxidant potential of paste treatments. Garcinia paste prepared with addition of 9% salt (T4) recorded an antioxidant activity of 90.64 % after one month of storage, 88.66 % after second month and 87.64 % after third month of storage. The treatment T5 reported the lowest antioxidant activity of 82.91, 80.68 and 79.65 % respectively for 1st, 2nd and 3rd month of storage. With respect to storage, the highest antioxidant activity of 90.35 % was recorded at the time of storage and it reduced to 85.01 % at the end of 3 months of storage .

4.4.2. 1. h Fibre content (%)

Fibre content of the paste samples was not significantly different among the treatments (Table 47) and varied from 4.34 to 4.37% among the treatments.. During storage, fibre content of the treatment T4 was observed as 4.37, 4.32 and 4.27 % after 1st, 2nd and 3rd month of storage respectively With respect to storage months, the highest fibre content of 4.47% was observed at the time of storage which decreased during storage and lowest value of 4.23 % was recorded at the end of storage of 3 months at room temperature.

Table 44. Effect of storage on reducing sugar (%) of *G. gummi-gutta* paste

Treatments (T)	Reducing sugar (%)				
	Months of storage (M)				
	At the time of storage	1	2	3	Mean (T)
T_1 (3% salt)	3.68	3.93	4.38	4.87	4.21[b]
T_2 (5% salt)	3.67	3.90	4.31	4.75	4.16[c]
T_3 (7% salt)	3.66	3.84	4.23	4.57	4.08[d]
T_4 (9% salt)	3.67	3.84	4.19	4.55	4.06[d]
T_5 (Control)	3.69	4.07	4.80	5.25	4.45[a]
Mean (M)	3.67[d]	3.92[c]	4.38[b]	4.79[a]	
CD (0.05)	T- 0.064		M-0.058	TXM-0.129	
SE(±m)	T-0.022		M-0.020	TXM-0.045	

Table 45. Effect of storage on total flavonoids (mg QE g^{-1}) of *G. gummi-gutta* paste

Treatments (T)	Total flavonoids (mg QE g^{-1})				
	Months of storage(M)				
	At storage	1	2	3	Mean (T)
T_1 (3% salt)	20.14	20.63	21.60	23.38	21.43
T_2 (5% salt)	20.62	21.11	22.08	23.86	21.92
T_3 (7% salt)	20.97	21.46	22.43	24.21	22.27
T_4 (9% salt)	20.49	20.98	21.95	23.73	21.78
T_5 (Control)	20.68	21.17	22.14	23.92	21.97
Mean (M)	20.58[c]	21.07[c]	22.04[b]	23.82[a]	
CD (0.05)	T- NS		M-1.131	TXM- NS	
SE(±m)	T- 0.441		M-0.394	TXM- 0.881	

Table 46. Effect of storage on antioxidant activity (%) of *Garcinia gummi-gutta* paste

Treatments (T)	Antioxidant activity (%)				
	Months after storage(M)				
	At storage	1	2	3	Mean (T)
T$_1$ (3% salt)	90.44	88.74	86.29	85.27	87.76^b
T$_2$ (5% salt)	90.48	89.25	87.02	85.99	88.21^{ab}
T$_3$ (7% salt)	90.50	89.75	87.52	86.50	88.54^a
T$_4$ (9% salt)	90.89	90.64	88.66	87.64	89.26^a
T$_5$ (Control)	90.21	82.91	80.68	79.65	83.36^c
Mean (M)	90.35	88.31	86.03	85.01	
CD (0.05)	T- 0.784 M-0.701 TXM- 1.568				
SE(±m)	T- 0.273 M-0.244 TXM- 0.546				

Table 47. Effect of storage on fibre content (%) of *G. gummi-gutta* paste

Treatments (T)	Fibre(%)				
	Months after storage(M)				
	At storage	1	2	3	Mean (T)
T$_1$ (3% salt)	4.49	4.37	4.33	4.23	4.36
T$_2$ (5% salt)	4.47	4.35	4.31	4.22	4.33
T$_3$ (7% salt)	4.43	4.38	4.33	4.24	4.35
T$_4$ (9% salt)	4.41	4.37	4.32	4.27	4.34
T$_5$ (Control)	4.53	4.42	4.32	4.21	4.37
Mean (M)	4.47	4.38	4.32	4.23	
CD (0.05)	T - NS M - 0.048 TXM –NS				
SE(±m)	T - 0.019 M - 0.024 TXM -0.037				

4.4.2. 2 Colour Analysis

Colour values (L*, a* and b*) of all the paste formulations were noted at monthly interval and from these values browning index was calculated.

4.4.2. 2.a Lightness (L)*

L* (lightness index) values of the malabar tamarind paste during storage is depicted in Table 48. Lightness index of the samples were significantly affected by the treatments and storage months. At the time of storage L* values of the paste samples ranged from 62.57 to 62.69 .With respect to treatment T_4 (salt 9% salt) recorded the highest L* value of 36.83 followed by T_3 (36.71)and T_2 (35.82).

With respect to storage months L* values were drastically reduced when colour of the paste changed from yellow to light brown and then dark brown. The highest value of 62.64 was observed at the time of storage and lowest value of 22.54 was recorded at the end of storage of third month. During storage, L* value of the treatment T_4 (19% salt) was observed as 32.45, 27.72 and 24.45 after 1st, 2nd and 3rd month of storage respectively.

4.4.2. 2.b Colour value (a)*

Colour value (a*) of malabar tamarind paste showed significant difference with treatments and storage period (Table 49). At the time of storage a* values ranged from 2.26 to 2.41 among the treatments. Addition of salt to the culinary paste resisted increase in a* values and the lowest a* value 10.55 was observed by the treatment T_4 (9% salt). The highest value of 12.20 was observed in control treatment (T_5) followed by 3 % salt with 11.89).

During storage a* value of paste samples increased from 2.32 to 16.77 from initial to 3 months after storage. a* values of culinary paste prepared with 9% salt addition (T_4) was observed as 11.02,13.86 and 15.02 after 1st, 2nd and 3rd month of storage respectively.

4.4.2. 2.c Colour value (b)*

Colour value (b*) of the malabar tamarind paste during storage is depicted in Table 50. The higher in b values indicates colour values towards yellowness. At the time of storage b* values of the paste samples ranged from 46.61 to 46.80.

With respect to storage months b* values were drastically reduced when colour of the paste changed from yellow to brown. The highest value of 46.71 was observed at the time of storage and lowest value of 15.66 was recorded at the end of storage of 3 months. During storage, b* value of the treatment T_4 (9% salt) was observed as 19.21, 16.20 and 16.07 after 1st, 2nd and 3rd month of storage respectively. The paste formulation without salt recorded the values as 19.31 after 1st month, 16.41 at 2nd month and 15.28 after 3rd month of storage.

4.4.2. 2.d Browning Index

Browning index score of malabar tamarind paste showed significant difference with treatments and storage period (Table 51). At the time of storage browning index values ranged from 10.22 to 10.35 between the treatments.

The lowest browning score (31.52) was recorded by the treatment T_4 (9% salt) whereas highest value of 41.72 was observed in control treatment (T_5) followed by T_1 (37.77) and T_2 (36).

During storage, browning index of paste samples were increased from 10.27 to 55.84 at the end of third month of storage. Culinary paste prepared with 9% salt addition (T_4) observed browning score as 29.34, 39.33 and 47.15 after 1st, 2nd and 3rd month of storage respectively.

4.4.2. 3 Enumeration of Microbial Load During Storage

The culinary pastes prepared from malabar tamarind fruit rinds on storage for 3 months were found to be microbiologically safe (Table 52). Result showed that the microbial load for all the samples increased with storage time and was within the permissible limit as per FSSAI.

Table 48. Lightness (L*) colour value of *Garcinia gummi-gutta* paste during storage

| Treatments (T) | L* | | | | |
| | Months after storage(M) | | | | |
	At the time of storage	1	2	3	Mean (T)
T₁ (3% salt)	62.65	29.61	25.14	21.61	34.76[d]
T₂ (5% salt)	62.67	31.67	25.26	23.67	35.82[c]
T₃ (7% salt)	62.63	31.84	27.18	23.84	36.37[b]
T₄ (9% salt)	62.69	32.45	27.72	24.45	36.83[a]
T₅ (Control)	62.57	27.14	23.56	19.14	33.10[e]
Mean (M)	62.64[a]	30.54[b]	25.77[c]	22.54[d]	
CD (0.05)	T - 0.049 M - 0.044 TXM -0.098				
SE(±m)	T - 0.017 M - 0.015 TXM -0.034				

Table 49. Colour value (a*) of *Garcinia gummi-gutta* paste during storage

| Treatments (T) | a* | | | | |
| | Months after storage(M) | | | | |
	At storage	1	2	3	Mean (T)
T₁ (3% salt)	2.41	13.47	14.19	17.47	11.89[b]
T₂ (5% salt)	2.29	13.49	14.19	17.49	11.86[b]
T₃ (7% salt)	2.33	11.87	14.28	15.87	11.08[c]
T₄ (9% salt)	2.32	11.02	13.86	15.02	10.55[d]
T₅ (Control)	2.26	14.02	14.49	18.02	12.20[a]
Mean (M)	2.32[d]	12.77[c]	14.20[b]	16.77[a]	
CD (0.05)	T - 0.100 M - 0.089 TXM -0.199				
SE(±m)	T - 0.035 M - 0.031 TXM -0.070				

130

Table 50. Colour value (b*) of *Garcinia gummi-gutta* paste during storage

Treatments (T)	b*				
	Months after storage(M)				
	At storage	1	2	3	Mean (T)
T$_1$ (3% salt)	46.61	19.68	16.66	15.59	24.64^a
T$_2$ (5% salt)	46.66	19.51	16.53	16.43	24.78^a
T$_3$ (7% salt)	46.70	18.28	15.26	14.94	24.57^b
T$_4$ (9% salt)	46.80	19.21	16.20	16.07	23.80^c
T$_5$ (Control)	46.77	19.31	16.41	15.28	24.42^d
Mean M	46.71^a	19.20^b	16.21^c	15.66^d	
CD (0.05)	T - 0.101 M - 0.090 TXM -0.202				
SE(±m)	T - 0.035 M - 0.031 TXM -0.070				

Table 51. Browning index (%) of *Garcinia gummi-gutta* paste during storage

Treatments (T)	Months after storage(M)				
	At storage	1	2	3	Mean (S)
T$_1$ (3% salt)	10.35	37.48	43.70	59.55	37.77^b
T$_2$ (5% salt)	10.22	35.13	43.88	54.79	36.00^c
T$_3$ (7% salt)	10.27	31.29	40.53	49.93	33.01^d
T$_4$ (9% salt)	10.27	29.34	39.33	47.15	31.52^e
T$_5$ (Control)	10.22	41.84	47.03	67.79	41.72^a
Mean T	10.27^d	35.02^c	42.89^b	55.84^a	
CD (0.05)	T - 0.209 M - 0.187 TXM -0.418				
±SE(m)	T - 0.073 M - 0.065 TXM -0.146				

At the time of storage bacterial population was absent in all the treatments. The lowest bacterial load from 0.67 to 1.99 log cfu ml^{-1} was observed for the paste prepared with 9% of salt (T4) from the first month of storage to the end of storage of three months. The bacterial load for control treatment (T$_5$) recorded as the highest which ranged from 1.67 to 3.35 log CFU g^{-1}.

Fungal population was absent in all the paste formulations even after 1st month of storage were as at the end of 2nd of month of storage control sample (T$_5$)exhibited fungal population of 1.83 log cfu ml^{-1}. At the end of storage, treatments T$_1$ (3% salt) and T$_5$ (control) recorded a count of 1.16 and 2.26 log CFU g^{-1} respectively. The storage study revealed that all the treatments were microbiologically safe and acceptable up to three months of storage.

Moisture content, HCA, antioxidant activity were decreased meanwhile TSS, total sugar, reducing sugar, acidity and total flavonoids of the paste increased during storage. The paste prepared with 9% salt (T$_4$) recorded the lowest browning index, bacterial load and the highest score for taste, flavour and overall acceptability after three months of storage and standardized as best treatment for paste preparation.

4.4.2. 4 Sensory Analysis of Malabar tamarind Paste During Storage

Sensory parameters *viz.,* taste, colour (dark yellow to reddish brown), flavour and overall acceptability for stored culinary paste were analyzed using 9 point hedonic scale at monthly interval and presented in Table 53 to Table 56.

Colour of the paste changed from yellow to reddish brown. on analyzing sensory attribute flavour of the paste formulations, the highest mean score (8.27) was recorded for ready to cook paste prepared with addition of 9% salt (T$_4$), followed by paste with 7% salt (T$_3$) and 5 % salt (T$_2$) at the end of third month of storage. Salt treatment during preparation of paste significantly influenced the sensory quality *viz.,*

Table 52. Effect of storage on microbial load (log cfu ml^{-1}) of *Garcinia gummi-gutta* paste

| Treatments | Bacterial count (log cfu ml^{-1}) | | | | Fungal count (log cfu ml^{-1}) | | | |
| | Months after storage | | | | Months after storage | | | |
	At storage	1	2	3	At storage	1	2	3
T$_1$ (3% salt)	-	1.59±0.11ab	2.20±0.03ab	3.20±0.17b	-	-	-	1.16±0.27a
T$_2$ (5% salt)	-	1.52±0.07ab	2.18±0.02b	2.34±0.00c	-	-	-	-
T$_3$ (7% salt)	-	1.10±0.17bc	2.04±0.07b	2.31±0.01c	-	-	-	-
T$_4$ (9% salt)	-	0.667±0.58c	1.17±0.29c	1.99±0.03d	-	-	-	-
T$_5$ (Control)	-	1.67±0.06a	2.52±0.01a	3.35±0.01a	-	-	1.83±0.30a	2.26±0.23b

Values are expressed as mean±SD (n=3)

Table 53. Effect of storage on colour of *Garcinia gummi-gutta* paste

Treatments	Months after storage			
	At storage	1	2	3
T_1 (3% salt)	8.50	7.20	6.93	6.77
T_2 (5% salt)	8.53	7.23	7.00	6.80
T_3 (7% salt)	8.50	7.27	7.07	7.00
T_4 (9% salt)	8.53	7.30	7.10	7.07
T_5 (Control)	8.53	6.90	6.87	6.60
KW value	1.19	3.12	2.18	2.39
χ^2 (0.05)	9.48			

Table 54. Effect of storage on flavour of *Garcinia gummi-gutta* paste

Treatments	Months after storage			
	At storage	1	2	3
T_1 (3% salt)	8.20	8.13	8.03	7.80
T_2 (5% salt)	8.27	8.23	8.13	8.00
T_3 (7% salt)	8.40	8.37	8.30	8.20
T_4 (9% salt)	8.57	8.43	8.37	8.27
T_5 (Control)	7.57	7.53	7.43	7.23
KW value	8.95	7.34	8.8	10.02
χ^2 (0.05)	9.48			

Table 55. Effect of storage on taste of *Garcinia gummi-gutta* paste

Treatments	Months after storage			
	At storage	1	2	3
T_1 (3% salt)	8.13	8.07	7.97	7.83
T_2 (5% salt)	8.28	8.23	8.13	8.00
T_3 (7% salt)	8.41	8.43	8.30	8.20
T_4 (9% salt)	8.50	8.53	8.40	8.33
T_5 (Control)	7.50	7.47	7.37	7.23
KW value	11.12	9.49	9.75	9.54
χ^2 (0.05)	9.48			

Table 56. Effect of storage on overall acceptability of *Garcinia gummi-gutta* paste

Treatments	Months after storage			
	At storage	1	2	3
T_1 (3% salt)	8.17	7.97	7.77	7.30
T_2 (5% salt)	8.33	8.07	7.93	7.60
T_3 (7% salt)	8.50	8.13	7.97	7.67
T_4 (9% salt)	8.63	8.27	8.00	7.87
T_5 (Control)	7.67	7.37	7.30	6.50
KW value	11.12	9.63	9.52	10.05
χ^2 (0.05)	9.48			

taste, and overall acceptability of the paste. It was observed that ready to cook paste prepared with addition of 9% salt (T$_4$) recorded highest mean score for taste (8.50) and overall acceptability (8.63) at the time of storage followed by paste with 7% salt (T$_3$). At the end of storage highest score for taste (8.23) and overall acceptability (7.87) was observed for the treatment T$_4$ (9% salt).

4.4.3 Development of pickle

Sweet pickles were prepared from osmo dehydrated (70^{0}Brix for 36 h) rind and sour pickles from fresh *G.gummi-gutta* rind (Plate 11). Biochemical parameters were analyzed during aging (14 days) at weekly interval and after aging biochemical, microbial and sensory analysis was conducted at fortnight interval for 2 months. Both the treatments were packed in glass bottles for storage stability studies.

4.4.3. 1 Biochemical Parameters

Biochemical parameters *viz.,* TSS (^{0}Brix),Total Dissolved Solid (mg L^{-1}), pH, acidity(%), vitamin C (mg 100g^{-1}), total sugar(%), reducing sugar(%),antioxidant activity (%)) of sour pickle (P$_1$) and sweet pickle (P$_2$) were analyzed and results are presented in Table 57a and Table 57b

4.4.3.1.a TSS (^{o}Brix)

Total Soluble Solids of pickle (Table 57a.) was recorded as 17.95 ^{0}Brix for sour pickle (P$_1$) and 41.66 % for sweet pickle (P$_2$) at the time of storage and it significantly reduced during storage. The TSS of sour pickle was observed as 17.74, 17.55, 17.34, 17.04, 16.90 and 16.82 ^{0}Brix at 1st, 2nd, 4th, 6th , 8th and 10th weeks of storage respectively. Sweet pickle recorded TSS of 41.42 ^{0}Brix after 1 week, 41.30 ^{0}Brix after 2 weeks, 40.94^0 Brix after four weeks storage.

Storage period significantly influenced TSS content of *Garcinia* pickles. The highest TSS of 40.62 ^{0}Brix was noticed for sweet pickle (P$_2$) whereas the lowest TSS of 17.33^{0}Brix was observed for sour pickle (P$_1$).

Plate 11. Sour pickle (A) and sweet pickle (B) from *Garcinia gummi-gutta* rind

4.4.3.1.b Total Dissolved Solid (TDS)(mg L^{-1})

Total Dissolved Solid of the both pickles are sown in Table 57a. At the time of storage sour pickle (P$_1$) recorded a TDS content of 6253.71 mg L^{-1} and sweet pickle (P$_2$) recorded 3554.86 mg L^{-1} and there was no significant difference among the interaction effects between both the treatments and storage period. Sour pickle (P$_1$) recorded the highest TDS of 5934. 63 mg L^{-1} whereas sweet pickle recorded the TDS of 3241.10 mg L^{-1}. The TDS content was decreased significantly during storage and lowest TDS of 4341.48 mg L^{-1} was observed after ten weeks of storage.

4.4.3.1.c pH

The pH content of sweet and sour pickles showed significant difference among the treatments and storage weeks (Table 57a). Sour pickle (P$_1$) recorded a pH of 3.21 and sweet pickle (P$_2$) recorded a pH of 4.30 at the time of storage.

Among the treatments lowest value (3.24) was for sour pickle and sweet pickle (P$_2$) recorded a value of 4.42. The pH of sour pickle decreased up to 2 weeks and then slightly increased up to 10 weeks of storage eventhough the increase was statistically non significant. pH of the sour pickle (P$_1$) was observed as 3.19, 3.14 after 1st, 2nd and 3rd weeks of aging respectively and then there noticed a significant increase in values during storage weeks.

4.4.3.1.d Total Acidity (%)

The sweet pickle (P$_1$) and sour pickle (P$_2$) recorded total acidity of 4.07% and 2.17% respectively at the time of storage (Table 57a). Among the pickle formulations, the highest acidity of 4.34 % was recorded for P$_1$ and P$_2$ recorded 2.19 % on storage during the storage of 10 weeks storage. Total acidity content of both pickles increased initially up to 2 weeks of storage and further decreased. During storage acidity of sour pickle (P$_2$) was observed as 4.28, 5.02. 4.70, 4.56,4.03 and

Table 57 a. Biochemical changes in sour and sweet *Garcinia gummi-gutta* pickles during storage

Treatments (P)	TSS(ºBrix)							
	Storage (weeks)							
	T_1 (initial)	T_2(1w)	T_3 (2w)	T_4 (4w)	T_5 (6w)	T6(8w)	T_7(10w)	Mean (P)
Sour pickle (P_1)	17.95	17.74	17.55	17.34	17.04	16.90	16.82	17.33
Sweet pickle(P_2)	41.66	41.42	41.30	40.94	40.80	39.83	38.43	40.62
Mean (W)	29.80	29.58	29.42	29.14	28.92	28.36	27.63	
CD(0.05)	P- 0.250 W-0.467 PXW-0.66							
SE(±m)	P- 0.052 W-0.098 PXW-0.138							
Treatments (P)	Total Dissolved Solid (TDS)(mg L^{-1})							
	T_1 (initial)	T_2(1w)	T_3 (2w)	T_4 (4w)	T_5 (6w)	T6(8w)	T_7(10w)	Mean (P)
Sour pickle (P_1)	6253.71	6114.00	5992.29	5938.57	5845.00	5734.29	5664.53	5934.63
Sweet pickle(P_2)	3554.86	3417.43	3176.14	3253.00	3160.00	3108.55	3017.74	3241.10
Mean (W)	4904.29	4765.71	4584.21	4595.79	4502.50	4421.42	4341.14	
CD(0.05)	P- 45.037 W-84.257 PXW-NS							
SE(±m)	P- 15.985 W-29.906 PXW-42.294							
Treatments (P)	pH							
	T_1 (initial)	T_2(1w)	T_3 (2w)	T_4 (4w)	T_5 (6w)	T6(8w)	T_7(10w)	Mean (P)
Sour pickle (P_1)	3.21	3.19	3.14	3.21	3.26	3.26	3.43	3.24
Sweet pickle(P_2)	4.30	4.23	4.23	4.39	4.57	4.59	4.61	4.42
Mean (W)	3.76	3.71	3.69	3.80	3.91	3.92	4.02	
CD(0.05)	P-0.060 W-0.112 PXW- NS							
SE(±m)	P-0.021, W- 0.040 PXW- 0.056							
Treatments (P)	Total acidity(%)							
	T_1 (initial)	T_2(1w)	T_3 (2w)	T_4 (4w)	T_5 (6w)	T6(8w)	T_7(10w)	Mean (P)
Sour pickle (P_1)	4.07	4.28	5.02	4.70	4.56	4.03	3.71	4.34
Sweet pickle(P_2)	2.17	2.31	2.43	2.39	2.12	2.06	1.86	2.19
Mean (W)	3.12	3.29	3.72	3.55	3.34	3.05	2.79	
CD(0.05)	P-0.074 W-0.139 PXW-0.196							
SE(±m)	P-0.026 W-0.049 PXW- 0.070							

3.71 % after 1st, 2nd, 4th, 6th, 8th and 10th weeks of storage respectively whereas sweet pickle (P_2) recorded total acidity of 2.31, 2.43, 2.39, 2.12, 2.06 and 1.86 % after 1st, 2nd, 4th, 6th, 8th and 10th weeks of storage.

4.4.3.1.e Vitamin C (mg 100g^{-1})

Vitamin C content of pickle treatments are presented in Table 57b. Sour pickle recorded a vitamin C content of 21.73 mg 100g^{-1} and sweet pickle of 15.13 mg 100g^{-1} at the time of storage. Among the sour and sweet pickle the highest vitamin C content of 20.77 mg 100g^{-1} was recorded for P_1 (sour pickle) and P_2 (sweet pickle) with 13.77 mg 100g^{-1}. During storage of pickle vitamin C content decreased from 18.43 mg 100g^{-1} to 16.07 mg 100g^{-1} at the end of 10 weeks storage.

4.4.3.1.f Total Sugar (%)

Total sugar content of two pickle treatments are presented in Table 57b. Sour pickle recorded a total sugar content of 4.99 % and sweet pickle showed 24.17% at the time storage.

The total sugar percentage of sour pickle (P_1) was observed as 4.75 and 4.43, after 2nd, 3rd week respectively whereas P_2 recorded total sugar of 23.83 and 23.56% after 1st and 2nd week of storage. Among the treatments P_2 (sweet pickle) recorded the highest total sugar content of 22.84 % whereas sour pickle recorded 4.19 %. With The total sugar of pickle samples significantly decreased and lowest reading 12.45 was recorded at the end of 10 weeks period.

4.4.3.1.g Reducing Sugar(%)

Reducing sugar of pickles during storage is depicted in Table 57b. Sour pickle (P_1) recorded a reducing sugar of 2.74 % and 13.46 % for sweet pickle at the time of storage. During storage, there was significant difference among the interaction effects

between treatments and storage. Sour pickle recorded reducing sugar content of 2.69, 2.56, 2.39, 2.23, 2.02 and 1.75% after 1st, 2nd, 4th, 6th, 8th and 10th weeks of storage respectively whereas, Sweet pickle (P_2) recorded reducing sugar of 13.09 12.86, 12.51, 12.18, 12.06 and 11.78 % after 1st, 2nd, 4th, 6th, 8th and 10th weeks of storage.

Among the treatments sweet pickle (P_2) recorded the highest reducing sugar content of 12.56 % whereas lowest value (2.34%) was for P_1(sour pickle). With respect to storage weeks, reducing sugar content decreased the highest reducing sugar content of 8.10 % was observed at the time of preparation whereas decreased to 6.77% after 10 weeks storage.

4.4.3.1. h Antioxidant Activity (%)

Antioxidant activity of sour and sweet pickles during storage is depicted in Table 57b. Initial antioxidant activity was reported as 85.86 and 77.16 % respectively for P_1 (sour pickle) and P_2 (sweet pickle). Sour pickle recorded an antioxidant activity of 84.70 % after one week, 84.17 % after second week, 82.99 % after fourth week 81.90 after 6th week, 79.60 after 8th week and 77.41 after ten weeks of storage. Antioxidant activity of sweet pickle was noticed as 76.76, 75.47, 74.43, 73.32, 71.94 and 70.04 after 1st, 2nd, 4th, 6th, 8th and 10th weeks of storage respectively.

During storage antioxidant activity of the pickle samples were significantly reduced. The highest antioxidant activity of 81.51 % was recorded at the time of storage and it reduced to 73.73 % at the end of ten weeks.

4.4.3. 2 Sensory Analysis

The two pickle treatments were analysed for various sensory attributes for their acceptance by using 9 point hedonic scale. The mean sensory scores of pickle obtained with respect to taste, colour, flavour, texture and overall acceptability during storage are presented in Table 58a and Table 58b.

Table 57 b. Biochemical changes in sour and sweet *Garcinia gummi-gutta* pickles during storage

Treatments (P)	Vitamin C (mg 100g^{-1})							
	Storage (weeks)							
	T$_1$ (initial)	T$_2$(1w)	T$_3$ (2w)	T$_4$ (4w)	T$_5$ (6w)	T6(8w)	T$_7$(10w)	Mean (P)
Sour pickle (P$_1$)	21.73	21.56	21.21	20.39	20.39	20.15	19.92	20.77
Sweet pickle(P$_2$)	15.17	14.46	14.16	13.93	13.38	13.15	12.23	13.77
Mean (W)	18.43	18.01	17.69	17.16	16.88	16.65	16.07	
CD (0.05)	P- 0.250 W- 0.467 PXW- NS							
SE(±m)	P-0.089 W- 0.166 PXW- 0.234							
Treatments (P)	Total sugar (%)							
	Aging time			Maturation time				
	T$_1$ (initial)	T$_2$(1w)	T$_3$ (2w)	T$_4$ (4w)	T$_5$ (6w)	T6(8w)	T$_7$(10w)	Mean (P)
Sour pickle (P$_1$)	4.99	4.75	4.43	4.15	3.88	3.74	3.41	4.19
Sweet pickle(P$_2$)	24.17	23.83	23.56	22.86	22.17	21.77	21.49	22.84
Mean (W)	14.58	14.29	13.99	13.50	13.02	12.75	12.45	
CD (0.05)	P- 0.158 W-0.296 PXW- 0.418							
SE(±m)	P-0.056 W-0.105 PXW- 0.149							
Treatments (P)	Reducing sugar (%)							
	Aging time			Maturation time				
	T$_1$ (initial)	T$_2$(1w)	T$_3$ (2w)	T$_4$ (4w)	T$_5$ (6w)	T6(8w)	T$_7$(10w)	Mean (P)
Sour pickle (P$_1$)	2.74	2.69	2.56	2.39	2.23	2.02	1.75	2.34
Sweet pickle(P$_2$)	13.46	13.09	12.86	12.51	12.18	12.06	11.78	12.56
Mean (W)	8.10	7.89	7.71	7.45	7.21	7.04	6.77	
CD (0.05)	P-0.078 W-0.146 PXW-0.146							
SE(±m)	P-0.028 W-0.052 PXW-0.073							
Treatments (P)	Antioxidant activity(%)							
	Aging time			Maturation time				
	T$_1$ (initial)	T$_2$(1w)	T$_3$ (2w)	T$_4$ (4w)	T$_5$ (6w)	T6(8w)	T$_7$(10w)	Mean (P)
Sour pickle (P$_1$)	85.86	84.70	84.17	82.99	81.90	79.60	77.41	82.38
Sweet pickle(P$_2$)	77.16	76.76	75.47	74.43	73.32	71.94	70.04	74.16
Mean (W)	81.51	80.73	79.82	78.71	77.61	75.77	73.73	
CD (0.05)	P- 0.777 W-1.454 PXW- NS							
SE(±m)	P-0.276 W- 0.516 PXW- 0.730							

At time of storage score for sensory characters of sour pickle (P_1) was 7.93 for taste, 8.67 for colour, 7.83 for flavour and 8.17 for overall acceptability (Table 58a). The highest sensory score for taste (8.40), flavour (8.33), texture (8.63) and overall acceptability (8.77) was observed at 4th week of storage. Mean score for parameters *viz.*, taste, flavour, texture and overall acceptability of the sour pickle was improved at 4 weeks of storage and further decreased up to 10 weeks. The lowest score for overall acceptability (8.13) was recorded at 10 weeks of storage.

The highest sensory score for taste (8.23), flavour (8.27), texture (8.37) and overall acceptability (8.43) was recorded for sweet pickle (P_2) at 4th week of storage. Mean score for parameters *viz.*, taste, flavour, texture and overall acceptability of the sour pickle was improved at 4 weeks of storage and further decreased up to 10 weeks. The lowest score for overall acceptability (7.93) was recorded at 10 weeks of storage.

4.4.3. 2 Enumeration of Bacterial Load

The microbial safety of sweet and sour pickles was analyzed by total plate count and the result (Table 59) showed that the bacterial load increased during storage. Mould /fungal population was absent throughout the storage period. At storage least bacterial population was observed for the sweet pickle (1.47 log CFU g^{-1}) and it was 2.16 log CFU g^{-1} for sour pickle. Sweet pickle recorded the lowest bacterial load of 3.51 log CFU g^{-1} whereas sour pickle recorded highest load of 4.95 at the end 10 weeks storage.

It was observed that both sweet and sour pickles were acceptable by the semi trained panel. Taste, flavour, texture and overall acceptability of the pickles were improved during initial storage period.

Table 58a. Effect of storage on sensory qualities of sour pickle

Storage (Weeks)	Sour pickle (P$_1$)				
	Taste	Colour	Flavour	Texture	Overall acceptability
T$_1$ (Initial)	7.93^c	8.67^a	7.83^d	7.50^d	8.17^c
T$_2$(4w)	8.40^a	8.53^a	8.33^a	8.63^a	8.77^a
T$_3$ (6w)	8.27^b	8.47^b	8.27^a	8.57^a	8.67^{ab}
T$_4$ (8w)	8.17^b	8.13^c	8.17^{bc}	8.17^b	8.47^b
T$_5$ (10w)	8.03^c	8.00^c	8.03^c	8.00^c	8.13^c
CD(0.05)	0.256	0.142	0.196	0.159	0.106
SE($\pm$m)	0.080	0.044	0.061	0.050	0.033

Table 58b. Effect of storage on sensory qualities of sweet pickle

Storage (Weeks)	Sweet pickle (P$_2$)				
	Taste	Colour	Flavour	Texture	Overall acceptability
T$_1$ (Initial)	8.00^{ab}	8.43^a	8.13^b	7.53^d	8.23^b
T$_2$(4w)	8.23^a	8.30^a	8.27^a	8.37^a	8.43^a
T$_3$ (6w)	8.13^a	8.17^b	8.20^a	8.30^a	8.37^a
T$_4$ (8w)	8.03^{ab}	8.03^b	8.08^b	8.07^b	8.13^{bc}
T$_5$ (10w)	7.87^c	7.83^c	8.00^{bc}	7.80^c	7.93^c
CD(0.05)	0.227	0.186	0.101	0.190	0.216
SE($\pm$m)	0.071	0.058	0.068	0.060	0.068

Table 59. Effect of storage on Total Bacterial population (log CFU g^{-1}) of sweet and sour pickles

Treatments	Total bacterial population (log CFU g^{-1})				
	Storage (weeks)				
	T_1(Initial)	T_4 (4)	T_5 (6)	T6(8)	T7(10)
Sour pickle (P_1)	2.16	3.92	3.98	4.23	4.95
Sweet pickle(P_2)	1.47	2.35	2.65	2.94	3.51
CD (0.05)	0.225	0.168	0.272	0.073	0.098
SE(m)	0.072	0.048	0.087	0.023	0.031

Discussion

5. DISCUSSION

The results obtained from the investigation on "Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala" are discussed in this chapter under following headings.

5.1 ASSESSMENT OF BIOACTIVE COMPOUNDS

5.2 COLOUR EXTRACTION FROM MANGOSTEEN PERICARP

5.3 DEVELOPMENT OF NECTAR FROM *GARCINIA* SPP.

5.4 VALUE ADDED PRODUCTS FROM *GARCINIA GUMMI-GUTTA*

5.1 ASSESSMENT OF BIOACTIVE COMPOUNDS

The pulp and pericarp of *Garcinia* fruits *G. gummi-gutta*, *G.mangostana* and *G. xanthochymus* were evaluated for biochemical quality parameters and secondary metabolites and are discussed below.

5.1.1 Proximate Composition of *Garcinia* Fruits

Total soluble solids (TSS) present in pulp and pericarp of *Garcinia* fruits varied significantly. The highest TSS of 27.93 ^{0}Brix was recorded for pericarp of *G.mangostana* fruit followed by mangosteen pulp (20.83 ^{0}Brix) (Fig 3.). Owolabi *et al.,* (2021) observed TSS of fully ripe mangosteen fruits as 16.8 ^{0}Brix. *Garcinia xanthochymus* fruit pulp recorded TSS of 14.80 ^{0}Brix for whereas *G. gummi-gutta* fruit recorded a TSS of 14.30 ^{0}Brix and 11.13 ^{0}Brix respectively for pulp and pericarp. Yellow mangosteen pulp from Brazil was found to have total soluble solids of 11.73 °Brix (Cavalcante *et al.,* 2006). Bohra and Waman (2019) compared pulp and rind of two *G.gummi-gutta* morphotypes for biochemical parameters and fruit pulp recorded higher TSS of 9.67 to 10.11 ^{0}Brix higher than fruit rind for both samples.
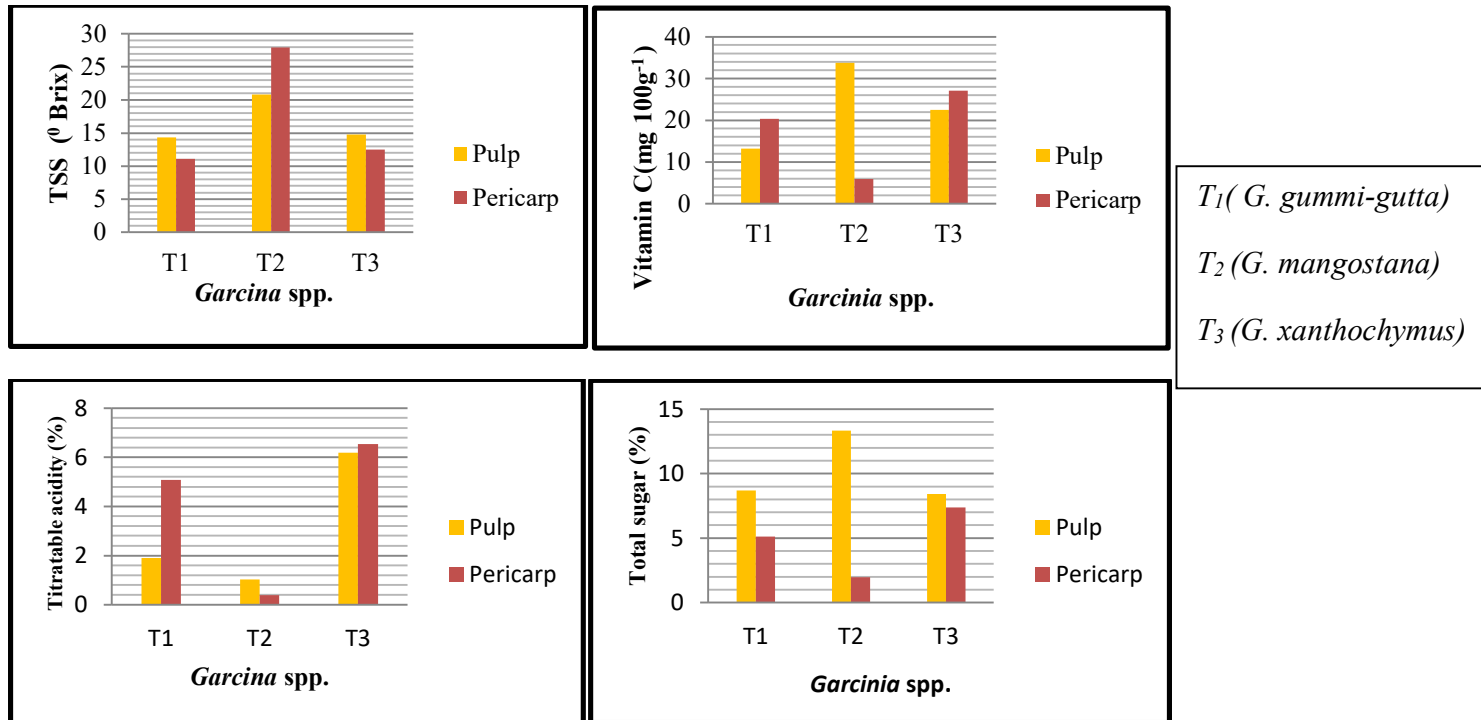
Fig. 3. TSS, total acidity, vitamin C and total sugar content of *Garcinia* fruits

Garcinia xanthochymus rind recorded the highest acidity of 6.54% followed by the fruit pulp 6.18 % and *G. gummi-gutta* pericarp (5.08 %) (Fig. 3). Parthasarathy and Nandakishore (2014) observed that total acidity of the *Garcinia* fruits varied significantly from 4.39% in *G. mangostana* to 27.3% in *G. kydia* as the most acidic followed by *G. gummi-gutta* (23.81%). Deylami *et al.*(2016) observed acidity of fully mature mangosteen aril as 0.53 % on citric acid basis. Present findings are in confirmation with Prakash *et al.*(2022) who reported that total acidity of lyophilized samples was found to be highest in yellow mangosteen pulp ($25.00 \pm 0.3\%$) and peel recorded an acidity of $20.65 \pm 0.09\%$.

Malabar tamarind fruits are commercially important as a rich source of the much valued antiobesity phytochemical hydroxycitric acid (HCA) (Hemesekhar *et al.*, 2011). *Garcinia gummi-gutta* fruit pericarp recorded the highest HCA (4.31%) followed by pulp of the fruit (0.92%). Hydroxy citric was not detected in *G. xanthochymus* (Yellow mangosteen) fruits. Parthasarathy and Nandhakishore (2016) reported HCA as major acid in *G.gummi-gutta* fruits with 15.48% and also reported that HCA was absent in *G. xanthochymus* fruits.

Ascorbic acid was reported as the major vitamin in *Garcinia* fruits and among eight species evaluated by Parthasarathy and Nandhakishore (2014), mangosteen fruit as richest source (60.430 mg $100g^{-1}$). Mangosteen fruit pulp (T_2P_1) noticed the highest ascorbic acid content of 33.80 mg $100g^{-1}$ followed by the yellow mangosteen fruit pulp (T_3P_1) with a content of 27.03 mg $100g^{-1}$ (Fig 3.). Cavalcante *et al.* (2006) observed vitamin C content of fresh yellow mangosteen in the range of 31.21 to 46.82 mg $100g^{-1}$. Malabar tamarind fruit pericarp recorded a value of 20.37 mg $100g^{-1}$ whereas the lowest ascorbic acid content was exhibited by mangosteen fruit rind with 5.96 mg $100g^{-1}$. Fruit pulp recorded comparatively higher vitamin C than pericarp of *Garcinia* fruits. Results are in accordance with the finding of Bohra and Waman (2019) reported that genotype of *G. gummi-gutta* rind recorded higher vitamin C content (25.09 mg $100g^{-1}$) compared to pulp.

Mangosteen fruit pulp recorded the highest total sugar (13.31 %) and reducing sugar (11.96 %) (Fig 3.). This is in confirmation with findings of Parthasarthy and Nandakishore (2014) who noticed that carbohydrate as the major metabolites present in *Garcinia* fruits and the highest reducing sugar content for *G.mangostana* fruits (1.28 g 100g^{-1}) and *G.gummi-gutta* fruit recorded a value of 0.51 g 100g^{-1}. The Malabar tamarind pulp recorded a reducing sugar of 7.17 %which was statistically on par with yellow mangosteen fruit pulp (7.10 %), and the lowest reducing sugar was reported in mangosteen pericarp. Virgolin *et al,* (2017) estimated total and reducing sugar contents (g glucose 100 mL^{-1} pulp) of the yellow mangosteen fruits were reported as 6.47 and 8.15 respectively.

Parthasarthy and Nandakishore (2014) noticed that total proteins in *Garcinia* fruits ranged from 1.82 % to 4.93 %. In the present study Yellow mangosteen pulp noticed the highest protein of 5.24 g 100g^{-1}and lowest protein (0.36 g 100g^{-1}) was recorded in malabar tamarind pulp whereas nangosteen pericarp recorded a protein content of 5.18 g 100g^{-1} followed by yellow mangosteen fruit rind of 4.32 g 100g^{-1}. Chemical evaluation of *G. humilis* fruits revealed that fruit peel showed the highest amount of protein compared to pulp and seed (Tome *et al.,* 2019). Virgolin *et al.,* (2017) reported yellow mangosteen contain 1.70 % protein and Suwardi *et al.* (2020) estimated crude protein of mangosteen fruits as 1.8±0.13%

Mangosteen fruits exhibited highest fibre content followed by yellow mangosteen fruits. This results are supported by the findings of Lago-Vanzela *et al.* (2011) who reported that peels of *Spondias cytherea* fruit showed higher contents of protein, lipids, ashe, food fiber, total carbohydrates and pectin than the pulp. The highest crude fibre content of 12.37 % was observed for the pericarp of mangosteen fruits and malabar tamarind pulp recorded a lower value of 1.44% which was on par with mangosteen fruit pulp (1.73%). Crude fibre content of pulp and pericarp of yellow mangosteen fruits were 6.50 and 7.03 % respectively. Suwardi *et al.* (2020)

observed fibre content of *G. xanthochymus* and *G .mangostana* fruits as 8.4% and 5.1 % respectively.

Highest fat content of 1.35 mg 100g^{-1} was recorded by mangosteen pericarp followed by mangosteen fruit pulp (0.51 mg 100g^{-1}). This agrees with the findings of Parthasarthy and Nandakishore (2014) who reported crude fat was higher in *G. mangostana* among the eight species evaluated. Prakash *et al.*(2022) estimated a fat content as 6.29 % and 6.08 % respectively for lyophilized peel and pulp of *G.xanthochymus*.

Mangosteen pericarp exhibited the highest total phenols (2603.68 mg GAE 100g^{-1}) followed by yellow mangosteen pericarp (1937.73 mg GAE 100g^{-1}). The lowest total phenols was observed for mangosteen fruit pulp (164.14 mg GAE 100g^{-1}). This is supported by the findings of Yoshimura *et al.* (2015) who reported that mangosteen peels contained 10 times more phenolic compounds when compared to mangosteen pulp. Janhavi *et al.* (2020) reported that peels as well as rind of yellow mangosteen fruits are rich in polyphenols (819.26 ± 23.65 and 927.71 ± 26.78 mg/100 g of fruit powder).

Highest total flavonoids were reported in mangosteen pericarp (61.55 mg QE g^{-1}) and lowest flavonoid was shown by mangosteen pulp (3.11 mg QE g^{-1}). Ngawhirunpat *et al.* (2010) estimated TFC of water extract of mangosteen hull as12.1 g epicatechin equivalents 100 g^{-1}. Total flavanoid content of pulp and pericarp of *G. xanthochymus* fruits 24.73 and 27.37 mg QE g^{-1} respectively. According to study conducted by Sudharani *et al*. (2018) *G. gummi-gutta* fresh rind recorded total flavonoids of 2.48 % and total poly phenols of 1.1%.

The pericarp of *G. mangostana* (T$_2$P$_2$) showed the highest antioxidant activity of 92.27 % which was on par with pericarp of *G. xanthochymus* (91.46%) and *G. gummi-gutta* fruit pericarp (89.83%). The antioxidant activities of leaves and fruits of *G. atroviridis* were positively correlated with the TPC values based on DPPH-radical-

scavenging activity and ferric reducing power estimation (Nursakinah *et al.,* 2012). Sudharani *et al*. (2018) reported that the antioxidant activity of fresh *G. gummi-gutta* rind at 60 mg concentration was 81.44%.

Carotenoids are natural pigments with many biological functions. Carotenoid content of *Garcinia* fruits showed difference with different fruits and fruit parts. The fruit pulp of yellow mangosteen fruits recorded carotenoid content of 9 mg $100g^{-1}$ followed by pericarp (8.51 mg $100g^{-1}$). This was supported by findings of Khoo *et al.* (2008) who stated that high carotene content was found in yellow colour pigmented fruits. Gogoi *et al.* (2016) estimated carotenoids in *G. xanthochymus* fruits as 30.34 $\mu g\ g^{-1}$ whereas Virgolin *et al.,* (2017) estimated 165.48 (μg β-carotene 100 g^{-1}).

5.1.2 Mineral Composition of *Garcinia* Fruits

Mangosteen pericarp recorded the highest Ca (1,910.00 ppm), K (3,323.33) and Fe (9.235 ppm),). Yellow mangosteen fruit pulp recorded a potassium content of 2233.33ppm which was followed by 1430.0 ppm for *G.gummi-gutta* periparp. This was supported by findings of Parthasarathy and Nandakishore (2014) who reported that magnesium and potassium were found to be the predominant minerals in *Garcinia* fruits. Potassium, calcium and magnesium are present in good percentage in fruit rind tissues, and make *Garcinia* an important medicinal fruit. Magnesium, phosphorus and iron contents were also higher in *Garcinia* than the commonly consumed fruits. Joseph *et al.* (2017) reported that N and K were the most abundant minerals in all the fruit portions of *G. livingstonei* followed by Ca, Mg , P, Fe and S.

5.1.3 Sugar Profiling of *Garcinia* Fruits

The most common sugar groups occurring in nature are glucose, rhamnose, xylose, galactose, arabinose and fructose (Delgado-Vargas *et al*., 2000) Twelve major sugars were quantified from the economic parts of the *Garcinia* fruits and *G.gummi-gutta* fruits recorded fructose (8.85±0.028 mg g^{-1}) in highest quantity followed by

ribose (4.87±0.019 mg g^{-1}) and glucose (3.14±0.033 mg g^{-1}). Fructose was the prominent sugar in *G. mangostana* (28.163±0.813 mg g^{-1}) and *G. xanthochymus* (25.842±0.151 mg g^{-1}) which was followed by glucose. Sugars such as glucose and fructose are the sweetness principles of a fruit and carbohydrates as the major metabolite present in Garcinia fruits followed by proteins (Parthasarathy and Nandhakishore, 2016).

5.1.4 Organic Acid Profiling of *Garcinia* Fruits

Acidity plays an important part in the perception of fruit quality. It affects not only the sour taste of the fruit but also sweetness, by masking the taste of sugars (Parthasarathy *et al.,* 2012). Organic acid profiling of the fruits revealed hydroxy citric acid (HCA) as the major organic acid in *G. gummi-gutta* fruits (547.458±4.185 mg g^{-1}). Whereas in other two species, *G. mangostana* and *G. xanthochymus,* HCA was detected in lower quantity as 4.30 ±0.475 mg g^{-1} DW and 6.789±0.089 mg g^{-1} DW respectively. Citric acid was the most abundant organic acid in *G. mangostana* (674.17±0.485 mg g^{-1} DW) and *G. xanthochymus* fruit (680.361±0.863mg g^{-1} DW) whereas it was the second most abundant acid in *G. gummi-gutta* fruits. Results are supported by the finding of Parthasarathy and Nandakishore (2014) who reported that HCA was found to be the major organic acid in Western Ghats species, viz., *G. gummi-gutta* and *G. indica*. HCA was absent in *G. xanthochymus* and citric acid was reported as the major acid and *G.mangostana* fruit reported very low acidity and low HCA content. Organic acid content of leaf extract of various *Garcinia* sp. varied from 95.0 mg g^{-1} to 0.99 mg g^{-1} (Pandey *et al*., 2015).

5.1.5 Phenolic Acid Profiling of Garcinia Fruits

Flavonoids, phenolic acids, bioflavonoids and triterpenoids, found in *Garcinia* are also responsible for various pharmacological activities of the plant parts (Hemshekhar, 2011; Ritthiwigrom *et al*., 2013). The *G.gummi-gutta* fruit rind and fruit pulp of mangosteen and yellow mangosteen had the highest levels for p-

coumaric acid which was quantified as 104.81±4.409 µg g^{-1} DW, 335.70±1.801µg g^{-1} DW and 353.155± 4.277 µg g^{-1} DW respectively (Fig 4.).   Zadernowski *et al.* (2009) identified ten phenolic acid from mangosteen out of which protocatechuic acid was the major phenolic acid in the peel and rind whereas *p*-hydroxybenzoic acid was the major compound in the aril. *They also confirmed that* hydroxybenzoic acid derivatives are the major phenolic acids found in mangosteen. Zarena and Shankar (2012) confirmed caffeic acid (1.51 mg g^{-1}), t-cinnamic acid (0.73 mg g^{-1}), vanillic acid (0.71 mg g^{-1}), sinapic acid (0.71 mg g^{-1}) and syringic acid (0.63 mg g^{-1}) as the predominant phenolic acids in mangosteen.Gallic acid 2,4-dihydroxybenzoic acid, caffeic acid, t-cinnamic acid were the other important phenoilc acid from *G.gummi-gutta* rind. Pandey *et al.* (2015) quantified phenolic acids such as protocatechulic acid, caffeic acid, ferulic acid and vanillic acid from the leaves of *G. gummi-gutta* tree. Ferulic acid , Protocatechuic acid , 2,4-dihydroxybenzoic acid, t-Cinnamic acid were the other important phenoilc acid from *G.xanthocymus* fruits.

5.1.6 Flavonoids Profiling of *Garcinia* Fruits

Total thirteen individual flavonoids were identified and quantified and epicatechin (18.699±0.211 µg g^{-1}), catechin (6.688±0.492 µg g^{-1}) and luteolin (8.814±0.791 µg g^{-1}) were the most predominant individual flavonoids in *G.gummi-gutt*a (Fig 5.) whereas epicatechin and catechin were not detected in *G. mangostana.* *G.xanthochymus* fruits were rich in naringenin (44.424±0.363µg g^{-1}DW) followed by luteolin (3.289±0.037µg g^{-1}DW). Zarena and Shankar (2012) identified two catechin and quercetin from mangosteen fruit. Janhavi *et al.*(2020) confirmed *G.xanthochymus* as rich source of epicatechin and catechin and suggested that this could be used as an alternate source for instead of green tea and black berry. Prakash *et al.* (2022) reported that yellow mangosteen fruit contain epicatechin (113.01 ± 0.68 mg 100 g^{-1}), catechin (25.25 ± 0.6 mg 100 g^{-1}), coumaric acid (6.15 ± 0.09 mg 100 g^{-1}), cinnamic acid (6.10 ± 0.05 mg 100 g^{-1}), chlorogenic acid (5.77 ± 0.23 mg 100 g^{-1}), and syringic acid (0.38 ± 0.03 mg 100 g^{-1}).
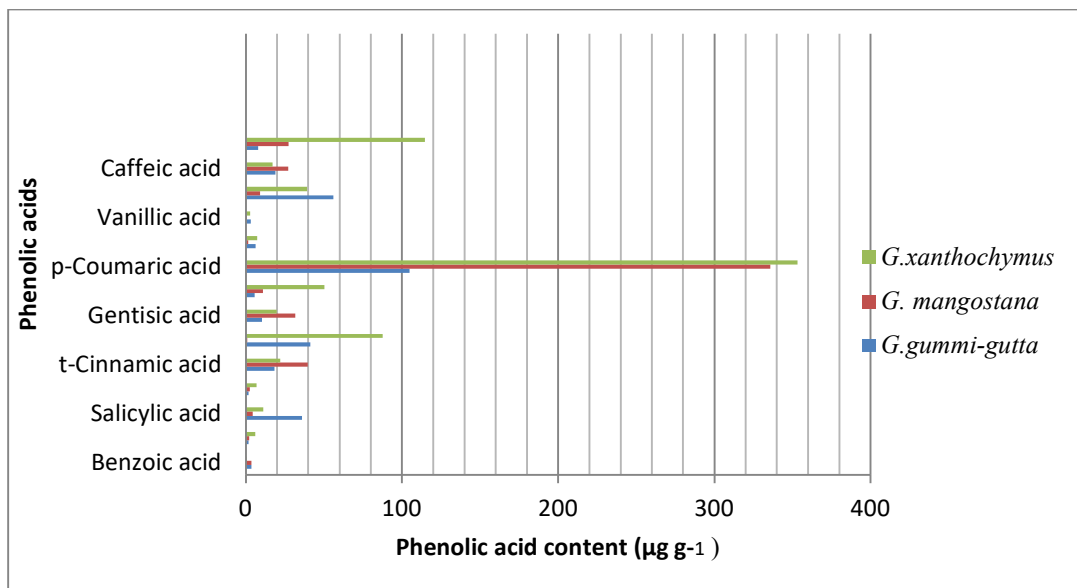
Fig . 4. Phenolic acid profiling of *Garcinia* spp.
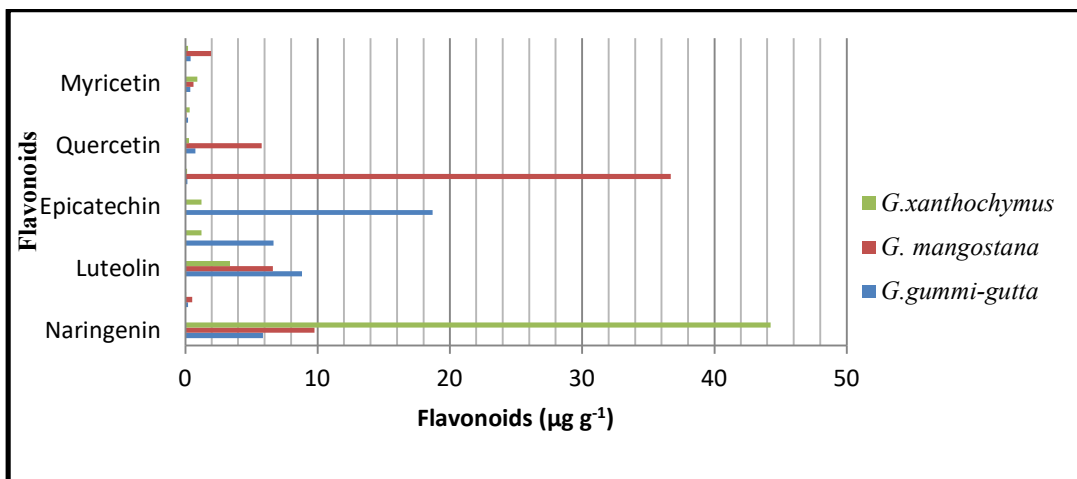
Fig. 5. Flavonoids profiling of *Garcinia* spp.

5.1.7 Extraction and Quantification of Major Benzophenones

λ max values for garcinol, isogarcinol and xanthochymol were 291, 204 and 296 nm respectively and structures were compared and confirmed with the earlier reports (Rao *et al.,* 1980; Kumar *et al.,* 2009*;* Bharate *et al*., 2014; Kumar et al., 2013) Camboginol (garcinol) and cambogin (isogarcinol, xanthochymol) are the important benzophenones isolated from the latex of *G. gummi-gutta* in large quantities (37.0% and 5.5% respectively) (Rao *et al.,* 1980). Garcinol was the major benzophenone in *G.gummi-gutta* (7.53±0.17%) and *G. xanthochymus* (8.26± 0.61 %) whereas *G.mangostana* fruits were rich in isogarcinol (8.10± 0.34%) followed by xanthochymol (4.75±0.27%). Kumar *et al.* (2009) quantified Isoxanthochymol and camboginol in methanol extracts of *G. cambogia* rind as 16.6 and 88.2 mg g^{-1} respectively

5.1.8 HPLC Profiling of α -mangostin

α-mangostin is the most common xanthone compound in the mangosteen fruit which is reported to have antioxidant, antiinflammatory, anticancer, and antimicrobial activities (Shan *et al.,* 2011) .The λ max of α-mangostin was set as 320 nm for HPLC analysis. From the standard curve obtained for the standard α-mangostin of the sample was calculated as 3.62 % on dry weight basis (Fig. 6). Misra *et al.* (2009) reported that methanol extract of mangosteen contain 4.298 % α-mangostin. Agustina *et al*. (2014) quantified 15.85% of α-mangostin from ripe rind of mangosteen. Extraction of α-mangostin from dried mangosteen rind reported the highest yield of 5.2% by Guo *et al.,*2016).

5.2 COLOUR EXTRACTION FROM MANGOSTEEN PERICARP

The effect of different acidified solvent system on extraction yield, quality parameters and colour parameters of mangosteen pericarp extracts were analyzed and are discussed below.
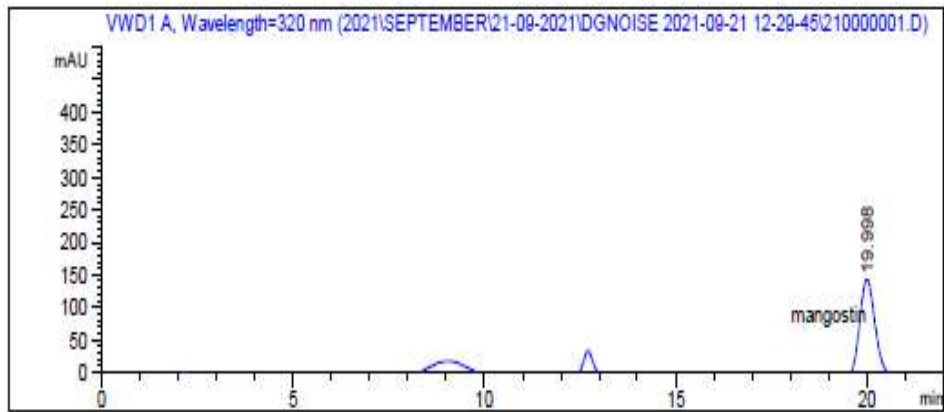
Fig. 6. HPLC chromatogram of mangosteen rind extract for α- mangostin standard

5.2.1 Effect of Treatments on Biochemical Parameters of Anthocyanin Extracts

The pH values of different anthocyanin extract ranged from 3.6 to 5.10. The highest pH (5.10) was observed by the anthocyanin extracted with ethanol which was followed by colour extracted with water (4.71). Colours extracted with acids were all on par with each other treatments. These results are supported by Ortega and Beltran, (2014) who reported that while extracting anthocyanin from hibiscus no significant difference was observed for parameters such as pH, moisture content and total acidity.

Anthocyanin extracted with ethanol and 2 % acetic acid recorded the highest yield (28.57 %) and the lowest (13.94 %) yield for the distilled water as solvent without acidification (Fig.7). Experimental results of Hutabarat et al. (2019) revealed that extraction time, solid to solvent ratio, and their interaction significantly influenced anthocyanin yield from blueberries.

The anthocyanin extracted with ethanol acidified at 2% acetic acid showed significantly higher total anthocyanin content of 294.73 mg 100g^{-1}. Anthocyanin extracted with ethanol acidified using acetic acid exhibited higher anthocyanin content than ethanol with citric acid. This was supported with the findings of Gerardi et al. (2015) and Espinosa-Acosta et al. (2018). Acetic acid is a weak acid and it will not damage anthocyanin even during evaporation. Hiranrangsee et al. (2016) reported anthocyanin content extracted from fresh and dried mangosteen pericarp were 23.54 ± 0.31 and 20.83 ± 0.96 mg Cyn-3-Glu 100 g^{-1} respectively.

The extracts obtained with ethanol as solvent exhibited relatively higher TPC, TFC and antioxidant activity than the aquous extracts. Anthocyanins are part of the flavonoid sub-group of the polyphenols and bear an oxidized C-ring (Andersen and Jordheim, 2013). Azima et al. (2017) confirmed that mangosteen peel extract exhibited higher phenolics, total anthocyanin and strongest antioxidant capacity
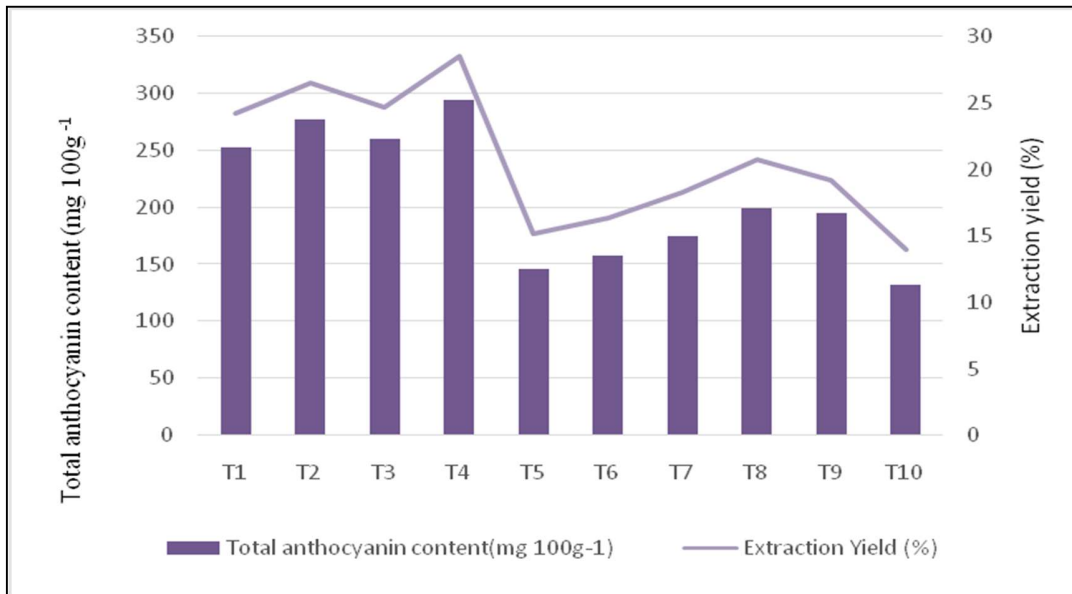
Fig. 7. Total anthocyanin content and yield of mangosteen pericarp extract

compared to other pigmented plant samples (*Ardisia colorata, Clitoria ternatea, and Syzygium cumini*).

The extraction using ethanol with 2% acetic acid recorded the highest total phenol content of 1549.55 mg GAE 100g^{-1} and there was no significant difference with treatment ethanol and 1% acetic acid. These results are supported by the finding of (Hiranrangsee *et al.,* 2016) where the highest values for TPC was reported for colour extraction by shaking water bath and values dried mangosteen pericarp was 2172.61 ± 30.02 mg GAE 100 g^{-1}. Ethanolic (50%) extraction for an extraction time of 30 minutes yielded the highest concentration of anthocyanins and total phenols from *Hibiscus sabdariffa* (Roselle) calyces (Ortega and Beltran, 2014). The lowest phenolic acid content of 1241 mg GAE 100g^{-1} was observed for distilled water extracts.

The highest TFC was recorded as 38.46 µg QE g^{-1} for the anthocyanin extracted with ethanol and 2% acetic acid which was followed T_2 (Ethanol+ 0.2% Citric acid) with 36.30 µg QE g^{-1}. Anthocyanin extracted with distilled water without acidification recorded the lowest TFC of 22.35 µg QE g.$^{-1}$. Makris *et al.* (2007) studied extraction of flavonoids from white and red grape pomace, and results showed that addition of HCl increased the flavonoid content. Acidity had enhanced hydrolysis of polymeric phenolic structures and release of monomeric metabolites which got solubilized easily during extraction (Putnik *et al.,* 2016). Ngawhirunpat *et al.* (2010) observed that water extract of mangosteen hull reported to haved higher total flavonoid when compared with methanol and hexane extract.

The highest antioxidant activity (82.68%) was recorded for the treatment ethanol acidified with 2% acetic acid. A correlation study conducted between TPC and antioxidant activity of mangosteen peel revealed that the samples with high total phenolic content exhibited higher antioxidant activity (Amin and Lee, 2005). Fugal *et al.* (2006) evaluated mangosteen pericarp for colour extraction and observed that

presence of xanthones contribute highe activity to the colour extracts. Zarena and Sankar (2012) reported that antioxidant activity of mangosteen extracts was mainly associated with the phenolics, due to their radical scavenging activity .

5.2.2 Effect of Extraction Conditions on Colour Parameters

The L* value for the treatments varied from 9.53 to 25.44 among the anthocyanin extracts. The a* and b* colour coordinates regulate the chroma (color intensity) and Hue angle (H^0) of a sample and the values in the range of 0 to 60 yield shades of red to yellow or 300 to 360 which have the shades of pink to red as described by Torskangerpoll and Anderson, (2005). Hue° angle values varied from 24.16 to 37.74 for the different anthocyanin extracts and all the values were in the red region. The results are supported by the findings of Yenrina *et al.* (2016) who grouped hue according to colour and reported Hue ^{0} of 18 to 54 come in the red region.

Chroma values of mangosteen peel extracts varied from 17.06 to 34.30 in different solvent systems. Colour extracted with Ethanol acidified using 2% Acetic acid recorded a chroma value of 22.72. A red sample with varied dilution strengths from pink to red will have the same hue angle but higher chroma values. Wrolstad (2005) reported that chroma values of the colour increases with pigment concentration to a maximum and then decreases as the colour darkens. The color intensity (chroma) presented values closer to 100 indicates pure color (Netravati *et al.,* 2022).

5.3 DEVELOPMENT OF NECTAR FROM *GARCINIA* SPP.

Biochemical and sensory qualities of different nectar formulations from *Garcinia* fruits were analyzed followed by supplementation with mangosteen colour extract and its storage stability evaluation are discussed below.

5.3.1 Biochemical Qualities of *Garcinia* Nectar

Fruits and derived products such as fruit juices are a significant source of many biologically active antioxidant compounds (Cilla *et al*., 2011). To develop fruit based beverages with potential health benefits, fruits rich in bioactive compounds with good sensory qualities and stable physical properties must be utilized (Wickramasinghe *et al.,* 2020).

Garcinia gummi-gutta nectar formulated with 20% fruit and 15^0Brix recorded the highest total acidity of 1.77% and the lowest acidity of 1.35 % was observed by the treatment with highest TSS (30^0Brix). Vitamin C content of the nectar formulations ranged from 3.71 to 4.80 mg $100g^{-1}$ among the treatments. Nectar formulated with 20 % fruit and 20^0Brix recorded the vitamin C content of 4.80 mg $100g^{-1}$. Highest total sugar and reducing sugar content of 15.68 % and 17.64% was observed for the formulation prepared with highest TSS content (30^0Brix). Antioxidant activity of the formulations ranged from 65.87 % to 71.95% with no significance difference among the formulations. Bensi (2017) developed RTS panakam from *G.cambogia* fruits with acidity of 0.32% and TSS of 15^0Brix, which exhibited a total sugar content of 16.12 % and 44.81% antioxidant activity. Total phenols in nectar formulations ranged from 130.17 to 161.93 mg GAE g^{-1} and total flavonoids of nectars ranged from 3.09 to 4.21 mg QE. HCA content of the formulations ranged from 1.06 to 1.45 % and formulation prepared with 20 % fruit and 20 ^{0}Brix recorded 1.41 % HCA content. Kim *et al.* (2003) reported that functional beverages containing *G.cambogia* was effective in reducing body fat which might be due to HCA content of the beverages.

Mangosteen nectar formulations were analysed for nutraceutical and sensory analysis inorder to develop a functional beverage formulation. Due to its biological properties associated to the presence of xanthones, the use of mangosteen in functional goods has been rising in recent years, particularly in food beverages and nutraceutical formulations (Masullo *et al.,* 2022).Total acidity of mangosteen nectar formulations ranged from 0.25 to 0.31 % and the parameters such as vitamin C,

antioxidant activity, total phenols and total flavonoids of nectar prepared with higher fruit percentage recorded comparatively higher values. Formulation with 20 % fruit and 15^0Brix recorded the vitamin C content of 6.12 mg $100g^{-1}$. Highest total sugar and reducing sugar content of 19.32 % and 16.12% was observed for the formulation prepared with highest TSS content (20 % fruit, 30^0Brix). Formulation with 20 % fruit with 15^0Brix recorded an antioxidant activity of 60.91 %. Recent studies showed that mangosteen juice has high levels antioxidant vitamins (B2, B5, or E), flavonoids, tannins, sugars, and dietary fibre (Ovalle-Magallanes *et al*., 2017).Total phenols of formulations with 20 % fruit pulp ranged from 49.64 to 53.13 mg GAE g^{-1} and flavonoids of 20% fruit and 15^0Brix was recorded as 1.21 mg QE g^{-1}. Xie *et al.* (2014) designed new functional beverages from mangosteen fruit along with green tea, aloe vera and bioavailability and antioxidant activity of the compounds. Mongkontanawat *et al.* (2022) formulated mangosteen beverage (mangosteen juice to water ratio 45:55) with TSS of 13°Brix and the beverage exhibited an antioxidant activity of 89.61 % and total phenols of 4.57±0.58 mg GA ml^{-1} .

Garcinia xanthochymus fruits are eaten fresh and could be preserved in jams and vinegars and beverages can be developed (Bagget *et al.,* 2005). *Garcinia xanthochymus* nectar formulation with 20 % fruit and 15^0 Brix, recorded the highest total acidity of 2.10% and 15 % fruit pulp and 20 ^{0}Brix recorded a vitamin C content of 7.15 mg $100g^{-1}$. Highest total sugar and reducing sugar content of 17.28 % and 15.56% was observed for the formulation prepared with highest TSS content (20 % fruit, 30^0Brix). Among the nectar formulations the highest antioxidant activity of 74.01 % was observed by the formulation 20 % fruit with TSS 20^0Brix. Nectar formulated from 15% pulp with TSS of 20ºBrix recorded an antioxidant activity of 69.56 %. . Fermented *Garcinia xanthochymus* beverage with 30 % must recorded a DPPH activity of 58.32 % and 0.110 % total phenolics as reported by Rai *et al*.(2010). Wickramasinghe *et al*.(2020) demonstrated that *G. xanthochymus* fruit could be used for the preparation of functional beverages with antioxidant and anti-

infammatory activities and the highest DPPH inhibition activity of 75.50% was achieved at 5.0 mg mL $^{-1}$ for the blanched fruits.

5.3.3 Sensory Qualities of *Garcinia* Nectar

The nectar formulation prepared with 20 % fruit pulp and TSS 20 ^{0}Brix recorded the highest mean score for flavour (8.40), taste (8.37) and overall acceptability (8.37) (Fig. 8a). Bensi (2017) and Bhagavathi *et al*., (2017) confirmed that *G. gummi-gutta* fruits could be effectively utilized for preparation of beverages with sensory acceptability. Sensory evaluation of *Garcinia cambogia* blended squash with pineapple juice (75% pineapple juice: 25% fresh *Garcinia* cambogia juice and 75% pineapple juice: 25% dried *Garcinia cambogia*) recorded higher overall acceptability score scores of 7.81 and 7.84 respectively as reported by Bhagavathi *et al*.(2017).

The mangosteen nectar formulations with 20 % fruit pulp and 15 ^{0}Brix recorded the highest mean score for flavour (8.67) followed by nectar with 15 % fruit pulp. Mangosteen nectar formulated with 20 % fruit pulp and TSS of 15 ^{0}Brix recorded the highest mean score for taste (8.57) (Fig 8b) and overall acceptability (8.57). The mean score for sensory attribute appearance could not show significant difference among the treatment. Mongkontanawat *et al.* (2022) reported that mangosteen beverage with TSS of 13 ^{0}Brix recorded highest sensory score for colour, aroma flavour and overall acceptability when compared with herbal extract added beverages.

Nectar prepared from *G. xanthochymus* with 15% fruit pulp and TSS of 20 ^{0}Brix recorded the highest mean score for flavour (8.47), taste (8.33) and overall acceptability (8.53) whereas, nectar with 20 % fruit and TSS of 15^{0}Brix showed the lowest mean score for the taste (7.17) and overall acceptability (7.43) (Fig 8c). The yellow mangosteen fruits can be used to prepare beverages with good sensory acceptability was reported by Rai *et al*.(2010) and Wickramasinghe *et al.*
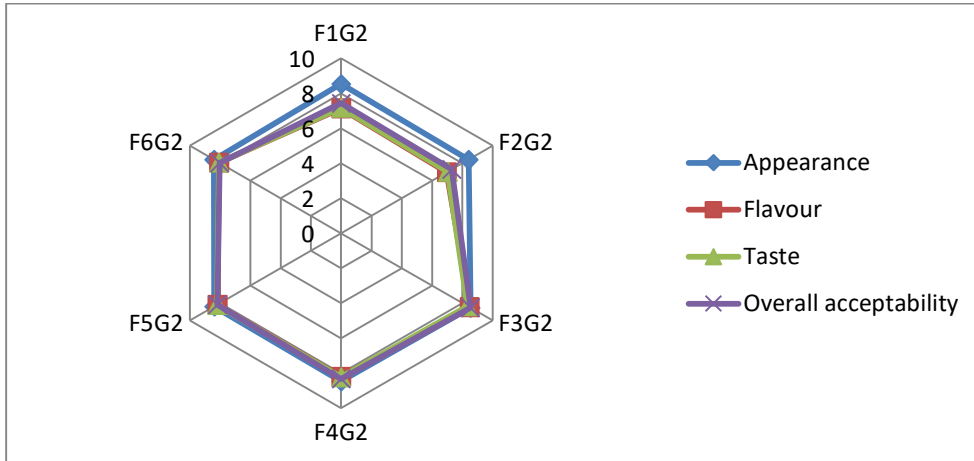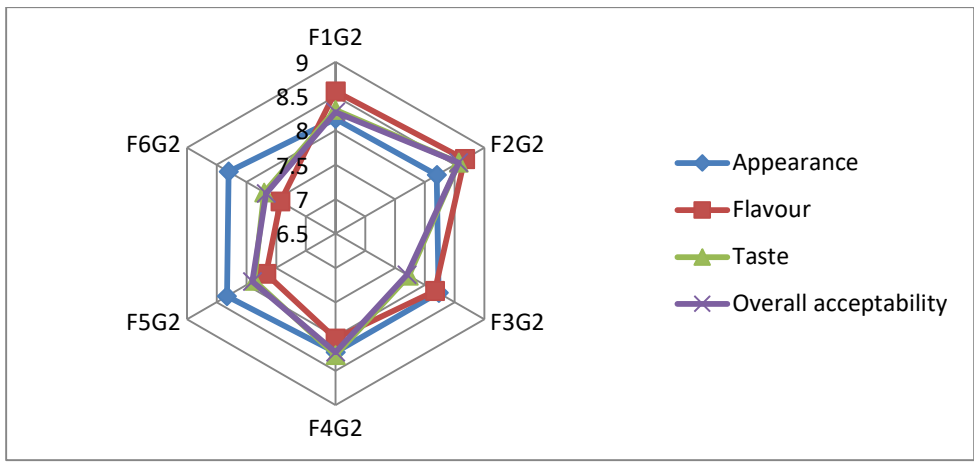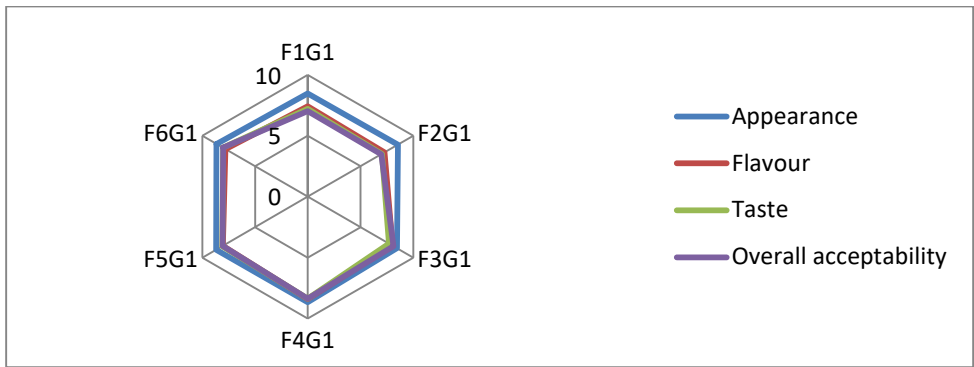
Fig. 8. Sensory evaluation of *Garcinia* nectar formulations

(2020).The acceptability of yellow mangosteen nectar with higher percentage of fruit pulp decreased which might be due to the high acidic taste of the fruit pulp.

5.3.4 Storage Stability Studies of *Garcinia* Nectar Formulations

The supplementation of natural colour extract from mangosteen pericarp to the *Garcinia* nectar significantly increased the TSS, acidity, vitamin C, sugars, total phenols and antioxidant activity when compared with beverages prepared without the addition of colour extract. This was supported by the findings of Sayuti *et al.(* 2020) who reported that, addition of mangosteen rind as a natural colorant to sugar palm fruit jam improved total dissolved solids and crude fiber of the jam. Addition of mangos ten pericarp extracts improved total phenols and antioxidant activity of green tea drink (Afifah and Niwath, 2015), ice-cream (Hiranrangsee *et al.,* 2016) and yoghurt (Shori *et al*., 2018; Wibawanti *et al.,* 2019) when compared with control. Mangosteen pericarp powder could be used as low cost polyphenol source to enhance the bioactive and flavor profile of chocolates was reported by Sim *et al.* (2016). Hanafi *et al.* (2017) developed a functional drink using mangosteen peel extract with higher anthocyanin and antioxidant levels.

TSS content of all the nectar formulation added with the natural colour extract from mangosteen pericarp increased as compared to the formulation without colour addition. At the time of storage *G. gummi-gutta* nectar with addition of colour recorded a TSS of 20.53 ^{0}Brix, *G. mangostana* nectar with addition of colour recorded 15.33 ^{0} Brix and *G. xanthochymus* nectar with colour recorded 20.47 ^{0}Brix which was increased to 21.31, 16.60 and 21.26 after third month of storage. Similar results were observed *G.cambogia* panakum (Bensi, 2017), Jack fruit nectar (Xess *et al.,* 2021), kokum RTS beverage (Jayashree and Susanna, 2023). Increase in the TSS of the product during storage could be due to the hydrolysis of the polysaccharides into simple sugars and other constituents (Hemalatha *et al*., 2018)

At the time of storage, acidity of colour added nectars were 1.62, 0.32 and 1.61 % respectively for *G. gummi-gutta, G. mangostana and G. xanthochymus* nectar, which was increased to 1.73, 0.42 and 1.73 %. The decrease in acidity may be related to the acidic hydrolysis of polysaccharides, in which acid was used to change non-reducing carbohydrates into reducing sugars (Bhardwaj and Pandey, 2011). Cherian (2016); Bensi (2017); Nawaz *et al.*(2021); Xess *et al.*(2021); Jayashree and Susanna (2023) reported that acidity of fruit beverages increased with increase in storage period.

The vitamin C content was recorded as 5.10, 6.44 and 7.53 mg 100g^{-1} respectively for *G. gummi-gutta* nectar, mangosteen nectar and *G. xanthochymus* nectar added with colour. During storage vitamin C content showed a decreasing trend. *G. gummi- gutta* nectar recorded lowest quantity of 4.93, 4.82 and 4.75 mg 100g^{-1} respectively after 1st, 2nd and 3rd month of storage (Fig 9). The loss of ascorbic acid might be the result of the storage-related irreversible oxidation process, which may have quickly changed L-ascorbic acid into dihydro-ascorbic acid (Tiwari *et al*. 2009). Bensi (2017) observed decreasing trend in ascorbic acid content of *Garcinia* panakam. Salaria and Reddy (2022) reported reduction of ascorbic acid during storage of musk melon RTS.

The total sugar content of *Garcinia* nectar with and without addition of colour varied from 14.14 to 14.99 among the treatments at the time of storage and during storage total sugar content increased in all nectar formulations. Nawaz *et al.*(2021) observed that total sugar content of apple-peach functional fruit drink supplemented with polyphenols extracted from lemon peels increased gradually for a period of 28 days. Total sugar content of kokum beverages increased from 15.03 % to 51 % and 49.26 % under ambient and refrigerated conditions as reported by Jayashree and Susanna (2023). *Garcinia gummi- gutta* nectar added with mangosteen colour recorded reducing sugar of 13.80 % where as *G.gummi-gutta* beverage without colour recorded 13.70 % after storage of three months. Reducing sugar content of the
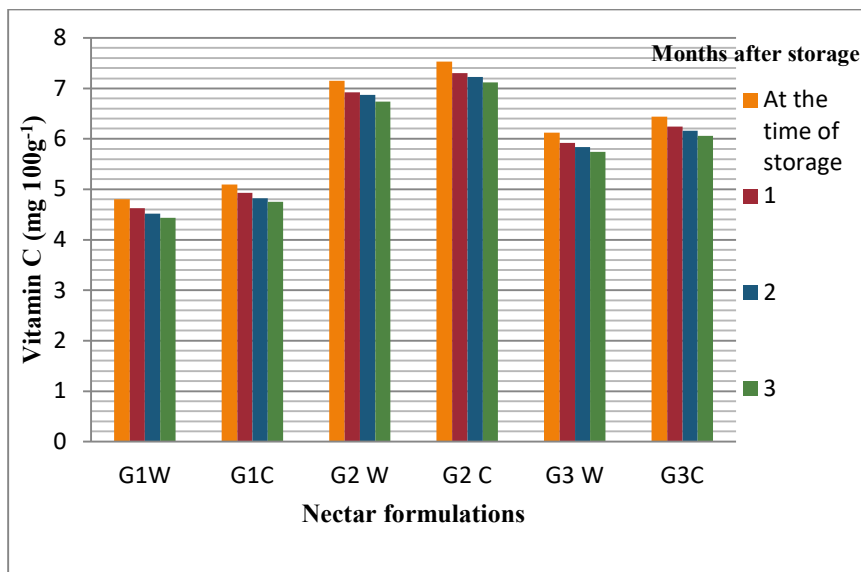
Fig. 9. Effect of storage on vitamin C (mg 100g^{-1}) of *Garcinia* nectar
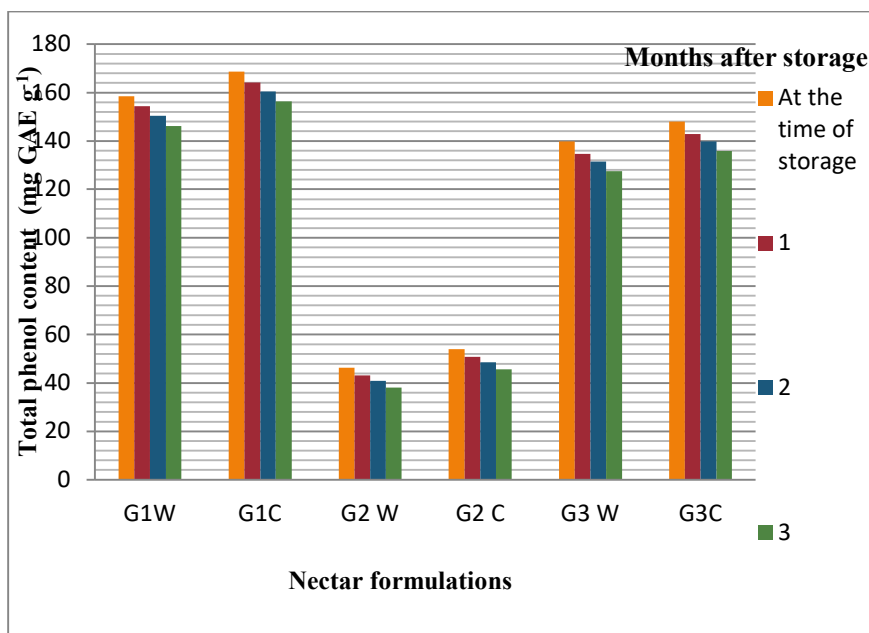
Fig. 10. Effect of storage on total phenols (mg GAE g^{-1}) of *Garcinia* nectar

G$_1$W- *G.gummi-gutta* nectar without colour, G$_1$ C- *G.gummi-gutta* nectar with colour,

G$_2$W- *G. mangostana* nectar Without colour, G$_2$C- *G. mangostana* nectar with colour,

G$_3$W- *G.xanthochymus* nectar without colour and G$_3$C- *G.xanthochymus* nectar with colour

mangosteen nectar with the colour increased from 11.35 % to 12.02 % at the end of storage. Increase in total sugar and reducing sugar during storage of fruits beverages was also reported by Xess *et al.* (2021) ; Kashyap *et al.* (2022); Salaria and Reddy (2022).

Total phenols of *G.gummi-gutta* nectar increased from 158.44 to 168.55 mg GAE g^{-1}, mangosteen nectar from 46.30 to 53.97 mg GAE g^{-1} and *G.xanthochymus* nectar from 139.72 to 148.06 mg GAE g^{-1} with addition of natural colour extract (Fig 10). During storage, total phenols of all the nectar formulation showed a decreasing trend and a gradual loss of total phenols during storage might be due to their condensation into brown pigments (Karpagavalli and Amutha, 2015). Nawaz *et al.* (2021) observed decrease in polyphenols of apple-peach drink up to 32.65% during a storage period of 28 days. During storage period of 90 days total phenolic contents gradually decreased for sapota RTS was reported by Fiaz *et al.* (2022).

Initial antioxidant activity was recorded as 75.94, 64.15 and 74.98 % respectively for *G.gummi-gutta* nectar, mangosteen nectar and *G.xanthochymus* nectar with mangosteen pericarp colour extract. Mangosteen nectar without colour recorded the lowest antioxidant activity of 59.63, 57.62, and 56.59 % respectively for 1st, 2nd and 3rd month of storage. This is supported by the findings of Bensi (2017) who reported decrease in antioxidant activity of *Garcinia* beverage during storage. DPPH activity of oleaster fruit extracts incorporated orange juice decreased during thirty day storage under refrigerated condition (Sarvarian *et al.,* 2022). This might be due to possible oxidation of bioactive components under favorable conditions as reported by Dar *et al.* (2016).

Batrial load for all the samples increased with storage time and was within the permisible limit. A study conducted by Soetikno *et al.* (2016) revealed the antibacterial activity of mangosteen rind extract they also stated that with increase in rind concentration percentage inhibition was more.

5.3.5 Sensory Qualities of Stored Garcinia Nectar

Sensory analysis of the nectars supplemented with mangosteen pericarp colour extract conducted at monthly interval revealed that mean scores of colour, flavour, taste and overall acceptability scores were decreased during storage.

When evaluating a product's marketability, the sensory qualitative profile of the beverage is crucial (Tariq *et al.,* 2020). Addition of mangosteen rind colour extract improved the colour scores of nectars from *G.gummi-gutta and G.mangostana* whereas the colour supplementation did not improve the colour mean score of yellow mangosteen nectar formulations. *G.gummi-gutta* nectar with mangosteen colour recorded the highest score for colour at storage (8.56) and the end of third month (8.39). Mangosteen nectar with colour recorded the highest mean score for colour (8.60) whereas mangosteen nectar without colour recorded a score of 7.73. *Garcinia xanthochymus* nectar showed a characteristic deep yellow colour was accepted more than the nectar incorporated with colour extract. At the time of storage highest mean score for overall acceptability (8.65) was for *G.gummi-gutta* nectar with mangosteen colour whereas *G.gummi-gutta* nectar without mangosteen colour recorded a score of 7.74. Mangosteen nectar with colour recorded highest mean score (8.51) for overall acceptability, whereas mangosteen nectar without colour recorded a score of 7.70. At the time of storage highest mean score for overall acceptability (8.54) was for *G.xanthochymus* nectar without mangosteen colour where as *G.xanthochymus* nectar with mangosteen colour recorded a score of 7.73. All the sensory attributes showed a slight decrease during storage for nectar formulations.

Pereda *et al.* (2020) evaluated sensory characters of cape gooseberry nectars, panelists did not detect any difference among samples for colour and aroma whereas significant differences were found for sweetness, texture and overall acceptability.Sensory evaluation of mangosteen juice supplemented with sappan wood extracts showed that, high concentration of sappan wood extract decreased the mean score of colour, aroma, taste and overall acceptability. Mangosteen juice mixed

with 0.20 % w/v Sappan wood extract and pure mangosteen juice did not show any significant difference (Mongkontanawat *et al*., 2022).

The sensory analysis in terms of overall acceptability for different kokum RTS was done for a period of 3 months showed that kokum RTS blended with cumin had the best flavour and taste with an overall acceptability score of 7.75 when stored under refrigerated condition followed by that stored under ambient condition with an acceptability score of 7.10 (Jayashree and Susanna, 2023). Siddharth and Sharma, (2013) studied the storage qualities of concord grape juice blended with kokum extract of different concentrations (from 0 to 0.6%) and reported that the highest overall acceptability in maintaining the sensory characteristics was obtained when the concentration of kokum extract was 0.4% followed by 0.6%. Flavour and taste of the nectar were not significantly influenced by the addition of mangosteen colour extract. During three month storage all the sensory qualities of the nectar showed a decreasing score but acceptable by the members. Tariq *et al.*(2020) reported that overall sensorial quality profile of apple - autumn olive RTS beverage's slightly dropped during storage but was still rated "Like very much" by the panel. Similar reports of decreasing sensory score during storage were observed in kinnow nectar (Shubhra *et al*., 2014), apple –peach drink (Nawaz *et al.,*2021)

5.3.6 Colour Stability of Anthocyanin in Nectar Formulations

Numerous variables, including temperature, pH, light, and the existence of complexing agents in the system, have an impact on the stability of anthocyanins. Most anthocyanins are found to be stable in the pH range 4.5–5 as reported by Wrolstad and Culver 2012. Acyalated anthocyanin reported to possess higher stability in aqueous solutions and are of interest to the food and beverage industry (Galaffu *et al*. 2015).

The initial anthocyanin content of nectar supplemented with natural colour extract was found higher than the nectars without colour addition. *G.gummi-gutta* nectar supplemented with colour exhibited total anthocyanin content of 10.53 and

11.52 mg 100g^{-1} respectively for transparent and amber containers at the end of storage. Total anthocyanin content of the mangosteen nectar added with colour in amber bottles was observed as 10.01, 9.30 and 8.74 after first, second and third months of storage. Anthocyanin content of *G.xanthochymus* nectar stored in amber bottles was 2.85 mg 100g^{-1} after third months of storage whereas, 2.67 mg 100g^{-1} for the nectar store in transparent bottle. Throughout the storage total anthocyanin content of the nectar showed a decreasing trend and least decrease was for the nectar stored in amber colour bottles. Siddharth and Sharma, (2013) observed minimum loss of anthocyanin during cold storage for a period of 4 months was recorded when 0.2% kokum extract was added to concord grape juice blended. Barbosa *et al.* (2021) evaluated stability of sorghum 3-deoxyanthocyanins in model beverages (pH 3.5) elaborated with crude sorghum phenolic extract, containing ascorbic acid and sulfite, under fluorescent light exposure and subjected to heat treatment and recorded anthocyanin 24.16% under light exposure and 20.72% under absence of light without significance difference.

Escher *et al.*(2020) reported that temperature is a critical parameter in food industry and thermal treatments above 50 °C will lead to partial or complete degradation of anthocyanins. Initial anthocyanin content of *G.gummi-gutta* nectar with colour was 16.85 mg 100g^{-1} which was reduced to 16.25 and 15.48 mg 100g^{-1} at 70 and 90 ^{0}C after 30 minutes of incubation, which was further reduced to 15.59 and 14.49 after 1 hour of heating (Fig 11). Anthocyanin content of *G.mangostana* nectar with colour was 10.97 mg 100g^{-1} which was reduced to 10.42 and 9.71 mg 100g^{-1} at 70 and 90 ^{0}C after 30 minutes of incubation, which was further reduced to 9.71 and 9.35 after 1 hour of heating. Initial anthocyanin content of *G.xanthochymus* nectar with colour was 14.65 mg 100g^{-1} which was reduced to 14.43 and 13.66 mg 100g^{-1} at 70 and 90 ^{0}C after 30 minutes of incubation, which was further reduced to 13.37 and 12.62 after 1 hour of heating. Total anthocyanin content of nectars showed a decreasing trend with increase in temperature and incubation time. Naresh (2016)
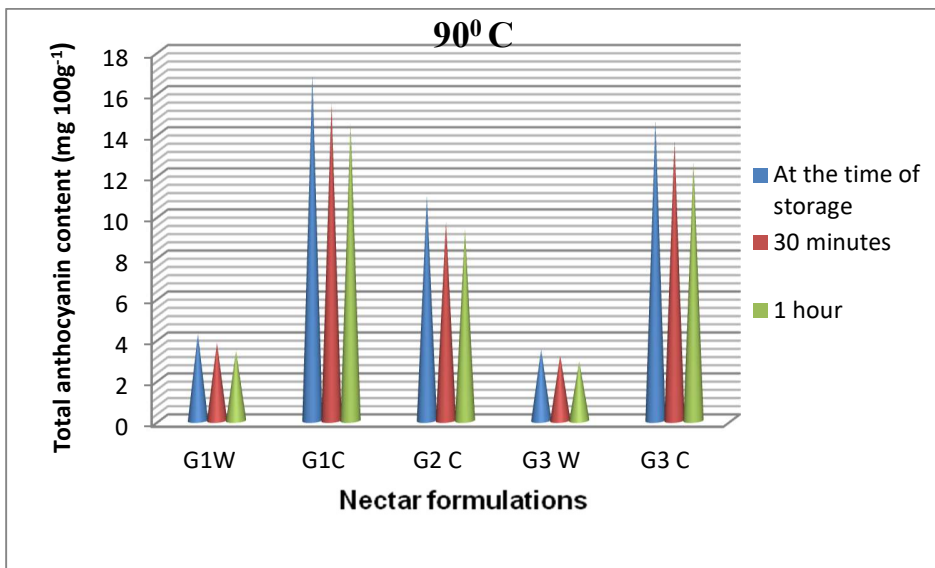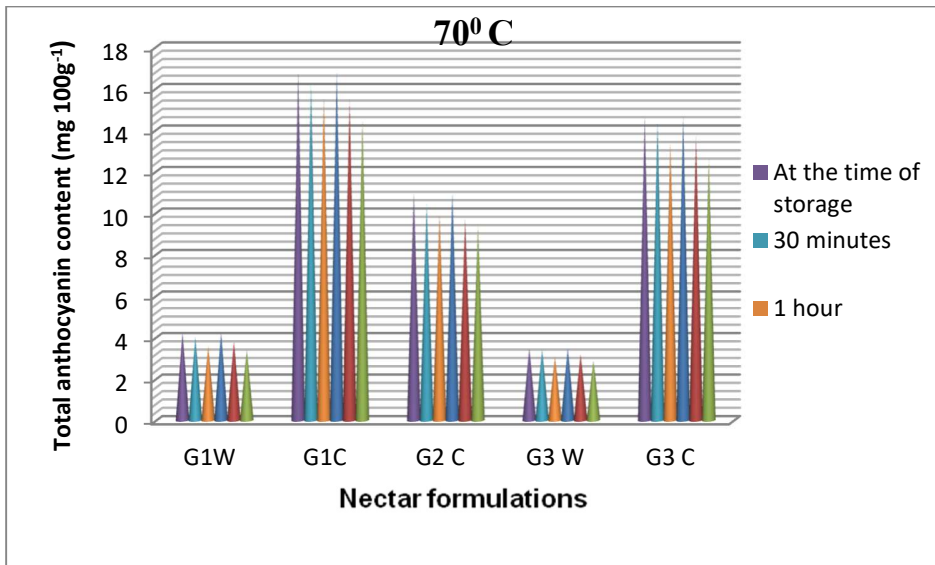
Fig. 11. Effect of temperature on colour stability of *Garcinia* nectar

G$_1$W- *G.gummi-gutta* nectar without colour, G$_1$ C- *G.gummi-gutta* nectar with colour,

G$_2$W- *G. mangostana* nectar Without colour, G$_2$C- *G. mangostana* nectar with colour,

G$_3$W- *G.xanthochymus* nectar without colour and G$_3$C- *G.xanthochymus* nectar with colour

observed decrease in anthocyanin content of jamun extract from 61.25 mg 100g^{-1}to 50.24 mg 100g^{-1} after one hour of heating at 90^0 C. Chen *et al*. (2020) reported that the total anthocyanin content of red raspberry fruit reduced by 90% when they stored at 37 °C for 30 days.

5.4 VALUE ADDED PRODUCTS FROM *G. GUMMI-GUTTA.*

Garcinia fruits are rich in bioactive compounds and have great potential in food products with health benefits. *Garcinia* fruits are available during specific seasons, therefore it is essential to preserve the fruits, so that they can be made available throughout the year. Various products such as osmodehydrated product, ready to use paste and pickle are standardized with consumer acceptability and results are discussed below.

5.4.1. Development of Osmodehydrated Product

In the present study 2cm^3 sized *G. gummi-gutta* rind slices were steam blanched and were subjected to osmodehydration with sucrose as osmotic medium at different levels of osmotic concentration (50⁰Brix and 70⁰Brix) and immersion time (24, 36 and 48 h) and mass transfer and biochemical properties of osmodehydrated *G.gummi-gutta* rind are discussed below.

5.4.1.1 Mass Transfer Characters

Mass transfer characters *viz.,* solid gain, weight reduction and water loss play an important role in the development of osmodehydrated products. These are were used to indicate the overall exchange of solute and water between osmodehydrated rind and osmotic solution.

Mass transfer characters of osmodehydrated *G.gummi-gutta* rind were significantly influenced by osmotic concentrations and immersion time. Osmodehydrated rind at 50^{0}Brix showed the lowest solid gain of 23.34 % and the

highest solid gain (27.46 %) was observed for 70^0Brix osmotic concentration. Among the immersion time, 48 h recorded the highest solid gain of 28.11 % followed by 36 h with 25.79% of solid gain (Fig 12 b). Maximum water loss (49.10 %) was observed for rind osmosed in 70 ^{0}Brix, 48 h, while minimum water loss (22.307 %) was in treatment with osmotic concentration of 50 ^{0}Brix for immersion time of 24 h. The fruit slices osmosed in 70^0Brix for 48 h recorded maximum weight reduction of 29.00 % and the minimum weight reduction of 18.93 % was observed for C_1T_1 (50 ^{0}Brix, 24 h) (Fig 12b). The results are in confirmation with the findings of Phisut (2013) and the higher osmotic concentration led to higher water loss and solid gain of the osmosed fruits. A similar trend of increase in mass transfer characters with increase in immersion time and diffusing solution concentrations were noticed in banana (Shukla *et al*., 2018 ; Archana and Lekshmi, 2019) bilimbi (Aparna *et al.,* 2022) and strawberries (Kolwalska *et al.,* 2023).

5.4.1.2 Biochemical Parameters of Stored Osmodehydrated G.gummi-gutta

Osmotic dehydration results in simultaneous counter current mass transfer of water from solution to hypertonic solution and of solute from solution into the sample thus soluble solids of the sample such as organic acids, minerals and vitamins also migrate relatively in the small quantities from sample to solution (Yadav and Singh 2014).

At the time of storage highest acidity of 3.14 % was observed for the treatment 50 ^{0} Brix, 24 h. With increase in immersion time and concentration of sugar syrup acidity was decreased and lowest acidity of 1.54 % was observed for rind immersed in 70 ^{0} Brix for 48 h (Fig 13 a). Osmodehydration of Japanese quince fruit resulted in increased content of sugars and a significant reduction in the content of organic acids (Turkiewicz *et al.,* 2020). *G.gumi-gutta* rind slices immersed at 70 ^{0}Brix for 36 hours recorded total acidity of 1.67 % at storage and increased during storage. Acidity of osmodehydrated slices in 70 ^{0}Brix for 36 h was observed as 1.72,
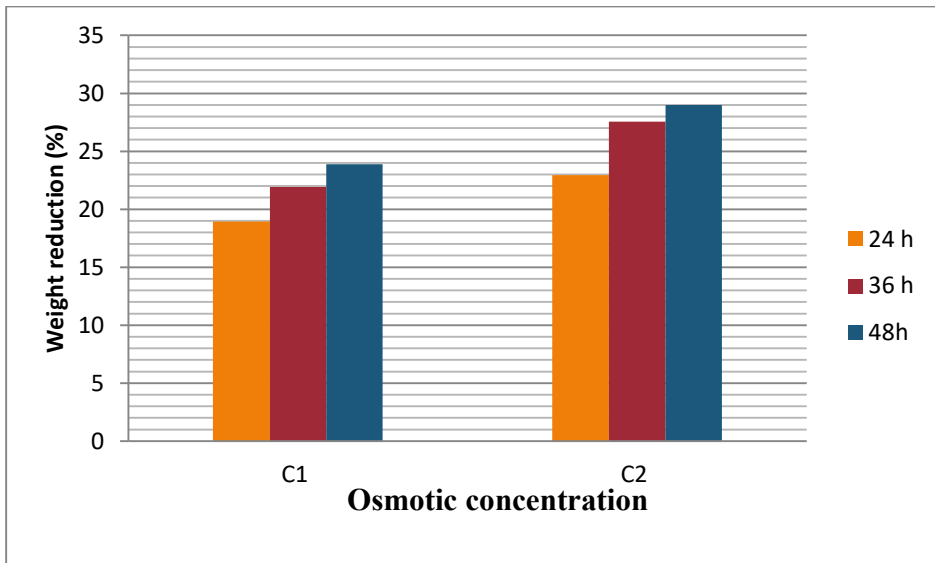
C₁ -50⁰ Brix

C₂ -70⁰ Brix
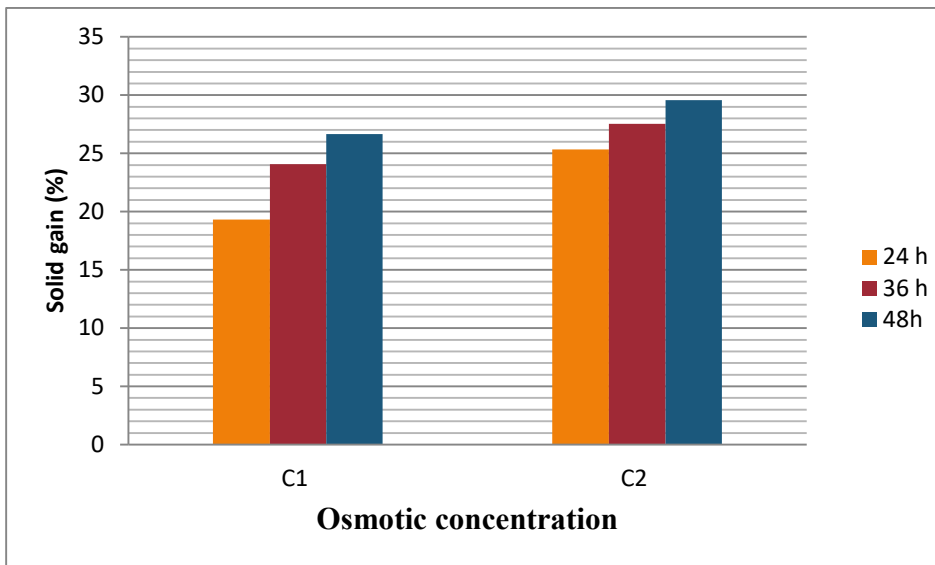
Fig. 12. Effect of osmotic concentration and immersion time on weight reduction (%) and solid gain (%) of osmodehydrated *G.gummi-gutta* rind

1.75 and 1.79 % at 1st, 2nd and 3rd month of storage respectively. Similar results were noticed during osmodehydration of mango (Mishra *et al.,* 2016).

Total Soluble Solids of osmodehydrated rind increased with osmotic concentration and immersion time. Among the treatments highest TSS of 47.88 °Brix was observed for the treatment osmodehydrated in 70 ^{0}Brix for 48 h followed by 70 ^{0}Brix for 36 h (40.46 %). These results are in confirmation with results of (Dionello *et al*., 2009 ; Gonzalez-Perez *et al.,* 2022). With respect to storage months TSS of the osmodehyrated samples increased and the highest TSS content of 39.23 ^{0}Brix was observed after three month of storage. storage. .

The highest total sugar of 48.04 % was recorded for rind osmosed in 70 ^{0}Brix for 48 h followed by 70 ^{0}Brix for 36 h (45.04 %) and the lowest total sugar of (36.20 %) was observed for rind in 50 ^{0}Brix for 24 h at storage (Fig 13b). During storage total sugar content increased, and the lowest total sugar of 42.26 % was noticed at the time of storage. Fruit rind osmodehydrated in 70^{0}Brix for 48 h recorded a reducing sugar of 17.48 %, 70^{0}Brix , 36 h recorded 16.82 % and 15.83% for malabar tamarind in 50^{0}Brix for 48 h at the time of storage (Fig 13 c). During storage TSS, total and reducing sugar content of the samples were significantly increased. Results are in accordance with the findings of Sagar and Kumar (2009) in mango and Prasannath and Mahendran (2009). Katsoufi *et al* (2017) confirmed that osmodehydrated fruits became more brittle and less tough due to the reinforcement of the cell walls due to the increase in total sugar concentration in the osmodehydrated fruit tissues.

Initial antioxidant activity was recorded as 78.38, 76.22 and 75.05 % respectively for treatments 50^{0}Brix for 24 h, 50^0 Brix for 36 h and 70 ^{0} Brix for 24 h and the lowest antioxidant activity (67.12%) was for rind osmosed in 70 ^{0}Brix for 48 h. The longer the duration osmotic dehydration was, the lower the antioxidant activity was observed. This might be due to higher leaching of soluble components during osmotic diffusion process as reported by Phisut *et al*. (2013). Anthocyanins, flavanols
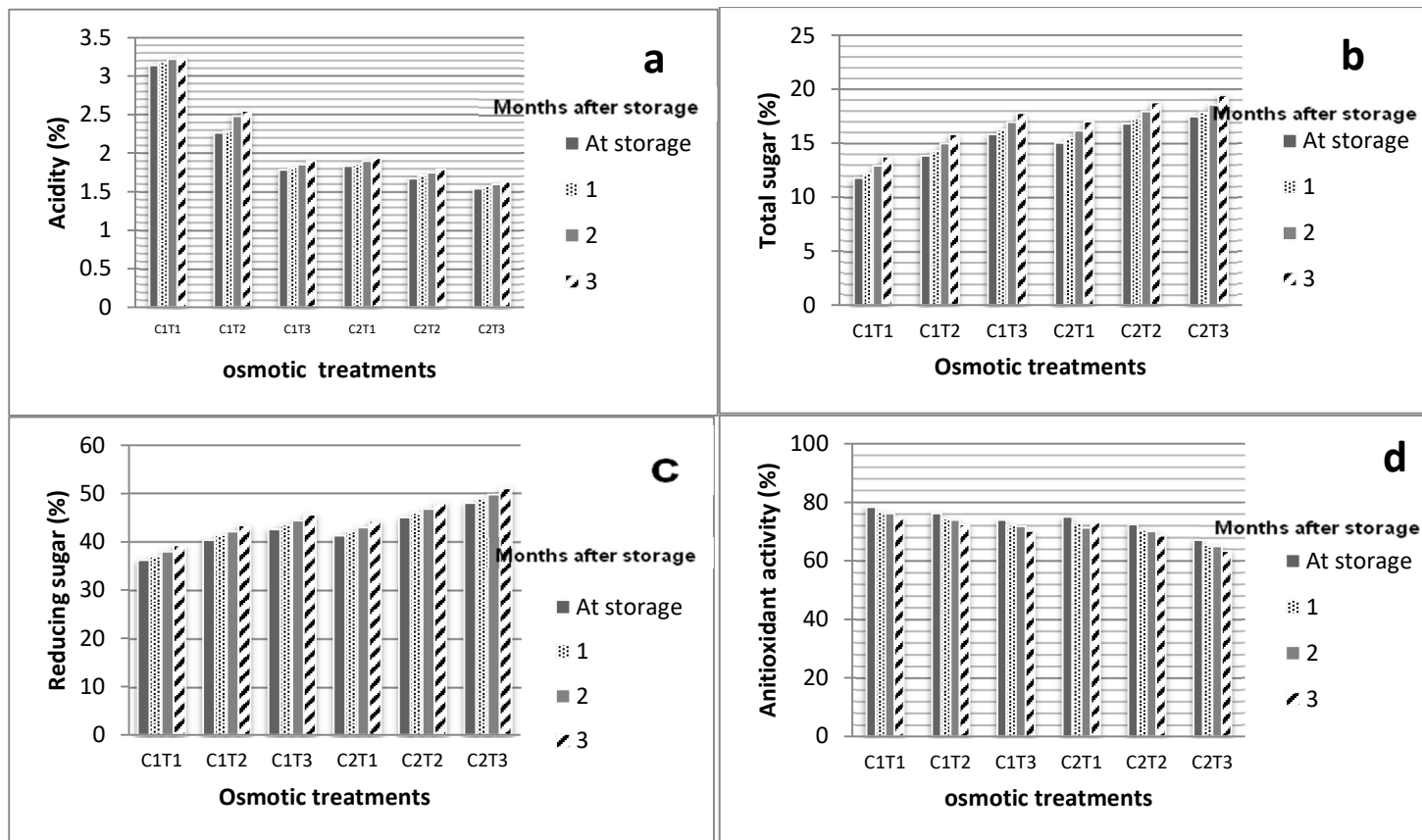
Fig 13. Changes in acidity (a), total sugar (b), reducing sugar (c) and antioxidant activity (d) of osmodehydrated *G. gummi-gutta* during storage

50°Brix (C_1) and 70°Brix (C_2) – Osmotic concentration, 24 h (T_1) 36 h (T_2) and 48 h (T_3)-Immersion time

and ascorbic acid are damaged during the drying process as well as drop in antioxidant content might be due to oxidation and sensitivity while drying (Wojdylo *et al*., 2009). Osmodehydrated rind in 70 ^{0}Brix for 36 h recorded an antioxidant activity of 70.61 % after one month of storage, 70.20 % after second month and 68.63 % after third month of storage. During storage antioxidant activity of rind showed a decreasing trend (Fig 13d). Similar results were reported by Alajil *et a.*(2020) during osmodehydration of apricot.

Hydroxy Citric Acid (HCA) content of osmdehydrated malabar tamarind fruit rind showed significant difference among the treatments and storage period. During storage, HCA of the osmodehydrated treatment 70^{0}Brix for 36 h was observed as 1.39, 1.36 and 1.31 % after 1st, 2nd and 3rd month of storage respectively.

5.4.1. 3 Sensory Analysis of Osmodehydrated Malabar tamarind During Storage

Sensory parameters *viz.,* taste, colour (golden yellow to light brown), flavour, texture and overall acceptability for osmodehydrated malabar tamarind fruits revealed that the highest mean score for taste (8.60) was recorded for osmodehydrated fruit in 70^{0}Brix for 36 h followed by 70^0 Brix for 48 h) with 8.47 and 50^0 Brix for 48 h (8.17). On analyzing colour of the osmodehydrated products, the highest mean score (8.53) was for fruit osmosed in 70^0 Brix for 48 h whereas the highest score for flavour (8.60) was recorded by the osmodehydrated fruit with the osmotic pre-treatment of 70^0 Brix for 36 h. Landim *et al.* (2016) confirmed that osmotic pretreatment protected the colour of fruits and vegetables. Osmodehydration process helped to retain initial fruit characteristics *viz*., colour, aroma, texture and nutritional composition, and product stability (Ramya and Jain, 2017). The sensory scores for all osmodehydrated fruit samples recorded a decreasing trend during storage and were acceptable even after three months of storage. Similar result was reported by Aparna *et al*. (2018) for osmo dehydrated bilimbi during storage.

5.4.1. 4 Enumeration of Microbial Load

Microbial load for all the samples increased with storage time and was within the permisible limit. The lowest fungal load (0.33 to 1.69 log CFU g^{-1}) and bacterial load (1.10 to 1.93 log CFU g^{-1}) was observed for the treatment 70^{0}Brix for 48 h from the first month of storage to the end of storage. Low microbial count may be probably due to high acidity, increased sugar and low moisture of the osmodehydrated product. Same results were reported in osmodehydrated bilimbi slices which were microbiologically safe for a period of four months (Aparna *et al*., 2018). Rahman *et al*. (2012) reported that the higher concentration of sugar in the syrup and added preservative (KMS) coupled with low moisture content in storage prevented microbial growth.

5.4. 2 Development of Paste

The effect of salt concentration (3%, 5%, 7%, 9% and control) on quality parameters of the *G.gummi- gutta* (malabar tamarind) culinary paste for a period of three months were statistically analyzed and discussed below.

5.4.2.1 Biochemical Parameters

Biochemical parameters *viz.,* moisture content, TSS, acidity, HCA, reducing sugar, TFC, antioxidant activity and fibre content in different formulations of culinary paste were assessed during storage and major findings are discussed here.

Addition of salt decreased the moisture content and lowest moisture content of778.55% was recorded for paste with9% salt at the time of storage. Moisture content showed a decreasing trend in all the treatments over a storage period of three months at ambient conditions. During storage moisture content of all the paste formulation decreased and the lowest (78.00%) was for pulp with 9%salt and the highest (84.04%) for paste without salt.Koh *et al.*(2012) observed a decrease in moisture content of tomato paste from 73.11% to 71.88% during storage for a period

of one year.   Decrease in moisture content during storage was also reported in tomato rasam paste (Maity and Raju, 2014), Bharwa Spice-Mix Paste (Fransis *et al.,* 2019) and onion paste (Majid *et al.,* 2021).

Addition of salt to the paste of *Garcinia gummi-gutta* significantly increased the TSS content of the paste. Paste prepared with 9 % of salt recorded highest TSS of 22.60 °Brix and lowest (11.70 °Brix) was recorded for the control ((Fig 14). Upon storage there was an increase in TSS of the all the treatments and at the end of the storage *Garcinia* paste with 9% salt recorded a TSS of 23.63 °Brix. Devi *et al.*(2016) observed slight increase in TSS of ginger paste during storage. Common salt (10%) was added while preparing onion paste in order to increase total solouble solids of paste and during storage sugar parameters showed an increasing trend (Majid *et al.,*2021).

Addition of salt to the paste decreased total acidity of the prepared paste formulations and the acidity increased during storage. Acidity of paste without salt addition increased from 5 to 5.38 % at the end of storage. Paste prepared with 9% salt recorded acidity values as 4.80, 4.83, 4.87 and 4.95 % for 0, 1, 2 and 3 months of storage respectively. Promjiam *et al.(2013)* reported that acidity of garcinia keang-hleung paste with salt (20%) increased from 1.40 ± 0.02 to 1.56 ± 0.03 % at 5 month of storage. Increase in acidity and pH during storage of *Garcinia cambogia* paste was also reported by Bensi (2017). Similar report was shown by Majid *et al*. (2021) in onion paste and the increase in acidity might be due to conversion of sugars into acids present in the paste samples (Gamli and Ibrahim, 2007).

Hydroxy Citric Acid (HCA) content of paste treatments at the time of storage were not significantly affected by salt addition even though the paste prepared without addition of salt recorded the highest HCA of 4.72 % whereas paste with 9% salt recorded 4.40 %. During storage HCA content of all the paste treatments decreased.

Reducing sugar content of the paste samples didn't show any significant difference at the time of storage. During storage reducing sugar content in all paste treatments increased and the paste without addition of salt recorded the highest reducing sugar of 5.25%. Similar results were seen in low salt soya paste , were the reducing sugar contents was increased from 6th to 11th week of fermentation, and decreased afterward (Lee and Mok,2010).

Salt addition to paste had no significant effect on TFC content of paste and it ranged from 20.14 to 20.97 *mg QE g*$^{-1}$ at the time of storage. With respect to storage months TFC of the paste samples were increased from 20.58% at the time of storage to 28.82 *mg QE g*$^{-}$1 after third month of storage. Koh *et al.*(2012) observed that quercetin level had no change for a period of one year in tomato paste.

Antioxidant activity of the all the paste formulations were decreased during storage and paste prepared with 9% salt recorded highest activity of 87.64% after 3 months of storage . Bensi (2017) observed the similar result in *G. gummi-gutta* paste where antioxidant activity was recorded as 38.09% and 40.29 % at the end of 120 days of storage respectively. Zhang *et al.,* (2020*)* reported that NaCl effectively delayed the decrease in DPPH activity in grape juice.

 Fiber content varied from 4.34 to 4.37% among the formulations without any significant difference. During storage, fibre content of the paste prepared with 9 % salt was observed as observed as 4.37, 4.32 and 4.27 % after 1st, 2nd and 3rdmonth of storage respectively. The fibre content of the paste decreased significantly during storage.

5.4. 2.2 Colour Analysis

Colour L∗ values of the paste drastically reduced with storage. The value L* and b * of the *Garcinia* paste decreased during storage whereas the colorimetric index a* increased (Fig 15). The colour value indicates change of colour from yellow
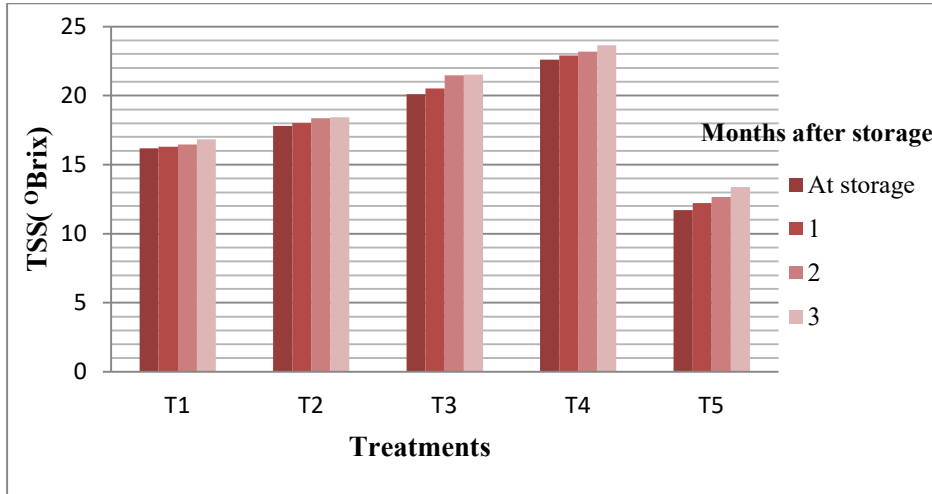
Fig. 14. Effect of storage on TSS (^{0}Brix) of *G. gummi-gutta* paste
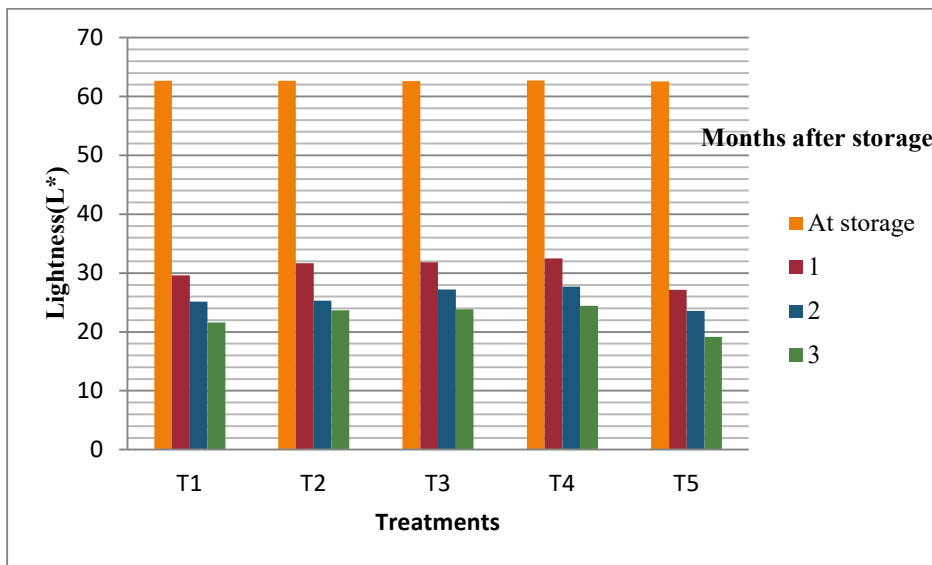
Fig. 15. Effect of storage on colour value (L*) of *G. gummi-gutta* paste
T_1 (3% salt) ,T_2 (5% salt) ;T_3 (7% salt); T_4 (9% salt); T_5 (Control)

to reddish brown during storage. This result is in agreement with Cosmai *et al.* (2017) and Difonzo *et al.* (2019) and could be due to moisture losses or pigment oxidation. There was an increasing trend in browning index of the paste during storage. Lowest browning index at the end of the storage was recorded for the paste prepared with 9% salt and it increased from 10.27 to 47.15 at the end of the storage (Fig 16). Paste without salt addition recorded the highest BI score (67.79%) at the end of three month storage and BI of all the formulation increased during storage. Browning not only reduced the visual quality of fruits but also resulted undesirable change in flavor and nutrition loss (Luo and Barbosa, 1997).Browning index, a measure of Maillard reaction and during storage colour of the pulp was changed from brown red to dark brown and then to black (Obulesu and Bhattaharya , 2011).

5.4. 2.3 Enumeration of Microbial Load

Total bacterial count in the paste increased with the storage time increased. Paste formulation without salt exhibited higher load for bacteria and fungal count. Data clearly showed that salt concentration significantly influenced in reduction of microbial load in the sample. Promjiam (2013) reported salt in *Garcinia* helped to prolong the shelf life of the paste in terms of microbiological quality Southern Sour Curry Paste, Keang-hleung. Rubila and Ranganathan (2016) reported that ginger paste could be stored at 5°C temperature for 60 days without any microbial infestation and maintained the colour, flavour and aroma.

5.4. 2.4 Sensory Qualities of Paste

Sensory evaluation of the sample was carried out for colour, flavour, taste and overall acceptability of the paste. Salt addition of paste significantly influenced the sensory quality *viz*., taste, and overall acceptability of the paste. Other parameters such as colour, texture and flavour where non significantly varied at storage. It was observed that ready to cook paste prepared with addition of 9% salt recorded highest
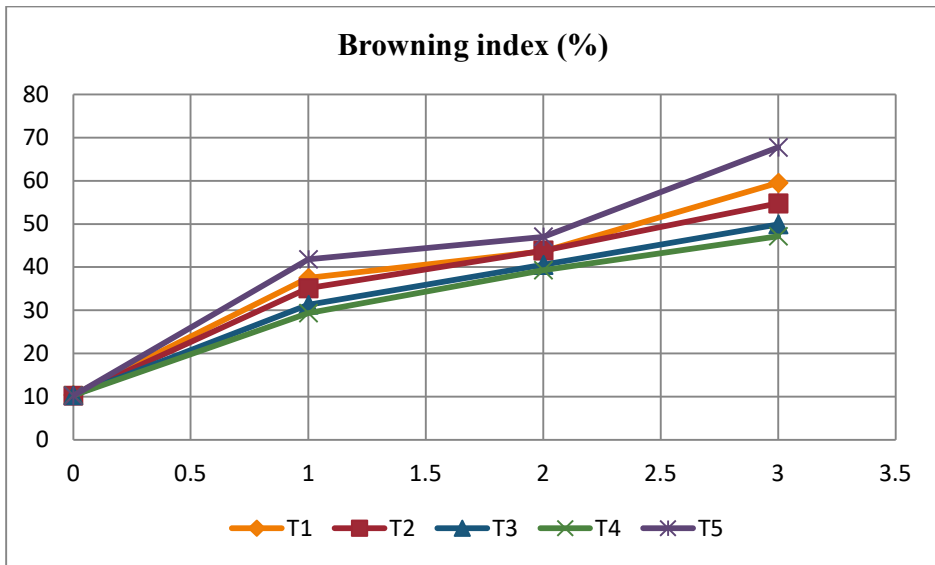
Fig. 16. Effect of storage on browning index of *G. gummi-gutta* paste

T_1 (3% salt), T_2 (5% salt); T_3 (7% salt); T_4 (9% salt); T_5 (Control)
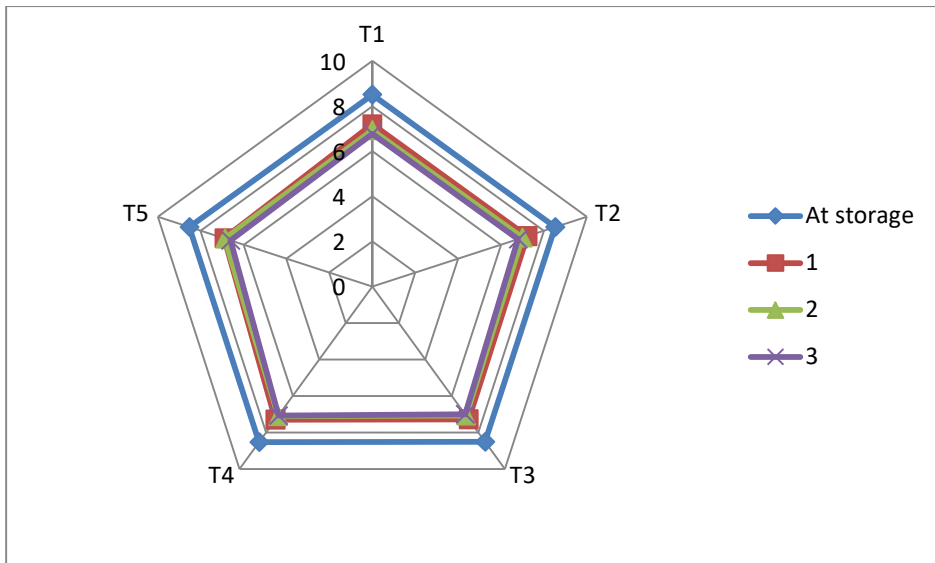
Fig. 17. Effect of storage on colour score of *G. gummi-gutta* paste

mean score for taste (8.58) and overall acceptability (8.63). At the end of storage ,colour values of the paste were drastically dropped from deep yellow to brown (Fig. 17). Sensory evaluation of tomato rasam paste showed that there was no significant difference in most of the sensory attributes during storage except colour (Maity and Raju., 2014)

5.4. 3 Development of Pickle

Pickles acts as food adjunct, appetizers and add palatability to foods along with their nutritional properties (Monika *et al.,* 2016). Biochemical, sensory and microbial enumeration of pickles were analysed and varied with the storage period. Sweet pickles were prepared from osmodehydrated (70^0Brix for 36 h) slices and sour pickles from fresh *G.gummi-gutta* slices.

5.4. 3.1 Biochemical Parameters

Total Soluble Solids (TSS) of pickle was 17.95 ^{0}Brix for sour pickle and 41.66 ^{0}Brix for sweet pickle at the time of storage. Storage period significantly increased TSS content of *Garcinia* pickles as shown in Fig 18. Singh *et al.* (2021) reported increase in TSS of cauliflower pickle during a storage period of three months. Similar trend was observed by Haokip *et al.*(2022) in mango pickle and they suggested that increase in the TSS value of pickles may be due to the mixing up of ingredients added during storage and loss of moisture during the storage of pickle.

Total Dissolved solids (TDS) is used to describe salinity level (Rusydi, 2019). At the time of storage, sour pickle recorded a TDS content of 6253.71 mg L^{-1} and sweet pickle recorded 3554.86 mg L^{-1}. During storage TDS content of both pickle decreased significantly indicating decrease of salinity during storage.

During fermentation, organic acids present in the fruits and vegetables slowly diffuses out into the brine solution, resulting in lowering pH and influenced

the growth of essential microbes across the surface of the material (Breidt *et al*. 2012). Sour pickle recorded a pH of 3.21 and sweet pickle recorded a pH of 4.30 at the time of storage.During storage of pickles pH was decreased upto 2 weeks and then slightly increased up to 10 weeks of storage. Haokip *et al* . (2022) observed that pH of mango pickles increased up to 1 month of storage and further decreased during 2nd and 3 rd months of storage. Sweet pickle and sour pickle recorded total acidity of 4.07 and 2.17 % respectively at the time of storage. During storage total acidity content was increased initially and further decreased (Fig 19). Results are in accordance with the finding of Lee *et al.* (2015) in aging and storage studies of bitter melon pickle. Thakur *et al.,* (2017) reported that acidity of mango seedling pickle decreased with increase in storage period

Sour pickle recorded a vitamin C content of 21.73 mg $100g^{-1}$ followed by sweet pickle of 15.13 mg $100g^{-1}$ at the time of storage. During storage vitamin C content decreased for both the pickles. . Manivasangan *et al* .(2007) observed loss of ascorbic acid during storage of sweet and sour karonda pickle.Gopakumar and Kavitha,(2014) observed Vitamin C retention (1.03 mg $100g^{-1}$) was more in sweet malabar tamarind pickle compared to spicy pickles Thakur *et al.* (2017) observed the same trend of decrease in ascorbic acid content during storage of seedling mango pickle.

Sour pickle recorded a total sugar content of 4.99 % and sweet pickle showed 24.17% at the time of storage while decreased during storage.This might be due to conversion of sugars to lactic acid in pickle (Manivasangan *et al.,*2007). Sour pickle (P$_1$) recorded a reducing sugar of 2.74 % and 13.46 % for sweet pickle at the time of storage which decreased significantly with storage. Lee *et al.* (2015) reported decrease in reducing sugar content of bitter melon pickle during storage.

The antioxidant activity was determined as 85.86 and 77.16 % respectively for treatments sour pickle and sweet pickle and during storage antioxidant activity of
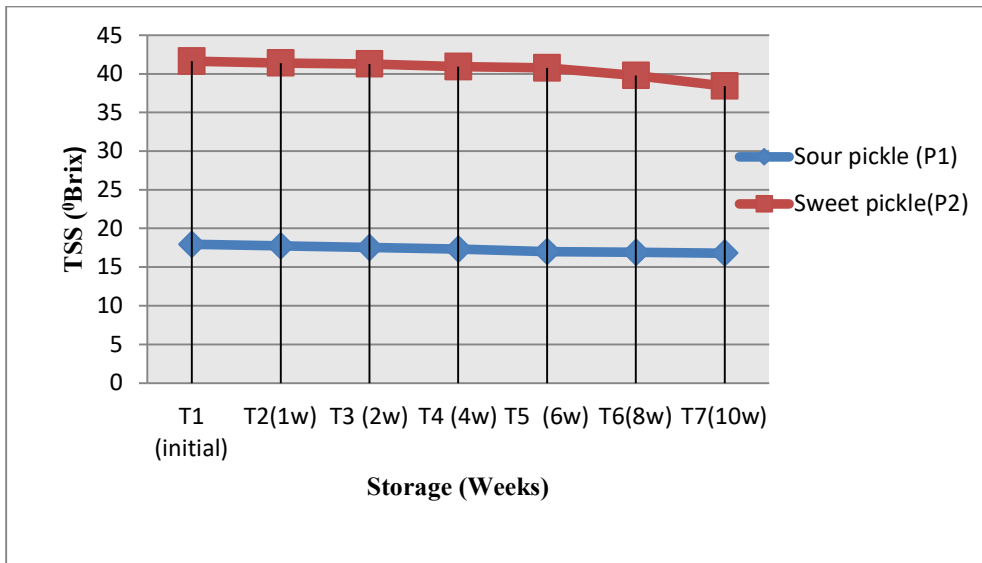
Fig. 18. Effect of storage on TSS (^{0}Brix) of *Garcinia* pickles
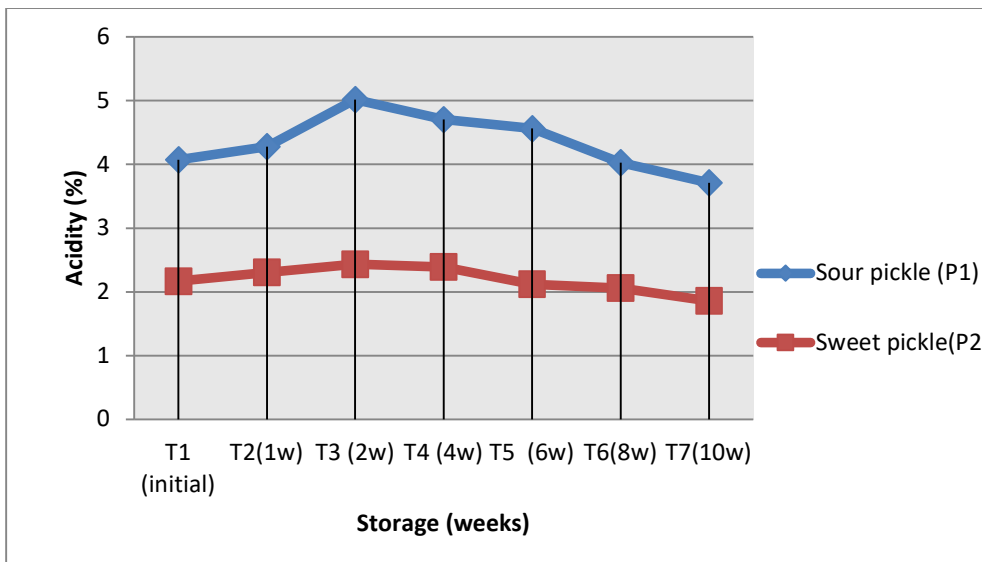
Fig. 19. Effect of storage on acidity (%) of *Garcinia* pickles

both pickles decreased. Nurul and Asmah (2012) reported papaya pickle is a poor source of antioxidant activity compared to fresh fruits. Khaskheli *et al.* (2017) reported fresh shiitake mushroom pickles with and without mustard oil exhibited scavenging activities.

5.4. 3. 2 Sensory Analysis

Pickling imparts unique and desirable changes in flavor, texture and color that take place over time in fermented pickles Behera *et al.* (2020). Soumya *et al.,* (2019) reported that kokum pickle can be developed with good sensory qualities. It was observed that sensory parameters taste, flavour, texture and overall acceptability of the both pickles were improved up to 4 weeks and decreased on further storage. At time of storage score for sensory characters of sour pickle (P_1)was 7.93 for taste, 8.67 for colour , 7.83 for flavour and 8.17 for overall acceptability . The highest sensory score for taste (8.23), flavour (8.27), texture (8.37) and overall acceptability (8.43) was recorded for sweet pickle (P_2) at 4th week of storage. Mean score for parameters *viz.,*taste, flavour, texture and overall acceptability of the sweet pickle was improved at 4 weeks of storage and further decreased up to 10 weeks. Sensory evaluation of mango pickle revealed that overall acceptability of pickles increased significantly with the increase in storage period Haokip *et al.*(2022). Mango oil pickle and vinegar pickle also scored higher which might be due to their gravy formation and salty pickle scored less due to its dryness. They also suggested that conversion of the insoluble fraction of pectin to soluble form might have resulted in softening of the pickle. Similar results were obtained for cauliflower pickle (Singh *et al.* 2021).

5.4 3.3 Enumeration of Bacterial load in Pickle

Monika *et al.* (2016) stated that addition of turmeric, red chilli and asafoetida powder will prevent microbial spoilage in pickles. Bacterial load for sour and sweet pickle increased during storage weeks and mould /fungal population was absent

throughout the storage period. The bacterial population of sour pickle increased from 2.16 log CFU g^{-1} at the time of storage to 4.95 log CFU g^{-1} after 10 weeks of storage.(Fig 20). Similar trend was observed for sweet pickle which recorded lowest population (1.47 log CFU g^{-1}) at the time of storage and 3.51 after 10 weeks. 1.47 log CFU g^{-1}. High salt content and acidity of pickle reduces the growth of harmful bacteria in the pickles (Mani *et al.,* 2017). Singh *et al.,* (2017) in mix-vegtable pickle reported increase in total bacterial count during storage.
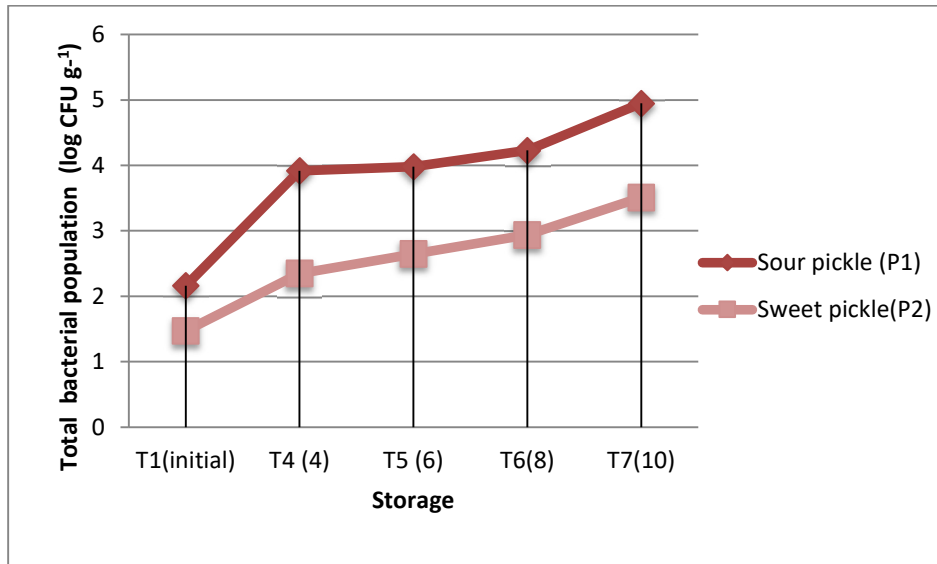
Fig. 20. Effect of storage on bacterial population (log CFU g⁻¹) of *Garcinia* pickles

Summary

6. SUMMARY

The present study entitled "Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala" was carried out in the Department of Postharvest Management of College of Agriculture, Vellayani during the period 2017-2021, with the objective to assess the bioactive compounds in major *Garcinia* spp. of Kerala *viz. G. gummi-gutta* (Malabar tamarind), *G. mangostana* (mangosteen), *G. xanthochymus* (yellow mangosteen) and development of value added products with nutraceutical importance

The study was carried out as four separate experiments

1. Assessment of bioactive compounds

2. Colour extraction from mangosteen pericarp

3. Development of nectar from *Garcinia* spp.

4. Value added products from *G. gummi-gutta*

Major findings of the study are summarized as below.

Pulp and pericarp of fruits of *G.gummi-gutta, G.mangostana* and *G.xanthochymus* were evaluated for biochemical quality parameters and secondary metabolites. Total soluble solids (TSS) present in all the three *Garcinia* fruits varied significantly. The highest TSS of 27.93 ^{0}Brix was recorded for the pericarp of *G.mangostana* and the lowest TSS of 11.13 ^{0}Brix was observed for *G.gummi-gutta* pericarp. *Garcinia xanthochymus* fruit recorded the highest acidity for pericarp (6.54%) and fruit pulp (6.18%) followed by *G.gummi-gutta* pericarp with 5.08% acidity. The lowest acidity (0.38 %) was observed in mangosteen pericarp and it was 1.03% for mangosteen pulp. Hydroxy Citric Acid (HCA) was highest (4.31%) in pericarp of Malabar tamarind followed by its pulp (0.92%). The HCA was not

detected in *G.mangostana* pericarp and *G.xanthochymus* (yellow mangosteen) pulp and pericarp.

Mangosteen fruit pulp noticed the highest ascorbic acid content of 33.80 mg 100g^{-1} followed by the yellow mangosteen fruit pulp with a content of 27.03mg 100g^{-1}. The highest reducing sugar (11.96 %) and total sugar content (13.31%) were recorded for mangosteen fruit pulp and rind recorded a lower value of 1.96%. The Malabar tamarind pulp recorded a reducing sugar of 7.17% which was statistically on par with yellow mangosteen fruit pulp (7.10 %), and the lowest reducing sugar was reported in mangosteen pericarp. *G.xanthochymus* (yellow mangosteen) noticed the highest protein of 5.24g 100g^{-1} and lowest protein (0.36g 100g^{-1}) was recorded in malabar tamarind pulp. Mangosteen pericarp recorded protein content of 5.18 g 100g^{-1} followed by yellow mangosteen fruit rind of 4.32 g 100g.$^{-1}$ The highest crude fibre content of 12.37 % was observed for mangosteen pericarp and malabar tamarind pulp recorded a lower value of 1.44% which showed no significant difference with fruit pulp (1.73%). The highest fat content of 1.35 mg 100g^{-1} was recorded by pericarp of *G.mangostana* followed by mangosteen pulp (0.51 mg 100g^{-1})

The highest total phenols was observed in mangosteen pericarp (2603.68 mg GAE 100 g $^{-1}$) followed by yellow mangosteen pericarp (1937.73 mg GAE 100g $^{-1}$). Total flavonoid content (TFC) of mangosteen pericarp was recorded as 61.55mg QE g^{-1} which was the highest and the total flavonoid content of *G.xanthochymus* pulp and pericarp were statistically on par and the values were 24.73 and 27.37 mg QE g^{-1} respectively. The pericarp of *G.mangostana* showed the highest antioxidant activity of 92.27 % with no significant difference with pericarp of *G.xanthochymus* (91.46 %) and *G. gummi-gutta* fruit pericarp (89.83 %). The fruit pulp of yellow mangosteen (*G. xanthochymus*) recorded the highest carotenoid content of   9.00 mg 100g^{-1} followed by its pericarp (8.51 mg 100g^{-1}). The pericarp of *G.mangostana* recorded the highest values for Ca (1910.00 ppm), K (3323.33 ppm) and Fe (9.235 ppm).

Calcium content in the pulp of *G. xanthochymus* was 920 ppm and all other *Garcinia* fruit pulp and pericarp showed no significant difference in calcium content

The major sugar in *G.gummi-gutta* fruit rind (pericarp) was fructose (8.850 ± 0.028mg g^{-1} DW) followed by ribose (4.87 ± 0.019 mg g^{-1} DW), and glucose (3.141 ± 0.033mg g^{-1} DW). Fructose (28.163 ± 0.813mg g^{-1} DW) and glucose (26.700 ± 0.436mg g^{-1} DW) were the major sugars in fruit pulp *G. mangostana* and *G. xanthochymus* recorded 25.842 ± 0.151 mg g^{-1} DW of fructose and 24.281 ± 0.187 mg g^{-1} DW glucose. Hydroxy Citric Acid was found as the major organic acid in *G. gummi-gutta* fruits and quantified as 547.458 ± 4.185mg g^{-1} DW flowed by citric acid (144.01 ± 1.383mg g^{-1} DW). Whereas in other two species, *G. mangostana* and *G. xanthochymus,* HCA was detected in lower quantity when analysed through LC-MS/MS..

The *G.gummi-gutta* fruit rind and pulp of mangosteen and yellow mangosteen had the highest levels for p-coumaric acid which was quantified as 104.81 ± 4.409µgg^{-1} DW, 335.70 ± 1.801µgg^{-1} DW and 353.155 ± 4.277 µgg^{-1} DW respectively. The epicatechin (18.699 ± 0.211 µgg^{-1}DW), luteolin (8.814 ± 0.791 µgg^{-1} DW, and catechin (6.688 ± 0.492 µgg^{-1} DW) were the most predominant flavonoids in *G.gummi-gutt*a whereas epicatechin and catechin were not detected in *G. mangostana*. Individual flavonoid hesperetin was the major flavonoid (36.980 ± 4.487µg g^{-1}DW) in *G. mangostana* fruits. *G.xanthochymus* fruits were rich in naringenin (44.424 ± 0.363µg g^{-1}DW) followed by luteolin (3.289 ± 0.037µg g^{-1}DW).

Natural polyisoprenylated benzophenones such as garcinol and isogarcinol were isolated by column chromatography followed by crystallization from the hexane extract of *G. indica* fruits. Another benzophenone xanthochymol was isolated by column chromatography from the hexane extract of *G.xanthochymus* fruits. The structures of the compounds were identified by spectroscopic methods like UV-Vis,

1H NMR and 13C NMR. HPTLC densitometry method was used to compare and quantify the benzophenones in three major *Garcinia* species. Results showed that garcinol was the major benzophenone in *G.gummi-gutta* (7.53%) and *G. xanthochymus* (8.26%) whereas *G.mangostana* fruits were high in isogarcinol (8.10%) composition. The major xanthone, α-mangostin was quantified in mangosteen rind as 3.62 % on dry weight basis.

The anthocyanin pigment was extracted from dried pericarp of mangosteen fruits by hot maceration using distilled water and ethanol as solvents, acidified at different levels with citric acid (0.1% and 0.2%) and acetic acid (1% and 2%). Based on higher yield (28.57 %), anthocyanin content (294.73 mg 100 g^{-1}), total phenols (1549.55 mg GAE 100 g^{-1}) and antioxidant activity (82.68 %) of the extracts, colour extracted with ethanol acidified using 2% acetic acid was selected as the best solvent system and was further utilized as natural colorant in *Garcinia* nectar formulations.

For the development of beverage formulations from *Garcinia* spp., *G. gummi-gutta* rind, mangosteen pulp and *G. xanthochymus*, was used with different fruit pulp concentration (15%, 20%) and TSS (15^0 Brix, 20^0 Brix, 25^0 Brix, 30^0 Brix). Biochemical quality parameters such as total acidity, vitamin C, total sugar, reducing sugar, antioxidant activity, total phenol content, total flavonoids and HCA were analyzed for all nectar formulations. Based on biochemical quality and sensory analysis of the formulations, *G. gummi-gutta* nectar prepared with 20 % fruit pulp and 20^0 Brix, *Garcinia mangostana* nectar formulation with 20% fruit with TSS 15^0 Brix and for *G. xanthochymus* nectar prepared with 15% fruit and 20^0 Brix were selected as the best formulation for addition of natural colour extracted from mangosteen pericarp.

The selected nectar formulation of *G. gummi- gutta* and *G. xanthochymus* was added with 0.5% mangosteen pericarp colour extract whereas 0.3 % was added to *G. mangostana* nectar. Incorporation of mangosteen colour extract to the *Garcinia* nectar significantly increased the TSS, acidity, vitamin C, sugars, total phenols and

antioxidant activity when compared with beverages prepared without addition of mangosteen pericarp colour. Storage stability studies of the nectar formulations were conducted under room temperature along with control (formulation without addition of natural colour). During storage, TSS, total acidity, total sugar and reducing sugar parameters of the nectars were increased whereas vitamin C, total phenols and antioxidant activity were shown decreasing trend. Effect of light on colour stability of the nectars was studied and nectar stored in amber bottles retained more anthocyanin than in transparent glass bottles. The temperature stability studies showed that with increase in temperature and time, total anthocyanin content of the beverages decreased. Sensory quality analysis of the nectar formulation revealed that beverages added with natural colour extract recorded the highest sensory mean score for colour and overall acceptability.

G.gummi-gutta fruit rind slices of 2cm^3 size were steam blanched and subjected to osmodehydration with sucrose as osmotic medium at different levels of osmotic concentration (50°Brix and 70°Brix) and immersion time (24, 36 and 48 h) and mass transfer and biochemical properties of osmodehydrated *G.gummi-gutta* rind were evaluated. Mass transfer characters of osmodehydrated *G.gummi-gutta* rind were significantly influenced by osmotic concentrations and immersion time. Osmodehydrated rind at 50 ^{0}Brix showed the lowest solid gain of 23.34 % and the highest solid gain (27.46 %) was observed for 70^{0}Brix osmotic concentration. Among the immersion time, 48 h recorded the highest solid gain of 28.11 % followed by 36 h with 25.79% of solid gain. Maximum water loss (49.10 %) was observed for rind osmosed in 70^{0}Brix, 48 h, while minimum water loss (22.31 %) was in treatment with osmotic concentration of 50^{0}Brix for immersion time of 24 h. The fruit slices osmosed in 70^{0}Brix for 48 h recorded maximum weight reduction of 29.00 % and the minimum weight reduction of 18.93 % was observed for osmodehydration in 50 ^{0}Brix, 24 h.

With increase in immersion time and concentration of sugar syrup, acidity decreased and lowest acidity of 1.54 % was observed for rind immersed in 70 ^{0} Brix for 48 h. Rind slices immersed at 70 ^{0}Brix for 36 h recorded total acidity of 1.67 % at storage. Total soluble solids of osmodehydrated samples increased with osmotic concentration and immersion time. With respect to storage months TSS of the osmodehydrated samples increased and the highest TSS content of 39.23 ^{0}Brix was observed after four month of storage and lowest value (37.53 ^{0}Brix) at the time of storage.

The highest total sugar of 48.04 % was recorded for rind osmosed in 70^{0}Brix for 48 h followed by 70^{0}Brix for 36 h (45.04 %) and the lowest total sugar of (36.20 %) was observed for rind in 50^{0}Brix for 24 h at storage. Fruit rind osmodehydrated in 70^{0}Brix for 48 h recorded a reducing sugar of 17.48 %, 70 ^{0}Brix , 36 h recorded 16.82% and 15.83% for malabar tamarind in 50^{0}Brix for 48 h at the time of storage. During storage TSS, acidity, total and reducing sugar content of the samples were significantly increased. Initial antioxidant activity was recorded as 78.38, 76.22 and 75.05 % respectively for treatments 50^{0}Brix for 24 h, 50^{0}Brix for 36 h and 70^{0}Brix for 24 h. The lowest antioxidant activity (67.12%) was for rind osmosed in 70 ^{0}Brix for 48 h. The longer the osmotic dehydration was, the lower the antioxidant activity was observed. HCA content of osmodehydrated malabar tamarind fruit rind showed significant difference among the treatments and storage period. During storage, HCA of the osmodehydrated treatment 70^{0}Brix for 36 h was observed as 1.39, 1.36 and 1.31 % after 1st, 2nd and 3rd month of storage respectively.

Sensory parameters *viz.,* taste, colour (golden yellow to light brown), flavour, texture and overall acceptability for osmodehydrated malabar tamarind fruits revealed that the highest mean score for taste (8.60) was recorded for osmodehydrated fruit in 70^{0}Brix for 36 h followed by 70^0 Brix for 48 h with 8.47 and 50^0 Brix for 48 h (8.17). On analyzing colour of the osmodehydrated products, the highest mean score (8.53)

was for fruit osmosed in 70^0 Brix for 48 h whereas the highest score for flavour (8.60) was recorded by the osmodehydrated fruit with the osmotic pre-treatment of 70^0 Brix for 36 h. The sensory scores for all osmodehydrated fruit samples recorded a decreasing trend during storage and were acceptable even after three months of storage. Microbial load for all the samples increased with storage time and was within the permitted limit only. All the treatment recorded lowest microbial population after first month storage. The lowest fungal load increased from 0.33 to 1.69 log CFU g^{-1} and bacterial load from 1.10 to 1.93 log CFU g^{-1} was observed for the treatment 70^0Brix for 48 h from the first month of storage to the end of third month storage.

The effect of salt concentration (3%, 5%, 7%, 9% and control) on quality parameters of the *G.gummi- gutta* (malabar tamarind) culinary paste for a period of three months were statistically analyzed.The paste treatment with 9% salt recorded initial moisture content of 78.33% and decreased to 78 .00% at the end of storage. Moisture content showed a decreasing trend in all the treatments over a storage period of three months at ambient conditions. Addition of salt to the paste of *Garcinia gummi-gutta* significantly increased the TSS content of the paste. Paste prepared with 9 % of salt recorded the highest TSS of 22.60 ^{0}Brix. *Garcinia* paste prepared without addition of salt recorded the highest HCA of 4.72 % whereas lowest value (4.40%) was for paste with 9% salt. During storage HCA content of paste samples were significantly decreased. Addition of salt to the paste decreased total acidity which increased during storage. Paste prepared with 9% salt recorded acidity values as 4.80, 4.83, 4.87 and 4.95 % for 0, 1, 2 and 3 months of storage respectively. Reducing sugar content of the paste increased during storage and addition of salt to paste had no significant effect on TFC content of paste and which ranged from 20.14 to 20.97 mg QE g^{-1} at the time of storage. Antioxidant activity of the all the paste treatments were decreased during storage and lowest activity was observed for the paste prepared with 9% salt (87.63%).

Salt treatment during preparation of paste significantly influenced the sensory quality *viz*., taste and overall acceptability and other attributes such as colour texture and flavour where non significantly varied at storage. It was observed that ready to cook paste prepared with addition of 9% salt recorded the highest mean score for taste (8.58) and overall acceptability (8.63). The value L* and b * of the *Garcinia* paste decreased during storage whereas the colorimetric index a* increased. There was an increasing trend in browning index (BI) of the paste during storage. Lowest browning index at the end of the storage was recorded for the paste prepared with 9% salt. The culinary paste prepared without salt addition recorded the highest BI score (67.79%) at the end of three months storage. *Garcinia* paste without salt treatment exhibited higher load for bacterial and fungal count.

Sweet pickles were prepared from osmo dehydrated (70^0Brix for 36 hours) slices and sour pickles from fresh *G.gummi-gutta* slices. Biochemical, sensory and microbial load of pickles were analyzed for 10 weeks. The TSS of pickle was 17.95 % for sour pickle and 41.66 % for sweet pickle at the time of storage and storage period significantly increased TSS content of *Garcinia* pickles. At the time of storage sour pickle recorded a TDS content of 6253.71 mg L^{-1} and sweet pickle recorded 3554.86 mg L^{-1}. With respect to ageing and storage months initially pH was decreased upto 2 weeks and then slightly increased up to 10 weeks of storage. Sweet pickle and sour pickle recorded total acidity of 4.07 and 2.17 % respectively at the time of storage. During ageing and maturation total acidity content increased initially and further decreased. Sour pickle recorded a vitamin C content of 21.73 mg $100g^{-1}$ followed by sweet pickle of 15.13 mg $100g^{-1}$ at the time of storage. During storage vitamin C content decreased from 18.43 mg $100g^{-1}$ to 16.07 mg $100g^{-1}$ at the end of 10 weeks storage. Sour pickle recorded a total sugar content of 4.99 % and sweet pickle showed 24.17 % at the time of storage. With respect to storage, total sugar content of the pickle decreased significantly and lowest reading 12.45 % was observed at the end of 10 weeks period. The antioxidant activity was reported as

85.86 and 77.16 % respectively for treatments sour pickle and sweet pickle at the time of storage. The highest antioxidant activity of 81.51 % was recorded at the time of storage and it reduced to 73.73% at the end of ten weeks.

It was observed that sensory parameters of the pickles were not significantly different with each other and sweet and sour pickles were acceptable by the semi trained panel. The sensory attributes, taste, flavour, texture and overall acceptability of the pickles were improved with ageing and decreased on further storage. During the ageing process taste characteristics of the pickles improved and recorded the highest scores after 4 weeks of storage as 8.40 (sour pickle) and 8.23 (sweet pickle) and the flavour also improved over maturation period. Bacterial load for the pickle increased during storage. Sweet pickle recorded the lowest bacterial load of 3.51 log CFU g^{-1} whereas sour pickle recorded highest load of 4.95 log CFU g^{-1} at the end of the storage and were within the permissible limit.

References

6. REFERENCES

Abas, F., Lajis, N. H., Israf, D. A., Khozirah, S., and Kalsom, Y. U. 2006. Antioxidant and nitric oxide inhibition activities of selected Malay traditional vegetables. *Food Chem*. 95: 566-573.

Abraham, Z., Malik, S. K., Rao, G. E., Narayanan.S. L., and Biju, S. 2006. Collection and characterisation of malabar tamarind (*Garcinia cambogia* (Gaertn.) Desr.). *Genet. Resour. Crop Evol*. 53: 401–406.

Afifah, R. A. and Niwat, C. 2015. The use of mangosteen pericarp (Garcinia mangostana L.) extract to fortify the green tea drink enchanced antioxidant activity. *Asia-Pacific J. Sci.Technol.20*(3)*:* 305-313.

Agustina, R., Andayani, R., and Dachriyanus, M. 2014. Development and validation of Thin-Layer Chromatographic method for determination of α-mangostin in young pericarp, ripe pericarp and bark extract of *Garcinia mangostana* L. using TLC-Densitometry. *Int. J. Res. Pharma. Sci.* 5(4): 294-298.

Ahmed, F., Zhao, J. H., Rui, H. U., Xiao, H. W., Yang, Y., Liu, Y., Gan, Z. N., and Yuan, Y. N. 2004. Osmotic dehydration pretreatment for improving the quality attributes of frozen mango: Effects of different osmotic solutes and concentrations on the samples. *Int. J. Food Sci. Technol.* 49(4): 960-968.

Aisha, A. F., Abdulmajid, A. M. S., Ismail, Z., Alrokayan, S. A., and Abusalah, K. M. 2016. Development of polymeric nanoparticles of *Garcinia mangostana* xanthones in Eudragit RL100/RS100 for anti-colon cancer drug delivery. *J. Nanomater*. 16(1): 385-386. Available: https://doi.org/10.1155/2015/701979 [06 Jan. 2023].

Akao, Y., Nakagawa, Y., and Nozawa, Y. 2008. Anti-cancer effects of xanthones from pericarps of mangosteen. *Int. J. Mol. Sci.* 9(3): 355–370.

Alajil, O., Sagar, V.R., Rudra, S.G., Sharma, R.R., Verma, M.K., Saha, S. and Dahuja, A. 2020. Influence of packaging and storage on the quality of osmodehydrated apricots (*Prunus armeniaca* L.). *Int. J. Chem. Stud. 8*(6): 1538-1543.

Amin, I. and Lee, W. Y. 2005. Effect of different blanching times on antioxidant properties in selected cruciferous vegetables. *J. Sci. Food Agric.* 85(13): 2314-2320.

Anantawan ,S and Petchlert, C. 2018. Antioxidant activity of some instant sour curry pastes. In: *Proceedings of 6th International Conference on Biochemistry and Molecular Biology*, 20-22 June 2018, Rayong, Thailand. Biochemistry and Molecular Section of the Science Society, Thailand, pp. 1-7.

Andersen, O. M. and Jordheim, M. 2013. Basic anthocyanin chemistry and dietary sources. In: Wallace, C.T. and Giusti, M. M.(eds), *Anthocyanins in Health and Disease*. CRC press, London, pp.13-89.

Aparna, G. S, Lekshmi, G. P. R., and Mini, C. 2022. Effect of osmo dehydration on quality attributes of bilimbi (*Averroha bilimbi*) Fruits. *Asian J. Dairy Food Res*. 41(1): 71-76.

AOAC, 1990. Official Methods of Analysis, 15th ed. AOAC (Association of Official Analytical Chemists), Washington, DC: 69–88.

Aparna, G. S. 2017. Development of osmo dehydrated bilimbi (*Averroha bilimbi* L.) and assessment of bioactive compounds. M.Sc.(Hort) thesis, Kerala Agricultural University, Thrissur, 121p.

Aparna, G. S., Lekshmi, G. P. R., Mini, C., and Chandran, T. T. 2018. Studies on sensory attributes and microbial analysis of stored osmo dehydrated bilimbi (*Averroha bilimbi*). *Asian J Dairy Food Res.* 37(2):154-157.

Aral, S. and Rameshkumar, K. B. 2016. Gamboge- The bark exudate from Garcinia species. In: Rameshkumar, K. B. (ed.), *Diversity of Garcinia species in the Western Ghats: Phytochemical Perspective.* Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram. Kerala, India, pp.162-169.

Aravind, A. P., Asha, K. R. T., and Rameshkumar, K. B. 2016. Phytochemical analysis and antioxidant potential of the leaves of *Garcinia travancorica* Bedd. *Nat. Product Res.* 30(2): 232-236.

Arazo, M., Bello, A., Rastrelli, L., Montelier, M., Delgado, L., and Panfet, C. 2011. Antioxidant properties of pulp and peel of yellow mangosteen fruits. *Emirates J. Food Agric.* 23(6): 517-524. Available: https://www.ejfa.me/index.php/journal/article/view/1284/938 [02 Feb 2023].

Archana, A. K. and Lekshmi, G. P. R. 2019. Mass transfer characters during osmo dehydration of red banana (*Musa* spp.). *J. Pharmacol. Phytochem.* 8(4): 2924-2928.

Arefin, S., Bhuiyan, M. H. R., Yeasmen, N., Islam, M. A., and Din, U. S. M. 2019. Study of ready to use onion paste for prolonged shelf life. *Progressive Agric.* 30(2): 219-226.

Attri, S. and Sharma, A. 2016. Standardization of recipes for preparation of sweet pickle from peach, *Prunus persica* L. Batsch fruit. *Int. J. Farm Sci.* 6(1): 148-155.

Azima, A. S., Noriham, A., and Manshoor, N. 2017. Phenolics, antioxidants and color properties of aqueous pigmented plant extracts: *Ardisia colorata* var. *elliptica*, *Clitoria ternatea*, *Garcinia mangostana* and *Syzygium cumini*. *J. Funct. Foods*. 38: 232-241.

Baggett, S., Mazzola, E. P., and Kennelly, E. J. 2005a. The benzophenones: Isolation, structural elucidation and biological activities. *Stud. Nat. Products Chem.* 32: 721-771. Available: https://www.doi.org/10.1016/S1572-5995(05)80067-5 [08 Jan. 2023].

Baggett, S., Protiva, P., Mazzola, E. P., Yang, H., Ressler, E. T., Basile, M. J., Weinstein, I. B., and Kennelly, E. J. 2005b. Bioactive benzophenones from *Garcinia xanthochymus* fruits. *J. Nat. Products*. 68(3): 354-360. Available: https://www.org/10.1021/np0497595 [02 Feb. 2023].

Bainto, L.C., Dizon, E.I. and Castillo-Isrel, K.A.T. 2018. Effects of various processing methods on hydroxycitric acid content of "batuan"[Garcinia binucao (Blanco) Choisy] fruits. *Int. Food Res. J.*25.

Barbosa, M. P., Rigolon, T. C. B., Borges, L. L. R., Queiroz, V. A.V., Stringheta, P.C. and de Barros, F.A.R. 2021. Effect of light, food additives and heat on the stability of sorghum 3-deoxyanthocyanins in model beverages. *Int. J. Food Sci. Technol.* 56(9): 4746-4755.

Behera, S. S., El Sheikha, A. F., Hammami, R., and Kumar, A., 2020. Traditionally fermented pickles: How the microbial diversity associated with their nutritional and health benefits. *J. Funct. Foods*. 70: 103-107.

Benny, A. 2003. Study on hydroxyl citric acid in *Garcinia*. Ph.D. (Chem.) thesis , Mahatma Gandhi. University, Ernakulam, 92p.

Bensi, P. S. 2017. Studies on encapsulation and value addition from *Garcinia cambigia* (Kudampuli) fruit. M.Sc. (Home sci.) thesis, Tamilnadu Agricultural University, Coimbatore. 155p.

Bhagavathi, T. P., Bensi, P. S., and Geetha, P. S. 2017. Sensory quality assessment of pineapple - *Garcinia cambogia* squash, principal component analysis. *J. Pharmacogn. Phytochem.* 6(5): 1359-1362.

Bharate, J. B., Vishwakarma, R. A., Bharate, S. B., Kushwaha, M., and Gupta, A. P. 2014. Quantification of the poly isoprenylated benzophenones garcinol and isogarcinol using multiple reaction monitoring LC/electrospray ionization-MS/MS analysis of ultrasound-assisted extracts of *Garcinia indica* fruits. *J. AOAC Int.* 97(5): 1317-1322.

Bhardwaj, R. L. and Pandey, S. 2011. Juice blends-a way of utilization of under-utilized fruits, vegetables, and spices: A review. *Crit. Rev. Food Sci. Nutr.* 51(6): 563-570.

Bheemaiah, M. M. and Kushalappa, B. A. 2019. Estimation and comparison of amount of organic acids from dried leaves of *Garcinia cambogia, Garcinia indica, Garcinia xanthochymus* and *Garcinia morella* by High-Performance Liquid Chromatography. *Pharmacogn. Res.* 11(1): 134-138.

Biswas, S. 2017. *Determination of total flavonoid content of different parts of Garcinia cowa* (Doctoral dissertation, East West University). 390p.

Bohra, P. and Waman, A. A. 2019. Morphological and biochemical studies in *Garcinia gummi-gutta* (L.) Roxb. *Erwerbs-Obstbau*. 61(3): 217-223. Available: https://doi.org/10.1007/s10341-019-00419-3 [18 Feb. 2023].

Breidt, F., McFeeters, R. F., Diaz, P. I., and Lee, H. C. 2012. Fermented vegetables. In: Doyle, P. M. and Buchann, L. R. (eds), *Food Microbiology: Fundamentals and Frontiers* (4th Ed). Blackwell Publishing, Oxford, pp. 841-855.

Cavalcante, I. H. L., Jesus, N. D., and Martins, A. B. G. 2006. Physical and chemical characterization of yellow mangosteen fruits. *Revista Brasileira de Fruticultura*. 28: 325-327.

Chaovanalikit, A. and Mingmuang, A., 2007. Anthocyanin and total phenolic content of mangosteen and its juices. *SWU Sci. J.* 23(1): 68-78.

Chaovanalikit, A., Mingmuang, A., Kitbunluewit, T., Choldumrongkool, N., Sondee, J., and Chupratum, S. 2012. Anthocyanin and total phenolics content of mangosteen and effect of processing on the quality of mangosteen products. *Int. Food Res. J.* 19(3): 1047-1053.

Chattopadhyay, S. K. and Kumar, S. 2006. Identification and quantification of two biologically active polyisoprenylated benzophenones xanthochymol and isoxanthochymol in *Garcinia* species using liquid chromatography–tandem mass spectrometry. *J. Chromatogr. B.* 844(1): 67-83. Available: https://doi.org/10.1016/j.jchromb.2006.07.045 [09 Feb. 2023].

Chattopadhyay, S. K. and Kumar, S. 2007. A rapid liquid chromatography–tandem mass spectrometry method for quantification of a biologically active molecule camboginol in the extract of *Garcinia cambogia*. *Biomed. Chromatogr.* 21(1): 55-66.

Chavan, U. D. 2012. Osmotic dehydration process for preservation of fruits and vegetables. *J. Food Res.* 1(2): 202-209.

Chen, H., Zuo, Y., and Deng, Y. 2001. Separation and determination of flavonoids and other phenolic compounds in cranberry juice by high-performance liquid chromatography. *J. Chromatogr.* 913(1-2):387-395

Chen, J.Y., Du, J., Li, M. L., and Li, C.M. 2020. Degradation kinetics and pathways of red raspberry anthocyanins in model and juice systems and their correlation with color and antioxidant changes during storage. *Food Sci. Technol.* 128: 102-109. Available: https://www.org/10.1016/j.lwt.2020.109448 [06 Feb. 2023].

Cheok, C. Y., Chin, N. L., Yusof, Y. A., Talib, R. A., and Law, C. L. 2013. Optimization of Total Monomeric Anthocyanin (TMA) and Total Phenolic Content (TPC) extractions from mangosteen (*Garcinia mangostana* Linn.) hull using ultrasonic treatments. *Ind. Crops Products*. 50: 1-7.

Cherian, S. 2016. Development of *Aloe vera* gel supplemented ready to serve fruit beverages. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 150p.

Choi, I. H., Noh, J. S., Han, J., Kim, H. J., Han, E., and Song, Y. O. 2013. Kimchi: A fermented vegetable, improves serum lipid profiles in healthy young adults: Randomized clinical trial. *J. Med. Food.* 16(3): 223- 229.

Chung, C., Rojanasasithara, T., Mutilangi, W., and McClements, D. J. 2016. Enhancement of colour stability of anthocyanins in model beverages by gum arabic addition. *Food Chem.* 201: 14-22.

Cilla, A., Perales, S., Lagarda, M. J., Barbera, R., Clemente, G., and Farre, R. 2011. Influence of storage and in vitro gastrointestinal digestion on total antioxidant capacity of fruit beverages. *J. Food Compos. Anal.* 24(1): 87-94. Available: https://www.doi.org/10.1016/j.jfca.2010.03.029 [27 Jan. 2023].

Cosmai, L., Caponio, F., Pasqualone, A., Paradiso, V. M., and Summo, C. 2017. Evolution of the oxidative stability, bio-active compounds and colour characteristics of non-thermally treated vegetable pates during frozen storage. *J. Sci. Food Agric.* 97: 4904–4911 Available: https://www.doi.org/10.1002/jsfa.8365 [21 Feb. 2023].

Croteau, R., Kutchan, T.M., and Lewis NG. 2000. Natural products (secondary metabolites). *Biochem. Mol. Biol. Plants*. 1250-1318

Cuesta-Rubio, O., Padron, A., Castro, H. V., Pizza, C., and Rastrelli, L. 2001. Aristophenones A and B: A new tautomeric pair of polyisoprenylated benzophenones from *Garcinia aristata*. *J. Nat. Prod*. 64(7): 973-975.

Cui, J., Hu, W., Cai, Z., Liu, Y., Li, S., Tao, W., and Xiang, H. 2010. New medicinal properties of mangostins: Analgesic activity and pharmacological characterization of active ingredients from the fruit hull of *Garcinia mangostana* L. *Pharma. Biochem. Behav*. 95(2): 166-172.

Dai, J. and Mumper, R. J. 2010. Plant phenolics: Extraction, analysis and their antioxidant and anticancer properties. *Molecules*. 15(10): 7313-7352.

Dar, B. N., Sharma, S., and Nayik, G. A. 2016. Effect of storage period on physiochemical, total phenolic content and antioxidant properties of bran enriched snacks. *J. Food Measurement Characteriz*. 10: 755-761.

Delgado-Vargas, F., Jiménez, A. R., and Paredes, L. O. 2000. Natural pigments: Carotenoids, anthocyanins, and betalains-characteristics, biosynthesis, processing, and stability. *Crit. Rev. Food Sci. Nutri*. 40(3): 173-289. https://Available: https://www.doi.org/10.1080/10408690091189257 [04 Feb. 2023].

Devi, T. B., Dash, S. K., Bal, L. M., and Sahoo, N. R. 2016. Physicochemical and microbiological characteristics of ginger paste (cv. *Suprabha*) during storage in different packaging and temperature conditions. *Cogent Food Agric.* 2(1): 23-32.

Deylami, M. Z., Rahman, R.A., Tan, C. P., Bakar, J. and Olusegun, L. 2016. Effect of blanching on enzyme activity, color changes, anthocyanin stability and extractability of mangosteen pericarp: A kinetic study. *J. Food Eng.* 178: 12-19.

Difonzo, G., Squeo, G., Calasso, M., Pasqualone, A., and Caponio, F. 2019. Physico-chemical, microbiological and sensory evaluation of ready-to-use vegetable pate added with olive leaf extract. *Foods*. 8(4): 138-139.

Dionello, R. G., Berbert, P. A., Molina, M. A., Pereira, R. C., Viana, A. P., and Carlesso, V. O. 2009. Osmotic dehydration of sliced pineapple of two cultivars in inverted sugar syrup. *Revista Brasileira de Engenharia Agricola e Ambiental Agriambi*.13(5): 596-605. Available: https://doi.org/10.1590/S1415-43662009000500013 [3 Feb. 2023].

Drenjancevic-Peric, I., Jelakovic, B., Lombard, J. H., Kunert, M. P., Kibel, A., and Gros, M., 2011. High-salt diet and hypertension: focus on the renin-angiotensin system. *Kidney Blood Press. Res.* 34(1): 1-11.

Du, C. T. and Francis, F. J. 1977. Anthocyanins of mangosteen, *Garcinia mangostana* L. *J. Food Sci.* 42: 1667-1669.

Enaru, B., Drețcanu, G., Pop, T. D., Stanila, A., and Diaconeasa, Z. 2021. Anthocyanins: Factors affecting their stability and degradation. *Antioxidants*. 10(12): 1967-1968.

Escher, G. B., Wen, M., Zhang, L., Rosso, N. D., and Granato, D. 2020. Phenolic composition by UHPLC-Q-TOF-MS/MS and stability of anthocyanins from *Clitoria ternatea* L. (butterfly pea) blue petals. *Food Chem.* 331(3):127341-127349. Available: https://www.doi.org/10.1016/j.food chem.2020.127341 [23 Feb. 2023].

Espinosa-Acosta, G., Ramos, J. A. L., Molina, G. A., Maya C. J., Esparza, R., Hernandez, M. A. R., and Estevez, M. 2018. Stability analysis of anthocyanins using alcoholic extracts from black carrot (*Daucus carota* ssp. *sativus* var. *atrorubens* Alef.). *Molecules.* 23(11): 2744-2751.

Etienne, C., Moing, A., Dirlewanger, E., Raymond, P., Monet, R., and Rothan, C. 2002. Isolation and characterization of six peach cDNAs encoding key proteins in organic acid metabolism and solute accumulation: involvement in regulating peach fruit acidity. *Physiologia Plant.* 114(2): 259-270. Available: https://www.doi:10.1034/j.1399-3054.2002.1140212.x. [12 Jan. 2023].

Famiani, F., Battistelli, A., Moscatello, S., Cruz, C. J. G., and Walker, R. P. 2015. The organic acids that are accumulated in the flesh of fruits: Occurrence, metabolism and factors affecting their contents-A review. *Revista Chapingo. Serie horticultura.* 21(2): 97-128.

Fiaz, K., Quddoos, M. Y., Nadeem, M., Yaqub, S., Batool, S. A., Rafique, A., Chaudhry, F., Noreen, S., Hussain, A., Qadeer, Z., and Kauser, S. 2022. Development and quality characterization of sapodilla ready to serve (RTS) drink. *Discov. Food.* 2(1): 1-8.

Flamini, R., Mattivi, F., De Rosso, M., Arapitsas, P. and Bavaresco, L. 2013. Advanced knowledge of three important classes of grape phenolics:

anthocyanins, stilbenes and flavonols. *Int. J. molecu. sci.* 14(10): 19651-19669.

Francis, A., Singh, S. K., Shukla, R. N., Atul, E. R., and Mishra, A. 2019. Sensory assessment of ready-to-use bharwa spicemix paste. *J. Pharmacogn. Phytochem.* 8(1): 1418-1422.

Fugal, K., Causland, T. M., Kou, X., and Keller, W. 2006. Neutraceutical composition containing mangosteen pericarp extract. United States Patent No. US200600088643A1 Available: https://patents.google.com/patent/US20060088643A1/en. [18 Dec. 2022].

Galaffu, N., Bortlik, K., and Michel, M. 2015. An industry perspective on natural food colour stability. In: Scotter, M. J. (ed.), *Colour Additives for Foods and Beverages.* Woodhead Publishing, Oxford, pp. 91-130. Available: https://www.doi.org/10.1016/B978-1-78242-011 [13 Feb. 2023].

Gamli, F. O. and Ibrahim, H. 2007. The effect of the different packaging and storage conditions on the quality of pistachio nut paste. *J. Food Eng.* 78(2): 443-448. Available: https://www.doi.org/10.1016/j.jfood eng.2005.10.013 [12 Feb. 2023].

Gautam, D., Jain, S. K., Bhatnagar, P., Meena, N., and Chippa, H. 2021. Utilization of custard apple pulp for preparation of blended nectar. *Indian J. Hortic.* 78(2): 229-235.

Geetha, N. S., Kumar, S., and Garg, M. K. 2005. Osmotic concentration kinetics of aonla preserve [abstract]. In: Abstracts, *Annual convention of Indian society of Agricultural Engineers,* 7-9, August, 2005, Hisar. Indian Society of Agricultural Engineers, Hisar, p.39. Abstract No. 278

Gerardi, C., Tommasi, N., Albano, C., Blando, F., Rescio, L., Pinthus, E., and Mita, G. 2015. *Prunus mahaleb* L. fruit extracts: A novel source for natural food pigments. *Eur. Food Res. Technol.* 241(5): 683-695.

Giusti, M. M. and Wallace, T. C. 2009. Flavonoids as natural pigments. In: Bechtold, T. (ed.), *Handbook of natural colorants*. John Wiley and Sons Publishing, New York, pp. 257-272.

Gogoi, B., Das, R. P., and Barua, U. 2016. Antioxidant activity of *Garcinia* species of Assam. *Int. J. Agric. Sci.* 8(29): 1611-1612.

Gonzalez-Perez, J. E., Jimenez, G. O., Ramirez, C. N., Guerrero, B. J. A., and Lopez, M. A. 2022. Vacuum impregnation on apples with grape juice concentrate: Effects of pressure, processing time, and juice concentration. *Innovative Food Sci. EmergTechnol.* 77(3): 102981-102983.

Gopakumar, A. S. and Kavita, M. S. 2014. Processing and preservation qualities of value added products based on *Garcinia cambogia* (Malabar Tamarind). *J. Environ. Sci. Toxicol. Food Technol.* 8(1): 1-9.

Guo, M., Wang, X., Lu, X., Wang, H.,and Brodelius, P. E. 2016. α-Mangostin Extraction from the Native Mangosteen (*Garcinia mangostana* L.) and the Binding Mechanisms of α-Mangostin to HSA or TRF. *PLoS One*. 11(9): 234-238. Available: https://www.doi.org/10.1371/journal.pone.0161566 [23 Jan.2023].

Gutierrez, O. F. and Failla, M. L. 2013. Biological activities and bioavailability of mangosteen xanthones: A critical review of the current evidence. *Nutr*. 5(8): 3163-3183.

Hammer, K. 2001.Guttiferae (Clusiaceae). In: Hanelt, P. and Institute of Plant Genetics and Crop Plant Research (eds), *Mansfeld's Encyclopedia of Agricultural and Horticultural Crops*, Springer, Berlin, pp. 1345–1360.

Hanafi, S. M. S., Candra, I., and Henny, R. 2017. Effect gelatine of the characteristic functional drink from mangosteen peel extract (*Garcinia mangostana*). *J. Pharmacogn. Phytochem.* 6(4): 332-335.

Hande, A. R., Swami, S. B., and Thakor, N. J. 2016. Open-air sun drying of Kokum (*Garcinia indica*) rind and its quality evaluation. *Agric. Res.* 5(4): 373-383.

Haokip, H., Singh, A., and Abonmai, T. 2022. Changes in physico-chemical properties of mango pickle during storage. *Int. J. Plant Soil Sci.* 34(23): 884-890.

He, B., Ge, J., Yue, P., Yue, X., Fu, R., Liang, J. and Gao, X., 2017. Loading of anthocyanins on chitosan nanoparticles influences anthocyanin degradation in gastrointestinal fluids and stability in a beverage. *Food Chem.* 221 :1671-1677.

Hellstrom, J., Mattila, P., and Karjalainen, R. 2013. Stability of anthocyanins in berry juices stored at different temperatures. *J. Food Compos. Anal.* 31(1): 12-19.

Hemalatha, R., Kumar, A., Prakash, O., Supriya, A., Chauhan, A. S., Kudachikar, V. B. 2018. Development and Quality Evaluation of Ready to Serve (RTS) Beverage from Cape Gooseberry (*Physalis peruviana* L.). *Beverages*. 4(2): 42-45. Available: https://www.doi.10.3390/beverages4020042. [2 Feb. 2023].

Hemshekhar, M., Sunitha, K., Santhosh, M. S., Devaraja, S., Kemparaju, K., Vishwanath, B. S., Niranjana, S. R., and Girish, K. S. 2011. An overview on

genus *Garcinia*: Phytochemical and therapeutical aspects. *Phytochem. Rev.* 10(4): 325–351.

Hiranrangsee, L., Kumaree, K. K., Sadiq, M. B., and Anal, A. K. 2016. Extraction of anthocyanins from pericarp and lipids from seeds of mangosteen (*Garcinia mangostana* L.) by Ultrasound-assisted extraction (UAE) and evaluation of pericarp extract enriched functional ice-cream. *J. food sci. technol.* 53(10): 3806-3813.

Ho, H. C., Chao, C. C., Han, Y. W., and Tzou, C. H. 2011. Application of taguchi method to optimize extracted ginger oil in different drying conditions. In: Dan, Y. and Baby, S. (eds), *Proceedings of twelth International Conference on Food Engineering and Biotechnology*, 7-9 May 2011, Bangkok. Asia-Pacific Chemical, Biological and Environmental Engineering Society, Hong Kong, pp.62-69.

Hossain, M. A., Dey, P., and Joy, R. I. 2021. Effect of osmotic pretreatment and drying temperature on drying kinetics, antioxidant activity, and overall quality of taikor (*Garcinia pedunculata* Roxb.) slices. *Saudi J. biol. sci.* 28(12): 7269-7280.

Hosseini, S., Gharachorloo, M., Ghiassi,T. B., and Ghavami, M. 2016. Evaluation the organic acids ability for extraction of anthocyanins and phenolic compounds from different sources and their degradation kinetics during cold storage. *Pol. J. Food Nutr. Sci.* 66(4):23-28.

Hu, B., Liu, X., Zhang, C. and Zeng, X., 2017. Food macromolecule based nanodelivery systems for enhancing the bioavailability of polyphenols. *J. Food Drug anal.* 25(1) :3-15.

Hutabarat, R. P., Xiao, Y.D., Wu, H., Wang, J., Li, D.J. and Huang, W.Y. 2019. Identification of anthocyanins and optimization of their extraction from rabbiteye blueberry fruits in Nanjing. *J. Food Quality. 2019.*

Ibnusaud, I., Puthiaparampil, T.T., and Thomas, B. 2000. Department of Science, Technology of Ministry of Science and Technology India. *Convenient method for the large scale isolation of garcinia acid.* U.S. Patent 6,147,228.

Jackson, M. L. 1973. *Soil chemical analysis: Advanced Course* (2nd Ed.). Parallel Press, Madison, p.511.

Janhavi, P., Sindhoora, S. and Muthukumar, S. P. 2020. Bioaccessibility and bioavailability of polyphenols from sour mangosteen (*Garcinia xanthochymus*) fruit. *J. Food Measurement. Character.*14(4): 2414-2423. Available: https://www.doi.org/10.1007/s11694-020-00488-z [22 Jan. 2023].

Jayaprakasha, G. K. and Sakariah, K. K. 2002. Determination of organic acids in leaves and rinds of *Garcinia indica* (Desr.) by LC. *J. Pharma. Biomed. Anal.* 28(2): 379-384.

Jayashree, E. and Susanna, R. K. 2023. Changes in physico-chemical characteristics of kokum (*Garcinia indica*) based RTS beverage during storage. *Pharma Innovation J.* 12(2): 1552-1559.

Jena, B. S., Jayaprakasha, G. K., Singh, R. P., and Sakariah, K.K. 2002. Chemistry and Biochemistry of (-)-Hydroxycitric Acid from Garcinia. *J. Agric. Food Chem.* 50: 10-22.

Joseph, K. S., Bolla, S., Joshi, K., Bhat, M., Naik, K., Patil, S., Bendre, S., Gangappa, B., Haibatti, V., Payamalle, S., and Shinde, S. 2017. Determination of chemical composition and nutritive value with fatty acid compositions of

African Mangosteen (*Garcinia Livingstonei*) *Erwerbs-Obstbau*. 59: 195-202. Available: https://www.doi.org 10.1007/s10341-016-0311-9 [03 Mar. 2023].

Jung, H. A., Su, B. N., Keller, W. J., Mehta, R. G., and Kinghorn, A. D. 2006. Antioxidant xanthones from the pericarp of *Garcinia mangostana* (Mangosteen). *J. Agric. Food Chem.* 54(6): 2077-2082.

Kalick, L. S., Khan, H. A., Maung, E., Baez, Y., Atkinson, A.N., Wallace, C.E., Day, F., Delgadillo, B.E., Mondal, A., Watanapokasin, R. and Barbalho, S.M. 2022. Mangosteen for malignancy prevention and intervention: Current evidence, molecular mechanisms, and future perspectives. *Pharmacol. Res:* 106630.

Kaomongkolgit, R., Jamdee, K., and Chaisomboon, N. 2009. Antifungal activity of alpha-mangostin against *Candida albicans*. *J. Oral Sci. 51*(3): 401-406.

Karovicova, J., Drdak, M., Greif, G., and Hybenova, E. 1999. The choice of strains of *Lactobacillus* species for the lactic acid fermentation of vegetable juices. *Eur. Food Res. Technol. 10*: 53-56.

Karpagavalli, B. and Amutha, S. 2015. Influence of storage condition on the antioxidant activity of pomegranate squash. *Plant Arch*. 15(1): 405-410.

Kashyap, C. 2022. Influence of storage duration on chemical changes in flavoured custard apple (*Annona squamosa* L.) shake. *Pharma Innovation J.* 11(11): 1550-1552.

Katsoufi, S., Lazou, A. E., Giannakourou, M. C., and Krokida, M. K. 2017. Mass transfer kinetics and quality attributes of osmo-dehydrated candied pumpkins using nutritious sweeteners. *J. Food Sci. Technol.* 54(10): 3338-3348.

Kaur, C. and Kapoor, H. C. 2001. Antioxidants in fruits and vegetables-The millennium's health. *Int. J. Food Sci. Technol.* 36(7): 703–725.

Kaur, R., Chattopadhyay, S. K., Tandon, S. and Sharma, S., 2012. Large scale extraction of the fruits of Garcinia indica for the isolation of new and known polyisoprenylated benzophenone derivatives. *Ind. crops products*, 37(1): 420-426.

Khoo, H. E., Ismail, A., Esa, M. N., and Idris, S. 2008. Carotenoid Content of Underutilized Tropical Fruits. *Plant Foods Hum. Nutr.* 63(3): 170–175. Available: https://www.doi.org/10.1007/s11130-008-0090-z [23 Jan. 2023].

Kim., S. K., Jung, H. J., Song, H. C., Sung, J. B. and Bong, Ju. S. 2003. The Effects of Combination of Functional Beverage (*Garcinia cambogia*, L-Carnitine, and Soy Peptide) and Exercise on the Improvement of Body Fat. *Biomolecules Ther.* 11(2): 99-108.

Khaskheli, A. A., Khaskheli, S. G., Liu, Y., Sheikh, S.A., Wang, Y.F., Soomro, A.H. and Huang, W. 2017. Analysis of physicochemical, antioxidant properties and sensory characteristic of shiitake mushroom pickles. *J. Food Nutri. Res. 5*(8): 562-568.

Koh, E., Charoenprasert, S., and Mitchell, E. A. 2012. Effects of industrial tomato paste processing on ascorbic acid, flavonoids and carotenoids and their stability over one-year storage. *J. Sci. Food Agric.* 92(1): 23-28. Available: https://www.doi/10.1002/jsfa.4580 21 Jan.2023].

Kong, J. M., Chia, L. S., Goh, N.K., Chia, T.F. and Brouillard, R. 2003. Analysis and biological activities of anthocyanins. *Phytochemistry*, *64*(5): 923-933.

Kowalska, H., Trusinska, M., Rybak, K., Wiktor, A., Witrowa, R. D., and Nowacka, M. 2023. Shaping the Properties of Osmo-Dehydrated Strawberries in Fruit Juice Concentrates. *Appl. Sci.* 13(4): 2728-2729.

Kowalski, S. J. and Mierzwa, D. 2011. Influence of preliminary osmotic dehydration on drying kinetics and final quality of carrot (*Daucus carota* L). *Chem. Eng. Process.* 32(3):185-194.

Krishnamurthy, N., Lewis, Y. S., and Ravindranath, B. 1982. Chemical constituents of kokam fruit rind. *J. Food Sci. Technol.* 19(3): 97-100.

Kumar, P. S. N., Gowda, D. G. B., Mantelingu, K., and Rangappa, K. S. 2013. Development and validation of a reversed-phase HPLC method for the analysis of garcinol and isogarcinol in *Garcinia indica. J. Pharmacol. Res.* 7(2): 103-106.

Kumar, S., Sharma, S., and Chattopadhyay, S. K. 2009. High-performance liquid chromatography and LC-ESI-MS method for identification and quantification of two isomeric polyisoprenylated benzophenones isoxanthochymol and camboginol in different extracts of *Garcinia* species. *Biomed. Chromatogr.* 23(8): 888-907.

Lacombe, A., Wu, V. C. H., Tyler, S., and Edwards, K. 2010. Antimicrobial action of the American cranberry constituents: Phenolics, anthocyanins, and organic acids against *Escherichia coli* 0157 H7. *Int. J. Food Microbiol.* 139:102-107.

Lago-Vanzela, E. S., Ramin, P., Umsza, G. M. A., Santos, G. V., Gomes, E., and Silva, R. D. 2011. Chemical and sensory characteristics of pulp and peel caja-manga(*Spondias cytherea* Sonn.) jelly. *Food Sci. Technol.* 31: 398-405.

Landim, A. P. M., Barbosa, M. I. M. J., and Júnior, J. L. B. 2016. Influence of osmotic dehydration on bioactive compounds, antioxidant capacity, color and texture of fruits and vegetables: A review. *Cienc. Rural*. 46(10): 1714-1722.

Lee, H. Y., Park, K .S., Joo, O. S., Hwang, C. E., Ahn, M. J., Jeong, Y. S., Hong, S. Y., Kwon, O. K., Kang, S. S., Yuk, H. J., and Kim, H. R. 2015. Changes in quality characteristics and antioxidant activity of bitter melon (*Momordica charantia* L.) pickle during ageing. *J. Korean Soc. Food Sci. Nutr.* 44(3): 401-411.

Lee, J. Y. and Mok, C. K. 2010. Changes in physicochemical properties of low salt soybean paste (Doenjang) during fermentation. *Food Eng. Prog*. 14(2): 153-158.

Lee, J., Durst, R.W. and Wrolstad, R.E. 2002. Impact of juice processing on blueberry anthocyanins and polyphenolics: Comparison of two pretreatments. *J.Food sci.* 67(5): 1660-1667.

Liao, C. H., Sang, S., Ho, C. T., and Lin, J. K. 2005. Garcinol modulates tyrosine phosphorylation of FAK and subsequently induces apoptosis through down-regulation of Src, ERK, and Akt survival signaling in human colon cancer cells. *J. cell. biochem.* 96(1): 155-169.

Lim, G. W., Jafarzadeh, S., and Norazatul, H. M. R. 2020. Kinetic study, optimization and comparison of sun drying and superheated steam drying of asam gelugor (*Garcinia cambogia*). *Food Res*. 4(2): 396-406.

Lim, T. K. 2012. *.Edible medicinal and non-medicinal plants: Vol. 1.Fruits.* Springer, London, pp. 21-128.

Lourith, N. and Kanlayavattanakul, M. 2011. Biological activity and stability of mangosteen as a potential natural color. *Biosci. Biotechnol. Biochem.* 75(11): 2257-2259.

Louter-van de Haar, J., Wielinga, P. Y., Scheurink, A. J., and Nieuwenhuizen, A. G., 2005. Comparison of the effects of three different (-)-hydroxycitric acid preparations on food intake in rats. *Nutr. Metabolism*. 2(1): 1-9.

Luo, Y. and Barbosa-Canovas, G. V. 1997. Enzymatic browning and its inhibition in new apple cultivars slices using 4-hexyl resorcinol in combination with ascorbic acid. *Food Sci. Technol. Int.* 3(3): 195-201.

Machado, Y. J., Murillo, A. W., and Hennessey, R. L. 2022. Evaluation of peel extract of mangosteen as a dye natural and antioxidant and its use as an additive in a fruit beverage. *Iraqi J. Agric. Sci.* 53(4): 857-866.

Magadula, J. J., and Z. H. Mbwambo. 2014. Garcinia Plant Species of African Origin: Ethnobotanical, Pharmacological and Phytochemical Studies. *Open sci.* 17-70.

Mahabusarakam, W., Wiriyachtra, P., and Taylor, W. 1987. Chemical constituents of *Garcinia mangostana*. *J. Nat. Prod.* 50: 474–478.

Mai, D. S., and Tan, L. V. 2013. Study the anthocyanin extraction from the rind of mangosteen (*Garcinia mangostana*) in Vietnam. International Conference on Environment, Energy and Biotechnology, 51: 28- 31. doi:10.7763/IPCBEE

Maity.,S and Raju, P. S. 2014. Development of tomato sambar paste stabilized by hurdle technology and evaluation of storage stability. *J. Culinary Sci. Technol*. 12(2): 153-157. Available: https://www.doi.org/10.1080/15428052.2014.880096 [23 Feb. 2023].

Majid, I., Dar, B., Nanda, V., Alwahibi, M. S., Alkahtani, J., Elshikh, M. S., Usmani, S., and Ansari, M. J. 2021. Rheological behavior and storage studies of sprouted onion pastes from four onion varieties. *J. King Saud Univ. Sci.* 33(2): 78-84. Available: https://www.doi.org/10.1016/ j.jksus.2020.101271 [21 Jan. 2023].

Makris, D. P., Boskou, G., and Andrikopoulos, N. K. 2007. Polyphenolic content and in vitro antioxidant characteristics of wine industry and other agri-food solid waste extracts. *J. Food Compos. Anal.* 20(2): 125-132. Available: https://www.doi.org/10.1016/j.jfca.2006.04.010 [21 Jan. 2023].

Mani, A., Ghosh, A., Dey, K., and Bhattacharjee, A. 2017. Effect of sodium substitution on lactic acid bacteria and total bacterial population in lime pickle under ambient storage conditions. *Pharma Innovation J.* 6(11): 682-686.

Manivasagan, S., Rana, G. S., Joon, M. S., and Godara, A. K. 2007. Study on qualitative changes in pickles prepared from karonda (*Carissa carandas* Linn.) during storage. *Haryana J. Hortic. Sci.* 36(1/2): 44-45.

Manurakchinakorn, S., Chainarong, Y., and Sawatpadungkit, C. 2016. Quality of mangosteen juice colored with mangosteen pericarp. *Int. Food Res. J.* 23(3): 1033-1036.

Maran, J. P., Sivakumar, V., Thirugnanasambandham, K., and Sridhar, R. 2015. Extraction of natural anthocyanin and colors from pulp of jamun fruit. *J. Food Sci. Technol.* 52: 3617-3626.

Masullo, M., Bassarello, C., Suzuki, H., Pizza, C., and Piacente, S. 2008. Polyisoprenylated benzophenones and an unusual polyisoprenylated

tetracyclic xanthone from the fruits of *Garcinia cambogia*. *J. Agric. Food Chem*. 56: 5205-5210.

Masullo, M., Cerulli, A., Cannavacciuolo, C., Kılınç, H., Pizza, C., and Piacente, S. 2022. *Garcinia mangostana* L. fruits and derived food supplements: Identification and quantitative determination of bioactive xanthones by NMR analysis. *J. Pharma. Biomed. Anal.* 218(3): 114835-114839.

Matsumoto, K., Akao, Y., Kobayashi, E., Ohguchi, K., Ito, T., Iinuma, M., and Nozawa, Y. 2003. Induction of apoptosis by xanthones from mangosteen in human leukemia cell lines. *J. Nat. Prod.* 66: 1124–1127.

Mattila, P. and Hellstrom, J. 2007. Phenolic acids in potatoes, vegetables, and some of their products. *J. Food Compos. Anal.* 20(3-4): 152-160.

Mauro, M. A., Monnerat, S. M., and Rodrigues, A. E. 2004. Vacuum drying of osmotic dehydrated apple slices. In: Silva, A. M.(ed.), *Proceedings of Fourteenth International Drying Symposium (IDS),* 22-25 August 2004, Sao Paulo City, Brazil. Institute of Biosciences, Language, and Physical Sciences, Department of Food Engineering and Technology, Sao Paulo City, Brazil, pp. 2084-2090.

Mayefis, D., Anugerah, Y., and Rasyid, R., 2019. Determination of total xanthone content in the preparation of mangosteen pericarp capsules (*Garcinia mangostana* L.) Available on the market using UV-Visible spectrophotometry method. *Majal Obat Tradisional*. 24(2): 98-103.

Mishra, P. K., Mishra, V. K., Mauryala, V. K., Chaurasiya, J., Sahay, S., Mauriya, A. K., and Tyagi1a, S. 2016. Evaluation of packaging containers for storage of osmo-dehydrated product of Mango. *Ecol. Environ. Conserv.* 22(2): 635-640.

Misra, H., Dwivedi, B.K., Mehta, D., Mehta, B.K. and Jain, D. C. 2009. Development and validation of high performance thin-layer chromatographic method for determination of [alpha]-mangostin in fruit Pericarp of Mangosteen Plant (*Garcinia mangostana L.*) using Ultraviolet-Visible Detection. *Records Nat. Products*. 3(4): 178.

Mongkontanawat, N., Phuangborisut, S., Chanawanno, T., and Khunphutthiraphi, T. 2022. Product development of functional beverage from mangosteen juice supplemented with high anti-inflammatory activity herbal plants from Thailand. *Technol.* 18(5): 2071-2088.

Monika., Savitri., Kumari, A., Angmo, K., and Bhalla, T. C. 2016. Traditional pickles of Himachal Pradesh. *Indian J. Tradit. Knowl.* 15(2): 330–336

Moongkarndi, P., Kosem, N., Kaslungka, S., Luanratana, O., Pongpan, N., and Neungton, N. 2004. Antiproliferation, antioxidation and induction of apoptosis by *Garcinia mangostana* (mangosteen) on SKBR3 human breast cancer cell line. *J. ethnopharmacol.* 90(1): 161-166.

Murmu, P., Kumar, S., Patra, J. K., Singh, N. R., and Rath, S. K .2016. Ethnobotanical, nutritional, phytochemical and antimicrobial studies of *Garcinia xanthochymus* fruit extracts. *Biotechnol. J. Int*. 13(2): 25244-25249.

Mustarichie, R. and Gozali, D. 2019. Lip color formulation using mangosteen rind extract (*Garcinia mangostana* L.). *Drug Invent. Today*. 11(11): 32-38.

Muzykiewicz, A., Zielonka, B. J., Siemak, J., and Klimowicz, A. 2020. Antioxidant activity and polyphenol content in extracts from various parts of fresh and frozen mangosteen. *Acta Scientiarum Polonorum Technol. Alimentaria*. 19(3): 261-270.

Nakatani, K., Atsumi, M., Arakawa, T., Oosawa, K., Shimura, S., Nakahata, N., and Ohizumi, Y. 2002. Inhibitions of histamine release and prostaglandin E2 synthesis by mangosteen, a Thai medicinal plant. *Biol. Pharma. Bull.* 25(9): 1137-1141.

Naresh, N. 2016. *Extraction and utilization of anthocyanin pigments from jamun (Syzygium cumini L.)* (Doctoral dissertation, Department of Processing Technology, College of Horticulture, Vellanikkara).

Nastaj, J. and Witkiewicz, K. 2004. Theoretical analysis of vacuum freeze drying of biomaterials at contact-radiant microwave heating. *Chem. Proc. Eng.* 25: 505-525.

Nawaz, R., Naeem, S. Ammara, A., and Saqib, J. 2021. Development and storage stability studies of functional fruit drink supplemented with polyphenols extracted from lemon peels. *J. Food Process. Preserv.* 45(3): 52-58. Available: https://www.doi/10.1111/jfpp.15268 [21 Jan. 2023].

Nayak, C. A., Srinivas, P., and Rastogi, N. K. 2010. Characterization of anthocyanin from *Garcinia indica* Choisy. *Food Chem.* 118: 719–724.

Netravati, N., Gomez, S., Pathrose, B. Mini, N., Meagle P.,and Kuruvila, B. 2022. Comparative evaluation of anthocyanin pigment yield and its attributes from Butterfly pea (*Clitorea ternatea* L.) flowers as prospective food colorant using different extraction methods. *Future Foods*. 6: 100199.

Ngawhirunpat, T., Opanasopi, P., Sukma, M., Sittisombut, C., Kat, A., and Adachi, I. 2010. Antioxidant, free radical-scavenging activity and cytotoxicity of different solvent extracts and their phenolic constituents from the fruit hull of mangosteen (*Garcinia mangostana*). *Pharma. Biol.* 48(1): 55-62.

Nursakinah, I., Zulkhairi, H. A., Norhafizah, M., Hasnah, B., and Razif, D.2012. Nutritional content and in vitro antioxidant potential of *Garcinia atroviridis* (Asam gelugor) leaves and fruits. *Malays. J. Nutr.* 18(3): 363-371.

Nurul, S. and Asmah, R. 2012. Evaluation of antioxidant properties in fresh and pickled papaya. *Int. Food Res. J.* 19: 1117-1120.

Obulesu, M. and Bhattacharya, S. 2011. Color changes of tamarind (*Tamarindus indica* L.) pulp during fruit development, ripening, and storage. *Int. J. Food Properties.* 14(3): 538-549. Available: https://www.doi/10.1080/10942910903262129 [21 Jan. 2023].

Omujal, F., Okullo, J. B. L., Bigirimana, C., Isubikalu, P., Agea, J. G., Malinga, M., Obaa, B. B., and Bizuru, E. 2021. Physico-chemical, proximate, mineral and bioactive composition of *Garcinia buchananii* baker fruit from Uganda and Rwanda. *Afr. J. Food Agric. Nutr. Dev.* 21(10): 18932-18949.

Ortega, S. C. and Beltran, J.A. G. 2014. Roselle Calyces Particle Size Effect on the Physicochemical and Phytochemicals Characteristics. *J. Food Res.* 3(5): 83-95.

Ovalle-Magallanes, B., Eugenio, P. D., and Pedraza, C. J. 2017. Medicinal properties of mangosteen (*Garcinia mangostana* L.): A comprehensive update. *Food Chem. Toxicol.* 109:102-122.

Owolabi, I. O., Songsamoe, S., and Matan, N. 2021. Combined impact of peppermint oil and lime oil on Mangosteen (*Garcinia mangostana*) fruit ripening and mold growth using closed system. *Postharvest Biol. Technol.* 175: 111488-111489.

Pandey, R., Chandra, P., Kumar, B., Srivastva, M., Aravind, A. A., Shameer, P. S., and Rameshkumar, K. B. 2015. Simultaneous determination of multi-class bioactive constituents for quality assessment of *Garcinia* species using UHPLC–QqQLIT–MS/MS. *Ind. Crops Products*. 77: 861-872.

Parthasarathy, U. and Nandakishore, O. P. 2014. Morphological characterisation of some important Indian *Garcinia* species. *Dataset Papers Sci.* 45(2): 823-705. Available: https://www.doi.org/10.1155/2014/823705 [21. Feb. 2023].

Parthasarathy, U. and Nandakishore, O. P. 2016. Garcinia bark exudates - An important phytochemical source. *Curr. Sci.* 110: 1617-1619.

Parthasarathy, U., Babu, N. K., Kumar, S. R., Ashis, G. R., Mohan, S., and Parthasarathy, V. A. 2013. Diversity of Indian Garcinia - A medicinally important spice crop in India. *Acta Hortic.* 979: 467-476.

Parthasarathy, U., Nandakishore, O. P., Kumar, S. R., Babu, N. K., Zachariah, T. J., and Parthasarathy, V. A. 2012. Chromatographic fingerprinting and estimation of organic acids in selected *Garcinia* species. *Int. J. Innovative Hortic.* 1(1): 28-34.

Pasha, P. F. and Ramachandran, H. D. 2014. Plant profile, phytochemistry and pharmacology of *Garcinia indica*: A review. *World J. Pharmacy Pharma. Sci.* 3(10): 1514-1528.

Patel, A. M., Ezhava, S. B., Rathod, I. S., Chhabria, M. T. and Patwari, A. H., 2015. HPTLC method for quantification of garcinol from dry fruit rinds of Garcinia indica and its market formulation. *World J. Pharmacy and Pharmaceut. Sci.* 4(3):595-604.

Patel, D. and Buch, A. 2019. Improvisation of a spectrophotometric method to quantify hydroxycitric acid. *Anal. biochem*. 586: 113412.

Patil, M. M. and Appaiah,. A. K. A. 2015. *Garcinia*: Bioactive compounds and health benefits. In: Martirosyan, D. M. (ed.), *Introduction to Functional Food Science*. Food Science Publisher, Dallas, pp. 110-125.

Patras, A., Brunton, N. P., Da Pieve, S., and Butler, F. 2009. Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purees. *Innovative Food Sci. Emerg. Technol.* 10(3): 308-313.

Pedraza- Chaverri. J., Cárdenas, R. N., Orozco, I. M., and Pérez, R. M..N. 2008. Medicinal properties of mangosteen (*Garcinia mangostana*). *Food Chem. Toxicol*. 46(10): 3227–3239.

Pereda,B. M.S., Nazareno, M.A. and Viturro, C.I. 2020. Optimized formulation of a *Physalis peruviana* L. fruit nectar: physicochemical characterization, sensorial traits and antioxidant properties. *J. Food Sci. Technol*. 57: 3267-3277.

Phisut, N., Rattanawedee, M., and Aekkasak, K. 2013. Effect of osmotic dehydration process on the physical, chemical and sensory properties of osmo-dried cantaloupe. *Int. Food Res. J.* 20(1): 189-196.

Policegoudra, R.S., Saikia, S., Das, J., Chattopadhyay, P., Singh, L., and Veer, V. 2012. Phenolic content, antioxidant activity, antibacterial activity and phytochemical composition of *Garcinia lancifolia*. *Indian J. Pharma. Sci.* 74(3): 268-269.

Pothitirat, W. and Gritsanapan, W. 2009. HPLC quantitative analysis method for the determination of α-mangostin in mangosteen fruit rind extract. *Thai J. Agric. Sci.* 42(1): 7-12.

Pragati, S. Dahiya and Dhawan, S. S. 2003. Effect of drying methods on nutritional composition of dehydrated aonla fruit (*Emblica officinalis* Garten) during storage. *Plant Foods Hum. Nutr.* 58: 1–9.

Prakash, J., Sallaram, S., Martin, A., Veeranna, R. P., and Peddha, M. S. 2022. Phytochemical and functional characterization of different parts of the *Garcinia xanthochymus* fruit. *ACS omega.* 7(24): 21172-21182. Available: https://pubs.acs.org/doi/10.1021/acsomega.2c01966 [8 Mar. 2023].

Prasannath, K. and Mahendran, T. 2009. Physico-chemical and sensory attributes of osmotically dehydrated jackfruit (*Artocarpus heterophyllus* Lam.). *J. Food Agric.* 2: 1-5.

Promjiam, P., Sunisa, S., Worapong, U., and Santad, W. 2013. Effect of added *Garcinia* fruit on total phenolic compound content, antioxidant properties and quality changes of the southern sour curry paste, Keang-hleung, during storage. *Food Nutr. Sci.* 4(8): 812-820. Available: https://www.doi.org/10.4236/fns.2013.48106 [29 Jan. 2023].

Putnik, P., Bursac, K. D., Radojcin, M., and Dragovic,U. V. 2016. Influence of acidity and extraction time on the recovery of flavonoids from grape skin pomace optimized by response surface methodology. *Chem. Biochem. Eng. Q.* *30*(4): 455-464.

Quettier-Deleu, C., Gressier, B., Vasseur, J., Dine, T., Brunet, C., Luyckx, M., and Trotin, F. 2000. Phenolic compounds and antioxidant activities of buckwheat

(*Fagopyrum esculentum* Moench) hulls and flour. *J. Ethnopharmacol.* 72(1-2): 35-42.

Rahman, M. M. D., Miaruddin, M. D., Chowdhury, M. G., Haque, H. M. D., and Rahman, M. E. M. D. 2012. Preservation of jack fruit (*Artocarpus heterophyllus*) by osmotic dehydration. *Bangladesh J. Agric. Res.* 37(10): 67-75.

Rai, A. K., Prakash, M., and Appaiah, A. K. A. 2010. Production of *Garcinia* wine: Changes in biochemical parameters, organic acids and free sugars during fermentation of *Garcinia* must. *Int. J. Food Sci. Technol.* 45(7): 1330–1336.

Ramakrishnan, C. A., Nagaraj, N., Jayaprakasha, G. K., Jena, V., Varadaraj, M. C. and Raghavarao, K. S. M. S. 2008. An a thermal process for the concentration of *Garcinia* extract. United States Patent No. US20070154578A1 Available: https://patents.google.com/patent/ US20070154578A1 [07 Mar. 2023].

Rameshkumar, K. B. 2016. *Diversity of Garcinia species in the Western Ghats: Phytochemical Perspective.* Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram, 204p.

Ramya, V. and Jain, N. K. 2017. A review on osmotic dehydration of fruits and vegetables: An integrated approach. *J. Food Process Eng.* 40(3):12440-12443. Available: https://doi.org/10.1111/jfpe.12440 [30 Jan. 2023].

Ranganna, S. 1986. *Handbook of analysis and quality control for fruit and vegetable products.* Tata McGraw-Hill Publishing company Limited, New Delhi, 182p.

Ranganna, S. 1997. *Handbook of analysis and quality control for fruits and vegetable products* (2nd Ed.). Tata McGraw-Hill Publishing company Limited, New Delhi, p. 112.

Rani, G. U., Mishra, S., Sen, G. and Jha, U. 2012. Polyacrylamide grafted Agar: Synthesis and applications of conventional and microwave assisted technique. *Carbohydrate polymers*. 90(2): 784-791.

Rani, M. P, Gokul, R. M. R., and Bahuleyan, R. K. 2022. *Garcinia gummi‑gutta* seeds: A novel source of edible oils. *J. Sci. Food Agric.* 102(8): 3475-3479.

Ranveer, R. C., Nanadane, A. S., Ganorkar, P.M. and Sahoo, A.K. 2020. Enzyme-assisted extraction of anthocyanin from kokum (*Garcinia indica* Choisy.) rinds. *European J. Nutri. Food Safety*. 12(10): 125-133.

Rao, A. R., Venkatswamy, G. and Pendse, D. 1980. Camboginol and cambogin. *Tetrahedron Letters*, 21(20): 1975-1978.

Ratanamarno, S., Uthaibutra, J., and Saengnil, K. 1999. Towards some quality b of mangosteen (*Garcinia mangostana* L.) fruit during maturation. *Songklanakarin J. Sci. Technol*. 21: 9-15.

Ratanamarno, S., Uthaibutra, J., and Saengnil, K. 2005. Effects of bagging and storage temperature on anthocyanin content and phenylalanine ammonia-lyase (PAL) activity in mangosteen (*Garcinia mangostana* L.) fruit pericarp during maturation. *Songklanakarin J. Sci. Technol.* 27(4): 711-717.

Rema, J. and Krishnamoorthy, B. 2000. *Garcinia* species, economic importance, distribution and uses. *Indian Spices*. 3(7): 20-23.

Ribeiro, B., Valentao, P., Baptista, P., Seabra, R. M., and Andrade, P. B. 2007. Phenolic compounds, organic acids profiles and antioxidative properties of beefsteak fungus (*Fistulina hepatica*). *Food Chem. Toxicol.* 45(10): 1805-1813.

Ritthiwigrom, T. Laphookhieo, S. and Pyne, S. G. 2013. Chemical constituents and biological activities of *Garcinia cowa* Roxb. *Maejo. Int. J. Sci. Technol. 7*: 212-231.

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

Robbins, R. J. 2003. Phenolic acids in foods: an overview of analytical methodology. *J. Agric. Food Chem.* 51(10): 2866-2887.

Rubila, S. and Ranganathan, T. V. 2016. Accelerated shelf life study of *Zingiber officinale* paste. *Int. J. Pharm. Biosci.* 7: 251-254.

Rusydi, A. F., Onodera, S. I., Saito, M., Ioka, S. and Maria, R. 2019. Estimation of ammonium sources in Indonesian coastal alluvial groundwater using Cl-and GIS. *Int. J. Geomate*. 17(62): 53-58.

Sadasivam, S. and Manickam, A. 1992. *Biochemical methods for agricultural sciences*. Wiley Eastern Limited, New Delhi, 436p.

Sagar, V. R. and Kumar, S. P. 2009. Effect of osmosis on chemical parameters and sensory attributes of mango, guava slices and aonla segments. *Indian J. Hortic*. 66(1): 53-57.

Saini, R. S., Sharma, K. D., Dhankar, O. P., and Kaushik, R. A. 2001. *Laboratory manual of agro techniques in horticulture.* Agro Bios, India, 135p.

Salaria, M. and Reddy A. H. 2022. Studies on standardization and quality evaluation of RTS beverage from muskmelon (*Cucumis melo* L.) variety Sarda. *Pharma Innovation J.* 11(3):1952-1956.

Sampathu, S. R. and Krishnamurthy, N. 1982. Processing and utilization of kokam (*Garcinia indica*). *Indian Cocoa Arecanut Spices J.* 6(1): 12-13.

Santo, B.L.S.D. E., Santana, L.F., Kato Junior, W.H., de Araújo, F.D.O., Bogo, D., Freitas, K.D.C., Guimarães, R.D.C.A., Hiane, P.A., Pott, A., Filiú, W.F.D.O. and Arakaki Asato, M., 2020. Medicinal potential of Garcinia species and their compounds. *Molecules*, *25*(19), p.4513.

Sari, P., Setiawan, A., and Siswoyo, T. A. 2015. Stability and antioxidant activity of acylated jambolan (*Syzygium cumini*) anthocyanins synthesized by lipase-catalyzed transesterification. *Int. Food Res. J.* 22:671-676.

Sarvarian, M., Jafarpour, A., Awuchi, C. G., Adeleye, A. O., and Okpala, C. O. R. 2022. Changes in physicochemical, free radical activity, total phenolic and sensory properties of orange (*Citrus sinensis* L.) juice fortified with different oleaster (*Elaeagnus angustifolia* L.) extracts. *Molecules*. 27: 1530-1535. Available: https://www.doi.org/10.3390/molecules27051530 [02 Feb. 2023].

Saure, M. C. 1990. External control of anthocyanin formation in apple. *Sci. Hortic.* 42(3): 181-218.

Sayin, F. K. and Alkan, S. B., 2015. The effect of pickling on total phenolic contents and antioxidant activity of 10 vegetables. *Food Health.* 1(3): 135-141.

Sayuti, K., Neswati, N., Hijra, R., and Effendi, E. 2020. Antioxidant activity of Kolang Kaling jam which is added with Pucuk Merah (*Syzygium oleana*) fruit juice. *Asian J. Appl. Res. Community Dev. Empower.* 4(1): 28-33.

Semwal, R. B., Semwal, D. K., Vermaak, I., and Viljoen, A. 2015. A comprehensive scientific overview of *Garcinia cambogia*. *Fitoterapia.* 102:134-148.

Sergio, W. 1988. A natural food, the malabar tamarind, may be effective in the treatment of obesity. *Med. Hypotheses*. 27(1): 39-40.

Shameer, P. S., Rameshkumar, K. B., and Mohanan. N. 2016. Diversity of *Garcinia* species in the Western Ghats. In: Rameshkumar, K. B. (ed.), *Diversity of Garcinia species in the Western Ghats: Phytochemical Perspective.* Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram. Kerala, India, pp. 1-18.

Shamrez, B., Aftab, S., Junaid, M., Ahmed, N., and Ahmed, S. 2013. Preparation and evaluation of candies from citron peel. *J. Environ. Sci. Toxic Food Technol*. 7: 21-24.

Shan, T., Ma, Q., Guo, K., Liu, J., Li, W., Wang, F. and Wu, E. 2011. Xanthones from mangosteen extracts as natural chemopreventive agents: potential anticancer drugs. *Current molecular medicine*, *11*(8): 666-677.

Sharma, S., 2010. *Postharvest Management and Processing of Fruits and Vegetables: Instant Notes*. New India Publishing Agency,New Delhi, 390p.

Sharma, O. P. and Bhat, T. K. 2009. DPPH antioxidant assay revisited. *Food Chem.* 113:1202-1205.

Sheela, S. and Sruthi, K. 2014. Evaluation of acceptability, nutrient content, antimicrobial activity and storage stability of formulated bitter gourd, mosambi, bitter gourd and lemon RTS beverages. *Int. J. Curr. Microbiol. Appl. Sci.* 3(6): 25-31.

Shori, A. B., Rashid, F., and Baba, A. S. 2018. Effect of the addition of phytomix-3+ mangosteen on antioxidant activity, viability of lactic acid bacteria, type 2

diabetes key-enzymes, and sensory evaluation of yogurt. *LWT-Food Sci. Technol.* 94: 33-39.

Shubhra, B., Swati, K., Singh, R. P., and Savita, S. 2014. Studies on *Aloe* juice supplemented Kinnow nectar. *Res. J. Agric. For. Sci.* 2320: 6063-6068.

Shukla, R. N., Khan, M. A., and Srivastava, A. K. 2018. Mass transfer kinetics during osmotic dehydration of banana in different osmotic agent. *Int. J. Agric. Eng.* 11(1): 108-122.

Siddharth, S. A. K. 2013. Blending of kokum extract in concord grape juice: Study on physico-chemical characteristics, sensory quality and storage. *Int. J. Food Fermentation Technol.* 3: 79-83.

Sim, S. Y., Ng, J. W., Ng, W. K., Forde, C. G., and Henry, C. J. 2016. Plant polyphenols to enhance the nutritional and sensory properties of chocolates. *Food Chem.* 200: 46-54.

Singh, A., Mani, A., Dutta, P., and Murmu, D. 2017. Changes in lactic acid bacteria and total bacterial population in sodium substituted mix-vegetable pickle under ambient storage conditions. *Int. J. Chem. Stud.* 5: 261-264.

Singh, S. N., Patel, V. A., Varma, M. G., Patel, S. G., and Savaliya, M. V. 2021. Effect of processing methods on physico-chemical properties, sensory evaluations and storage studies of cauliflower (*Brassica oleracea* L. var. *botrytis*) pickle. *Int. J. Curr. Microbiol. Appl. Sci.* 10(1): 1413-1428.

Soetikno, J. S., Handayani, R. and Rahayu, R. D., 2016. Assay for antimicrobial activity of mangosteen rind extracts. *J. Inn. Pharma. Biol. Sci.* 3(1): 54-60.

Sothornvit, R. 2010. Drying process and mangosteen rind powder product. In: Wuensche, N., Albrigo, L. G., Gubbuk, H., Reinhardt, D. H., Staver, C., and Bergh, I. (eds), *Proceedings of 28th International Horticultural Congress on Science and Horticulture for People,* 7-8 August 2010, Lisbon, Portugal. International Society of Horticultural Science, Lisbon, pp. 233-241.

Sowmya, M., Kuna, A., Sahoo, M. R., Mayengbam, P. D., Dasgupta, M., and Sreedhar, M. 2019. Formulation and sensory evaluation of value added products developed with underutilized *Garcinia indica* fruit. *J. Pharmacogn. Phytochem.* 8(1): 435-439.

Sridevi, M. and Genitha, T. R. 2012. Optimization of osmotic dehydration process of pineapple by response surface methodology. *J. Food Process. Technol.* 3(8): 173-178.

Steppuhn, A. and Wäckers, F. L. 2004. HPLC sugar analysis reveals the nutritional state and the feeding history of parasitoids. *Funct. Ecol.* 42(3): 812-819.

Stintzing, F. C., Herbach, K. M., Mosshammer, M. R., Carle, R., Yi, W., Sellappan, S., Akoh, C. C., Bunch, R., and Felker, P. 2005. Color, betalain pattern, and antioxidant properties of cactus pear (*Opunti*a spp.) clones. *J. Agric. Food Chem.* 53(2): 442-451.

Sudharani, N., Umadevi, S. H., Jamuna, K. V., Naik, H., and Shobha, D. 2018. Anti-microbial activity of *Garcinia gummigutta* fruit rind. *J. Pharmacogn. Phytochem.* 7(3): 461-466.

Sulaiman, C. T. and Balachandran, I. 2017. LC/MS characterization of phenolic antioxidants of Brindle berry (*Garcinia gummi-gutta* (L.) Robson). *Nat. Product Res.* 31(10): 1191-1194.

Susilowati, S., Laia, S. and Purnomo, H., 2018. The effect of salt concentration and fermentation time on pH value, total acidity and microbial characteristic of pickled ginger (*Zingiber officinale* Rosc.). *Int. Food Res. J.* 25(6): 2301-2306.

Suwardi, A. B., Navia, Z. I., Harmawan, T., and Mukhtar, E. 2020. *Ethnobotany, nutritional composition and sensory evaluation of Garcinia from Aceh, Indonesia.* IOP Conference Series: Materials Science and Engineering. No. 725(1), IOP Publishing, Bristol, United Kingdom, p. 012064.

Swer, T. L., Chauhan, K., Mukhim, C., Bashir, K., and Kumar, A. 2019. Application of anthocyanins extracted from Sohiong (*Prunus nepalensis* L.) in food processing. *LWT-Food Sci. Technol. 114*: 108360-108362.

Tang, Y. P., Li, P. G., Kondo, M., Ji, H. P., Kou, Y. and Ou, B. 2009. Effect of a mangosteen dietary supplement on human immune function: A randomized, double-blind, placebo-controlled trial. *J. Med. Food.* 12(4): 755-763.

Tariq, H., Hayat, I., Rafiq, S., Qayyum, A., and Qayyum, S. 2020. Designing a functional beverage blend for optimal antioxidant activity and its storage stability. *Pakist. J. Agric. Res.* 33(3): 516-526.

Tewtrakul, S., Subhadhirasakul, S., Karalai, C., Ponglimanont, C., and Cheenpracha, S. 2009. Anti-inflammatory effects of compounds from *Kaempferia parviflora* and *Boesenbergia pandurata. Food Chem.* 115(2): 534-538.

Thakur, N. S., Thakur, A., Chauhan, M., and Kumar, P. 2017. Studies on development and storage quality of seedling mango (*Mangifera indica* L.) pickle of Himachal Pradesh. *Indian J. Ecol.* 44: 690-696.

Tiwari, B. K., Donnell, C. P., Muthukumarappan, K. and Cullen, P. J. 2009. Ascorbic acid degradation kinetics of sonicated orange juice during storage and

comparison with thermally pasteurised juice. *LWT-Food Sci. Technol.* 42(3): 700-704.

Tome, A. C., Marsico, E. T., Silva, F. A., Kato, L., Nascimento, T. P., and Monteiro, M. L. G. 2019. Achachairu (*Garcinia humilis*): Chemical characterization, antioxidant activity and mineral profile. *J. Food Measurement Charact.* 13: 213-221.

Tongdee, S. C. and Suwanagul, A. M. 1989. Postharvest mechanical damage in mangosteens. *ASEAN Food J.* 4: 151-155.

Torskangerpoll, K. and Andersen, O. M. 2005. Colour stability of anthocyanins in aqueous solutions at various pH values. *Food Chem.* 89 (3): 427–440.

Turkiewicz, I. P., Wojdylo, A., Tkacz, K., Lech, K., and Nowicka, P. 2020. Osmotic dehydration as a pretreatment modulating the physicochemical and biological properties of the Japanese quince fruit dried by the convective and vacuum-microwave method. *Food Bioprocess. Technol.* 13 (10): 1801-1816.

Vinson, J. A., Xuchui, S., Ligia, Z., and Bose, P. 2001. Phenol antioxidant quantity and quality in foods: Fruits. *J. Agric. Food Chem.* 49: 5315–5321.

Virgolin, L. B., Seixas, F. R. F., and Janzantti, N. S. 2017. Composition, content of bioactive compounds, and antioxidant activity of fruit pulps from the Brazilian Amazon biome. *Pesquisa Agropecuaria Brasileira.* (52(10): 933-941. Available: https://www.doi.org/10.1590/S0100-204X2017001000013 [07 Mar. 2023].

Waskar, D. P. and Garande, V. K. 2003. Studies on blending of pomegranate and kokum juices. *Bevarage Food World.* 30: 27-28

Weidner, S., Amarowicz, R., Karamac, M., and Dabrowski, G. 1999. Phenolic acids in caryopses of two cultivars of wheat, rye and triticale that display different resistance to pre-harvest sprouting. *Eur. Food Res. Technol.* 210: 109-113.

Wibawanti, J. M. W., Zulfanita, Z., and Runanto, D. 2019. The Antioxidant activity of yogurt drink by mangosteen rind extract (*Garcinia mangostana* L.). *J. Appl. Food Technol.* 6(1): 15-18.

Wickramasinghe, P. C., Murray, A. F., Sahoo, M. R., Dein, M., Luckett, C. R., Dia, V. P., and Munafo, J. P. 2020. The effects of processing on *Garcinia xanthochymus* fruit beverage. *J. Food Measurement Charact.* 14: 55-68.

Wojdylo, A., Figiel, A., and Oszmianski, J. 2009. Effect of drying methods with the application of vacuum microwaves on the bioactive compounds, color and antioxidant activity of strawberry fruits. *J. Agric. Food Chem.* 57(4): 1337-1343.

Wrolstad, R. E. and Culver, C. A. 2012. Alternatives to those artificial food colorants. *Annu. Rev. Food Sci. Technol.* 3: 59-77. Available: https://www.doi.org/10.1146/annurev-food-022811-101118 [04 Feb. 2023].

Wrolstad, R. E., Durst, R. W., and Lee, J. 2005. Tracking color and pigment changes in anthocyanin products. *Trends Food Sci. Technol.* 16(9): 423-428.

Xess, R., Kumar, V., Patel, D., and Tripathi, A. 2021. Changes in chemical constituents and overall acceptability of jackfruit nectar during storage. *Pharma Innovation J.* 10(7): 332-336.

Xie, Z., Sintara, M., Chang, T., and Ou, B. 2014. Functional beverage of *Garcinia mangostana* (mangosteen) enhances plasma antioxidant capacity in healthy

adults. *Food Sci. Nutr.* 3: 32-38. Available: https://www.doi.org/10.1002/fsn3.187 [21 Jan. 2023].

Yadav, A. K. and Singh, S. V. 2014. Osmotic dehydration of fruits and vegetables: A review. *J. Food Sci. Technol.* 51: 1654-1673.

Yadav, B. S., Ritika, B., Jatain, M. 2012. Optimisation of osmotic dehydration conditions of peach slices in sucrose solution using response surface methodology. *J. Food Sci. Technol.* 49(5):547-555.

Yamada, T., Hida, H., and Yamada, Y. 2007. Chemistry, physiological properties, and microbial production of hydroxycitric acid. *Appl. Microbiol. Biotechnol.* 75: 977-982.

Yamaguchi, F., Saito, M., Ariga, T., Yoshimura, Y., and Nakazawa, H. 2000. Free radical scavenging activity and antiulcer activity of garcinol from *Garcinia indica* fruit rind. *J. Agric. Food Chem.* 48(6): 2320-2325.

Yamano, T., Iino, H., Takada, M., Blum, S., Rochat, F., and Fukushima, Y. 2006. Improvement of the human intestinal flora by ingestion of the probiotic strain *Lactobacillus johnsonii* La1. *Br. J. Nutr.* 95(2): 303-312.

Yenrina, R., Sayuti, K., and Anggraini, T. 2016. Effect of natural colorants on color and antioxidant activity of "Kolang Kaling" (Sugar Palm Fruit) Jam. *Pakist. J. Nutr.* 15(12): 1061-1066.

Yoshimura, M., Ninomiya, K., Tagashira, Y., Maejima, K., Yoshida, T., and Amakura, Y. 2015. Polyphenolic constituents of the pericarp of mangosteen (*Garcinia mangostana* L.). *J. Agric. Food Chem.* 63(35): 7670-7674.

Yu, L., Zhao, M., Yang, B., Zhao, Q., and Jiang, Y. 2007. Phenolics from hull of *Garcinia mangostana* fruit and their antioxidant activities. *Food chem.* 104(1): 176-181.

Zadernowski, R., Czaplicki, S.,and Naczk, M. 2009. Phenolic acid profiles of mangosteen fruits (*Garcinia mangostana*). *Food Chem.* 112(3): 685-689. Available: https://www.doi.org/10.1016/j.foodchem.2008.06.030 [04 Jan. 2023].

Zafra-Stone S, Yasmin, T., Bagchi, M., Chatterjee, A., Vinson, J. A., and Bagchi, D. 2007. Berry anthocyanins as novel antioxidants in human health and disease prevention. *Mol. Nutr. Food Res*. 51: 583-675.

Zarena, A. S. and Sankar, K. U. 2012. Isolation and identification of pelargonidin 3-glucoside in mangosteen pericarp. *Food chem.* 130(3): 665-670.

Zarena, A. S. and Sankar, K. U. 2011. Phenolic acids, flavonoid profile and antioxidant activity in mangosteen (*Garcinia mangostana* L.) pericarp. *J. Food Biochem.* 36(5): 627-633.

Zhang, X., Liu, J., Yong, H., Qin, Y., Liu, J., and Jin, C. 2020. Development of antioxidant and antimicrobial packaging films based on chitosan and mangosteen (*Garcinia mangostana* L.) rind powder. *Int. J. Biol. Macromol.* 145: 1129-1139.

ASSESSMENT OF BIOACTIVE COMPOUNDS AND PRODUCT DEVELOPMENT FROM MAJOR *GARCINIA* SPP. OF KERALA

by

APARNA G. S.

(2017-22-004)

Abstract of the thesis

submitted in partial fulfillment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POSTHARVEST MANAGEMENT

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

2023

ABSTRACT

The present study entitled "Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala" was carried out in the Department of Postharvest Management, College of Agriculture, Vellayani during 2017-21 with the objective to assess the bioactive compounds in major *Garcinia* spp. of Kerala *viz*. *G. gummi-gutta* (malabar tamarind), *G. mangostana* (mangosteen), *G. xanthochymus* (yellow mangosteen) and development of value added products with nutraceutical importance.

Primary and secondary metabolites present in pulp and pericarp of the three species were assessed. The *G. mangostana* recorded highest TSS for pulp as 20.83 ^{0}Brix and 27.93 ^{0}Brix in pericarp whereas the highest acidity was recorded in *Garcinia xanthochymus* rind (6.54%) and pulp (6.18%). Mangosteen fruit pulp recorded the highest vitamin C (33.80 mg 100g^{-1}) and total sugar (13.31%) and the yellow mangosteen pulp noticed the highest protein content of 7.24 g 100g^{-1}. Crude fibre (12.37%), fat content (1.35 mg 100g^{-1}), total phenols (2603.68 mg GAE 100g^{-1}), antioxidant activity (92.27 %), total flavonoids (1.55mg QE g^{-1}), Ca (1910.00 ppm), K (3323.33 ppm) and Fe (9.24 ppm) were found the highest in mangosteen pericarp.

Twelve major sugars were quantified from the economic parts of the *Garcinia* fruits. *Garcinia gummi-gutta* fruits recorded fructose (8.85±0.028mg g^{-1}) in the highest quantity followed by ribose (4.87±0.019 mg g^{-1}) and glucose (3.14±0.033mg g^{-1}). The prominent sugar was fructose in *G. mangostana* (28.163±0.813mg g^{-1}) and *G. xanthochymus* (25.842±0.151 mg g^{-1}). Organic acid profiling of the fruits revealed Hydroxy Citric Acid (HCA) as the major organic acid in *G. gummi-gutta* fruits (547.458±4.185mg g^{-1}) and citric acid was the most abundant organic acid in *G. mangostana* (674.17±0.485 mg g^{-1}) and *G. xanthochymus* fruit (680.361±0.863mg g^{-1}).

The phenolic profiling of *Garcinia* fruits showed p-coumaric acid as the major phenolic acid in *G. gummi-gutta* (104.81 µgg^{-1}), *G. xanthochymus* (353.61 µgg^{-1}) and *G. mangostana* (335.70 µgg^{-1}). A total of thirteen individual flavonoids were identified and quantified from selected *Garcinia* fruits and epicatechin (18.699±0.211 µgg^{-1}), catechin (6.688±0.492 µgg^{-1}) and luteolin (8.814±0.791 µgg^{-1}) were the predominant individual flavonoids in *G.gummi-gutt*a. Mangosteen fruit pulp recorded the highest quantity of hespertin (36.980 µgg^{-1}) whereas naringenin (44.424±0.363 µgg^{-1}) was the abundant flavonoids in *G. xanthochymus fruits*.

Natural polyisoprenylated benzophenones such as garcinol and isogarcinol were isolated by column chromatography followed by crystallization from the hexane extract of *G. indica* fruits. Another benzophenone xanthochymol was isolated by column chromatography using hexane extract of *G.xanthochymus* fruits. The structural identification of the compounds was done by spectroscopic methods like UV-Vis, 1H NMR and 13C NMR. HPTLC densitometry method was used to compare and quantify the benzophenones in three major *Garcinia* species. Results showed that garcinol was the major benzophenone in *G.gummi-gutta* (7.53 %) and *G. xanthochymus* (8.26%) whereas *G.mangostana* fruits were high in isogarcinol (8.10%). The major xanthone, α-mangostin was quantified in mangosteen rind as 3.62 % on dry weight basis.

The pigment was extracted from dried and powdered pericarp of ripe mangosteen fruits by the method of hot maceration where distilled water (aqueous extraction) and ethanol as solvents, acidified with citric acid (0.1% and 0.2%) and acetic acid (1% and 2%) at different levels. Based on higher extraction yield (28.57%), anthocyanin content (294.73 mg 100 g^{-1}), total phenols (1549.55 mg GAE 100 g^{-1}) and antioxidant activity (82.68%), colour extracted with acidified ethanol (2% acetic acid) was selected as the best solvent system and was further utilized as a natural colourant in *Garcinia nectar* formulations.

For the development of nectar formulations from *Garcinia* spp., *G. gummi-gutta* rind, mangosteen pulp and *G. xanthochymus pulp*, was used at different fruit pulp concentration (15%, 20%) and TSS (15^0 Brix, 20^0 Brix, 25^0 Brix, 30^0 Brix). Biochemical quality parameters such as titratable acidity, vitamin C, total sugar, reducing sugar, antioxidant activity, total phenol content, total flavonoids and HCA were analyzed for all nectar formulations. Based on biochemical quality and sensory mean scores of the formulations, *G. gummi-gutta* nectar prepared with 20 % fruit and 20^0 Brix, *Garcinia mangostana* nectar formulation with 20% fruit with TSS 15^0 Brix and for *G. xanthochymus* fruit beverage prepared with 15% fruit and 20^0 Brix were selected as the best formulations for the supplementation of natural colour extracted from mangosteen pericarp.

The selected nectar formulation of *G. gummi- gutta* and *G. xanthochymus* was added with 0.5% mangosteen pericarp colour extract whereas 0.3 % was added to *G. mangostana* nectar. Storage stability studies of the nectar formulations were conducted under room temperature along with control (formulation without addition of natural colour). During storage, TSS, titratable acidity, total sugar and reducing sugar parameters of the nectars were increased whereas vitamin C, total phenols and antioxidant activity showed a decreasing trend. The effect of light on colour stability of the nectars was studied and nectar stored in amber bottles retained more anthocyanin than in transparent glass bottles. The temperature stability studies revealed that with the increase in temperature and time, total anthocyanin content of the beverages decreased. Sensory quality analysis of the nectar formulation revealed that beverages added with natural colour extract recorded the highest sensory mean score for colour and overall acceptability without affecting the taste and flavour.

Garcinia gummi-gutta fruit rind was utilized for preparation of various value-added products *viz.* osmodehydrated rind, culinary paste and pickles. The effect of different osmotic concentrations (50^0 Brix and 70^0 Brix) and immersion time (24, 36 and 48 h) on mass transfer characters, and quality parameters of osmodehydrated rind

were evaluated. The mass transfer characters *viz.* solid gain, water loss, and weight reduction were increased with increase in immersion time and osmotic concentration. Osmodehydrated products packaged in polypropylene were stored for a period of 3 months and storage stability studies were conducted. The TSS, acidity and sugars were increased during storage whereas HCA and antioxidant activity decreased. The storage study revealed that osmotic treatment, 70^0 Brix for 36 h exhibited highest acceptability and used for pickle development studies.

The fresh malabar tamarind rind was used for the preparation of culinary paste with different levels of salt concentration (3%, 5%,7%, 9%) and without the addition of salt as control. The moisture content, HCA, and antioxidant activity were decreased meanwhile TSS, total sugar, reducing sugar, acidity and total flavonoids of the paste increased during storage. The paste prepared with 9% salt recorded the lowest browning index (31.52 %), bacterial load and the highest score for taste (8.33), flavour (8.27) and overall acceptability (7.87) after three months of storage.

Sweet pickle from osmodehydrated (70^0Brix for 36 h) slices and sour pickle from fresh *G.gummi-gutta* rind were prepared and analysed for biochemical, microbial and sensory quality during storage of 2 months. The total sugar, reducing sugar, vitamin C and antioxidant activity of the pickles decreased during storage and both sweet and sour pickles were found acceptable.

The major *Garcinia* spp. *viz*. *G. gummi-gutta* (malabar tamarind), *G. mangostana* (mangosteen), *G. xanthochymus* (yellow mangosteen) were found rich in bioactive compounds. The anthocyanin colour was effectively extracted from mangosteen pericarp with acidified ethanol and was used as a natural colourant in *Garcinia* fruit beverages. Value added products viz., osmodehydrated rind, culinary paste, sweet and sour pickles were developed from *G. gummi-gutta* rind with good acceptability and storage stability.

സംഗ്രഹം

കേരളത്തിലെ പ്രധാന ഗാർസീനിയ സ്പീഷിസുകളായ ഗാർസിനിയ ഗമ്മി-ഗട്ട (കുടംപുളി), ഗാർസീനിയ മാംഗോസ്റ്റാന (മാംഗോസ്റ്റീൻ), ഗാർസീനിയ സാന്തോകൈമസ് (യെല്ലോ മാംഗോസ്റ്റിൻ/ രാജാപുളി) എന്നിവയിൽ അടങ്ങിരിക്കുന്ന ബയോ ആക്റ്റീവ് സംയുക്തങ്ങൾ വിലയിരുത്തുന്നതിനോടൊപ്പം തന്നെ ന്യൂട്രാസ്യൂട്ടിക്കൽ പ്രാധാന്യമുള്ള മൂല്യവർദ്ധിത ഉൽപ്പന്നങ്ങൾ വികസിപ്പിക്കുക എന്ന ലക്ഷ്യത്തോടെ വെള്ളായണി കാർഷിക കോളേജിലെ പോസ്റ്റ് ഹാർവെസ്റ്റ് മാനേജ്മെന്റ് ഡിപ്പാർട്ട്മെന്റിൽ 2017-21 കാലയളവിൽ "പ്രധാന ഗാർസിനിയ സ്പീഷീസ്ൽ നിന്നുള്ള ഉൽപ്പന്ന വികസനവും ബയോആക്ടീവ് സംയുക്തങ്ങളുടെ വിലയിരുത്തലും " എന്ന പഠനം നടത്തുക ഉണ്ടായി.

മൂന്ന് സ്പീഷീസുകളുടെയും പൾപ്പിലും പെരികാർപ്പിലും ഉള്ള പ്രാഥമികവും ദ്വിതീയവുമായ മെറ്റാബോളൈറ്റുകൾ വിലയിരുത്തി. മാംഗോസ്റ്റീൻ പഴങ്ങളിൽ ഏറ്റവും ഉയർന്ന TSS പൾപ്പിലും (20.83^{0}Brix) പെരികാർപ്പിലും (27.93^{0}Brix) രേഖപ്പെടുത്തി, എന്നാൽ രാജാപുളി യുടെ തൊണ്ടിലും (6.54%), അക്കാമ്പിലും (6.18%) ഉയർന്ന അസിഡിറ്റി രേഖപ്പെടുത്തി. മാംഗോസ്റ്റീൻ പൾപ്പിൽ ഏറ്റവും ഉയർന്ന വിറ്റാമിൻ - സിയും (33.80 mg 100g-1) ടോട്ടൽ ഷുഗർ (13.31%) രേഖപ്പെടുത്തി. ക്രൂഡ് ഫൈബർ (12.37%), കൊഴുപ്പിന്റെ അളവ് (1.35 mg 100g-1), ടോട്ടൽ ഫിനോൾസ് (2603.68 mg GAE 100g -1), നിരോക്സികരണ പ്രവർത്തനം (92.27 %), ടോട്ടൽ ഫ്ലേവനോയിഡുകൾ (1.55mg QE g-1), കാൽസ്യം (1910.00 ppm), പൊട്ടാസിയം (3323.33 ppm), അയേൺ (9.24 ppm) എന്നിവ മാംഗോസ്റ്റീൻ പുറംതോടിൽ ഏറ്റവും കൂടുതലായി കണ്ടെത്തി.

ഗാർസിനിയ പഴങ്ങളിൽ കാണുന്ന പ്രധാനപ്പെട്ട 12 ഷുഗറുകൾ കണക്കാക്കുകയും ഫ്രക്ടോസ് ഏറ്റവും അധികമായി കാണുന്നതായും രേഖപ്പെടുത്തി. കുടംപുളിയിൽ അടങ്ങിയിരിക്കുന്ന പ്രധാന ഓർഗാനിക് ആസിഡ് ഹൈഡ്രോക്സി സിട്രിക് ആസിഡും (547.458±4.185mg g-1) എന്നാൽ മംഗോസ്റ്റീലും (674.170±.485 mg g-1) രാജപുളിയും (680.361±0.863mg g-1) അടങ്ങിയിരിക്കുന്ന പ്രധാന ആസിഡ് സിട്രിക് ആസിഡുമാണ് എന്ന് വിലയിരുത്തി. ഫിനോളിക് ആസിഡുകളുടെ പ്രൊഫൈലിങ്ങിൽ നിന്നും p -കൗമാറിക്കാസിഡ് ഏറ്റവും കൂടുതലായി കാണുന്ന ഫിനോളിക് ആസിഡ് ആയി രേഖപെടുത്തി.

ഗാർസിനിയ പഴങ്ങളിൽ നിന്ന് ആകെ പതിമൂന്ന് ഫ്ലേവനോയിഡുകൾ കണ്ടെത്തി കണക്കാക്കി. ഗാർസിനോൾ, ഐസോഗാർസിനോൾ തുടങ്ങിയ പ്രകൃതിദത്ത പോളി ഐസോപ്രൈനിലേറ്റഡ് ബെൻസോഫിനോണുകളെ കോളം ക്രോമാറ്റോഗ്രാഫി ഉപയോഗിച്ച് ഗാർസിനിയ ഇൻഡിക്ക (kokum) പഴങ്ങളുടെ

ഹെക്സെൻ സത്തിൽ നിന്ന് ക്രിസ്റ്റലൈസേഷൻ നടത്തി. വേർതിരിച്ചെടുത്തു. തുടർന്ന് മറ്റൊരു ബെൻസോഫിനോൺ ആയ സന്തോകൈമോൾ രാജപുളി പഴങ്ങളുടെ ഹെക്സെയ്ൻ സത്തിൽ നിന്ന് കോളം ക്രോമാറ്റോഗ്രഫി വഴി വേർതിരിച്ചു. UV-Vis, 1H NMR, 13C NMR തുടങ്ങിയ സ്പെക്ട്രോസ്കോപ്പിക് രീതികൾ ഉപയോഗിച്ചാണ് സംയുക്തങ്ങളുടെ ഘടനകൾ തിരിച്ചറിഞ്ഞത്. ബെൻസോഫിനോണുകളെ താരതമ്യം ചെയ്യുന്നതിനും അളക്കുന്നതിനും HPTLC ഡെൻസിമെട്രി രീതി ഉപയോഗിച്ചു. കുടംപുളിയിലും രാജപുളിയിലും അടങ്ങിയ പ്രധാന ബെൻസോഫിനോൺ ഗാർസിനോളും എന്നാൽ മംഗോസ്റ്റീൻ പഴങ്ങളിൽ ഏറ്റവും കൂടുത്തൽ കണ്ടത് ഐസോഗാർസിനോളും ആയിരുന്നു

ഉണക്കി പൊടിച്ച മാങ്കോസ്റ്റിൻ പുറംതോടിൽ നിന്നും ഹോട്ട് മാസ്റേഷൻ വഴി സിട്രിക് ആസിഡും (0.1%, 0.2%) അസറ്റിക് ആസിഡും (1%, 2%) ഉപയോഗിച്ച് അമ്ലീകരിച്ച ഡിസ്റ്റിൽഡ് വാട്ടർ, ഈഥനോൾ എന്നീ ലായകങ്ങൾ ഉപയോഗിച് ആന്തോസയാനിൻ നിറം വേർതിരിച്ചെടുത്തു. ഉയർന്ന അളവ് (28.57%), ആന്തോസയാനിൻ (294.73 mg 100 g-1), ടോട്ടൽ ഫിനോൾ (1549.55 mg GAE 100 g-1), നിരോക്ഷികരണ പ്രവർത്തനം (82.68%) എന്നിവയെ അടിസ്ഥാനമാക്കി, അസറ്റിക് ആസിഡ് ഉപയോഗിച്ച് അമ്ലീകരിച്ച എഥനോൾ മികച്ച ലായക സംവിധാനമായി തിരഞ്ഞെടുത്തു.

നെക്ർ പാനീയങ്ങളുടെ വികസനത്തിന് കുടംപുളിയുടെ പുറംതോട്, മാങ്കോസ്റ്റീനിന്റെയും രാജപുളിയുടെയും അകക്കാമ്പ് എന്നിവയുടെ വിവിധ സാന്ദ്രതയിലുള്ള പൾപ്പ് (15%, 20%) ,TSS (15^0 Brix, 20^{0}Brix, 25^0 Brix, 30^0 Brix) എന്നിവ ഉപയോഗിച്ചു. നെക്ർ ഫോർമുലേഷനുകളുടെ ബയോകെമിക്കൽ ഗുണനിലവാര പാരാമീറ്ററുകളായ ടൈട്രേറ്റബിൾ അസിഡിറ്റി, വിറ്റാമിൻ സി, ടോട്ടൽ ഷുഗർ, റെഡ്യൂസിങ് ഷുഗർ, ടോട്ടൽ ഫീനോൾ, ടോട്ടൽ ഫ്ലാവാനോയിഡ്സ്, നിരോക്ഷികരണ പ്രവർത്തനം, HCA എന്നിവ പരിശോധിച്ചു.

ബയോകെമിക്കൽ ഗുണമേന്മയും സെൻസറി സ്കോറുകളും അടിസ്ഥാനമാക്കി മൂന്നു പഴങ്ങളുടെയും ഓരോ നെക്ർ ഫോർമുലേഷൻ തിരഞ്ഞെടുക്കുകയും മാങ്കോസ്റ്റീനിൽ നിന്നും വേർതിരിച്ച നിറം 0.5% എന്ന തോതിൽ കുടമ്പുളി, രാജപുളി പാനീയങ്ങളിലും 0.3% എന്ന തോതിൽ മംഗോസ്റ്റീൻ പാനീയത്തിലും പ്രകൃതിദത്ത നിറമായി ചേർത്തു. പാനീയങ്ങളുടെ സംഭരണ സ്ഥിരത പഠനങ്ങൾ അന്തരീക്ഷ താപനിലയിൽ നടത്തുകയും സൂക്ഷിപ് കാലവധിക്കനുസരിച് TSS, അസിഡിറ്റി, ടോട്ടൽ ഷുഗർ, റെഡ്യൂസിങ് ഷുഗർ, എന്നിവ വർദ്ധിക്കുകയും അതേസമയം വിറ്റാമിൻ സി, ടോട്ടൽ ഫിനോൾ, നിരോക്ഷികരണ പ്രവർത്തനം എന്നിവ കുറയുന്ന പ്രവണതയും കാണിച്ചു. സംഭരണ സമയത്ത് പാനീയങ്ങളുടെ വർണ സ്ഥിരതയിൽ പ്രകാശത്തിന്റെ സ്വാധീനം പഠിക്കുകയും

ആമ്പർ കുപ്പികളിൽ സൂക്ഷിച്ച പാനീയങ്ങൾ ഗ്ലാസ് ബോട്ടിലുകളേക്കാൾ കൂടുതൽ ആന്തോസയാനിൻ നിലനിർത്തുന്നതായും കണ്ടെത്തി . താപനിലയും സമയവും കൂടുന്നതിനനുസരിച്ച് പാനീയങ്ങളിലെ ആന്തോസയാനിൻ കുറയുന്നതായും താപനില സ്ഥിരത പഠനങ്ങൾ വെളിപ്പെടുത്തി. പ്രകൃതിദത്തമായ നിറം ചേർത്ത പാനീയങ്ങൾ രുചിയെ ബാധിക്കാതെ നിറത്തിനും മൊത്തത്തിലുള്ള സ്വീകാര്യതയ്ക്കും ഉയർന്ന സെൻസറി സ്കോറുകൾ രേഖപ്പെടുത്തി.

ഓസ്മോഡീഹൈഡ്രേഷൻ ചെയ്യുന്നതിനായി കുടംപുളിയുടെ പുറംതോട് 50^0 Brix, 70^0 Brix ഗാഢതയിലുള്ള സുക്രോസ് ലായനിയിൽ 24,36,48 മണിക്കൂർ നേരം മുക്കിവെച്ചു. മൂന്ന് മാസത്തെ സംഭരണ സമയത്ത്, TSS, അസിഡിറ്റി, ഷുഗറുകൾ എന്നിവയുടെ അളവ് കൂടുകയും HCA, നിരോക്സിയകരണ പ്രവർത്തനം എന്നിവ കുറയുകയും ചെയ്തു. 70^0 ബ്രിക്സ് ലായനിയിൽ 36 മണിക്കൂർ മുക്കിവെച്ച പുറംതോട് ഉയർന്ന സ്വീകാര്യത പ്രകടമാക്കുകയും അച്ചാർ വികസന പഠനങ്ങൾക്കായി ഉപയോഗിക്കുകയും ചെയ്തു,

കുടംപുളി പേസ്റ്റ് പേസ്റ്റ് തയ്യാറാക്കുന്നതിനായി കുടംപുളിയുടെ പുറംതോട് പൾപ്പ് ആക്കി മാറ്റിയ ശേഷം (0, 3, 5, 7, 9 %) കറിയുപ്പ് ചേർത്തു പ്രോസസ്സ് ചെയ്തെടുത്തു. മൂന്നു മാസത്തെ സംഭരണ സമയത്തു ഈർപ്പം, HCA, നിരോക്ലികരണ പ്രവർത്തനം എന്നിവ കുറയുകയും അതേസമയം TSS, ഷുഗറുകൾ, അസിഡിറ്റി, ടോട്ടൽ ഫ്ലേവനോയിഡുകൾ എന്നിവ വർദ്ധിക്കുകയും ചെയ്തു. 9% ഉപ്പ് ഉപയോഗിച്ച് തയ്യാറാക്കിയ പേസ്റ്റ് മൂന്ന് മാസത്തെ സംഭരണത്തിന് ശേഷം ഏറ്റവും കുറഞ്ഞ ബ്രൗണിംഗ് സൂചിക (31.52 %), ബാക്ടീരിയൽ ലോഡ്, രുചി (8.33), ഫ്ലേവർ (8.27), മൊത്തത്തിലുള്ള സ്വീകാര്യത (7.87) എന്നിവയ്ക്ക് ഉയർന്ന സ്കോർ രേഖപ്പെടുത്തി.

ഓസ്മോഡ്ഹൈഡ്രേറ്റഡ് ചെയ്ത പുറംതോടിൽ നിന്ന് ഉണ്ടാക്കിയ മധുരമുള്ള അച്ചാറും പുതിയ പുറംതോട് ഉപയോഗിച് ഉണ്ടാക്കിയ പുളിയുള്ള അച്ചാറും 2 മാസത്തെ സംഭരണ സമയത്ത് ബയോകെമിക്കൽ, മൈക്രോബയൽ, സെൻസറി ഗുണനിലവാരം എന്നിവ പരിശോധിച്ചു. സൂക്ഷിപ്പ് കാലാവധി സമയത്തു അച്ചാറിലടങ്ങിയിരിക്കുന്ന ഷുഗറുകൾ, വിറ്റാമിൻ സി, നിരോക്ലികരണ പ്രവർത്തനം എന്നിവ കുറയുന്നതായി കണ്ടെത്തി.

ഗാർസീനിയ പഴങ്ങളുടെ പ്രോക്സിമേറ്റ് കോമ്പോസിഷൻ വിലയിരുത്തലിൽ, പഞ്ചസാരയുടെ ഘടകങ്ങൾ, അസിഡിറ്റി, പ്രോട്ടീൻ, കൊഴുപ്പ്, നാരുകൾ, ഫിനോൾസ്, ഫ്ലേവനോയ്ഡുകൾ, നിരോക്ലികരണ പ്രവർത്തനം എന്നിവ പെരികാർപ്പിന് പൾപ്പിനെക്കാൾ വളരെ കൂടുതലാണെന്ന് കണ്ടെത്തി. മൂന്ന് ഇനങ്ങളിലെ പെരികാർപ്പിൽ, മാംഗോസ്റ്റീൻ പുറംതൊലി ഉയർന്ന പ്രവർത്തനവും പ്രോക്ലിമേറ്റ്

ഘടനയും പ്രകടിപ്പിച്ചു. ആന്തോസയാനിൻ നിറം മാംഗോസ്റ്റീൻ പെരികാർപ്പിൽ നിന്ന് അമ്ലീകരിക്കപ്പെട്ട ഏഥനോൾ ഉപയോഗിച്ച് ഫലപ്രദമായി വേർതിരിച്ചെടുക്കുകയും പഴങ്ങളുടെ പാനീയങ്ങളിൽ സ്വാഭാവിക നിറമായി ഉപയോഗിക്കുകയും ചെയ്തു. കുടംപുളി പഴങ്ങൾ ഉപയോഗിച്ചു ഓസ്മോഡിഹൈഡ്രേറ്റഡ് ഉൽപ്പന്നം, കുടംപുളി പേസ്റ്റ്, മധുരവും പുളിയുമുള്ള അച്ചാറുകൾ എന്നിവ വികസിപ്പിച്ചെടുക്കുകയും ഉൽപ്പന്നങ്ങളെല്ലാം സൂക്ഷിപ്പുകലാവധി തീരുന്നത് വരെ സ്വീകാര്യവും സുരക്ഷിതവും ആണെന്നു കണ്ടെത്തി.

Appendices

COLLEGE OF AGRICULTURE, VELLAYANI
Dept. of Postharvest Management

Title: Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala

Score card for assessing the organoleptic qualities of *Garcinia* nectar

Sample: Garcinia nectar formulations

Instructions: You are given six samples. Evaluate them and give scores for each criteria

Criteria	Samples					
	1	2	**3**	4	5	**6**
Taste						
Appearance						
Flavour						
Overall accepatability						

Score

Like extremely	-9
Like very much	-8
Like moderately	-7
Like slightly	-6
Neither like or dislike	-5
Dislike slightly	-4
Dislike moderately	-3
Dislike very much	-2
Dislike extremely	-1

Date :   Name :

                                               Signature :

COLLEGE OF AGRICULTURE, VELLAYANI
Dept. of Postharvest Management

Title: Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala

Score card for assessing the organoleptic qualities of osmo dehydrated *G.gummi-gutta* rind

Sample: Osmodehydrated *G.gummi-gutta* rind

Instructions : Your are given 6 osmo dehydrated samples. Evaluate them and give scores for each criteria

Criteria	Samples					
	1	2	3	4	5	6
Taste						
Colour						
Flavour						
Texture(hard/firm/soft)						
Overall acceptability						
Any other remarks						

<u>Score</u>

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

Date :   Name :

                                             Signature :

APPENDIX III

COLLEGE OF AGRICULTURE, VELLAYANI
Dept. of Post Harvest Technology

Title: Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala

Score card for assessing the organoleptic qualities of ready to cook paste from *G.gummi-gutta*

Sample: *G.gummi-gutta* paste

Instructions: You are given 5 samples. Evaluate them and give scores for each criteria

Criteria	Samples				
	1	2	3	4	5
Taste					
Colour					
Flavour					
Overall accepatability					

Score

Like extremely	-9
Like very much	-8
Like moderately	-7
Like slightly	-6
Neither like or dislike	-5
Dislike slightly	-4
Dislike moderately	-3
Dislike very much	-2
Dislike extremely	-1

Date :   Name :
                                          Signature :

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Postharvest Management

Title: Assessment of bioactive compounds and product development from major *Garcinia* spp. of Kerala

Score card for assessing the organoleptic qualities of sweet and sour pickles

Sample: **Garcinia pickle**

Instructions : Your are given 2 pickle samples. Evaluate them and give scores for each criteria

Criteria	Samples	
	1	2
Taste		
Colour		
Flavour		
Texture(hard/firm/soft)		
Overall acceptability		
Any other remarks		

Score

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

Date :   Name :

                                              Signature :