JACKFRUIT (*Artocarpusheterophyllus* Lam.) AS A POTENTIAL SOURCE OF BIOACTIVE COMPOUNDS.

VIRESH

(2017-22-003)

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM – 695522

KERALA, INDIA.

2022

JACKFRUIT (*Artocarpusheterophyllus* Lam.) AS A POTENTIAL SOURCE OF BIOACTIVE COMPOUNDS.

by

VIRESH

(2017-22-003)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2022

DECLARATION

I hereby declare that this thesis entitled **"JACKFRUIT (*Artocarpus heterophyllus* Lam.) AS A POTENTIAL SOURCE OF BIOACTIVE COMPOUNDS"** is bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellayani

Date: 22-03-2022

Viresh

(2017-22-003)

CERTIFICATE

Certified that this thesis, entitled **"JACKFRUIT (*Artocarpus heterophyllus* Lam.) AS A POTENTIAL SOURCE OF BIOACTIVE COMPOUNDS"** is a record of research work done independently by Mr. Viresh (2017-22-003) 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 him.

Mini C.
(Major Advisor, Advisory committee)
Professor and Head
Dept. of Post Harvest Technology
College of Agriculture, Vellayani

Vellayani
Date: 22-03-2022

CERTIFICATE

We, the undersigned members of the advisory committee of Mr. Viresh, a candidate for the degree of **Doctor of Philosophy in Horticulture** with major in Post Harvest Technology, agree that the thesis entitled **"JACKFRUIT (*Artocarpus heterophyllus* Lam.) AS A POTENTIAL SOURCE OF BIOACTIVE COMPOUNDS"** may be submitted by Mr. Viresh, in partial fulfilment of the requirement for the degree.

Dr. Mini C.
(Chairman, Advisory committee)
Professor and head
Department of Post Harvest Technology
College of Agriculture, Vellayani

Dr. Geetha Lekshmi P.R.
(Member, Advisory committee)
Assistant Professor
Departmentof Post Harvest Technology
College of Agriculture Vellayani

Dr. Soni K.B.
(Member, Advisory committee)
Professor
Department of Plant Biotechnology
College of Agriculture Vellayani.

Dr. Thomas George
(Member, Advisory committee)
Professor, AINP on Pesticide Residue
College of Agriculture, Vellayani.

Dr. A. N. Jyothi
(Member, Advisory committee)
Principal Scientist
Department of Crop Utilization
CTCRI, Sreekaraym,
Thriuvananthapuram-695017

22.3.22
Dr. K.R. VASUDEVA
Professor - PHT
Dept. of Postharvest Technology
College of Horticulture
UHS Campus, Bengaluru - 560 065

(EXTERNAL EXAMINER)

ACKNOWLEDGEMENT

I feel immense pleasure to express my profound and heartfelt thankfulness to Dr. Mini C.Professor and Head, Department of Post HarvestTechnology and Chairperson of the advisory committee, for her guidance, suggestions, constant encouragement, support, unfailing patience and above all the kind of understanding throughout the course of this research work and preparation of the thesis.

I wish to express my sincere gratitude to Dr. P.R. Geethalekshmi, Assistant Professor, Department of Post Harvest Technology and member of advisory committee, for her valuable suggestions, timely support, co-operation and critical evaluation during the course of this work.

.

I am thankful to Dr. Soni K.B,, Professor., Department of Plant Biotecnology, for her valuable suggestion, encouragement and co-operation rendered throughout the study, as amember of advisory committee.

I am grateful to Dr. Thomas George rofessor, AINP on Pesticide ResidueCollege of Agriculture, Vellayani and member of advisory committee for his valuable suggestions, timely support, co-operation and critical evaluation during the course of this work.

I am thankful to Dr. A. N. Jyothi Principal Scientist Department of Crop Utilization CTCRI, Sreekaraym, Thriuvananthapuram for her valuable suggestion, encouragement and co-operation rendered throughout the study, as a member of advisory committee.

I am thankful to the staff and faculty of Department of PHT, College of Horticulture UHS campus GKVK, Bengaluru and COH, Bagalkot for sharing the laboratory facility.

I take this opportunity to express my obligation to Aparna G S, Lekshmi, Kerrtahana, Swathi, Archana, Athira, Avinash, Tejashwi, Vijet, Sharanappa for the help rendered during the course of investigation.

I greatly acknowledge the sincere co-operation and assistance rendered by Archanachechi, Sreejachechi and Babychechi of Department of Post Harvest Technology to carry out the research work in proper time.

I also express my sincere thanks to all my classmates and juniors for their help, good company, positive criticism, unconditional love, care and moral support throughout my P.G. programme.

I am most indebted to my family members especially my wife Dr. Bhagyashree, daughter Anagha, my father, brother Dr.Sangamesh, sisters Sujatha and Savitri for their affection, constant encouragement, moral support and blessings that have enabled me to finish this work, without which I would not have completed this research.

Above all, I believe it is the unbound love and blessings of Lord Sangameshwara,Veerbhadreshwara and Guru RaghavendraSwamywhich is the prime factor that led to the successful completion of my entire work. I humbly bow my head before that almighty for the numberless blessings that he shower upon my life.

Viresh

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	Per cent
RH	Relative humidity
Mg	Milligram
Ml	Milliliter
O_2	Oxygen
CO_2	Carbondioxide
°C	DegreeCelsius
CD	Critical difference
Cm	Centimeter
et al.	And other co workers
Fig.	Figure
SE	Standard error
^oB	Degree brix
D	Days
IU	International Unit
G	Grams
µg	Micro gram
Mm	Micro molar
pH	Negativelogarithmof hydrogen ions
IC_{50}	Half-maximal inhibitory concentration
TSS	Total soluble solids
viz.	Namely
TPC	Total Phenolic Content
TFC	Total Flavonoid Content
GAE	Gallic Acid Equivalent
QE	Quercetin Equivalent

DPPH	2,2-diphenyl-1-picrylhydrazyl
rpm	Revolution Per Minute
min	Minute
UV-vis	Ultraviolet–visible
DMEM	Dolbecco's Modified Eagle Media
MTT	MTT (3[4,5-dimethylthiazol-2-yl]-2,5diphenyl tetrazolium bromide) method.
DMSO	Dimethyl sulfoxide
EDTA	Ethylenediaminetetraacetic acid
LCMS/MS	Liquid Chromatography with tandem mass spectrometry
PDA	Photodiode-Array Detection
DE	Dextrose Equivalent
MD	Maltodextrin
CRD	Completely Randomized Design
FSSAI	Food Safety and Standards Authority of India
RTS	Ready to serve

LIST OF APPENDICES

1. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.), evergreen tree belonging to the moraceae family is indigenous to India and is one of the important trees found in the home gardens of India and Bangladesh. It widely grows in Malaysia, Sri Lanka, India, Philippines, Burma, Indonesia, Pakistan China, etc. The most striking characteristic feature of this tree is its capacity to provide a fruit, which is considered to be the largest tree-borne fruit in the world (Jagadeesh *et al*., 2007). It is popularly known as the poor man's fruit in the eastern and southern parts of India. The fruit is the gigantic syncarp, which may weigh up to 45 kg and up to 36" length and 20" in diameter containing numerous hard cone-like points on the surface (Prakash *et al.,* 2009). The top five producers of jackfruit are India, Bangladesh, Thailand, Indonesia and Nepal (Tejpal and Amrita, 2016). In India the fruit is grown in an area of 185.00 thousand hectare with production of 1764 thousand tones (NHB, 2018). In Kerala area under jackfruit is 9.21 thousand hectare with the production of 286 million (number) fruits (GOK, 2019).

A bioactive compound is simply a substance that has a biological activity (Cammack, 2006). In a strictly scientific sense, the term "bioactive" is an alternative term for "biologically active" In medical dictionaries, a bioactive substance is defined as a substance having an effect on, causes a reaction, or triggers a response in the living tissue (Miller-Keane and O'Toole, 2003). These compounds are experiencing a growing interest in wide range of applications *viz*., geo- medicine, plant science, modern pharmacology, agrochemicals, cosmetics, food industry, nano-bioscience etc.

Jackfruit is not only consumed as a fresh fruit when ripe but also used as a vegetable in the unripe stage (Ong *et al*., 2006). About 60% of the fruit goes as inedible and unutilized (Subburamu *et al.,* 1992). These fruit wastes create problems for the processing industries and by-product recovery from fruit wastes not only improves the overall economics of processing units but also reduces the problem of environmental pollution considerably.

The work of several researchers has demonstrated the occurrence of different bioactive compounds in both jackfruit pulp and wastes and fruit wastes are proved to be rich sources compared to the pulp (Zhang *et al*., 2017). The growing interest in the substitution of synthetic chemicals by natural ones has made the researchers to focus on bulk vegetative sources and the screening of raw materials for identifying new phytochemicals. These can find ready use in processing industries for replacing their synthetic counterparts. Studies have shown that jackfruit contains many classes of compounds *viz*., carotenoids, flavonoids, volatile acids, sterols, and tannins, and their concentration varies with the variety (Arung, *et al*., 2007). Several studies conducted have validated jackfruit's pharmacological properties *viz.*, antioxidant, anti-inflammatory, and antibacterial, anti-cariogenic, anti-cancerous and wound healing and other properties. Hence, special attention needs to be given on their effective extraction from inexpensive or residual sources from processing industries and utilizing them in the treatment of chronic diseases.

Diabetes mellitus is a metabolic disease characterized by high blood glucose levels, which has been one of the major causes of death in people younger than 60 years. It is predicted that over 552 million people will suffer from diabetes by the year 2030 (Whiting *et al*., 2011). Randomized controlled trials revealed that the clinical glucosidase inhibitors, acarbose, and miglitol, possess many gastrointestinal side effects on patients, causing flatulence, diarrhoea, borborygmus, abdominal pain, and distension (Chiasson *et al*., 2002). Plant based natural α- glucosidase inhibitors are attractive to researchers and consumers due to their low cost and relatively higher safety. Both *in vivo* and *in vitro* studies have proven the anti-hyperglycemic property of jackfruit.

Cancer is one of the major causes of morbidity and mortality in the world, with 14.1 million new cases and 8.2 million deaths annually (Leal *et al*., 2016). Cervical cancer ranks third among all female cancers and is the fourth-leading cause of death worldwide. In contrast to developed countries, cervical cancer is a public health problem in developing countries like India, and India

alone accounts for one-quarter of the worldwide burden of cervical cancers (Ferlay *et al*., 2015). Cancer patients receiving chemotherapy or radiotherapy routinely experience various side effects, including toxicity, damage to other non-targeted tissues, hair loss, neurotoxicity, multidrug resistance, nausea, anemia, and neutropenia. These side effects limit and/or compromise the effectiveness of therapeutic processes. Phytochemicals can interfere with almost every stage of carcinogenesis to prevent cancer development (Yadav *et al*., 2020). Therefore, there is an urgent need for the development of new anticancer agents with better efficacy and lesser side effects. In the US approximately 50–60% of cancer patients use plant derived nutrients as complementary and alternative medicine, with or without traditional chemotherapy and/or radiation therapy.

The commercial utilization of phytochemical extracts in their crude form generally exhibit some formulation problems *viz*., lack of long-term stability, making these natural compounds sensitive to light and heat. Many of these molecules possess a very astringent and bitter taste, which limits their use directly in food and must be masked before their incorporation in foodstuffs. Among the existing stabilization methods, encapsulation is an efficient means and the microencapsulated products are widely used in the food, pharmaceutical and cosmetic industries (Ray *et al*., 2016). Different techniques *viz*., spray-chilling, freeze-drying, melt extrusion and melt injection are used for the encapsulation of bioactive compounds. Though spray drying is widely used in the food industry due to its rapidity and low cost, spray-drying conditions of polyphenols must be optimized in order to avoid accelerated degradation. Freeze-drying can be utilized for the encapsulating bioactive compounds that are sensitive to high temperature (Ballesteros *et al*., 2017). Compared to spray-drying, freeze-drying requires significantly higher processing times and higher unit cost which is a major disadvantage.

Fortification of beverage with phytochemicals can be done by incorporation of microencapsulated extracts to improve solubility and stability. Mango (*Mangifera indica* L.) RTS is one of the favored beverages that can be

utilized for preparing a antioxidant rich drink by utilizing encapsulated phytochemicals.

Hence the present study was conducted with the objective to standardize the extraction procedure for maximizing the antioxidant, anti-cancerous and anti-hyperglycemic properties of fruit wastes from varikka and koozha jackfruit types, phytochemical profiling, encapsulation and commercial exploitation of encapsulated extracts for fortification of fruit juice beverages

2. REVIEW OF LITERATURE

The consumption of bioactive plant products is gaining significance all over the world. Jackfruit contains many classes of compounds *viz*., carotenoids, flavonoids, volatile acids, sterols and tannins, the concentration of these varies with the variety (Arung *et al*., 2007). Quite a number of works have demonstrated the occurrence of different bioactive compounds in both jackfruit pulp and wastes and fruit wastes are proved to be rich sources compared to pulp. The growing interest in the substitution of synthetic chemicals by natural ones has made the researchers to focus on bulk vegetative sources and screening of raw materials for identifying new phytochemicals. Several studies conducted have validated jackfruit's pharmacological properties *viz.*, antioxidant, anti-inflammatory, and antibacterial, anti-cariogenic, anti-cancerous and wound healing and other properties. Reports suggest that almost all parts of the jackfruit tree are of use in the preparations of various Ayurvedic and Yunani medicines (Saxena *et al*., 2009).

In this chapter, research works on extraction of bioactive compounds, pharmacological properties, encapsulation of extracts by microencapsulation techniques and utilization of encapsulates in fortification of beverages and other foods from jackfruit and other related fruit crops are reviewed.

2.1 PREPARARION OF CRUDE EXTRACTS

2.1.1 Effect of Extraction Methods and Solvents on Bioactivity of Phytochemicals

Appropriate extraction technique is required to conduct separation, identification, and characterization of bioactive compounds. Both conventional and non-conventional extraction techniques are employed. In solid-liquid extraction, the solvent has a major impact on the extraction of bioactive compounds. Choice of appropriate solvent depends on factors *viz*., polarity of solvent, solutes extracted, compound/solvent interactions etc. Generally, a crude

extract and a pure compound are considered important if the IC_{50} values are below 100 µg mL^{-1} and 25 µM, respectively (Cos *et al*., 2006).

To overcome major challenges of conventional extraction *viz.*, longer extraction time, requirement of costly and high purity solvent, evaporation of the huge amount of solvent, low extraction selectivity and thermal decomposition of thermo labile compounds advanced extraction techniques are getting importance (De Castro and Garcia-Ayuso, 1998). Some of the most promising techniques are Microwave assisted extraction, Ultrasound assisted extraction, Supercritical fluid extraction, Pressurized liquid extraction, Hydrotropic extraction and Enzyme-assisted extraction.

2.1.1.1 Antioxidant Activity

Jagtap *et al.* (2010) evaluated antioxidant properties of jackfruit pulp extract (JFP) from Western Ghats and found ethanol and water as the best solvents for antioxidant extraction. Water was the best solvent for extracting flavonoid compounds whereas for phenols it was ethanol. The JFP extract showed higher ability to reduce Fe^{3+} to Fe^{2+} for methanolic compared to water extract. For the DMPD (N, N-dimethyl-p-phenylendiamine) assay lowest IC_{50} values were recorded for methanolic extract. The capacity of antioxidant property of JFP extract against DPPH radical, (FRAP) and DMPD assay was established.

Jackfruit seeds were extracted using two different solvent systems: dichloromethane: methanol (1:1) and acetone by Gupta *et al*. (2011). *In vitro* antioxidant activity assays indicated that, seed extracts possessed appreciable DPPH, ABTS scavenging effects and metal ion chelating activity in a concentration-dependent manner. Polyphenolic content and antioxidant properties of dichloromethane: methanol (1:1) extract of jackfruit seeds was found to be high and well correlated. Results of the study indicated that jackfruit seeds could be used in balanced diets and functional foods, which can be consumed safely without any health risks.

Zhu *et al.* (2017) extracted a water soluble polysaccharide from jackfruit pulp (JFP-Ps) and purified its physicochemical properties. Evaluation of *in vitro* antioxidant activities of pulp showed that JFP-Ps exhibited strong DPPH and OH radical scavenging activities, with a relatively lower reducing power, suggesting that JFP-Ps can be utilized as effective natural antioxidant in medical and food industries.

Daud *et al.* (2017) evaluated antioxidant potential of jackfruit variety J33 fruit waste (rind and rachis separately) prepared using different extraction methods *viz.*, maceration, percolation and soxhlet techniques with 70 % ethanol. In the DPPH assay, extract from maceration of rind (RDM) showed the highest scavenging activity followed by rind percolation (RDP) and Rind Soxhlet (RDS). The rachis crude extracts from the three extraction methods showed the same trend in the order of RCM > RCP > RCS for percent inhibition respectively. Similarly, in terms of the reductive ability of antioxidants, as evaluated by the FRAP assay, RDM exhibited the highest value followed by RDP and RDS. For both rind and rachis, the maceration technique yielded extracts with the strongest antioxidant activities which correlated with the highest Total Phenolic Content (TPC) and Flavonoid Content (TFC). LCMS analyses suggested that protocatechuic acid and chlorogenic acid derivatives could be the two major constituents responsible for the observed higher antioxidant activities.

Xu *et al*. (2018) reported ultrasonic-microwave assisted extraction (UMAE) of pectin from jackfruit peel. The results of extraction revealed that the pectin yield of UMAE was higher than conventional heating. The optimal conditions of UMAE were determined as: extraction temperature of 86^{o}C, extraction time of 29 min, and solid-liquid ratio of 1:48 (*w/v*) with a maximum pectin yield of 21.5%. Antioxidant activity by DPPH shown, pectin from UMAE (UM-P) stronger than pectin obtained from conventional heat method(CH-P).

Oven dried Jackfruit peel was extracted with ultrasonic transducer clubbed with microwave oven using aqueous ethanol as solvent at varied solvent to liquid

ratios. The optimum extraction conditions based on Response Surface Methadology were: ethanol concentration 63%, solvent-to-solid ratio 34 mL g^{-1}, microwave power 160 W and irradiation time of 20 min. As the ratio exceeded 30 mL g^{-1}, the extraction yields were almost constant regardless of increase of ratio of solvent to solid. Under the optimal condition, the phenolic content was found to be 8.14 mg GAE g^{-1} DW. (Jiang *et al*., 2019).

Adan *et al*. (2020) determined the phytochemical profile, antioxidant and antimicrobial activities of extracts from three parts (peel, fiber and the core) of jackfruit using different solvents and extraction techniques. Phenolic and flavonoid contents were found highest in methanol extracts obtained from 48 hours incubation, whereas the highest content of tannins was obtained with distilled water and homogenization process. The extracts of unutilized parts of jackfruit have potential antioxidant and antimicrobial properties that varied depending on the extraction solvent used. These results of the study established that peels, fiber and the core of jackfruits exhibited high antioxidant and antibacterial activities *in vitro*.

Mustafa *et al*. (2020) studied effect of different drying treatments and ethanol/water ratios on antioxidant properties and colour attribute of jackfruit leaves. Leaves dried in shade were able to preserve the green pigment better than oven (OV) and sun drying (SN) treatments. Leaves dried in oven at 80º C and extracted with 80% ethanol have shown highest phenolic content, flavonoid content and antioxidant activities compared to the sun and shade drying. The leaves dried in oven at 80º C also possessed the highest artocarpin, squalene, and β-sitosterol contents.

Hossain *et al*. (2020) developed a protocol to achieve the maximum antioxidant yield from jackfruit seed and pulp by optimizing the optimum extraction conditions. Using response surface methodology (RSM). The optimum condition for maximum antioxidant activity in seeds was observed when acetone was used as solvent at 65°C and 10 min, showing 8.76 per cent DPPH, 2.81 mg

GAE 100 g^{-1} DM TPC, 149.99 mg AAE 100 g^{-1} DM FRAP and 0.99 desirability. The optimum condition for maximum yield of antioxidant activity in pulp was obtained with acetone at 50°C for 10 min, exhibiting 45.42 % DPPH, 3.06 mg GAE 100 g^{-1} DM TPC, 129.05 mg AAE 100 g^{-1} DM FRAP and 0.99 desirability. Extraction of antioxidants from jackfruit seed and pulp can be performed more efficiently by maintaining the optimum conditions.

Dorta *et al*. (2012) studied the effect of different drying methods (freeze drying and oven drying) on the antioxidant activity of mango peel and seed of cultivar Keitt. Freeze-drying stabilized peel and seed powder extracts (ethanol and water) without diminishing their antioxidant activity and also improved mango peel's antiradical capacity against $ABTS^{\bullet+}$, DPPH and lipid peroxidation. Extracts from oven dried samples at 70 °C (with static or forced air) have shown considerable decrease in the antioxidant activity. Effect of drying methods have influenced the phenol and anthocyanin content of mango peel or seed and is related to antioxidant activity, indicating that the phenol content of both materials is largely responsible for their antioxidant activity.

The influence of variety (Cavendish and Dream), stage of ripeness (green and ripe) and parts (pulp and peel) on antioxidative compounds and antioxidant activity of banana fruit was investigated. Cavendish banana flour contained higher TPC and TFC compared to Dream variety. TPC and TFC values of banana peel were higher than those of banana pulp. Green banana showed higher TPC and TFC values than those of ripe fruit. Although Dream banana peel extracts appeared to have low TPC and TFC, its antioxidant activities were ranked moderate to high. This implies that antioxidative compounds other than phenolics and flavonoids were probably responsible for inhibition of DPPH (Fatemeh *et al*., 2012).

Oven dried papaya peel and seed powder were extracted using water and acetone as solvents. Papaya peel extracted using 90% acetone (v/v) for 60 min have recorded the highest TPC. Extraction of papaya seed powder using deionised

water for 120 min had the highest TPC. Papaya peel and seed extracts demonstrated potent antioxidant activity to a certain extent and could be of nutraceutical importance for food industry application (Ang *et al*., 2012).

Phenolic composition and biological activities of pomegranate peel extracted with 70 per cent ethanol and its fractions (petroleum ether, ethyl acetate, butanol and water) by liquid/liquid extractions were studied by Savikin *et al*. (2018). The highest total phenolic content was obtained in ethyl acetate fraction. Ethyl acetate fraction had the highest amounts of gallic acid and ellagic acid, while water fraction contained the highest contents of punicalin and punicalagin. Antioxidant activity was evaluated by four different methods and butanol and ethyl acetate fractions were the most active in 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2′-azino-bis (3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS) assays, whereas water fraction showed the strongest activity in ferric reducing antioxidant power (FRAP) and β-carotene tests.

Dried and fresh pineapple peel waste (PPW) were extracted using mixtures of ethanol and water in various concentrations ranging from 0:100, 15:85, 35:65, 55:45, 75:25 and 100:0 v/v at ambient room temperature for 24 h. The highest antioxidant activity was noticed in water extract and it also contained the highest total phenolic content (Saraswaty *et al*., 2017).

2.1.1.2 Antidiabetic Property

Type- 2 diabetes is more prevalent than Type-1 and postprandial hyperglycemia plays an important role in the development of Type-2 diabetes (Baron, 1998). The ability of a drug or diet to delay the production or absorption of glucose by inhibiting carbohydrate-hydrolyzing enzymes is one of the therapeutic approaches for decreasing postprandial hyperglycemia (Tiwari and Rao, 2002). α-Glucosidase inhibitors(AGIs) are generally recommended as effective approaches for managing the fasting and postprandial blood glucose levels (Kalra, 2014). Acarbose and miglitol, the two commonly used clinical drugs for management of Type-2 diabetes are reported to cause many

gastrointestinal side effects. The need for plant based natural alpha glucosidase inhibitors (AGIs) and application of traditional knowledge in exploring relevant plants is becoming attractive to researchers and consumers due to their low cost and relatively higher safety.

Kotowaroo *et al*. (2006) have shown that aqueous extract from dried jackfruit leaves inhibited α-amylase activity *in vitro*. Incubation of graded concentrations of the aqueous leaf extract with α-amylase and starch caused a significant decrease in the enzyme activity in the chemical assay. Studies also showed that the extract inhibited the α-amylase activity in rat plasma *in vitro*. The highest inhibitory activity was reported at a concentration of 1000 μg/ml with dose dependency. Detailed enzyme kinetic studies showed that the leaf extract behaved as a competitive inhibitor of α-amylase.

Osmani *et al.* (2009) studied the effect of *in vivo* antidiabetic potential of ethanolic seed extract of jackfruit (extracted using soxhlet) on normal and strepozotocin induced diabetic rats using oral administration. Extracts were administered at doses of 400 mg kg^{-1} body weight and blood glucose levels were monitored at specific intervals. Ethanol extract (400 mg kg^{-1}) showed significant antidiabetic activity compared to standard drug (Glibenclamide 2.5 mg kg^{-1}). The phytochemical constituents present in the seed extracts makes it possible form of antidiabetic drug.

Oleksii *et al* (2014) reported that application of Pulsed Electric Field and supplementary aqueous extraction at 50°C had allowed a significant enhancement of antioxidant capacities of the extracted components from papaya peels even at neutral pH.

Biworo *et al.* (2015) evaluated antidiabetic and antioxidant activity of aqueous extract of jackfruit. The antidiabetic activity was determined by inhibition of haemoglobin glycation method. Result of this study revealed that, jackfruit extracts could inhibit the haemoglobin glycation. An increase in haemoglobin glycation concentration that can be inhibited by the extracts was

observed (with the increasing jackfruit extracts concentration). The inhibition might be caused by the presence of phytochemical constituent in jackfruit extract *viz*., ascorbic acid, β -carotene and lycopene.

The α-glucosidase inhibition(AGIs) of methanolic extract of jackfruit peel, pulp, fruit flake and seed revealed that, all the extracts were capable of inhibiting the activity of α-glucosidase in a concentration-dependent manner, and the inhibition followed the pattern of peel extract > seed extract > pulp extract > flake extract. The highest inhibition was observed in peel extract with the lowest IC_{50} value which was 10.8 times higher than positive control acarbose. This indicates that jackfruit peel can be a promising source of effective natural AGIs. Correlation analysis revealed that α-glucosidase inhibition was moderately correlated with total phenolics content (r = -0.621), however, no correlation was observed between α-glucosidase inhibition and total flavonoids content. It can be speculated that phenolics are one of the major AGIs present in jackfruit peel, and other class of compounds may contribute to the similar activity detected in pulp and seed. (Zhang *et al*., 2017).

Freeze dried pomegranate peel (PP) was extracted with hexane (C1), ethyl acetate (C2), methanol (C3), methanol/water (C4) and water (C5) and the extracts were assessed for its antioxidant and antidiabetic potential. Extracts, C2 and C3, which exhibited maximum free radical scavenging and α-glucosidase inhibitory activity, were further fractionated using hexane, ethyl acetate and methanol (C2–F1, F2, F3; C3–F4, F5, F6). Fractions, F1 and F5, of methanol extract showed α-glucosidase inhibition.. F5 demonstrated promising inhibition against LDL oxidation (low density lipoprotein oxidation) and ACE (Angiotensin-1 Converting Enzyme) inhibition properties. These findings suggest the ability of pomegranate peel extracts to manage type 2 diabetes and associated complications (Arun *et al*., 2017).

Savikin *et al*. (2018) studied phenolic composition and biological activities of pomegranate peel extracted with 70 per cent ethanol and its fractions

(petroleum ether, ethyl acetate, butanol and water) obtained by liquid/liquid extractions. All the fractions showed better inhibitory effect on α-glucosidase, with inhibition concentration $IC_{50} = 0.26–4.57$ μg/mL, than α-amylase ($IC_{50} = 23.6–284.3$ μg/mL), and the most active was ethyl acetate fraction. Pomegranate peel could be considered as a valuable agro-industrial waste product which could be used as low-cost natural source of biologically active compounds.

Effect of hydro alcoholic extract of mango leaves cv Anwar Ratol on alloxan induced diabetic mice followed by evaluation through oral glucose tolerance was studied. The extract prevented the rise in blood glucose level than the disease control group, 2 h following the administration of glucose solution. A therapy for seven days with 550, 750 or 950 mg/kg extract in diabetic mice showed remarkable decrease in postprandial blood glucose level compared to untreated diabetic mice. The postprandial blood glucose level in experimental groups was comparable to the glibenclamide treated mice. The findings of the study clearly suggested that the leaf extract of the plant might possess anti-diabetic activity possibly due to the presence of mangiferin and other phytochemicals such as phenolic and flavonoid compounds (Begum and Srivalli., 2019)

Kato-Schwartz *et al*. (2020) studied effect of hydro alcoholic (40% ethanol + 60% water) extract of Merlot grape pomace extract (MGPE) by quantifying its effect (in vitro inhibition) using potato starch (for amylases) and maltose (for α-glucosidase) as substrates. Both α-amylases, pancreatic and salivary, were inhibited by the MGPE, however α-glucosidase inhibition was not detected. *In vivo* inhibition was evaluated by running starch and maltose tolerance tests in rats with or without administration of MGPE. Ranking of the extract compounds for its affinity to the α-amylases was accomplished by computer simulations using three different programs. Kinetically this inhibition showed a complex pattern, with multiple binding of the extract constituents to the enzymes.

Agada *et al*. (2021) studied the antioxidant and anti-diabetic activities of bioactive fractions of *Carica papaya* seeds extracts. Extracts were prepared from the powder of shade-dried seeds from ripen fruits using soxhlet protocol and the resulting crude extracts were fractionated using different solvents viz., hexane, ethyl acetate, methanol, and water. Results revealed that ethyl acetate fraction C and D showed maximum inhibition for α-amylase. Likewise, ethyl acetate fraction C and D exhibited α-glucosidase inhibition activity. The ethyl acetate fractions C and D were further purified to obtain sub-fraction K, L, M, and N and evaluated for in vitro antioxidant and anti-diabetic activities. However, the sub-fraction K elicited the most conspicuous anti-diabetic activity towards α-amylase and intestinal α-glucosidase. Sub-fraction K exhibited a competitive mechanism of inhibition on both α-amylase and α-glucosidase. The GC-MS profile confirmed the presence of diverse metabolites in the sub-fraction and the major bioactive compounds detected were hexadecanoic acid, methyl ester, 11-octadecenoic acid, methyl ester, N, N-dimethyl, n-hexadecanoic acid, and oleic acid.

2.1.1.3 Anti-cancerous Property

Cancer is one of the major causes of morbidity and mortality in the world, with 14.1 million new cases and 8.2 million deaths annually (Leal *et al*., 2016). Cervical cancer ranks third among all female cancers and is the fourth-leading cause of death worldwide. In contrast to developed countries, cervical cancer is a public health problem in developing countries and India alone accounts for one-quarter of the worldwide burden of cervical cancers (Ferlay *et al*., 2015). Cancer patients receiving chemotherapy or radiotherapy routinely experience various side effects including toxicity, damage to other non-targeted tissues, hair loss, neurotoxicity, multidrug resistance, nausea, anemia, and neutropenia. These side effects limit and/or compromise the effectiveness of therapeutic processes. Phytochemicals can interfere with almost every stage of carcinogenesis to prevent cancer development (Yadav *et al*., 2020). Therefore, there is an urgent need for the development of new anticancer agents with better efficacy and lesser side effects. In the US approximately 50–60% of cancer patients use plant derived

nutrients as complementary and alternative medicine, with or without traditional chemotherapy and/or radiation therapy.

Ruiz-Montanez *et al*. (2015) extracted jackfruits pulp with methanol, acetone or hexane at physiological and commercial maturity stages. Fractionation of jackfruit pulp extracts was carried out by semi preparative HPLC using semi preparative column. The extracts were tested on M12.C3.F6 murine cell line at 200 µg/ml in order to select the fraction with the highest antiproliferative activity. The extracts of pulp from fruit harvested at physiological maturity with methanol (MF) and acetone (Af) and pulp from fruit harvested at commercial maturity extracted with hexane (Hm) exerted a significant antiproliferative activity compared to the others. The inhibition activity of different concentrations of the fractions, from 50 to 400 µg/ml, were evaluated. These fractions were partitioned with hexane and methanol solvents. The maximum antiproliferation activity was obtained with the fractions M-Hm and M-Af at concentrations of 100 and 200 µg/ml respectively.

Arung *et al*., (2010a) investigated the cytotoxic effects of the isoprenoid-substituted flavonoids isolated from the methanolic extract of the jackfruit wood on B16 melanoma cells. Culturing B16 melanoma cells in the presence of these phytochemicals (for 72 h) caused a concentration dependent cytotoxicity and the antineoplastic efficacy was in the order of increasing IC_{50}, norartocarpin (7.8 µM), cudraflavone C (9.2 µM), nartocarpin (10.3 µM), nbrosimone I (10.7 µM), ncudraflavone B (12.5 µM), nkuwanon C (14.2 µM), N6-prenylapigenin (32.5 µM), nalbanin A (84.7 µM), nartocarpanone (122.2 µM). Except for the albanin A and artocarpanone all other phytochemicals were more active than the clinically used vinblastine (IC_{50} of 50 µM), carmustine (120 µM), and 5-fluorourasil (240 µM). The results clearly indicated that the flavonoids with an isoprenoid substituent were more effective than those without isoprenoid substituents and cytotoxic potency was in proportion to the number of isoprenoid moiety substitutions.

Artocarpin exhibited potent cytotoxic activity on cultured human T47D breast cancer cells *in vitro*. Incubation of the cells with graded doses of artocarpin for 24 hours resulted in a concentration dependent cytotoxic effects. Artocarpin caused concentration dependent apoptosis and mechanistic and it was mediated by the activation of caspase 3 and caspase 8 but not caspase 9 or caspase 10. These observations clearly indicated that the isoprenoid-substituted flavonoids of jackfruit (artocarpin) possess cytotoxic effects. Future studies should be extended to animal models as these studies will clearly indicate the anticancer effects and whether this effect will be at a physiologically attainable concentration (Arung *et al*., 2010b).

Extracts from different parts of the pomegranate fruit *viz*., whole fruit, pulp and peel were assessed for their anticancer and antioxidant properties. Extract from 50% ethanol was found to contain higher total polyphenols compared to 70 per cent ethanol. The peel extract showed the highest antioxidant activity compared to the other two extracts and also a pronounced anticancer activity against MCF-7 human breast cancer cells and HCT-116 colon cancer cells. The standardized peel extract was formulated into capsules which gives a possible scope for use of pomegranate peels, a biological waste product, to develop natural pharmaceutical preparations. (Motaal and Shaker, 2011)

Identification of individual gallotannins and evaluation of antiproliferative activities of gallotannin-rich extracts from kernel and peel of three chinese mango cultivars were carried out by Luo *et al*.(2014). Five gallotannins, i.e. penta-, hexa-, hepta-, octa-, and nona-*O*-galloyl-glucoside were isolated and identified by LC-ESI-MS/MS and NMR, and quantified by HPLC. Mango kernel was a much richer source of gallotannins than its peel, and its antiproliferative effects on MDA-MB-231 breast, HepG2 liver, and HL-60 leukemia cancer cells were reported for the first time. $DPPH^{\bullet}$ scavenging and antiproliferative activities of the mango kernel and peel extracts may be partially caused by penta-*O*-galloyl-glucoside or its analogs with different galloyl groups since penta-*O*-galloyl-glucoside and gallic_acid also revealed high antioxidant and antiproliferative

activities. Therefore, the gallotannin-rich extracts of mango kernel and peel may serve as natural sources of anticancer agents and may have important pharmaceutical potential

2.1.1.4 Antifungal Activity

The extract of the jackfruit leaf reported to be ineffective on *Aspergillus niger, A. rubrum, A. ersicolor, A. vitis, Candida albican, C. tropicalis, Cladosporium cladosporiods, Penicillium notatum, Trychophyton mentagrophytes and T. tronsurum* (Khan *et al*., 2003). Chitin binding lectin present in the seeds of jackfruit shown to inhibit the growth of *Fusarium moniliforme* and *Saccharomyces cerevisiae* (Trindade *et al*., 2006).

Vázquez-González *et al.* (2020) reported that, the extracts from the jackfruit leaves obtained by high-hydrostatic pressure (HHP) showed the best antifungal activity against *Colletotrichum gloeosporioides* and *Penicillium italicum in* comparison with microwave assisted and ultrasound assisted extraction (MAE). The antifungal activity was enhanced by selective extractions, observing that the intermediate polarity fractions showed the highest antifungal activity due to the presence of phenolic compounds identified as quinic acid, catechin and chlorogenic acid. The leaf extract obtained may be a viable biocontrol strategy in controlling post harvest disease management by using the extract as coating.

2.1.1.5 Antibacterial Effects

Total water extract, ethyl acetate, and aqueous fractions from the leaves of jackfruit were evaluated for antibacterial activities against common foodborne pathogens. The minimum inhibitory concentration (MICs) of extract and fractions determined by the agar dilution method were ranged from 221.9 μg mL^{-1} for ethyl acetate fraction to 488.1 μg/mL for total extract. In the agar diffusion method the diameters of inhibition were 12.2 for the total extract, 10.7 and 11.5 for ethyl

acetate and aqueous fractions respectively. The natural origin of these extract and fractions means more safety for people and environment and low risk for resistance development by pathogenic microorganism (Loizzo *et al*., 2010).

2.1.1.6 Anti-inflammatory Effect

Surfeit generation of free radicals especially under conditions of chronic inflammation is harmful to the cells. The anti-inflammatory activity of the new protease fraction Artocarpain-H extracted from the jackfruit stem latex of the plant was evaluated using carrageenan induced rat paw oedema and cotton pellet-induced granuloma model. The Artocarpain-H dose dependently inhibited carrageenan induced rat paw edema. It also showed reduction on the granuloma weight in the cotton pellet granuloma method. As the test drug is effective in both models of inflammation, there is a possibility that these drugs may be effective in acute and chronic inflammation.

2.2 PHYTOCHEMICAL PROFILING

Daud *et al.* (2017) conducted phytochemical profiling of jackfruit rind and rachis extracts by LCMS in the negative mode. Studies on phenolic constituents of the extracts by mass spectrometry have identified five peaks (a to e). Gluconic acid, vaccihein A, stachyose hydrate were identified in peak a. quinic acid (peak b), pyromeconic acid and comenic acid (peak c), protocatechuic acid (peak d), quincic acid and chlorogenic acid (peak e) were identified from the extracts.

The phytochemical profile of jackfruit peel extract was characterized using HPLC-QTOF-MS/MS to explore the possible functional compounds by (Zhang *et al*., 2017). Eight organic acids were found in jackfruit peel extract viz., quinic acid, malic acid, quinic acid isomers, and citric acid, naphthalenedicarboxylic acid-O-hexose, resorcylic acid-O-hexose and hydroxycaproic acid-O-hexose. A total of 9 hydroxycinnamic acids and 3 hydroxycoumarins were detected in

sample, including 6 caffeoylquinic acid (CQA) isomers, a 3,4-dihydroxybenzoic acid methyl ester-C-dihexoside, a feruloylglucose , a caffeoylglucose. Three esculetin glycosides were the major phenolic acids present in the extract. Flavonoids were the dominant compounds present in jackfruit peel extract and 18 flavonoids were found in this experiment.

Sundarraj and Ranganathan (2018) conducted investigation to know phytochemicals present in the fruit peel extract of jackfruit (*Artocarpus integer*) and the development of new solvent system for thin-layer chromatography (TLC). TLC – was performed using ethyl acetate: acetic acid in the ratio of 95:5. The results showed that the peels contain a maximum amount of carbohydrates, flavonoid, and some phenolic compounds.

Jiang *et al*., 2019 analyzed chromatograph of Jackfruit peel extracted with Ultrasonic microwave-assisted extraction coupled with macroporous resin using HPLC DAD. Gallic acid, chlorogenic acid and catechin were identified in the extract of jackfruit peels by comparing the retention times with authentic standards. The purification of phenolics was performed by the adsorption of resin and desorption of aqueous ethanol. The amount of individual phenolics in jackfruit peels (expressed as mg g^{-1} DW) were *viz*., gallic acid (0.68 ± 0.01), chlorogenic acid (2.53 ± 0.04) , catechin (0.56 ± 0.01) in jackfruit peels. The results revealed that chlorogenic acid was the dominant phenolic compound in and might be mainly responsible for the antioxidant activity shown by jackfruit peels.

The LCMS analysis was conducted for the identification of bioactive constituents in the oleoresin extracts of *A. heterophyllus* seed waste by Olalere *et al,* (2020). A total of 90 and 148 bioactive constituents were identified at positive and negative Electrospray ionization (ESI) modes respectively. The bioactive compounds were identified with their mass-to-charge ratio (m/z), retention time and adducts. The FT-infrared emission spectrum showed the presence of some

specific carbohydrates and amide protein functional groups directly linked to C–O (1008 cm^{-1}) the carbonyl (C=O) groups, respectively. The morphological characteristics of the jackfruit raw and crude extracts conspicuously revealed large-sized globules which suggest the carbohydrates and protein contents. From the positive ionization, the pungent shogaols (m/z ¼ 543.20, RT ¼ 5.93 min) which is similar to the established piperine and capsaicin from chilli and black pepper was identified.

A water-soluble polysaccharide from *Artocarpus heterophyllus* Lam. (jackfruit) pulp (JFP-Ps) was purified and profiling was done using Fourier transform infrared spectroscopy (FT-IR) and High Performance Gel Permeation Chromatography (HP-GPC). The amino acid compositions of JFP-Ps were determined by comparing chromatograms of sample with 18 amino acid standards and 15 general amino acids were detected in JFP-Ps. The chromatogram of JFP-Ps showed that the abundant amino acids in JFP-Ps were asparagic acid (Asp), Glutamic acid (Glu), Valine (Val), Leucine (Leu) and Lysine (Lys) (Zhu *et al*., 2017).

The artocarpin, squalene, and β-sitosterol content of jackfruit leaves dried with different drying treatments *viz*., shade (SD), sun (SN), and oven (OV) and extracted with 80% ethanol/water ratio and analyzed with HPLC varied significantly. Among all the crude samples assayed OV80 showed significantly higher artocarpin content compared to other drying treatments. Squalene content was also find high in OV80 (1.47 mg/g) drying treatments. Sun drying had the lowest values of both volatile compounds. Oven dried samples dried at low temperature and extracted using 80% ethanol/water resulted in more release of bound phenolic and flavonoid contents from the plant matrix which resulted in thick mass recovered in the extract during the extraction (Mustafa *et al*., 2020).

2.3 ENCAPSULATION OF EXTRACTS

The commercial utilization of phytochemical extracts in their crude form generally exhibit some formulation problems *viz*., lack of long-term stability, making natural compounds sensitive to light and heat. Many of these molecules possess a very astringent and bitter taste, which limits their use directly in food and must be masked before their incorporation in foodstuffs. Therefore, the commercialization of these extracts requires the formulation of a protecting product, able to maintain the structural integrity of the phytochemical until consumption, mask its unpleasant taste, and convey the properties precisely and efficiently to the processed product. Among the existing stabilization methods, encapsulation is an efficient means and the microencapsulated products are widely used in the food, pharmaceutical and cosmetic industries (Ray *et al*., 2016).

Bioactive compounds are often unstable in the presence of oxygen, light, heat and moisture. A promising approach to preserve their native properties over time is encapsulation based on reservoir or matricial particles. These systems may constitute a physicochemical barrier against pro-oxidant elements such as free radicals, oxygen or UV. Encapsulation also represents a way to improve biological efficiencies *viz.*, shelf life, control active components delivery and could prevent side effects (Shahidi and Han, 1993). Compounds with biological activities are reported frequently in the jackfruit. These compounds are susceptible to structural changes *viz.*, isomerization and/or loss of bonds due to environmental factors. In such circumstances encapsulation for protecting biological activities gains importance and becomes inevitable.

Ruiz-Montañez *et al*., (2017) investigated the development of an eco-friendly nanoemulsion to maintain the bioactivity of a carotenoids rich extract from jackfruit (*Artocarpus heterophyllus* Lam) pulp. The influence of the sucrose monostearate (SMS) content (0.5–2%, w/w), miglyol content (5–20%, w/w) and

homogenization pressure (400–800 bar) on the droplet size distribution, rheology and stability of emulsions processed by high-pressure homogenization was studied. The pulp extract was incorporated in the oily phase of the selected emulsion (5% miglyol + 0.5% SMS processed twice in a high-pressure homogenizer at 800 bar). The antioxidant activity of the jackfruit extract loaded in the selected emulsion stored at 4 °C exhibited a longer stability compared to the same extract dissolved only in miglyol.

Wong and Tan (2017) encapsulated jackfruit (Type: Honey) puree liquefied with 1.0% (v/w) Pectinex Ultra SP-L and 0.5% (v/w) Celluclast 1.5 L for 1.5 h by spray drying at different inlet temperatures (140º and 180º C) and maltodextrin concentrations (10–30% w/w). Results indicated that the spray-dried honey jackfruit powder produced at 160º C with 30% w/w maltodextrin gave the highest product yield with good powder qualities in terms of water activity, solubility, moisture content, hygroscopicity, color and bulk density. The spraydried honey jackfruit powder could potentially be incorporated into various food products.

Ruiz-Montañez *et al*. (2019) developed stable and safe eco-friendly microcapsules from jackfruit extract by ultrasound and spray drying using three safe ingredients; sucrose ester (SE), miglyol and maltodextrin (DE = 10). Encapsulation process by spray drying produced stable microcapsules, with adequate physicochemical and fluid properties. The cell viability on the proliferation of M12.C3.F6 cell line was not affected by powder microcapsules without jackfruit extract, indicating that capsules are not toxic for these cells. Microcapsules with jackfruit extract (100 μg mL^{-1}) were able to significantly inhibit the proliferation of M12.C3.F6 cells.

Kaushik and Roos., (2007) could encapsulate limonene by freeze-drying of various matrices consisting of gum arabic, sucrose and gelatin 1:1:1 ratio. High

etention of limonene may be achieved by homogenising the emulsion containing gum arabic, sucrose and gelatin (1:1:1) at a single stage pressure of 100 MPa.

Dried fruit rind of *Garcinia cowa* (cowa fruit) was soaked overnight in water, autoclaved for 30 min, filtered and the extract was concentrated to 30% (w/w-dry weight solid) using a flash evaporator at 60º C. The extract was encapsulated using Whey Protein Isolate (WPI), Maltodextrin (MD) and combination of WPI and MD (1:1 ratio) as carrier material by freeze drying. The microcapsules exhibited wider particle size and HPLC analysis showed that all the three encapsulates yielded higher free (above 85%) and net (above 90%) HCA recovery (Ezhilarasi *et al*., 2013).

Cortes-Rojas *et al.,* (2014) conducted studies on lipid formulations containing clove extract by spray drying. The aim was to encapsulate the volatile and poor water soluble compounds, eugenol and eugenyl acetate to obtain solid re-dispersible powders. Five formulations were prepared to test two different solid lipids, two surfactants, and three carriers. The dried product was characterized by the eugenol and eugenyl acetate retention, *in* vitro antioxidant activity, and relevant physical properties. The formulation containing glyceryl behenate, Poloxamer 188, and Maltodextrin DE10 presented better retention of bioactive compounds and good antioxidant activity. Studies on dispersion of the above encapsulate were conducted using high-shear mixing ultraTurrax, ultrasonication and high-pressure homogenization and the drying technique (spray- and freeze-drying). The freeze-dried samples presented significantly higher retention of eugenol and eugenyl acetate than the spray-dried ones.

Blackberry (*Rubus fruticosus*) residue extracted with acidified ethanol was encapsulated in polyvinylpyrrolidone (PVP) by three methods *viz.,* spray-drying (SD), freeze-drying (FD) and the supercritical antisolvent (SAS)- using CO_2 as antisolvent and ethanol as solvent of the organic solution (extract + PVP). SD, FD

and SAS achieved particles with good anthocyanin yields, high antioxidant capacity and were effective to concentrate anthocyanins in PVP without great degradation. Using SAS, particles with 1.42 mg ECy3Gl/g were produced. SAS particles presented high residual ethanol (8.17% w/w) and moisture (11.30% w/w), whereas in SD and FD particles these contents remained below 2 and 5%, respectively. Scanning electron microscopy revealed a spherical shape in the particles obtained by SD, while those produced by SAS and FD produced irregular agglomerates (da Fonseca Machado *et al*., 2018)..

Bordo grape skin extract was microencapsulated by spray-drying and freeze-drying, using gum arabic (GA), partially hydrolyzed guar gum (PHGG), and polydextrose (PD) as encapsulating agents and the retention of phenolics and anthocyanins in the encapsulates ranged from 81.4% to 95.3%, and 80.8% to 99.6%, respectively, while the retention of antioxidant activity ranged from 45.4% to 83.7%. Treatments subjected to spray-drying had lower moisture, water activity (a_w), particle size with greater solubility, while the freeze-dried samples were less hygroscopic. Glass transition temperature (Tg) values ranged from 10.1 to 52.2°C, and the highest values corresponded to the spray-dried encapsulates. The spray-dried particles had spherical shape, while the freeze-dried powders showed irregular structures. The spray drying technique 5% PHGG and 5 per cent PD was proved to be the best treatment (Kuck and Norena, 2016)

Azarpazhooh *et al*., (2019) studied microencapsulation of the acidified ethanol extract of pomegranate (*Punica granatum* L.) peel bioactive compounds by freeze drying. Among the carrier concentrations tested 15 per cent maltodextrin (MD) had the highest total phenolic content (TPC), total anthocyanin content (TAC) and antioxidant capacity by FRAP, and the DPPH assay with the lowest IC_{50} and the lowest glass transition temperature indicating the highest antioxidant capacity among other wall materials. With respect to morphology, the

particles of encapsulated with high concentration of MD were larger and smoother. Stability and half-life of encapsulated powders were measured from 42 days of storage study at 4 °C and 25 °C, at 52 and 75% relative humidity. The TAC of the microencapsulated powders with wall material of 15 per cent and control decreased by 18% and 33% respectively, after 42 days storage at 4 °C, while at the storage temperature of 25 °C, the decreases were in the order of 24% and 38% respectively over the same period of time. The highest anthocyanin content was observed in the extract encapsulated by freeze-drying with MD 15 per cent-and storage at 4 °C with75% relative humidity.

The enzyme assisted cum hydraulic pressed black carrot extract was encapsulated through spray drier using a coating mixture of jack fruit seed starch, soy protein and NBRE-15 (a plant source emulsifier) (SET -1) and in the second set of experiment using jack fruit seed starch, whey protein and NBRE-15 (SET-2). SET-1 was found to be better-encapsulating material as compared to SET-2. SET-1 had higher retention of anthocyanin content, color, antioxidant activity during storage at 25^{o} C (Mishra *et al*., 2019).

Chranioti *et al*.,(2015) encapsulated aqueous extract of saffron and beetroot by freeze drying using maltodextrin (MD-21DE), gum arabic, gum arabic–modified starch, modified starch–chitosan and modified starch–maltodextrin–chitosan as carrier and evaluated their coloring strength by storing at 40º for 10 weeks. MD along with gum arabic was proved to be effective agents for freeze encapsulation of beetroot and saffron. MD presented the greatest protection against heat during storage accompanied by high half-life period ($t_{1/2}$) with average values of 53.03 and 60.03 weeks for beetroot and saffron, respectively. The water sorption study showed that MD and gum arabic retained their structural integrity up to water activities of 0.66 and 0.82 respectively.

Black carrot juice extracted using pectinase enzyme was encapsulated in three different carrier materials *viz*., maltodextrin 20DE, gum arabic and tapioca starch using spray drying at four inlet temperatures of 150º, 175º, 200º and 225ºC and freeze drying at a constant temperature of -53ºC and vacuum of 0.22–0.11 mbar with the constant feed mixture (Murali *et al*., 2015). The analysis of the encapsulate revealed maltodextrin 20DE as the better carrier material as it resulted in maximum anthocyanin retention and higher antioxidant activity compared to gum arabic and tapioca starch. Air inlet temperature of 150ºC was found to be best for encapsulation using spray drying for both maltodextrin 20DE and gum arabic. Higher air inlet temperatures (>150ºC) caused more anthocyanin loss. Freeze drying was found to be the better encapsulation technique with respect to the maximum anthocyanin retention and antioxidant activity.

Saikia *et al*., (2015) encapsulated ethanoic extract of carambola (*Averrhoa carambola*) with maltodextrin (≤ DE l20) by spray and freeze drying methods at three different extract to carrier ratio (1:10, 1:15, and 1:20). In both spray dried and freeze dried encapsulates, the Core Phenolic Content (CPC) values were found to increase with increase in the maltodextrin concentration whereas the reverse was noticed for Surface Phenolic Content (SPC). The SPC values of the spray dried encapsulate was higher than freeze dried encapsulates. The encapsulating efficiency of the freeze dried samples (78–97%) was more than the spray dried ones (62.99 to 79.07).

Aqueous extract of lemon peel was encapsulated by freeze and spray drying with different combinations of coating agents *viz*., maltodextrin alone and in combination with soybean protein and carrageenan, and effect of encapsulation on bioactive compounds and antioxidant activity was studied. Encapsulation of the extract with MD + soybean protein resulted in the highest retention of TPC, TFC and FRAP activity. Freeze-drying resulted in micro particles with lower

moisture content and water activity than those produced by spray-drying. Scanning electron microscopy revealed that spray-drying results in the formation of spherical particles of different sizes regardless of the type of coating agent. Although freeze-drying resulted in micro particles with amorphous glassy shapes, the mixture of MD+ soybean protein resulted in the formation of spherical porous particles. X-ray diffraction revealed a low degree of crystallinity for the samples produced by both techniques (Papoutsis *et al*., 2018).

Pomegranate (*Punica granatum*) juice and ethanolic extracts were encapsulated with maltodextrin (MD) and soybean protein isolates (SPI) by spray drying considering the proportion of coating material and the inlet temperature as independent variables. The polyphenols encapsulating efficiency was significantly better in SPI matrix whereas for anthocyanins, it was in MD matrix. The MD microcapsules provided a significant greater protective effect on the polyphenols and anthocyanins than SPI during the storage (Robert *et al*., 2010).

Vu *et al*. (2020), studied impact of spray drying conditions and coating materials on the physical, phytochemical, and antioxidant properties of the banana peel extract to identify the most suitable encapsulation process. Inlet temperature (140 to 180º C) and feeding rate (3–15 mL/min) did not significantly affect the total phenolic content (TPC) and antioxidant capacity but influenced the moisture content and recovery yield of the powder. The ratio of dry matter in fresh extract-to-coating material (DM-to-CM) (1:1–1:7 (w/w)) did not affect the moisture content. However, it affected the TPC, antioxidant properties, and recovery yield of the powder. The type of coating materials did not significantly affect TPC and antioxidant properties, but other physical properties, dopamine levels and recovery yield. The most suitable encapsulation conditions were identified as an inlet drying temperature of 150º C, a feeding rate of 9 mL/min, a ratio of DM-to-CM of 1:1 (w/w), and coating with a combination of maltodextrin M100 and gum

acacia. Powder prepared under the most suitable conditions had a spherical shape with a rough surface and had stable TPC under storage conditions of 40º C for 4 weeks. It also had ideal physical, phytochemical and antioxidant properties and was suitable for further applications.

2.4 COMMERCIAL APPLICATION OF ENCAPSULATED EXTRACT

Mango ready-to-serve (RTS) beverage was fortified with hydrolysed and native whey protein was used at 2, 3 and 4% levels and its rheological properties were studied. Whey protein was hydrolysed with papain to improve its stability in acidic medium. Addition of hydrolysed whey protein at all the three levels did not significantly change the flow behavior of the beverage. Native whey protein fortification resulted in precipitation; however, addition of hydrolysed whey protein led to stable beverage formulation at all the three levels. Hydrolysed whey protein imparted slight bitter taste to the RTS beverage, which was masked by b-cyclodextrin @ 0.15% of total protein. The mango RTS beverage with 3.0% hydrolysed whey protein was found acceptable with good sensory appeal and stability during thermal processing as well as storage in glass bottles (Yadav *et al.*, 2016).

Ahmed *et al*., (2018) developed the protein fortified mango RTS beverage by utilizing varied concentration of soya protein isolate (SPI), peanut protein isolates (PPI) and rice bran protein concentrate (RBPC). There was progressive decrease in the sensory scores of the beverage with increase in proportion of protein concentrate in it. The overall acceptability scores w.r.t. control were lower for protein fortified beverage, however, the beverage fortified with protein from different sources were not showing significant difference among themselves. Throughout the storage period, beverage prepared with fructose scored more in flavor, taste, mouth feel and overall acceptability than those prepared from

sucrose. The organoleptic scores of all the variants of protein fortified RTS beverage remained acceptable up to 90 days of storage at room temperature.

Pandey and Ojha (2020) prepared mango beverage enriched with whey protein and evaluated the quality. Beverage was prepared by blending whey and mango pulp in a ratio of 59.9:30, 64.9:2, 69.9:20 and 74.9:15 (with 10% sugar and 0.1% CMC-Carboxymethylcellulose at 0.3% acidity level). Best formulation of the beverage (based on sensory property) was found to be the whey and mango pulp ratio of 69.9:20 with 10% sugar and 0.1% CMC. The color, flavor and storage properties of the whey beverage was found good. The sugar and mango pulp were able to mask the undesirable flavor of whey, thus making whey a possible source of protein enrichment for fruit beverages.

Extracts of dried powders of *Garcinia cowa* were encapsulated using maltodextrin (MD) and combination of whey protein isolate and maltodextrin (WPI + MD in 1:1 ratio) by freeze drying. Encapsulates were incorporated into wheat flour along with other ingredients for bread preparation. Wheat flour and garcinia powder (with and without encapsulation) were taken in the ratio of 100:2 for bread making. Microencapsulates incorporated breads had significantly enhanced qualitative characteristics than the water extract incorporated bread. Comparatively, bread with WPI encapsulates exhibited significantly higher volume, softer crumb texture, highly desirable sensory attributes due to its efficient encapsulation. WPI also efficiently encapsulated and well protected the retained Hydroxycitric acid in bread, during baking and resulted in higher HCA content in the bread (Ezhilarasi *et al*., 2013)

Chewing gum was incorporated with encapsulates of beet root and saffron. The incorporation study demonstrated higher stability for food chewing gum model (low moisture product model) prepared with extracts encapsulated in gum arabica and modified starch. Microencapsulation by freeze-drying could be

suggested not only as a suitable method for color stabilizing of beetroot and saffron extracts, but also as a feasible means for production of food-grade colorants (Chranioti *et al*.,2015).

Cashew gum (CG) and gelatin (GE) complexation was explored to encapsulate green coffee oil (GCO), rich in cafestol and kahweol, for use as ingredient in tamarind juice. Particles with 25% GCO (14.56 ± 6.36 μm) presented good encapsulation efficiency (85.57 ± 1.41%), reduced the GCO oxidation by six-fold and were resisted in the pasteurization conditions. The beverage added with encapsulates showed good sensory quality when compared to the control formulation. For the first time, the incorporation of GCO capsules into fruit juice has been reported, promoting a diterpene-rich drink with good rheological and sensory properties (De Oliveira *et al*., 2020).

3. MATERIALS AND METHODS

The present investigation on "Jackfruit (*Artocarpus heterophyllus* Lam.) as a potential source of bioactive compounds" was conducted in the Department of Postharvest Technology, College of Agriculture, Vellayani from 2018 to 2020 with the objective to standardize the extraction procedure for maximizing the antioxidant, anti-cancerous and anti-hyperglycemic properties of fruit wastes from varikka and koozha jackfruit types, phytochemical profiling, encapsulation and commercial exploitation of encapsulated extracts for fortification of fruit juice beverages.

The study was carried out as four different continuous experiments

3.1. Standardization of extraction procedure

3.2. Phytochemical profiling

3.3. Encapsulation of extracts

3.4. Commercial application of encapsulated extract

3.1 STANDARDIZATION OF EXTRACTION PROCEDURE

3.1.1 Preparation of Powder

Appropriate extraction technique is required to conduct separation, identification, and characterization of bioactive compounds. This process included sample preparation, selection of solvents and extraction techniques. Experiment was carried out for two jackfruit types *viz*.,varikka and koozha, popular in the state of Kerala independently.

The fruits were collected from the Instructional Farm, Vellayani at optimum maturity stage and utilized for the experiment. Fruits were allowed to ripe and cut opened at optimum ripening stage after removing the green horny/spiny portion of the fruit. Excluding bulbs and seeds, all other portions of

the fruits *viz*., rind, rachis, rag, core and seed coat were cut into small pieces of 1.0-2.0 cm and utilized for the experiment. The samples were dried in cabinet drier (D_1) and freeze drier (D_2) (Plate 1 and 2). To find out the optimum temperature for cabinet drying a preliminary study was conducted.

3.1.2 Preliminary Trial for Standardization of Optimum Temperature for Drying in Cabinet Drier

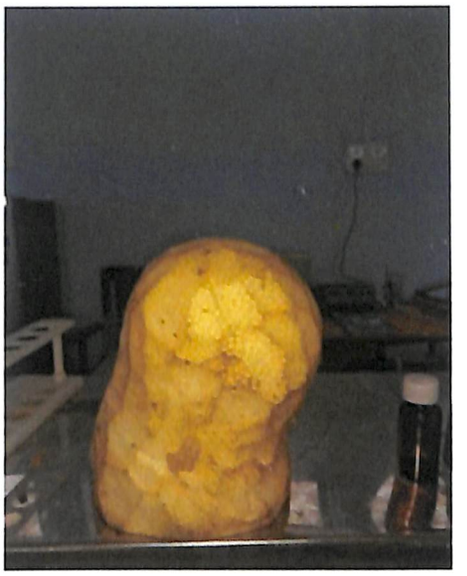
The optimum temperature for cabinet drying was determined by conducting a preliminary trial. The samples were dried at 50^o, 60^o and 70^o C until it reached a constant weight which corresponded to 12-15 per cent moisture content. The dried samples were pulverized, made into fine powder and analyzed for ascorbic acid, Total Flavonoid Content (TFC) and Total Phenolic Content (TPC) for selection of optimum temperature for cabinet drying.

3.1.2.1 Ascorbic Acid Content (mg 100 g^{-1})

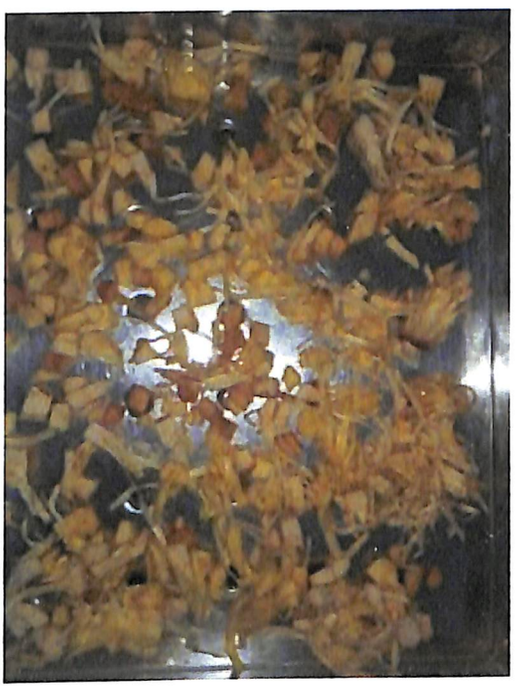
Ascorbic acid content of the cabinet dried samples were estimated titrimetrically using 2,6-dichlorophenol indophenol dye as per the AOAC procedure (Sadasivam and Manickam, 1992). A stock solution of standard ascorbic acid was prepared by dissolving 100.0 mg of ascorbic acid in 4 per cent oxalic acid and adjusting the final volume to 100.0 mL (1mg mL^{-1}). A working standard solution of the ascorbic acid was prepared by diluting 10.0 mL of stock standard solution to 100 mL with 4 per cent oxalic acid (1mg 100 mL^{-1}). 10.0mL of oxalic acid (4%) was added to 5.0 mL working standard solution of ascorbic acid and was titrated against the standard dye of 2, 6 dichlorophenol indophenol till the appearance of pink color which persisted for few minutes. The amount of dye consumed was recorded as V_1 (mL).

5.0 g of the dried powder was extracted in 4% oxalic acid in a mortar and pestle and was filtered using thin muslin cloth. The residue was re-extracted 2-3

Mature firm ripe jackfruit



Removal of Green Horny portion



Cut samples

Plate 1. Preparation of jackfruit samples for drying

Initial

Cabinet drying

Cabinet dried sample

Initial

Freeze drying

Freeze dried sample

Plate 2. Preparation of dried jackfruit samples

times and final volume was made up to 100mL. The extract was centrifuged (Tota4-V/F Plasto Crafts centrifuge) and the supernatant was collected. 5.0 mL of the supernatant was mixed with 10.0 mL of 4% oxalic acid and titrated against the standard dye till the end point. The amount of dye consumed was recorded as V_2 (mL). Amount of ascorbic acid content (mg 100 g^{-1}) of sample was calculated by using the following formula

$$\text{Ascorbic acid (mg } 100g^{-1}) = \frac{0.5 \times \text{Titre value of the sample} \times 100}{\text{Titre value of the standard solution} \times 5 \times \text{Weight of sample (g)}}$$

3.1.2.2 Total Flavonoid Content (mg QE 100 mL^{-1})

5.0 g of the dried powder was ground in 10.0 mL of 80 per cent ethanol in a mortar and pestle and and the homogenate was centrifuged at 10000 rpm for 10 minutes. The residue was re-extracted with 10 mL of 80 per cent ethanol and the supernatant collected was pooled after centrifugation. The supernatant was kept in hot water bath at 70^{o}C and solvent was removed completely. The residue left over was mixed in 5.0 mL of distilled water.

Aliquot of 0.1 mL (from 5.0 mL) was mixed with 0.9 mL of distilled water and 0.3 mL of 5 per cent $NaNO_2$, 0.3 mL of $AlCl_3$ (10%) was added after five minutes and 2 mL of 1N NaOH was added after 6 minutes. The reaction mixture was mixed well and absorbance was measured at 510nm using *UV–vis* spectrophotometer. The total flavonoid content was quantified according to the standard curve prepared from Quercetin (0-100µg) using the following formula and the concentration of flavonoids was expressed as mg of Quercetin equivalents per 100 g of dry weight (mg QE 100 g^{-1}) (Chun *et al*., 2003)

$$\text{Total flavonoid content (mg QE } 100\ g^{-1}) = \frac{OD_{510\ nm} \text{ x Std. value (µg } OD^{-1}) \text{ x Total volume of extract x } 100}{\text{Assay volume x Weight of sample (g) x } 1000}$$

3.1.2.3 Total Phenolic Content (mg GAE 100 mL^{-1})

The total phenolic content was estimated according to the Folin-Ciocalteu method (Singleton and Rossi, 1965).

The Ethanolic extract of dried powders were prepared as per the procedure as mentioned in 3.1.2.2.

0.5 mL of the extract was diluted with 1.0 mL distilled water and was mixed 0.5 mL Folin-Ciocalteu reagent (1.0N). After 3 minutes 2.0 mL of 10 per cent Na_2CO_3 was added and the sample mixture was incubated in hot water bath at 60^o C for 10 minutes. Distilled water in place of test samples with all reagents was used as the blank. Absorbance of samples was read at 650 nm in *UV-Vis* spectrophotometer against the blank. Gallic acid (0-100µg) was used as standard and total phenolic content was calculated using the following formula and expressed as mg of Gallic acid equivalents per 100 gram of dry powder (mg GAE 100 g^{-1} DM).

$$\text{Total phenol content (mg GAE 100 g}^{-1}\text{)} = \frac{OD_{650\ nm} \text{ x Std. value (µg OD}^{-1}\text{) x Total volume of extract x 100}}{\text{Assay volume x Weight of sample (g) x 1000}}$$

As the jackfruit samples dried at 50^o C had the highest Total Flavonoid content, Total phenolic content and ascorbic acid content, 50^o C was selected as optimum temperature for further studies.

Extraction

Jackfruit samples of both varikka and koozha prepared as per procedure mentioned in 3.1.1 (sample preparation) were dried using two different drying methods D_1: cabinet dryer (selected based on preliminary studies) at 50^{o}C and D_2: freeze dryer at -45 to -50^o C at pressure up to 0.05 mbar. The samples were dried until it reached a moisture content of 12-15 percentage. The dried samples

were pulverized and made into fine powder by sieving through 80-mesh size sieve. Extraction of pulverized dried samples was carried out using five solvents with three different concentrations as mentioned below.

The jackfruit samples were dried by two methods of drying

D_1- Cabinet drying

D_2- Freeze drying

Extraction of pulverized dried samples was carried out using five solvents with different concentrations

S_1-Methanol-90%

S_2-Methanol-80%

S_3-Methanol-50%

S_4-Ethanol-60%

S_5-Ethanol-80%

The samples were dispersed in solvents at three solid/liquid ratios (w/v).

R_1- 1:30

R_2- 1:40

R_3- 1:50

Number of Treatments : 30 (2×5×3)

Replications : 3

Design : CRD

The extraction was carried out at room temperature (Annexure-I) for 6 hours in a mechanical shaker (end to end) at 100 rpm, followed by centrifugation at 5000 rpm for 10 min. The supernatants were collected and the residues were re-extracted twice under similar conditions. The supernatants thus collected were combined, filtered and concentrated in rotary vacuum evaporator at 20 rpm. The final contents were dissolved in double distilled water and volume was made up to 50 mL for further biochemical analysis (Plate 3).

3.1.3 Evaluation of Extract for Antioxidant and Anti-hyperglycemic Properties

The extracts were evaluated for antioxidant and anti-hyperglycemic properties for selection of superior three treatments. Anti-oxidant activity of the extract was assessed by evaluating Total Flavonoid content (TFC), Total Phenolic Content (TPC), Ascorbic Acid Content and Total Antioxidant Activity.

3.1.3.1 Total Flavonoid Content

Total flavonoid content of extracts was calculated according to Aluminium chloride calorimetric method as described in by 3.1.2.2 (Chun *et al*., 2003) Singleton and Rossi, 1965.

3.1.3.2 Total Phenolic Content

The total phenolic content of the extracts were calculated according to the Folin-Ciocalteu method which is based on colorimetric oxidation/reduction reaction of phenols (Singleton and Rossi, 1965) as described in 3.1.2.3.

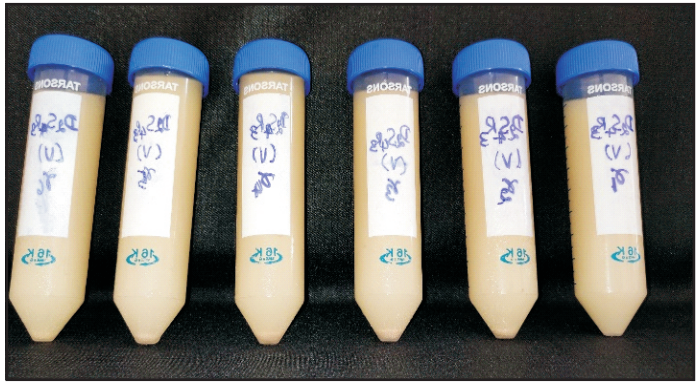
3.1.3.3 DPPH Radical Scavenging Activity

Antioxidant activity of the extracts was calculated by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay with suitable modifications (Kang and Saltveit 2002). The reagent solution was prepared by dissolving 3.94 mg (0.1mM) of DPPH in 100 ml methanol. The absorbance value of the dye was tested using a

Jackfuit samples mixed with solvents

Shaking in mechanical shaker

Centrifugation



Final extracts dissolved in water

Concentration of extracts

Filteration

Plate 3. Preparation of jackfruit extracts

spectrophotometer at 517 nm (1.1056-1.062). Different concentrations of the extracts were prepared (2.0 mg/mL to 10.0 mg/mL) and allowed to react with 3 ml of DPPH solution. The reaction mixture was shaken vigorously and left to stand at room temperature for 30 min in the dark. The absorbance of the sample mixtures was measured using *UV-vis* spectrophotometer at 517 nm. A control without the sample was analyzed and the results were expressed as radical scavenging activity (% RSA).

$$\% \text{ Radical Scavenging Activity} = \frac{\text{Absorbance}_{(\text{control})} - \text{Absorbance}_{(\text{sample})}}{\text{Absorbance}_{(\text{control})}} \times 100$$

3.1.3.4 Ascorbic Acid Content (mg $100g^{-1}$)

1.0 mL of extract was used for analyzing the ascorbic acid content of the extracts. Rest of the procedure was followed as per the procedure described in 3.1. 2.1 of this chapter (Sadasivam and Manickam, 1992).

3.1.3.5 α-glucosidase Inhibitory Activity

The extracts were evaluated for anti-hyperglycemic activity through α-glucosidase inhibition and compared with standard anti diabetic drug, acarbose. α-glucosidase inhibitory activity of the various extracts was carried out according to the standard method with minor modifications (Zengin, 2016).

In a 96-well plate, reaction mixture containing 50 µl phosphate buffer (100 mM, pH = 6. 8), 10 µL alpha-glucosidase (1 U/mL), and 50 µL of varying concentrations of extract and fractions (0.4, 0.8, 1.2, 1.6, and 2.0 mg/mL) were pre-incubated at 37°C for 15 min. 20 µL of 5 mM P-Nitrophenol-α-D-glucopyranoside (P-NPG) was added as a substrate and incubated further at 37°C for 20 min. The reaction was stopped by adding 50 µl Na_2CO_3 (0.1 M). The absorbance of the released p-nitrophenol was measured at 405 nm using Multiplate Reader (Multiskan, Thermo scientific). Acarbose at various concentrations (0.4–2.0 mg/mL) was used as a standard. Without test substance another set was run in parallel as a control and each experiment was performed in

triplicates (Plate 4). The results were expressed as percentage inhibition, which was calculated using the formula,

$$\% \text{ Inhibition} = \frac{\text{Absorbance}_{(\text{control})} - \text{Absorbance}_{(\text{sample})}}{\text{Absorbance}_{(\text{control})}} \times 100$$

Based on antioxidant and anti-hyperglycemic properties of the extracts, the three superior extraction procedure were selected and analyzed for anti-cancerous properties.

3.1.4 Anti-cancerous Properties

Cytotoxic studies of the selected three superior extracts was conducted by anti-proliferative assay *in vitro* using cancer cell lines through direct microscopic observation and MTT (3[4,5-dimethylthiazol-2-yl]-2,5diphenyl tetrazolium bromide) method (Crouch *et al*., 1993).

Preparation of test solutions:

Standard: Doxorubicin

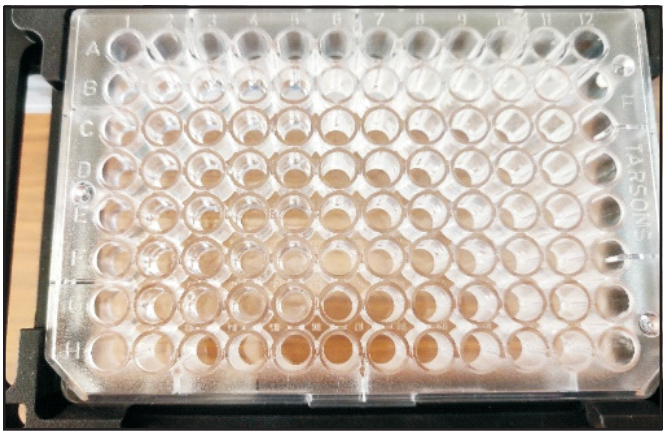
10mM stocks were taken and further serial two fold dilutions were prepared from 100µM to 3.125µM using DMEM plain media for treatment.

Test sample preparation:

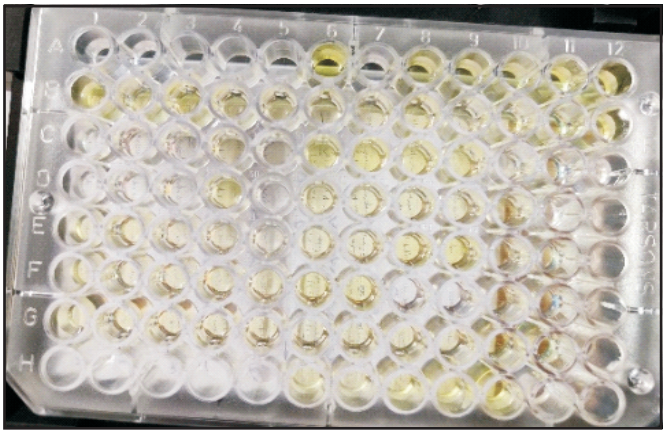
1.28g/mL stocks were prepared using DMSO. Serial two fold dilutions were prepared from 1280µg/ml to 10µg mL^{-1} using DMEM plain media for treatment.

Cell lines and culture medium:

All the cell lines were procured from American Type Culture Collection (ATCC), stock cells were cultured in DMEM supplemented with 10% inactivated Fetal Bovine Serum (FBS), penicillin (100 IU/ml), streptomycin (100 µg/ml) in a humidified atmosphere of 5% CO_2 at 37^{o}C until confluent. The cells were



Pre Incubation



Post Incubation

Multiple Plate Reader

Plate 4. á-glucosidase inhibition activity

dissociated with cell dissociating solution (0.2 % trypsin, 0.02 % EDTA, 0.05 % glucose in PBS). The viability of the cells was checked and centrifuged. Further, 50,000 cells /well were seeded in a 96 well plate and incubated for 24 hrs at 37^{o}C, in a humidified 5% CO_2 incubator.

Procedure

The monolayer cell culture was trypsinized and the cell count was adjusted to 5.0 x 10^5 cells/ml using respective media containing 10% FBS. To each well of the 96 well microtiter plate, 100 µl of the diluted cell suspension (50,000cells/well) was added. After 24 h, when a partial monolayer was formed, the supernatant was flicked off, washed the monolayer once with medium. 100 µl of different concentrations of test drugs were added on to the partial monolayer in microtiter plates. The plates were then incubated at 37^{o}C for 24hrs in 5% CO_2 atmosphere. After incubation, the test solutions in the wells were discarded and 100 µl of MTT (5 mg/10 ml of MTT in PBS) was added to each well. The plates were incubated for 4 h at 37^{o} C in 5% CO_2 atmosphere. The supernatant was removed and 100 µl of DMSO was added and the plates were gently shaken to solubilize the formed formazan. The absorbance was measured using a microplate reader at a wavelength of 590 nm (Tecan Plate reader). The percentage growth inhibition was calculated using the following formula and concentration of test drug needed to inhibit cell growth by 50% (IC_{50}) values was generated from the dose-response curves for each cell line.

$$\% \text{ Inhibition} = \frac{\text{OD of control} - \text{OD of sample}_{)}}{\text{OD of control}} \times 100$$

IC_{50} Value

IC_{50} values for cytotoxicity tests were derived from a nonlinear regression analysis (curve fit) based on sigmoid dose response curve (variable) and computed using Graph Pad Prism 6 (Graph pad, SanDiego, CA, USA)

3.2 PHYTOCHEMICAL PROFILING

Extracts of the three superior treatments (extraction procedures) selected from both varikka and koozha types were independently subjected to phytochemical profiling using LCMS/MS (Waters UPLC H class system fitted with TQD MS/MS system). The extracts were analysed for sugars, organic acids, phenolic acids and flavonoids. (Plates).

3.2.1 Profiling of Sugars

Sugars were extracted by following the methods by Steppuhn and Wackers, (2004) with slight modifications. 0.1g of sample was diluted 20 times with mobile phase (Solvent A: 80:20-Acetonitrile: Water; Solvent B: 30:70-Acetonitrile: Water + 0.1% Ammonium hydroxide), 1ml was filtered, out of which 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 8^{th} minute, the gradient was changed to 88% of solvent A and 12 per cent of solvent B, held for 1 min 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 19^{th} 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 1.7µm 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

3.2.2 Profiling of Organic Acids

The extraction procedure for organic acids was carried out as per Ribeiro *et al*. (2007). 1g of sample 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 5^{th} minute, the gradient was changed to 95% aqueous phase and 5% organic phase, held for 0.5 min, then system was returned to the initial conditions at 6^{th} min 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 4 µL. 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

3.2.3 Profiling of Phenolic Acids and Flavonoids

The individual phenolic acids and flavonoids for LC-MS/MS analysis were isolated from 80% methanol extract as per Weidner *et al*. (2000) and Chen *et al*. (2001) with slight modifications. 1g sample was homogenized in methanol (80%), subjected to centrifugation and the final volume was made up to 50 mL. Out of 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 in 40 mL of ethyl acetate using separating funnel. 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 2 μL. 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

3.3 ENCAPSULATION OF EXTRACTS

Extract of the three superior treatments selected based on Part-I (3.2) of the experiment were encapsulated independently by two methods *viz*., spray drying and freeze using maltodextrin as carrier.

3.3.1. Encapsulation by Spray Drying

Encapsulation of the three selected extracts was done independently for varikka and koozha by spray drying technique using two carrier concentration, three carrier ratio, and two temperatures of the spray drier as process variables.

Carrier concentration-2

C_1-10 Dextrose Equivalent

C_2-20 Dextrose Equivalent

Carrier ratio-3

Cr_1- 1:10

Cr_2- 1:15

Cr_3- 1:20

Temperature of spray drier-2

T_1 -Inlet 180^0 C and outlet 80°C

T_2 -Inlet 190^0 C and outlet 90° C

Treatments : 12

Replications : 3

Design : CRD

Maltodextrin was homogenized with the extracts using magnetic stirrer at 1500 rpm for 20-25 minutes. The homogenized mixture was spray dried in SprayMate (JISML Pvt. Ltd. Mumbai) laboratory scale spray drier. The feed flow rate aspirator speed and temperature were set at 10% and 2000 rpm and T_1 (Inlet 180° C - outlet 80° C) and T_2 (Inlet 190°C - outlet 90° C) respectively (Plate 5).

3.3.2 Encapsulation by Freeze-drying

Encapsulation of the three selected extracts was carried out by freeze drying technique using maltodextrin as carrier. Carrier concentration and carrier ratio were considered as process variables.

Carrier concentration-2

C_1-10 Dextrose Equivalent

C_2-20 Dextrose Equivalent

Carrier ratio-3

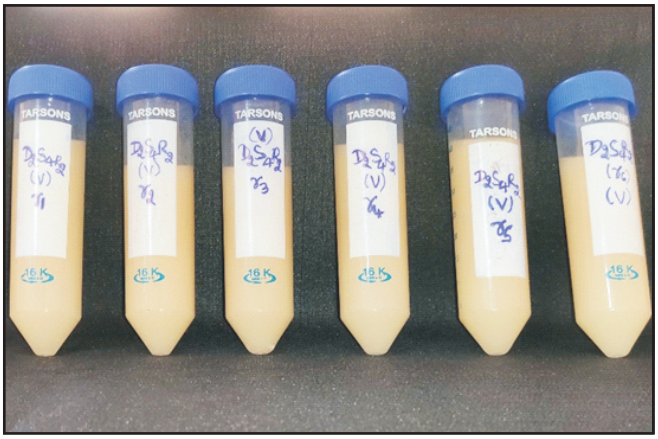
Cr_1- 1:10

Cr_2- 1:15

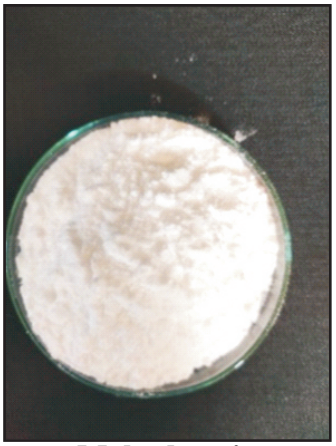
Cr_3- 1:20

Treatments : 6

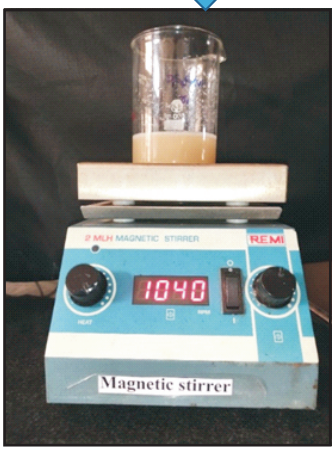
Replications : 4



Extracts



Maltodextrin



Homogenization with (MD)

Spray drying

Encapsulate collected in cyclone

Spray encapsulate

Plate 5. Preparation of Spray dried encapsulates of jackfruit extract

Design : CRD

Extracts were homogenized with maltodexrin (10 and 20DE) as mentioned in 3.3.1 and freeze dried in a laboratory scale freeze drier (CoolSafe, SCANVAC, *mas tek* INSRUMENTS CO., Banglore) at condenser temperature of -45 to -49^{o}C and pressure up to 0.05mbar. Drying was continued until the encapsulates reached a constant weight. Microencapsulates thus obtained after drying were ground in a mortar and pestle (Plate 6).

The spay and freeze dried encapsulates were analyzed for TFC, TPC, ascorbic acid content and antioxidant (DPPH) activity.

3.3.3 Total Flavonoid Content (TFC)

The TFC of the encapsultes was determined according to methods narrated by Zhishen *et al*., (1999). 0.5 g of encapsulates were dissolved in water, volume adjusted to 10.0mL and the mixture was vortexed and filtered. 0.5 mL of encapsulate mixture was mixed with 1.0 mL distilled water and 0.15 mL of 5% (*w*/*v*) $NaNO_2$ and incubated at ambient temperature for 6 min. Then, 0.15 mL of 10% (*w*/*v*) $AlCl_3$ was added and the mixture was left at room temperature for 6 min. Subsequently, 2 mL of 4% (*w*/*v*) NaOH and 0.7 mL of H_2O were added and the solution was left at room temperature for 15 min before the absorbance was measured at 510 nm. The total flavonoid content was calculated in mg QE 100 g^{-1} by using a standard curve (R^2 = 0.9928) which was built by dissolving quercetin in methanol.

3.3.4 Total Phenolic Content (TPC)

The TPC of the encapsulates was determined as described by Skerget *et al*., (2005) with suitable modifications. 2.5 mL of 10% (*v*/*v*) Folin–Ciocalteu reagent was mixed with a 0.5 mL sample, followed by the addition of 2 mL of 7.5% (*w*/*v*) Na_2CO_3. The mixture was incubated for 1 hour at ambient temperature

and the absorbance was recorded at 760 nm. The total phenolic content was calculated using a standard curve (R^2 = 0.9960) which was built by dissolving gallic acid in water at different concentrations (0, 10, 20, 30, 40, and 50 μg mL^{-1}) and expressed as mg of gallic acid equivalents per g sample on dry basis (mg GAE $100g^{-1}$)

3.3.5 Total Antioxidant (DPPH) Activity

Different concentrations of the encapsulates were prepared (0.5 mg/mL to 5.0 mg/mL) and allowed to react with 3 ml of DPPH solution. The reaction mixture was shaken vigorously and left to stand at room temperature for 30 min in the dark. The absorbance of the mixture was measured using *UV-vis* spectrophotometer at 517 nm. A control sample without the encapsulate was also analyzed and the results were expressed as radical scavenging activity (% RSA) by using the formula mentioned in 3.2.3

3.3.6 Ascorbic Acid Content

Ascorbic acid content of the encapsulates were determined following the procedure narrated in 3.1.2.1

3.3.7 Recovery Percentage of Encapsulation (%)

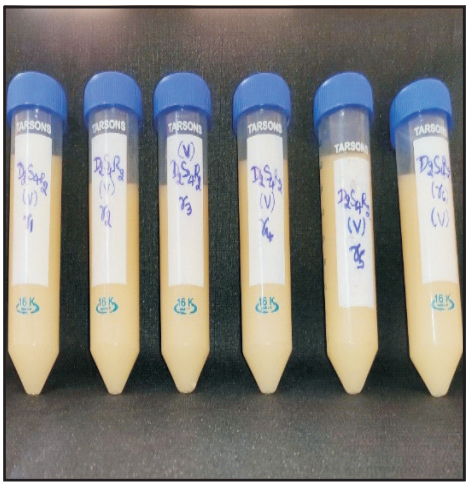
Recovery percentage of encapsulation was calculated for both spray and freeze drying, using the formula

$$\text{Recovery (\%)} = \frac{(M_1X(100\text{-}X))}{M_2XV} \times 100$$

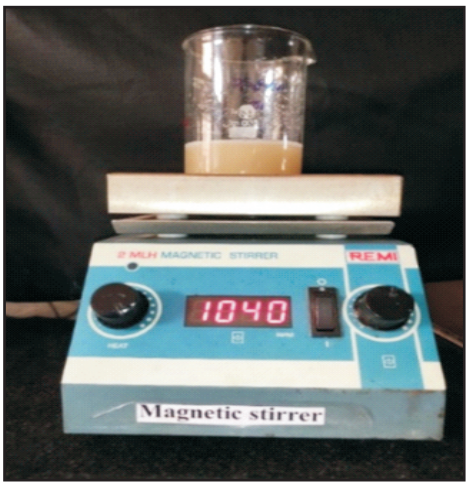
Where

M_1 - the weight of the encapsulated powder (g)

X- moisture content of the encapsulated powder (%)



Extracts

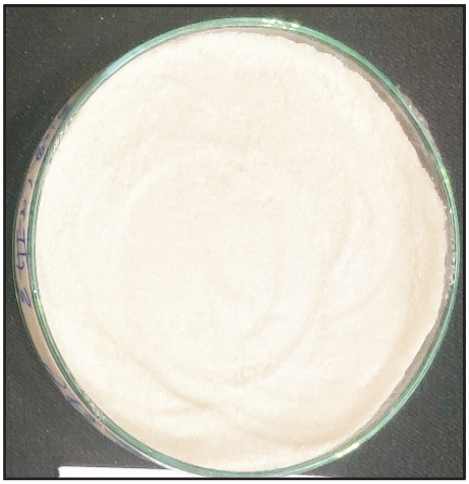


Homogenization with Carrier (MD)

Pre freeze homogenate

Homogenate

Freeze drying



Freeze encapsulate

Plate 6. Preparation of Freeze dried encapsulates of jackfruit extract

M_2- the dry matter in 1 mL feed (g)

V - the input volume feed (mL).

3.3.8 Moisture Content of the Encapsulated Product

The moisture content of the encapsulated product was determined according to Paini *et al.* (2015). The spray and freeze encapsulates were dried at 105^{o} C in an oven until it reached a constant weight. The moisture content was calculated based on the weight loss recorded after drying.

Based on the high recovery percentage, TPC, TFC, ascorbic acid content and retention of antioxidant properties, technology for encapsulation was standardized and the superior quality encapsulate, one each from spray and freeze drying were selected for commercial application.

3.4 COMMERCIAL APPLICATION OF ENCAPSULATED EXTRACTS

The two superior encapsulated extracts, one each from spray and freeze drying selected from Part-III of the experiment were utilized for commercial application. These encapsulates were utilized for preparation of fortified mango RTS beverages as per FSSAI standards and compared with a commercial fortified beverage available in the market (Plate 7).

3.4.1 Priliminary Trial to Fix Concentration of Encapsulate

A preliminary study was conducted to know the quantity of encapsulates to be dissolved in mango RTS beverage, prepared following FSSAI standards (TSS: 14.5-14.75º B, Acidity: 0.25-0.28%; Pulp content:12 to 13%; Potassium metabisulphite:70 ppm). The encapsulates were dissolved in varied concentration (10-100 mg mL^{-1}) and sensory evaluation was conducted on nine point hedonic scale. Organoleptic scoring was done by a semi trained panel consisting of 30 members comprising of students and staff of the department/college. The panel were asked to score for color and appearance, consistency, mouthfeel, flavor, taste

and overall acceptability (Annexure). Based on sensory evaluation scores for taste, it was decided to dissolve 50 mg of encapsulate per 100 mL of mango RTS beverage.

3.4.2 Incorporation of Encapsulates

1. Mango RTS beverage + 50 mg spray dried encapsulate per 100 mL

2. Mango RTS beverage + 50 mg freeze dried encapsulate per 100 mL

3. Commercial fortified beverage

4. Pure mango RTS beverage without addition of encapsulate (Control)

Number of treatment-4

Replications -4

Design -CRD

3.4.3 Quality Parameters of the Beverages

The mango RTS beverages prepared were analyzed for biochemical and sensory analysis.

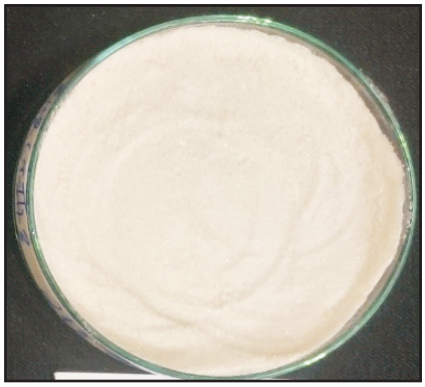
3.4.3.1 Total Soluble Solids (^{o} Brix)

TSS of the prepared RTS beverage was measured using hand refractometer (0-32 range).

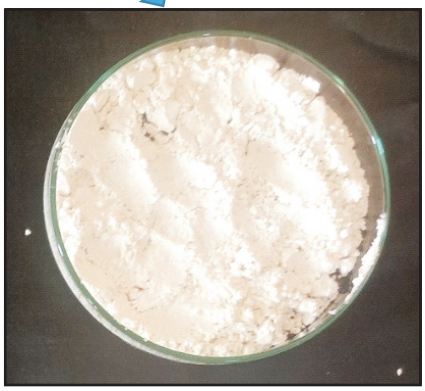
3.4.3.2 Sugars (g 100g^{-1})

The total sugar content of the prepared mango RTS beverage was expressed as per cent in terms of invert sugar according to the following formula (Ranganna, 1986).

Mango RTS beverage



Freeze encapsulate



Spray encapsulate

Mango RTS enriched with encapsulates

Plate 7. Preparation of encapsulate enriched mango RTS beverage

$$\text{Total sugar} = \frac{\text{Glucose Eq. (0.05) x Total volume made up (ml) x Volume made up after inversion (ml)}}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (ml)}} \times 100$$

3.4.3.3 Acidity (%)

Acidity of the mango RTS beverages was determined by titration method (AOAC, 942.15). Volume of 10.0mL of RTS beverage was made up to 50.0mL with distilled water. A known volume of the beverage (10 mL) was titrated against 0.01N NaOH using phenolphthalein as indicator. Acidity was calculated as percentage of citric acid equivalents using citric acid standard curve.

Acidity (%)

$$= \frac{\text{Titre value x Normality of NaOH (0.1N) x Volume made up (100 ml) x Equivalent weight of citric acid (0.064) } x\ 100}{\text{Assay volume x Wt. of the sample (g) x 1000}}$$

3.4.3.4 Polyphenol Content (mg GAE 100 mL^{-1})

Polyphenol content of the prepared mango RTS beverages was carried out as per the procedure narrated in 3.1.2.3.

3.4.3.5 Antioxidant Activity (%)

Antioxidant activity (DPPH) of the prepared beverages was determined as per the procedure mentioned in 3.2.3.

3.4.3.6 Sensory analysis

Sensory analysis was carried out by semi-trained panel of experts, based on nine point hedonic sale (as mentioned in 3.4.1).

3.5 STASTICAL ANALYSIS

Statistical analysis of the results was done with the OPSTAT (Online Agriculture Data Analysis Tool, at a level of $p < 0.05$. IC_{50} values for cytotoxicity studies (anti-cancerous studies) were derived from a nonlinear regression analysis (curve fit) based on sigmoid dose response curve (variable) and computed using Graph Pad Prism 6 (Graph pad, SanDiego, C)

4. RESULTS

The data collected from the research on "Jackfruit (*Artocarpus heterophyllus* Lam.) as a potential source of bioactive compounds" were analyzed and the results are presented in this chapter under the following heads

4.1. Standardization of extraction procedure

4.2. Phytochemical profiling

4.3. Encapsulation of extracts

4.4. Commercial application of encapsulated extract

4.1 STANDARDIZATION OF EXRACTION PROCEDURE

4.1.1 Standardization of Optimum Temperature for Cabinet Drying

A preliminary study was conducted to standardize optimum temperature of drying the jackfruit samples in cabinet drier. Samples from varikka and koozha were dried at 50, 60 and 70° C till 12-15 per cent moisture and were analyzed for total flavonoid content (TFC), total phenolic content (TPC), and ascorbic acid content.

Varikka

The data on TFC, TPC, and ascorbic acid content of cabinet dried varikka samples are presented in Table 1. Significantly highest TFC **(**9.52 mg QE100 g^{-1}), TPC (110.20 mg GAE 100 g^{-1}) and ascorbic acid content (25.19 mg 100 g^{-1}) were recorded in varikka samples dried at 50° C (T_1), while the lowest values for the same were recorded in samples dried at 70º C.

Koozha

The TFC, TPC and ascorbic acid content of cabinet dried koozha samples as influenced by temperature of drying is shown in Table 2. Koozha samples dried

Table 1. Effect of cabinet drying temperature on total flavonoid, total phenolic content and ascorbic acid content of varikka

Treatments	Total Flavonoid Content (mg $QE100g^{-1}$)	Total Phenolic Content (mg $GAE100g^{-1}$)	Ascorbic Acid (mg $100g^{-1}$)
T_1	9.52	110.20	25.19
T_2	8.38	102.14	21.62
T_3	7.61	98.85	19.08
C.D. (0.05)	0.07	1.87	1.20
SE±(m)	0.02	0.60	0.37

T_1-Cabinet drying at 50º C; T_2-Cabinet drying at 60º C; T_3-Cabinet drying at 70º C

Table 2. Effect of cabinet drying temperature on total flavonoid, total phenolic content and ascorbic acid content of koozha

Treatments	Total Flavonoid Content (mg $QE/100g^{-1}$)	Total Phenolic Content (mg $GAE\ 100g^{-1}$)	Ascorbic Acid (mg $100g^{-1}$)
T_1	10.07	114.42	29.87
T_2	8.84	106.57	26.30
T_3	7.77	102.37	21.62
C.D. (0.05)	0.09	2.19	1.72
SE±(m)	0.03	0.70	0.53

T_1-Cabinet drying at 50º C; T_2-Cabinet drying at 60º C; T_3-Cabinet drying at 70º C

at 50º C were found to contain significantly highest TFC (10.07 mg QE100 g^{-1}), TPC (114.42 mg GAE 100 g^{-1}) and ascorbic acid (29.87 mg 100 g^{-1}). Significantly, lowest contents for the same were recorded in samples dried at 70º C.

Hence, the optimum temperature of cabinet drying was standardized as 50º C.

Extracts of varikka and koozha were prepared from cabinet and freeze dried samples using solvents *viz*., methanol (90, 80 and 50%) and ethanol at (60 and 80%) at solid to solvent ratios of 1:30, 1:40 and 1:50. The solvents were removed completely by rotary evaporator and the contents obtained were analyzed for following parameters.

4.1.2 Total Flavonoid Content (TFC) (mg QE 100 g^{-1})

Varikka

Total flavonoid content (TFC) of varikka extracts was significantly influenced by drying methods (D), solvents (S), solid to liquid ratio (R) and their interaction (Table 3).

Extract of freeze dried samples had higher (9.66 mg QE 100g^{-1}) total flavonoid content compared to extract of cabinet dried samples (8.63 mg QE 100 g^{-1}).

The highest TFC of 13.48 mg QE 100 g^{-1} was recorded in varikka samples extracted using 60% ethanol (S_4) followed by those extracted using 80% ethanol (S_5) with 11.47 mg QE 100g^{-1} TFC. The samples extracted using 90% methanol recorded the lowest TFC (5.52 mg QE100 g^{-1}).

Significantly highest TFC of 10.16 mg QE 100 g^{-1} was recorded, when the extracts were prepared using 1:50 solid to solvent ratio (R_3) followed by those prepared using 1:40 solid to solvent ratio (R_2) with 9.34 mg QE 100 g^{-1} TFC.

Table 3. Effect of drying methods, solvents and solid to solvent ratio on total lavonoid content (mg QE 100 g^{-1}) of varikka extract

Total flavonoid content (TFC) (mg QE 100g^{-1})								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	D_1R	
Cabinet Drying (D_1)	1:30 (R_1)	4.83	6.37	5.80	8.81	10.41	7.24	R_1- 7.93 R_2- 9.34 R_3-10.16
	1:40 (R_2)	5.24	7.35	6.90	14.01	11.16	8.93	
	1:50 (R_3)	5.59	8.15	8.82	14.51	11.49	9.71	
	Mean	5.22	7.29	7.17	12.45	11.02	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	5.33	7.53	5.77	13.18	11.31	8.63	
	1:40 (R_2)	5.70	9.02	7.19	14.71	12.11	9.75	
	1:50 (R_3)	6.45	9.28	9.31	15.66	12.36	10.61	
	Mean	5.83	8.61	7.43	14.52	11.93		
	Mean S	5.52	7.95	7.30	13.48	11.47		
Mean D	D_1-8.63 D_2-9.66							

Factor	**CD (0.05)**	**SE±(m)**
D	0.13	0.05
S	0.20	0.07
R	0.16	0.06
DxSxR	0.50	0.18

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest TFC content of 15.66 mg QE 100 g^{-1}, followed by freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio ($D_2S_4R_2$) (14.71 mg QE 100 g^{-1}), which was on par with cabinet dried samples extracted using 60% ethanol at 1:50 solid liquid ratio $D_1S_4R_3$ (14.51 mg QE 100 g^{-1}). The lowest total flavonoid content (4.83 mg QE 100g^{-1}) was recorded in cabinet dried samples extracted using 90 per cent methanol in 1:30 solid to liquid ratio ($D_1S_1R_1$) which was on par with cabinet dried samples extracted using 90 per cent methanol in 1:40 solid to liquid ratio, $D_1S_1R_2$ (5.24 mg QE 100 g^{-1}) and freeze dried samples extracted using 90 per cent methanol in 1:30 solid to liquid ratio,$D_2S_1R_1$ (5.33 mg QE 100 g^{-1}).

Koozha

Total flavonoid content (TFC) of koozha extracts as influenced by drying methods, solvents and solid to solvent ratio is presented in Table 4. TFC of koozha extracts was significantly influenced by all the three factors.

Extract of freeze dried samples had significantly higher TFC (9.83 mg QE 100 g^{-1}) compared extract of cabinet dried samples (8.41 mg QE 100 g^{-1}).

TFC content was significantly differed by the solvents used. The highest TFC of 13.05 mg QE 100 g^{-1} was recorded in koozha samples extracted using 60% ethanol (S_4) followed by those extracted using 80% ethanol (S_5) with 11.42 mg QE 100g^{-1} TFC. The lowest TFC of 5.60 mg QE 100 g^{-1} was recorded in samples extracted using 90% methanol.

TFC was recorded significantly highest in the extracts prepared using 1:50 solid to solvent ratio (9.91 mg QE 100 g^{-1}) ($R_{3)}$ followed by those prepared using 1:40 solid to solvent ratio (9.42 mg QE 100 g^{-1})

Table 4. Effect of drying methods, solvents and solid to solvent ratio on total flavonoid content (mg QE 100g^{-1}) of koozha extract

Total flavonoid content (TFC) (mg QE 100g^{-1})								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**		
Cabinet Drying (D_1)	1:30 (R_1)	4.54	7.04	5.26	10.49	9.61	7.39	R_1- 8.02 R_2- 9.42 R_3-9.91
	1:40 (R_2)	5.15	7.83	7.02	12.48	11.15	8.73	
	1:50 (R_3)	5.43	8.25	7.44	12.99	11.44	9.11	
	Mean	5.04	7.70	6.57	11.99	10.74	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	5.88	7.73	6.32	11.92	11.42	8.65	
	1:40 (R_2)	6.12	8.74	8.89	14.57	12.21	10.11	
	1:50 (R_3)	6.48	9.08	9.48	15.88	12.68	10.72	
	Mean	6.16	8.52	8.23	14.12	12.10		
	Mean S	5.60	8.11	7.40	13.05	11.42		
Mean D	D_1-8.41 D_2-9.83							
Factor	**CD (0.05)**			**SE±(m)**				
D	0.04			0.01				
S	0.06			0.02				
R	0.05			0.02				
DxSxR	0.15			0.05				

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest TFC content of 15.88 mg QE 100 g^{-1}, followed by freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio ($D_2S_4R_2$) (14.57mg QE 100g^{-1}). The lowest total flavonoid content (4.54 mg QE 100 g^{-1}) was recorded in cabinet dried samples extracted using 90 per cent methanol in 1:30 solid to liquid ratio ($D_1S_1R_1$).

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

Varikka

Total phenolic content (TPC) of varikka extracts was significantly influenced by drying methods (D), solvents (S), solid to liquid ratio (R) and their interaction (Table 5).

Extract of freeze-dried samples had higher (103.92 mg GAE 100g^{-1}) total phenolic content compared to) extract of cabinet dried samples (96.60 mg GAE 100 g^{-1}.

The highest TPC of 144.88 mg GAE 100 g^{-1} was recorded in varikka samples extracted using 60% ethanol (S_4) followed by those extracted using 80% ethanol (S_5) with 118.81 mg GAE 100 g^{-1} TPC. The samples extracted using 90% methanol had the lowest TPC (62.62 mg GAE 100 g^{-1}).

TPC was found to be significantly highest (105.93 mg GAE 100 g^{-1}) when the extracts were prepared using 1:50 solid to solvent ratio (R_3) followed by those prepared using 1:40 solid to solvent ratio (R_2) with 103.71 mg GAE 100 g^{-1} TPC.

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the highest TPC content of 156.10 mg GAE 100 g^{-1}, followed by freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio ($D_2S_4R_2$) (154.26 mg GAE 100 g^{-1}). The lowest TPC of 56.52 mg GAE 100 g^{-1} was

Table 5. Effect of drying methods, solvents and solid to solvent ratio on total phenolic content (mg GAE $100g^{-1}$) of varikka extract

Total phenol content (TPC) (mg GAE $100g^{-1}$)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**D_1R**	
Cabinet Drying (D_1)	1:30 (R_1)	56.52	78.42	77.68	128.67	94.97	87.25	R_1- 91.14 R_2- 103.71 R_3-105.93
	1:40 (R_2)	63.18	85.28	87.74	143.66	120.16	100.01	
	1:50 (R_3)	65.71	88.01	88.57	147.18	123.23	102.54	
	Mean	61.80	83.90	84.67	139.84	112.79	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	60.21	81.05	87.00	139.44	107.45	95.03	
	1:40 (R_2)	64.09	88.20	98.28	154.26	132.26	107.42	
	1:50 (R_3)	66.01	89.83	99.83	156.10	134.79	109.31	
	Mean	63.44	86.36	95.04	149.93	124.83		
	Mean S	62.62	85.13	89.85	144.88	118.81		
Mean D	D_1-96.60 D_2-103.92							

Factor	**CD (0.05)**	**SE±(m)**
D	0.27	0.10
S	0.43	0.15
R	0.33	0.12
DxSxR	1.05	0.37

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

recorded in cabinet dried samples extracted using 90 per cent methanol in 1:30 solid to liquid ratio ($D_1S_1R_1$).

Koozha

TPC of extracts prepared from koozha type is presented in Table 6. TPC of the koozha extracts was significantly influenced by drying methods, solvents solid to solvent ratio and their interaction.

Between the two methods employed for drying samples, extracts from freeze-dried samples had higher TPC of 110.05 mg GAE 100 g^{-1} compared to extracts from cabinet dried (100.38 mg GAE 100 g^{-1}) samples.

Among the solvents, the highest TPC of 146.99 mg GAE 100 g^{-1} was recorded in varikka samples extracted using 60% ethanol (S_4) followed by those extracted using 80% ethanol (S_5) with 125.22 mg GAE 100 g^{-1} TPC. The samples extracted using 90% methanol was found to contain the lowest TPC (67.88 mg GAE 100 g^{-1}).

Significantly highest TPC of 112.81 mg GAE 100 g^{-1} was found in the extracts prepared using 1:50 solid to solvent ratio (R_3) followed by those prepared using 1:40 solid to solvent ratio (R_2) with 107.75 mg GAE 100 g^{-1}.

The interaction effects across the three factors revealed that, freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest TPC content of 164.63 mg GAE 100 g^{-1}, which was statistically on par with freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio, $D_2S_4R_2$ (161.71 mg GAE 100 g^{-1}) followed by cabinet dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_1S_4R_3$) (154.09 mg GAE 100 g^{-1}). The lowest TPC of 63.53 mg GAE 100 g^{-1} was recorded in cabinet dried samples extracted using 90 per cent methanol in 1:30 solid to liquid ratio ($D_1S_1R_1$) which was on par with the samples cabinet dried and extracted with 90 percent methanol at 1:40 ($D_1S_1R_2$) (66.40 mg GAE 100 g^{-1}) and freeze dried

Table 6. Effect of drying methods, solvents and solid to solvent ratio on total phenolic content (mg GAE $100g^{-1}$) of Jackfruit koozha extract

Total phenol content (TPC) (mg GAE $100g^{-1}$)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**D_1R**	
Cabinet Drying (D_1)	1:30 (R_1)	63.53	76.40	87.17	125.69	100.99	90.76	R_1- 95.09 R_2- 107.75 R_3-112.81
	1:40 (R_2)	66.40	89.09	91.35	131.57	127.98	101.28	
	1:50 (R_3)	69.47	92.46	100.35	154.09	129.18	109.11	
	Mean	66.47	85.98	92.96	137.12	119.38	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	63.94	81.74	93.15	144.23	114.07	99.43	
	1:40 (R_2)	70.78	91.30	107.85	161.71	139.51	114.23	
	1:50 (R_3)	73.14	93.00	110.35	164.63	141.38	116.50	
	Mean	69.29	88.68	103.78	156.86	131.65		
	Mean S	67.88	87.33	98.37	146.99	125.52		
Mean D	D_1-100.38 D_2-110.05							

Factor	**CD (0.05)**	**SE±(m)**
D	0.98	0.35
S	1.55	0.55
R	1.20	0.43
DxSxR	3.80	1.35

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

samples extracted with 90 per cent methanol at 1:30 solid to solvent ratio ($D_2S_1R_1$) (63.94 mg GAE 100 g^{-1}).

4.1.3 Total Antioxidant (DPPH) Activity (% inhibition)

Varikka

DPPH scavenging activity of varikka extracts was significantly influenced by drying methods (D), solvents (S), solid to solvent ratio (R) and their interaction (Table 7).

Extracts from freeze dried samples had higher scavenging activity with 57.43 per cent inhibition compared to extract from cabinet dried samples (42.55 per cent).

The highest scavenging activity with 59.04 per cent inhibition was recorded in varikka samples extracted using 60% ethanol (S_4) followed by those extracted using 80% ethanol (52.37 per cent). The samples extracted using 90% methanol recorded the lowest scavenging activity with 46.22 per cent inhibition.

Significantly highest DPPH scavenging activity of 52.03 per cent was recorded, when the extracts were prepared using 1:50 solid to solvent ratio (R_3) while the lowest activity (47.65 per cent) was recorded in extracts prepared using 1:30 solid to solvent ratio (R_3).

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest scavenging activity with per cent inhibition of 69.29, followed by freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio ($D_2S_4R_2$) (68.34 per cent inhibition). The lowest DPPH scavenging activity with per cent inhibition of 37.61 was observed in cabinet dried sample extracted with 90 per cent methanol at 1:30 solid to solvent ratio ($D_1S_1R_1$) which was on par with cabinet dried samples in 80 per cent methanol at 1:40 solid to

Table 7. DPPH scavenging activity (per cent inhibition) of varikka extracts as influenced by drying methods, solvent type and solid to solvent ratio

DPPH scavenging activity (per cent inhibition)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**D_1R**	
Cabinet Drying (D_1)	1:30 (R_1)	37.61	38.91	40.30	48.84	39.84	41.10	R_1- 47.65 R_2- 50.29 R_3-52.03
	1:40 (R_2)	38.77	38.26	41.70	50.81	42.26	42.36	
	1:50 (R_3)	40.51	38.11	40.71	52.77	48.85	44.19	
	Mean	38.96	38.43	40.90	50.81	43.65	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	52.19	43.20	53.71	64.21	57.66	54.19	
	1:40 (R_2)	54.77	48.13	58.13	68.34	61.70	58.22	
	1:50 (R_3)	53.46	51.67	61.02	69.29	63.92	59.87	
	Mean	53.47	47.67	57.62	67.28	61.09		
	Mean S	46.22	43.05	49.26	59.04	52.37		
Mean D	D_1-42.55 D_2-57.43							

Factor	**CD (0.05)**	**SE±(m)**
D	0.18	0.06
S	0.28	0.01
R	0.22	0.08
DxSxR	0.69	2.43

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

solvent ratio and (38.26 %) ($D_1S_2R_2$) and with 1:50 solid to solvent ratio (38.11%) ($D_1S_2R_3$).

Koozha

Koozha extracts differed significantly for DPPH scavenging activity with respect to drying methods (D), solvents (S) and solid to liquid ratio (R) (Table 8).

Extracts prepared from freeze dried samples exhibited higher scavenging activity with 59.29 per cent inhibition compared to extracts from cabinet dried samples (41.90 per cent).

Koozha samples extracted using 60 per cent ethanol (S_4) exhibited highest scavenging activity with 58.69 per cent inhibition followed by samples extracted using 50% methanol (S_3) with 52.76 per cent inhibition. The samples extracted using 80 per cent methanol (S_2) recorded the lowest scavenging activity (44.17 per cent inhibition).

Significantly highest DPPH scavenging activity of 53.38 per cent was recorded, when the extracts were prepared using 1:50 solid to solvent ratio (R_3) while the lowest activity was recorded in extracts prepared using 1:30 solid to solvent ratio (R_1) with 47.08 per cent inhibition.

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$)recorded the significantly highest scavenging activity with per cent inhibition of 68.64, followed by freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio ($D_2S_4R_2$) (66.05 per cent). The lowest DPPH scavenging activity with per cent inhibition of 32.49 was observed in the cabinet dried sample extracted with 80 per cent methanol at 1:30 solid to solvent ratio ($D_1S_2R_3$).

Table 8. DPPH scavenging activity (per cent inhibition) of koozha extracts as influenced by drying methods, solvent type and solid to solvent ratio

DPPH scavenging activity (per cent inhibition)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**D_1R**	
Cabinet Drying (D_1)	1:30 (R_1)	34.37	32.49	34.41	49.42	34.72	37.08	R_1- 47.08 R_2- 51.33 R_3-53.38
	1:40 (R_2)	35.80	39.38	45.49	51.28	43.93	43.18	
	1:50 (R_3)	38.80	40.72	47.00	51.87	48.90	45.46	
	Mean	36.32	37.53	42.30	50.86	42.52	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	53.53	48.16	60.29	64.88	58.52	57.07	
	1:40 (R_2)	53.63	51.24	63.75	66.05	62.73	59.48	
	1:50 (R_3)	54.57	53.02	65.65	68.64	64.64	61.30	
	Mean	53.91	50.81	63.23	66.52	61.96		
	Mean S	45.12	44.17	52.76	58.69	52.24		
Mean D	D_1-41.90 D_2-59.29							

Factor	**CD (0.05)**	**SE±(m)**
D	0.18	0.06
S	0.28	0.10
R	0.22	0.08
DxSxR	0.67	0.24

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

4.1.4 Ascorbic Acid Content (mg 100 g^{-1})

Varikka

Ascorbic acid content of varikka extracts was significantly influenced by drying methods (D), solvents (S) and solid to liquid ratio (R) (Table 9).

Extract of freeze-dried extracts had higher (40.48 mg 100 g^{-1}) ascorbic acid content compared to extracts of cabinet dried (26.87 mg 100 g^{-1}).

The highest ascorbic acid content of 36.83 mg 100 g^{-1} was recorded in varikka samples extracted using 90% methanol (S_1) followed by those extracted using 60% ethanol (S_4) with 34.60 mg 100 g^{-1}. The samples extracted using 50% methanol recorded the lowest ascorbic acid (31.30 mg 100 g^{-1}) content which was statistically on par with extracts prepared using 80 per cent ethanol (S_5) (31.91 mg 100g^{-1})

Significantly highest ascorbic acid content of 35.09 mg 100 g^{-1} was recorded, when the extracts were prepared using 1:50 solid to solvent ratio (R_3) which was found to be on par with those prepared using 1:40 solid to solvent ratio (R_2) with 34.58 mg 100 g^{-1} ascorbic acid content.

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 90 per cent methanol at 1:50 solid liquid ratio ($D_2S_1R_3$) recorded the significantly highest ascorbic acid content of 45.88 mg 100 g^{-1}, which was on par with freeze dried samples extracted using 90 per cent methanol at 1:40 solid liquid ratio $D_2S_1R_2$ (45.53 mg 100 g^{-1}). The lowest ascorbic acid content (22.59 mg 100 g^{-1}) was recorded in cabinet dried samples extracted using 80 per cent ethanol in 1:30 solid to liquid ratio ($D_1S_5R_1$) which was on par with cabinet dried samples extracted using 80 per cent ethanol in 1:40 solid to solvent ratio ($D_1S_5R_2$) (23.77 mg 100 g^{-1}), cabinet dried sample with 80 per cent methanol at 1:30 solid to solvent ratio ($D_1S_2R_1$) (23.78 mg QE 100 g^{-1}) and

Table 9. Effect of drying methods, solvents and solid to solvent ratio on ascorbic acid content (mg $100g^{-1}$) of varikka extract

Ascorbic acid content (mg $100g^{-1}$)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**D_1R**	
Cabinet Drying (D_1)	1:30 (R_1)	26.75	23.78	24.07	25.86	22.59	24.61	R_1- 31.34 R_2- 34.58 R_3- 35.09
	1:40 (R_2)	30.91	28.71	25.86	29.36	23.77	27.72	
	1:50 (R_3)	31.50	29.12	26.21	28.95	25.56	28.27	
	Mean	29.72	27.20	25.38	28.06	23.97	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	40.42	38.64	32.69	40.24	38.40	38.08	
	1:40 (R_2)	45.53	41.31	38.93	41.31	40.12	41.44	
	1:50 (R_3)	45.88	40.71	40.06	41.90	41.01	41.91	
	Mean	43.94	40.22	37.23	41.15	39.84		
	Mean S	36.83	33.71	31.30	34.60	31.91		
Mean D	D_1-26.87 D_2-40.48							

Factor	**CD (0.05)**	**SE±(m)**
D	0.46	0.16
S	0.73	0.26
R	0.57	0.20
DxSxR	1.80	0.64

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

cabinet dried samples extracted using 50 per cent methanol in 1:30 solid to liquid ratio, $D_1S_3R_1$ (24.07 mg 100 g^{-1}).

Koozha

Koozha extracts differed significantly for ascorbic acid content with respect to drying methods (D), solvents (S) and solid to liquid ratio (R) (Table 10).

Extracts prepared from freeze dried samples had higher ascorbic acid content of 41.44 mg 100 g^{-1} compared to extracts of cabinet dried samples (27.42 mg 100 g^{-1}).

Koozha samples extracted using 90 per cent methanol (S_1) contained highest ascorbic acid of 38.36 mg 100 g^{-1} followed by those samples extracted using 60% ethanol (S_4) with 34.92 mg 100 g^{-1} which was on par with sample extracted with 80 per cent methanol ($S_{2)}$ (34.61 mg 100 g^{-1}). The samples extracted using 80 per cent ethanol (S_5) recorded the lowest ascorbic acid content of 31.99 mg 100 g^{-1}, which was on par with 50 per cent methanol (S_3) (32.29 mg 100 g^{-1})

Significantly highest ascorbic acid content of 35.80 mg 100g^{-1} was recorded, when the extracts were prepared using 1:50 solid to solvent ratio (R_3) while the lowest was recorded in extracts prepared using 1:30 solid to solvent ratio (R_1) with 32.87 mg 100g^{-1} ascorbic acid content.

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 90% methanol at 1:40 solid liquid ratio ($D_2S_1R_2$) recorded the significantly highest ascorbic acid content of 47.37 mg 100 $g^{-1,}$ which was statistically on par at 1 per cent level of significance with freeze dried samples extracted using 90% methanol at 1:50 solid liquid ratio ($D_2S_1R_3$) (46.48 mg 100 g^{-1}). The lowest ascorbic acid content of 23.77 mg 100 g^{-1} was observed in the extracts prepared from cabinet dried sample using 80 per cent ethanol at 1:30

Table 10. Effect of drying methods, solvents and solid to solvent ratio on ascorbic acid content (mg $100g^{-1}$) of koozha extract

Ascorbic acid content (mg $100g^{-1}$)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**D_1R**	
Cabinet Drying (D_1)	1:30 (R_1)	29.72	27.94	25.92	26.16	23.77	26.70	R_1- 32.87 R_2-34.63 R_3-35.80
	1:40 (R_2)	32.69	26.15	25.14	26.75	24.61	27.07	
	1:50 (R_3)	32.69	27.94	26.27	28.23	27.34	28.50	
	Mean	31.70	27.34	25.78	27.05	25.24	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	41.19	41.90	34.06	41.84	36.20	39.04	
	1:40 (R_2)	47.37	41.55	39.70	43.09	39.23	42.19	
	1:50 (R_3)	46.48	42.20	42.62	43.45	40.77	43.11	
	Mean	45.01	41.88	38.79	42.79	38.73		
	Mean S	38.36	34.61	32.29	34.92	31.99		
Mean D	D_1-27.42 D_2-41.44							

Factor	**CD (0.05)**	**SE±(m)**
D	0.44	0.16
S	0.69	0.24
R	0.54	0.19
DxSxR	1.69	0.60

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

solid to solvent ratio ($D_1S_5R_1$) which was found to be on par with samples extracted with 80 per cent ethanol at 1:40 solid to solvent ratio ($D_1S_5R_2$) (24.61 mg 100 $g^{-1)}$ and also the cabinet dried samples extracted with 50 per cent methanol at 1:40 solid to solvent ratio ($D_1S_3R_2$) (25.14 mg 100 $g^{-1)}$

4.1.5. α-glucosidase Inhibition Activity (%)

Varikka

α-glucosidase inhibition activity of varikka extracts was significantly influenced by drying methods (D), solvents (S) and solid to liquid ratio (R) (Table 11).

Extracts from freeze dried had higher glucosidase inhibition activity of 66.95 per cent compared to extracts of cabinet dried samples (59.23 per cent).

The highest enzyme inhibition activity of 82.73 per cent was recorded in varikka samples extracted using 60% ethanol (S_4) followed by those extracted using 80% ethanol (S_5) (76.57 per cent). The samples extracted using 90% methanol (S_1) recorded the lowest glucosidase inhibition activity (47.10 per cent).

Significantly highest glucosidase inhibition activity of 64.81 per cent was recorded, when the extracts were prepared using 1:50 solid to solvent ratio (R_3) while the lowest enzyme inhibition activity was recorded in extracts prepared using 1:30 solid to solvent ratio (R_1) with 61.28 per cent inhibition.

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest glucosidase inhibition activity of 90.24 per cent, followed by freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio ($D_2S_4R_2$) (87.62 per cent). The lowest activity of. α-glucosidase inhibition (39.91) was observed in the extracts from cabinet dried sample with 90 per cent methanol at 1:30 solid to solvent ratio ($D_1S_1R_1$).

Table 11. Inhibition of α- glucosidase enzyme activity (per cent inhibition) of varikka extract

Inhibition of α- glucosidase enzyme activity (per cent inhibition)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**D_1R**	
Cabinet Drying (D_1)	1:30 (R_1)	39.91	48.25	52.37	75.72	70.31	57.31	R_1- 61.28 R_2- 63.19 R_3-64.81
	1:40 (R_2)	41.54	50.15	54.30	78.21	72.37	59.31	
	1:50 (R_3)	43.92	51.62	56.08	79.59	74.14	61.07	
	Mean	41.79	50.00	54.25	77.84	72.27	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	51.44	54.68	55.84	85.01	79.26	65.24	
	1:40 (R_2)	52.57	55.66	58.45	87.62	81.02	67.07	
	1:50 (R_3)	53.22	56.48	60.47	90.24	82.35	68.55	
	Mean	52.41	55.60	58.25	87.62	80.87		
	Mean S	47.10	52.80	56.25	82.73	76.57		
Mean D	D_1-59.23 D_2-66.95							

Factor	**CD (0.05)**	**SE±(m)**
D	0.15	0.05
S	0.24	0.09
R	0.19	0.07
DxSxR	0.59	0.21

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

Koozha

Koozha extracts differed significantly for α- glucosidase inhibition activity with respect to drying methods (D), solvents (S) and solid to liquid ratio (R) (Table 12).

Extracts from freeze dried samples exhibited higher inhibition of glucosidase activity (70.49 per cent) compared to extracts prepared from cabinet dried samples (63.00 per cent).

Koozha samples extracted using 60 per cent ethanol (S_4) exhibited highest enzyme inhibition activity of 83.01 per cent followed by samples extracted using 80% ethanol (S_5) (78.63 per cent). The samples extracted using 90 per cent methanol (S_1) recorded the lowest alpha glucosidase inhibition activity (48.75 per cent).

Significantly highest enzyme inhibition of 68.75 per cent was recorded, when the extracts were prepared using 1:50 solid to solvent ratio (R_3) while the lowest activity (64.81 per cent inhibition) was recorded for extracts prepared using 1:30 solid to solvent ratio (R_1)

The interaction effects across all the three factors revealed that, the freeze dried koozha samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest alpha glucosidase inhibition activity with per cent inhibition of 92.28, followed by freeze dried samples extracted using 60% ethanol at 1:40 solid liquid ratio ($D_2S_4R_2$) (86.53 per cent) which was statistically on par with the extracts from freeze dried sample extracted using 80 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_5R_3$) (85.98 per cent). The lowest α-glucosidase inhibition activity of 43.97 per cent was observed in the extracts from cabinet dried sample prepared with 90 per cent methanol at 1:30 solid to solvent ratio ($D_1S_1R_1$).

Table 12. Inhibition of α- glucosidase enzyme activity (per cent inhibition) of koozha extract lines

Inhibition of α- glucosidase enzyme activity (per cent inhibition)								
Drying methods (D)		**Type of solvents (S)**					**Mean**	
	Solid to liquid ratio (R)	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	D_1R	
Cabinet Drying (D_1)	1:30 (R_1)	43.97	53.56	61.61	76.69	70.88	61.34	R_1- 64.81 R_2- 66.68 R_3 - 68.75
	1:40 (R_2)	45.36	54.79	63.84	78.12	73.11	63.04	
	1:50 (R_3)	47.59	56.01	64.76	79.92	74.85	64.63	
	Mean	45.64	54.79	63.41	78.24	72.95	D_2R	
Freeze Drying (D_2)	1:30 (R_1)	50.33	57.09	67.08	84.54	82.29	68.27	
	1:40 (R_2)	51.34	60.25	68.78	86.53	84.65	70.31	
	1:50 (R_3)	53.91	62.27	69.97	92.28	85.98	72.88	
	Mean	51.86	59.87	68.61	87.78	84.31		
	Mean S	48.75	57.33	66.01	83.01	78.63		
Mean D	D_1-63.00 D_2-70.49							

Factor	**CD (0.05)**	**SE±(m)**
D	0.16	0.06
S	0.25	0.09
R	0.20	0.07
DxSxR	0.62	0.22

S_1-Methanol-90% ; S_2-Methanol-80%; S_3-Methanol-50% ; S_4-Ethanol-60% ; S_5-Ethanol-80%

Based on the efficiency and economics, extract of freeze dried samples using 60% ethanol at 1:40 solid to solvent ratio ($D_2S_4R_2$), similar samples using 60% ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) and cabinet dried samples with 60% ethanol at 1:50 solid to solvent ratio ($D_1S_4R_3$) were selected as three superior extraction methods for further studying anti-cancerous property.

4.1.6 Anti-cancerous Properties

Cytotoxicity effect of the three selected extracts (based on antioxidant and anti-hyperglycemic properties of the extracts), was carried out on HeLa cell lines by studying ,anti-proliferative activity (*in vitro*) using MTT assay (3-[4, 5-dimethylthiazol-2-yl]-2, 5-diphenyl tetrazolium bromide) with Doxorubicin as a positive standard.

Varikka

In vitro anti proliferative effect of varikka and koozha extracts on HeLa cell lines is presented in Table 13 as IC_{50} values. The extracts exhibited a dose dependent inhibition against the cell viability and proliferation. *In vitro* anti proliferative effect of varikka and koozha extracts on HeLa cell lines is presented in Table 13 as IC_{50} (half-maximal inhibitory concentration) values. Among the extracts freeze dried jackfruit sample extracted using 60 percent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) had the significantly lowest IC_{50} value of 129.30 µg mL^{-1}, followed by the extract prepared from freeze dried sample using 60 per cent ethanol at 1:40 solid to solvent ratio with IC_{50} value of 861.20 µg mL^{-1}. Significantly, lowest IC_{50} value of 18.86 µg mL^{-1} was recorded by control (Doxorubicin) across all the treatments.

Koozha

Among the extracts freeze dried koozha sample extracted in 60 percent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) had the significantly lowest IC_{50} value of 157.58 µg mL^{-1}, followed by the extract prepared from cabinet dried

Table 13. *In vitro* anti proliferative effect of varikka and koozha extracts on HeLa cell

Extract	IC_{50} values of MTT assay	
	Varikka	Koozha
$D_1S_4R_3$	901.82	501.65
$D_2S_4R_2$	861.22	539.35
$D_2S_4R_3$	129.32	157.58
Doxorubicin	18.86	18.86
CD (0.05)	8.47	8.71
SE±(m)	2.80	2.88

$D_1S_4R_3$ -Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

$D_2S_4R_2$-Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio

$D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

sample using 60 per cent ethanol at 1:50 solid to solvent ratio ($D_1S_4R_3$) with IC_{50} value of 501.65 µg mL^{-1}. Significantly, lowest IC_{50} value of 18.86 µg mL^{-1} was recorded by control (Doxorubicin) across all the treatments (Table 13).

4.2 PHYTOCHEMICAL PROFILING

The phytochemical profile of jackfruit (varikka and koozha) extracts was characterized by using LCMS/MS (Waters UPLC H class system fitted with TQD MS/MS system) to explore the presence of possible functional compounds. Following three extracts selected from part-I of the experiment were analysed for sugars, organic acids, phenolic acids and flavonoids.

$D_1S_4R_3$-Cabinet dried samples extracted with 60% ethanol at 1:50 solid to solvent ratio

$D_2S_4R_2$-Freeze dried samples extracted with 60% ethanol at 1:40 solid to solvent ratio

$D_2S_4R_3$-Freeze dried samples extracted with 60% ethanol at 1:50 solid to solvent ratio

4.2.1 Profiling of Sugars (mg g^{-1} DW)

Fifteen individual sugars were fractioned and quantified from the jackfruit extract. Sugar profile of the jackfruit extracts as influenced by type and extraction methods are shown in Tables from 14 to 18.

4.2.1.1 Fructose

Fructose content of the extracts was significantly influenced by jackfruit types and extraction methods and their interaction (Table 14).

Koozha extract had higher (445.28 mg g^{-1} DW) fructose content compared to varikka (422.73 mg g^{-1} DW) extract.

Table 14. Sugar (fructose, glucose and mannose) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Fructose			Mean	Glucose			Mean	Mannose			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	318.79	400.97	548.42	422.73	150.96	164.83	206.32	174.04	20.67	23.13	25.34	23.05
Koozha (K)	416.94	442.85	476.05	445.28	143.85	133.02	222.36	166.41	40.88	33.99	61.66	45.51
Mean	367.87	421.91	512.24		147.40	148.93	214.34		30.78	28.56	43.50	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	3.63	1.24			0.50	0.17			0.37	0.13		
E	4.45	1.52			0.61	0.21			0.45	0.15		
T x E	6.29	2.14			0.86	0.29			0.64	0.22		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

The highest fructose content of 512.24 mg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio, followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (421.91mg g^{-1} DW)

Considering the interaction effect of both the factors, it was observed that extracts prepared from freeze dried varikka type using 60% ethanol in 1:50 ratio had significantly highest fructose content of 548.42 mg g^{-1}, followed by extracts prepared from freeze dried koozha type using 60% ethanol in 1:50 ratio (476.05 mg g^{-1} DW). The minimum fructose content of 318.79 mg g^{-1} DW was observed in extracts prepared from cabinet dried varikka type using 60% ethanol in 1:50 ratio.

4.2.1.2 Glucose

Glucose content of the jackfruit extracts as influenced by types of the fruit, extraction methods and their interaction is shown in the Table 14.

Varikka extract had higher (174.04 mg g^{-1} DW) glucose content compared to koozha (166.41 mg g^{-1} DW) extract.

The highest glucose content of 214.34 mg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio, followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (148.93 mg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest glucose content of 222.36 mg g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (206.32 mg g^{-1} DW). The minimum glucose content of 133.02 mg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.1.3 Mannose

Mannose content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 14).

Koozha extract had higher (45.51 mg g^{-1} DW) mannose content compared to varikka (23.05 mg g^{-1} DW) extract.

The highest mannose content of 43.50 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (30.78 mg g^{-1} DW)

Considering the combined effect of jackfruit type and method of extraction, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest mannose content of 61.66 mg g^{-1}, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (40.88 mg g^{-1} DW). The minimum mannose content of 20.67 mg g^{-1} DW was observed in extracts prepared from cabinet dried varikka type using 60% ethanol in 1:50 ratio.

4.2.1.4 Sorbitol

Sorbitol content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 15).

Koozha extract had higher (11.04 mg g-1 DW) sorbitol content compared to varikka (0.91 mg g^{-1} DW) extract.

The highest sorbitol content of 13.03 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (2.93 mg g^{-1} DW)

Table 15. Sugar (sorbitol, sucrose and ribose) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Sorbitol			Mean	Sucrose			Mean	Ribose			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	0.97	0.84	0.93	0.91	32.40	11.45	27.54	23.80	5.91	6.85	6.79	6.52
Koozha (K)	4.90	3.09	25.14	11.04	9.62	14.03	17.37	13.67	7.33	7.98	10.08	8.47
Mean	2.93	1.97	13.03		21.01	12.74	22.46		6.62	7.42	8.44	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.06	0.02			0.20	0.07			0.15	0.05		
E	0.07	0.02			0.25	0.08			0.18	0.06		
T x E	0.10	0.03			0.35	0.12			0.25	0.09		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Considering the interaction effect of of jackfruit type and method of extraction, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest sorbitol content of 25.14 mg g^{-1} DW, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (4.90 mg g^{-1} DW). The minimum sorbitol content of 0.84 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio which was on par with freeze dried varikka extracts prepared from 60% ethanol in 1:50 solid to solvent ratio (0.93 mg g^{-1} DW).

4.2.1.5 Sucrose

Sucrose content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 15).

Varikka extract had higher (23.80 mg g^{-1} DW) sucrose content compared to koozha (13.67 mg g^{-1} DW) extract.

The highest sucrose content of 22.46 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (21.01 mg g^{-1} DW)

Considering the interaction effect of of jackfruit type and method of extraction, it was observed that extracts prepared from cabinet dried varikka type using 60% ethanol in 1:50 ratio had significantly highest sucrose content of 32.40 mg g^{-1} DW, followed by extracts prepared from freeze dried varikka type using 60% ethanol in 1:50 ratio (27.54mg g^{-1} DW). The minimum sucrose content of 9.62 mg g^{-1} DW was observed in extracts prepared from cabinet dried koozha type using 60% ethanol in 1:50 ratio.

4.2.1.6 Ribose

Ribose content of the extracts was significantly influenced by jack fruit types, extraction methods and their interaction (Table 15).

Koozha extract had higher (8.47 mg g^{-1} DW) ribose content compared to varikka (6.52 mg g^{-1} DW) extract.

The highest ribose content of 8.44 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (7.42 mg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest ribose content of 10.08 mg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (7.98 mg g^{-1}). The minimum ribose content of 5.91 mg g^{-1} was observed in extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio.

4.2.1.7 Inositol

Inositol content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 16).

Koozha extract had higher inositol content of 2.88 mg g^{-1} DW compared to varikka (1.16 mg g^{-1} DW) extract.

The highest inositol content of 2.67 mg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio (E_3) followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (E_2) (1.83 mg g^{-1} DW)

Considering the combined effect, it was observed that extracts prepared from freeze dried koozha type using 60% ethanol in 1:50 ratio had significantly highest inositol content of 3.88 mg g-1, followed by extracts prepared from freeze dried koozha type using 60% ethanol in 1:40 ratio (2.71 mg g^{-1}). The minimum inositol content of 0.95 mg g^{-1} was observed in extracts prepared from freeze dried varikka type using 60% ethanol in 1:40 ratio.

Table 16. Sugar (inositol, galactose and arabinose) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Inositol			Mean	Galactose			Mean	Arabinose			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	1.07	0.95	1.45	1.16	1.48	1.13	2.35	1.65	1.13	0.89	1.15	1.06
Koozha (K)	2.05	2.71	3.88	2.88	2.46	2.70	3.09	2.75	1.86	1.75	2.06	1.89
Mean	1.56	1.83	2.67		1.97	1.91	2.72		1.49	1.32	1.61	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.05	0.02			0.07	0.03			0.04	0.01		
E	0.06	0.02			0.09	0.03			0.05	0.02		
T x E	0.08	0.03			0.13	0.04			0.07	0.02		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

4.2.1.8 Galactose

Galactose content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 16).

Koozha extract had higher (2.75 mg g^{-1} DW) galactose content compared to varikka (1.65 mg g^{-1} DW) extract.

The highest galactose content of 2.72 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio (E_3) followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (E_1) (1.97 mg g^{-1} DW) which was found to be on par with extracts prepared from freeze dried samples using 60 per cent at 1:40 solid to solvent ratio (E_2) (1.91 mg g^{-1} DW).

Considering the combined effect of jackfruit type and method of extraction, the extracts prepared from freeze dried koozha type using 60% ethanol in 1:50 ratio had significantly highest galactose content of 3.09 mg g^{-1} DW, followed by extracts prepared from cabinet dried koozha type using 60% ethanol in 1:50 ratio (2.46 mg g^{-1} DW) which was found to be on par with varikka samples extracted with 60 per cent ethanol at 1:50 solid to solvent ratio. The minimum galactose content of 1.13 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka samples using 60% ethanol in 1:40 ratio (1.13 mg g^{-1} DW).

4.2.1.9 Arabinose

Arabinose content of the extracts was significantly influenced by jack fruit types, extraction methods and their interaction (Table 16).

Koozha extract had higher (1.89 mg g^{-1} DW) arabinose content compared to varikka (1.06 mg g^{-1} DW) extract.

The highest arabinose content of 1.61 mg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio (E_3) followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (E_1) (1.49 mg g^{-1} DW)

Considering the combined effect of jackfruit types and extraction methods, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest arabinose content of 2.06 mg g^{-1}, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (1.86 mg g^{-1}). The minimum arabinose content of 0.89 mg g^{-1} was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.1.10 Maltose

Maltose content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 17).

Koozha extract had higher (1.01 mg g^{-1} DW) maltose content compared to varikka (0.27 mg g^{-1} DW) extract.

The highest maltose content of 0.90 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio (E_3) followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (E_1) (0.61mg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest maltose content of 1.53 mg g^{-1}, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (0.88 mg g^{-1} DW). The minimum maltose content of 0.18 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio, which was on par with

Table 17. Sugar (maltose, xylose and lactose) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Maltose			Mean	Xylose			Mean	Lactose			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	0.33	0.18	0.28	0.27	0.47	0.41	0.41	0.43	0.35	0.25	0.28	0.29
Koozha (K)	0.88	0.62	1.53	1.01	0.52	0.65	0.87	0.68	0.67	0.54	0.76	0.66
Mean	0.61	0.40	0.90		0.49	0.53	0.64		0.51	0.40	0.52	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.06	0.02			0.01	0.00			0.01	0.00		
E	0.07	0.02			0.01	0.01			0.01	0.01		
T x E	0.10	0.03			0.02	0.01			0.02	0.01		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (0.28 mg g^{-1} DW).

4.2.1.11 Xylose

Xylose content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 17).

Koozha extract had higher (0.68 mg g^{-1} DW) xylose content compared to varikka (0.43 mg g^{-1} DW) extract.

The highest xylose content of 0.64 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (0.53 mg g^{-1} DW)

Considering the combined effect of jackfruit type and method of extraction, the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest xylose content of 0.87 mg g^{-1} DW, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (0.65 mg g^{-1} DW). The minimum xylose content of 0.41 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:50 and 1:40 solid to solvent ratio.

4.2.1.12 Lactose

Lactose content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 17).

Koozha extract had higher (0.66 mg g^{-1} DW) lactose content compared to varikka (0.29 mg g^{-1} DW) extract.

The highest lactose content of 0.52 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio which

was on par with those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.51 mg g^{-1} DW).

Considering the combined effect of jackfruit type and method of extraction, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest lactose content of 0.76 mg g^{-1} DW, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (0.51 mg g^{-1} DW). The minimum lactose content of 0.25 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 solid to solvent ratio.

4.2.1.13 Trehalose

Trehalose content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 18).

Koozha extract had higher (0.16 mg g^{-1} DW) trehalose content compared to varikka (0.06 mg g^{-1} DW) extract.

The highest trehalose content of 0.13 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.10 mg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction method, the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest trehalose content of 0.19 mg g^{-1} DW, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (0.14 mg g^{-1} DW). The minimum trehalose content of 0.05 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.1.14 Fucose

Fucose content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 18).

Table 18. Sugar (trehalose, fucose and rhamnose) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Trehalose			Mean	Fucose			Mean	Rhamnose			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	0.06	0.05	0.06	0.06	0.077	0.065	0.112	0.085	0.073	0.056	0.059	0.062
Koozha (K)	0.14	0.13	0.19	0.16	0.088	0.12	0.161	0.123	0.090	0.088	0.143	0.107
Mean	0.10	0.09	0.13		0.083	0.093	0.136		0.081	0.072	0.101	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.005	0.002			0.004	0.004			0.003	0.001		
E	0.006	0.002			0.005	0.005			0.004	0.001		
T x E	0.009	0.003			0.007	0.007			0.005	0.002		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Koozha extract had higher (0.123 mg g^{-1} DW) fucose content compared to varikka (0.085 mg g^{-1} DW) extract.

The highest fucose content of 0.136 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio while the lowest content was recorded by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.083 mg g^{-1} DW)

Considering the combined effect of jackfruit type and method of extraction, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest fucose content of 0.161 mg g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (0.112 mg g^{-1} DW). The minimum fucose content of 0.065 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 solid to solvent ratio.

4.2.1.15 Rhamnose

Rhamnose content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 18)

Koozha extract had higher (0.107 mg g^{-1} DW) rhamnose content compared to varikka (0.062 mg g^{-1} DW) extract.

The highest rhamnose content of 0.101 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.081 mg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction methods, the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest rhamnose content of 0.143 mg g^{-1} DW, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (0.09 mg g^{-1} DW) which was found to be on par with extract prepared from freeze dried

koozha at 1:40 (0.088 mg g^{-1} DW). The minimum rhamnose content of 0.056 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio which was on par with extracts from freeze dried varikka at 1:50solid to solvent ratio (0.059 mg g^{-1} DW).

4.2.2 Organic Acids (mg g^{-1} DW)

A total of ten different organic acids was fractioned and quantified from jackfruit extracts. Organic acid profile of the jackfruit extracts as influenced by jackfruit type and extraction methods are shown in Tables from 19 to 22.

4.2.2.1 Citric Acid

Citric acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 19).

Varikka extract had higher (32.17mg g^{-1} DW) citric acid content compared to koozha (29.57 mg g^{-1} DW) extract.

The highest citric acid content of 35.92 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (29.61 mg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction methods, the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest citric acid content of 39.72 mg g^{-1} DW, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (34.09 mg g^{-1} DW). The minimum citric acid content of 22.50 mg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.2.2 Malic Acid

Malic acid content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 19).

Table 19. Organic acids (citric acid, malic acid and shikimic acid) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Citric acid			Mean	Malic acid			Mean	Shikimic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	25.13	31.65	39.72	32.17	20.19	18.89	34.35	24.48	19.51	18.61	25.44	21.19
Koozha (K)	34.09	22.50	32.11	29.57	42.45	23.89	43.49	36.61	15.05	12.92	25.10	17.69
Mean	29.61	27.08	35.92		31.32	21.39	38.92		17.28	15.76	25.27	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.56	0.19			0.40	0.14			0.38	0.13		
E	0.68	0.23			0.49	0.17			0.46	0.16		
T x E	0.96	0.33			0.69	0.24			0.66	0.22		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Koozha extract had higher (36.61 mg g^{-1} DW) malic acid content compared to varikka (24.48 mg g^{-1} DW) extract.

The highest malic acid content of 38.92 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (31.32 mg g^{-1} DW).

Considering the combined effect of jackfruit type and method of extraction, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest malic acid content of 43.49 mg g^{-1} DW, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (42.45 mg g^{-1} DW). The minimum malic acid content of 18.89 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 solid to solvent ratio.

4.2.2.3 Shikimic Acid

Shikimic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 19).

Varikka extract had higher (21.19 mg g^{-1} DW) shikimic acid content compared to koozha (17.69 mg g^{-1} DW) extract.

The highest shikimic content of 25.27 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (17.28 mg g^{-1} DW)

Considering the interaction effect of jackfruit type and extraction methods, the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest shikimic acid content of 25.44 mg g^{-1} DW, which was found to be on par with extracts from freeze dried koozha using 60% ethanol in 1:50 ratio, followed by extracts prepared from cabinet dried varikka using 60%

ethanol in 1:50 ratio (19.51 mg g^{-1} DW). The minimum shikimic acid content of 12.92 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.2.4 Succinic Acid

Succinic acid content of the extracts was significantly influenced by jackfruit types, methods of extraction and their interaction (Table 20).

Varikka extract had higher (14.39 mg g^{-1} DW) succinic acid content compared to koozha (13.04 mg g^{-1} DW) extract.

The highest succinic content of 17.03 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (14.96 mg g^{-1} DW)

Considering the combined effect of jackfruit type and method of extraction, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest succinic acid content of 17.04 mg g^{-1} DW, which was found to be on par with extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (17.02 mg g^{-1} DW). The minimum succinic acid content of 8.83 mg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 solid to solvent ratio.

4.2.2.5 Hydroxycitric Acid

Hydroxycitric acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 20).

Varikka extract had higher (11.22 mg g^{-1} DW) hydroxycitric acid content compared to koozha (9.03 mg g^{-1} DW) extract.

The highest hydroxycitric acid content of 11.52 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50

Table 20. Organic acids (succinic acid, hydroxycitric acid and malonic acid) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Succinic acid			Mean	Hydroxycitric acid			Mean	Malonic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	16.66	9.49	17.02	14.39	10.57	11.49	11.61	11.22	2.30	2.70	3.27	2.76
Koozha (K)	13.27	8.83	17.04	13.04	9.40	6.27	11.42	9.03	2.33	1.65	2.59	2.19
Mean	14.96	9.16	17.03		9.99	8.88	11.52		2.31	2.17	2.93	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.20	0.07			0.22	0.07			0.12	0.04		
E	0.24	0.08			0.27	0.09			0.14	0.05		
T x E	0.34	0.12			0.38	0.13			0.20	0.07		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (9.99 mg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction methods, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest hydroxycitric acid content of 11.61 mg g^{-1} DW, which was on par with extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio (11.49 mg g^{-1} DW) and koozha extracts obtained from 60% ethanol at 1:50 ratio (11.42 mg g^{-1} DW). The minimum hydroxycitric acid content of 6.27 mg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.2.6 Malonic Acid

Jackfruit types, extraction methods significantly influenced malonic acid content of the extracts (Table 20)

Varikka extract contained higher (2.76 mg g^{-1} DW) malonic acid content compared to koozha (2.19 mg g^{-1} DW) extract.

The highest malonic acid content of 2.93 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (2.31 mg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction methods, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest malonic acid content of 3.27 mg g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio (2.70 mg g^{-1} DW) which was found to be on par with extract prepared from freeze dried koozha at 1:50 (2.59 mg g^{-1} DW). The minimum malonic acid content of 1.65 mg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.2.7 Pyruvic Acid

Pyruvic acid content of the extracts was significantly influenced by jackfruit types and methods of extraction (Table 21).

Varikka extract had higher (1.87 mg g^{-1} DW) pyruvic acid content compared to koozha (1.35 mg g^{-1} DW) extract.

The highest pyruvic acid content of 2.05 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (1.46 mg g^{-1} DW)

Considering the combined effect of jackfruit type and method of extraction, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest pyruvic acid content of 2.16 mg g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio (2.02 mg g^{-1} DW). The minimum pyruic acid content of 0.90 mg g^{-1} DW was observed in extracts prepared from freeze dried type using 60% ethanol in 1:40 solid to solvent ratio.

4.2.2.8 Tartaric Acid

Tartaric acid content of the extracts was significantly influenced by jackfruit types and extraction methods (Table 21).

Koozha extract had higher (1.64 mg g^{-1} DW) tartaric acid content compared to varikka (0.87 mg g^{-1} DW) extract.

The highest tartaric content of 2.61 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (0.64 mg g^{-1} DW)

Table 21. Organic acids (pyruvic acid, tartaric acid and fumaric acid) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Pyruvic acid			Mean	Tartaric acid			Mean	Fumaric acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	1.42	2.02	2.16	1.87	0.53	1.03	1.05	0.87	0.747	0.231	0.844	0.608
Koozha (K)	1.22	0.90	1.94	1.35	0.50	0.24	4.17	1.64	0.667	0.762	1.480	0.970
Mean	1.32	1.46	2.05		0.51	0.64	2.61		0.707	0.497	1.162	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.06	0.02			0.04	0.01			0.014	0.014		
E	0.07	0.02			0.04	0.02			0.017	0.017		
T x E	0.10	0.03			0.06	0.02			0.024	0.024		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Considering the combined effect of jackfruit type and extraction methods, the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest tartaric acid content of 4.17 mg g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (1.05 mg g^{-1} DW) and was found to be on par with extracts prepared from freeze dried varikka using 60% ethanol at 1:40 solid to solvent ratio (1.03 mg g^{-1} DW). The minimum tartaric acid content of 0.24 mg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.2.9 Fumaric Acid

Jackfruit types and extraction methods significantly influenced fumaric acid content of the extracts (Table 21)

Koozha extract contained higher (0.970 mg g^{-1} DW) fumaric acid compared to varikka (0.608 mg g^{-1} DW) extract.

The highest fumaric acid content of 1.162 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.707 mg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction methods, the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest fumaric acid content of 1.48 mg g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (0.844 mg g^{-1} DW). The minimum fumaric acid content of 0.231 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.2.10 Maleic Acid

Maleic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 22).

Table 22. Organic acids (maleic acid) content (mg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Maleic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	0.34	0.25	0.36	0.32
Koozha (K)	0.54	0.76	0.78	0.70
Mean	0.44	0.50	0.57	
Factors	C.D. (0.05)	SE(m) ±		
T	0.011	0.004		
E	0.013	0.005		
T x E	0.019	0.006		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio
$D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio
$D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Koozha extract had higher (0.70 mg g^{-1} DW) maleic acid content compared to varikka (0.32 mg g^{-1} DW) extract.

The highest maleic acid content of 0.57 mg 100 g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (0.50 mg g^{-1} DW)

Considering the interaction effect of jackfruit type and extraction methods, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest maleic acid content of 0.78 mg g^{-1} DW, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (0.76 mg g^{-1} DW). The minimum maleic acid content of 0.25 mg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.3 Phenolic Compounds (µg g^{-1} DW)

A total eighteen individual phenolic acids were fractioned and quantified from the extracts of varikka and koozha extracts by HPLC analysis. Phenolic acid profile of the jackfruit extracts as influenced by type and extraction methods are shown in Tables from 23 to 28.

4.2.3.1 Ferulic Acid

Ferulic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 23).

Varikka extract had higher (146.36 µg g^{-1} DW) ferulic acid content compared to koozha (89.48 µg g^{-1} DW) extract.

The highest ferulic acid content was (148.29 µg 100 g^{-1} DW) recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio

Table 23. Phenolic acids (ferulic acid, p- Coumaric acid and caffeic acid) content of extracts as influenced by extraction methods and jackfruit types

Type	Ferulic acid			Mean	p-Coumaric acid			Mean	Caffeic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	106.81	152.30	179.96	146.36	40.52	24.57	44.82	36.64	16.57	15.90	32.72	21.73
Koozha (K)	91.59	60.23	116.61	89.48	47.15	35.90	75.24	52.76	45.37	9.39	65.03	39.93
Mean	99.20	106.26	148.29		43.83	30.24	60.03		30.97	12.64	48.87	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	2.03	0.69			0.99	0.34			0.47	0.16		
E	2.48	0.85			1.21	0.41			0.58	0.20		
T x E	3.51	1.20			1.71	0.58			0.82	0.28		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (106.26 µg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction methods, the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest ferulic acid content of 179.96 µg g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio (152.30 µg g^{-1} DW). The minimum ferulic acid content of 60.23 µg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio.

4.2.3.2 p-Coumaric Acid

p-Coumaric acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 23).

Koozha extract had higher p-Coumaric acid content (52.76 µg g^{-1} DW) compared to varikka (36.64 µg g^{-1} DW) extract.

The highest p-Coumaric acid content (60.03 µg 100 g^{-1} DW) was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (43.83 µg g^{-1} DW)

Considering the combined effect of jackfruit type and methods of extraction, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest p-Coumaric acid content of 75.24 µg g^{-1} DW, followed by extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio (47.15 µg g^{-1} DW). The minimum p-Coumaric acid content of 24.57 µg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.3.3 Caffeic Acid

Caffeic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 23).

Koozha extract had higher caffeic acid of 39.93 µg g^{-1} DW content compared to varikka (21.73 µg g^{-1} DW) extract.

The highest caffeic acid content (48.87 µg 100 g^{-1} DW) was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (30.97 µg g^{-1} DW)

Considering the combined effect of jackfruit type and method of extraction, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest caffeic acid content of 65.03 µg g^{-1} DW, followed by extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio (45.37 µg g^{-1} DW) The minimum caffeic acid content of 9.39 µg g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.3.4 Benzoic Acid

Benzoic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 24).

Koozha extract had higher benzoic acid content (21.17 µg g^{-1} DW) compared to varikka (8.30 µg g^{-1} DW) extract.

The highest benzoic acid content (21.73 µg 100 g^{-1} DW) was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (12.26 µg g^{-1} DW)

Table 24. Phenolic acids (benzoic acid, o-Coumaric acid2,4-dihydroxybenzoic acid) content (µg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Benzoic acid			Mean	o-Coumaric acid			Mean	2,4-dihydroxybenzoic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	4.14	3.83	16.94	8.30	10.79	6.92	8.08	8.60	10.28	4.48	63.57	26.11
Koozha (K)	16.31	20.69	26.52	21.17	16.62	12.92	22.96	17.50	13.15	9.02	21.88	14.68
Mean	10.23	12.26	21.73		13.70	9.92	15.52		11.72	6.75	42.72	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.24	0.08			0.50	0.17			0.52	0.18		
E	0.29	0.10			0.61	0.21			0.63	0.22		
T x E	0.41	0.14			0.86	0.29			0.89	0.30		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Considering the interaction effect of jackfruit types and extraction methods, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest benzoic acid content of 26.52 µg g^{-1} DW, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (20.69 µg g^{-1} DW). The minimum benzoic acid content of 3.83 µg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.3.5 o-Coumaric Acid

o -Coumaric acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 24).

Koozha extract had higher o-Coumaric acid content (17.50 µg g^{-1} DW) compared to varikka (8.60 µg g^{-1} DW) extract.

The highest o-Coumaric acid content (15.52 µg 100 g^{-1} DW) was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (13.70 µg g^{-1} DW)

Considering the combined effect of jackfruit type and extraction methods, it was observed that extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest o -Coumaric acid content of 22.96 µg g^{-1} DW, followed by extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio (16.62 µg g^{-1} DW). The minimum o -Coumaric acid content of 6.92 µg g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.3.6 2, 4-dihydroxybenzoic acid

2,4-dihydroxybenzoic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 24).

Varikka extract had higher (26.11 µg g^{-1} DW) 2,4-dihydroxybenzoic acid content compared to koozha (14.68 µg g^{-1} DW) extract.

The highest 2,4-dihydroxybenzoic acid content of 42.72 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio (E_3) followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (E_2) (11.72 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest 2,4-dihydroxybenzoic acid content of 63.57 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (21.88 µg g^{-1}). The minimum 2,4-dihydroxybenzoic acid content of 4.48 µg g^{-1} was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.3.7 Gentisic Acid

Gentisic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 25).

Varikka extract had higher (41.92 µg g^{-1} DW) gentisic acid content compared to koozha (4.55 µg g^{-1} DW) extract.

The highest gentisic acid content of 47.36 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (11.90 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest gentisic acid content of 89.35 µg g^{-1}, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio (21.88

μg g^{-1}). The minimum gentisic acid content of 1.91 μg g^{-1} was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.3.8 Vanillic Acid

Vanillic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 25).

Koozha extract had higher vanillic acid content of 1.46 μg g^{-1} DW compared to varikka (1.30 μg g^{-1} DW) extract.

The highest vanillic acid content of 2.38 μg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (1.20 μg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest acid content of 3.21 μg g^{-1}, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio (1.62 μg g^{-1}) which was on par with extracts prepared from varikka with 60% ethanol at 1:50 solid to solvent ratio (1.54 μg g^{-1}). The minimum vanillic acid content of 0.37 μg g^{-1} was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.2.3.9 Gallic Acid

Gallic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 25).

Varikka extract had higher (1.53 μg g^{-1} DW) gallic acid content compared to koozha (1.35 μg g^{-1} DW) extract.

Table 25. Phenolic acids (gentisic acid, vanillic acid and gallic acid) content (µg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Gentisic acid			Mean	Vanillic acid			Mean	Gallic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	14.52	21.88	89.35	41.92	0.74	1.62	1.54	1.30	1.44	1.63	1.52	1.53
Koozha (K)	6.38	1.91	5.37	4.55	0.37	0.79	3.21	1.46	0.52	1.35	2.20	1.35
Mean	10.45	11.90	47.36		0.56	1.20	2.38		0.98	1.49	1.86	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.42	0.14			0.06	0.02			0.035	0.012		
E	0.52	0.18			0.07	0.02			0.042	0.014		
T x E	0.73	0.25			0.10	0.03			0.06	0.020		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

The highest gallic acid content of 1.86 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (1.49 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried koozha type using 60% ethanol in 1:50 ratio had significantly highest gallic acid content of 2.20 µg g^{-1}, followed by extracts prepared from freeze dried varikka type using 60% ethanol in 1:40 ratio (1.63 µg g^{-1}). The minimum gallic acid content of 0.52 µg g^{-1} was observed in extracts prepared from cabinet dried koozha type using 60% ethanol in 1:50 ratio.

4.2.3.10 Salicylic acid

Salicylic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 26).

Koozha extract had higher (2.06 µg g^{-1} DW) salicylic acid content compared to varikka (1.97 µg g^{-1} DW) extract.

The highest salicylic acid content of 2.87 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:40 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:50 ratio (1.62 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio had significantly highest salicylic acid content of 3.38 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (2.36 µg g^{-1} DW). The minimum salicylic acid content of 1.23 µg g^{-1} was observed in extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio which was on par with extract prepared using freeze dried varikka with ethanol in 1:50 solid to solvent ratio (1.29 µg g^{-1}).

Table 26. Phenolic acids (salicylic acid, t-Cinnamic acid and protocatechuic acid) content (µg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Salicylic acid			Mean	t-Cinnamic acid			Mean	Protocatechuic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	1.23	3.38	1.29	1.97	0.83	0.74	7.95	3.17	0.40	0.37	0.96	0.58
Koozha (K)	1.88	2.36	1.95	2.06	0.89	2.75	1.07	1.57	0.44	0.63	0.74	0.60
Mean	1.55	2.87	1.62		0.86	1.75	4.51		0.42	0.50	0.85	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.055	0.019			0.08	0.03			0.016	0.005		
E	0.067	0.023			0.10	0.04			0.019	0.007		
T x E	0.095	0.032			0.15	0.05			0.028	0.009		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

4.2.3.11 t-Cinnamic Acid

t-Cinnamic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 26).

Varikka extract had higher (3.17 µg g^{-1} DW) t-Cinnamic acid content compared to koozha (1.57 µg g^{-1} DW) extract.

The highest t-Cinnamic acid content of 4.51 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (1.75 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest t-Cinnamic acid acid content of 7.95 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (2.75 µg g^{-1}). The minimum t-Cinnamic acid acid content of 0.74 µg g^{-1} was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio which was on par with extract prepared using cabinet dried varikka with ethanol in 1:50 solid to solvent ratio (0.83 µg g^{-1} DW).

4.2.3.12 Protocatechuic Acid

Protocatechuic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 26).

Koozha extract had higher (0.60 µg g^{-1} DW) protocatechuic acid content compared to varikka (0.58 µg g^{-1} DW) extract.

The highest protocatechuic acid content of 0.85 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (0.50 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest protocatechuic acid content of 0.96 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (0.74 µg g^{-1}). The minimum protocatechuic acid content of 0.37 µg g^{-1} was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.3.13 3-Hydroxy benzoic acid

3-Hydroxy benzoic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 27).

Varikka extract had higher (0.62 µg g^{-1} DW) 3-Hydroxy benzoic acid content compared to koozha (0.41 µg g^{-1} DW) extract.

The highest 3-Hydroxy benzoic acid content of 0.90 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.34 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest 3-Hydroxy benzoic acid content of 1.36 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio and cabinet dried koozha sample extracted using 60% ethanol at 1:50 ratio (0.44 µg g^{-1}). The minimum 3-Hydroxy benzoic acid content of 0.24 µg g^{-1} was observed in extracts prepared from cabinet dried varikka sample using 60% ethanol in 1:50 ratio.

4.2.3.14 p-Hydroxy benzoic acid

p-Hydroxy benzoic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 27).

Table 27. Phenolic acids (3-Hydroxy benzoic acid, p-Hydroxy benzoic acid and sinapic acid) content (µg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	3-Hydroxy benzoic acid			Mean	p-Hydroxy benzoic acid			Mean	Sinapic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	0.24	0.26	1.36	0.62	0.256	0.203	0.758	0.406	0.065	0.083	0.181	0.11
Koozha (K)	0.44	0.36	0.44	0.41	0.332	0.307	0.632	0.424	0.077	0.033	0.087	0.066
Mean	0.34	0.31	0.90		0.294	0.255	0.695		0.071	0.058	0.134	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.009	0.003			0.005	0.002			0.005	0.002		
E	0.011	0.004			0.006	0.002			0.006	0.002		
T x E	0.016	0.005			0.009	0.003			0.008	0.003		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Koozha extract had higher (0.424 µg g^{-1} DW) p-Hydroxy benzoic acid content compared to varikka (0.406 µg g^{-1} DW) extract.

The highest p-Hydroxy benzoic acid content of 0.695 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio, followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.294 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest p-Hydroxy benzoic acid content of 0.758 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (0.632 µg g^{-1}). The minimum p-Hydroxy benzoic acid content of 0.203 µg g^{-1} was observed in extracts prepared from freeze dried varikka sample using 60% ethanol in 1:40 ratio.

4.2.3.15 Sinapic Acid

Sinapic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 27).

Varikka extract had higher (0.11 µg g^{-1} DW) sinapic acid content compared to koozha (0.066 µg g^{-1} DW) extract.

The highest sinapic acid content of 0.134 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.071 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest sinapic acid content of 0.181 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (0.087 µg g^{-1}).

The minimum sinapic acid content of 0.033 µg g^{-1} was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.3.16 Syringic Acid

Syringic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 28).

Varikka extract had higher (0.054 µg g^{-1} DW) syringic acid content compared to koozha (0.039 µg g^{-1} DW) extract.

The highest syringic acid content of 0.061 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.042 µg g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest syringic acid content of 0.067 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (0.055 µg g^{-1}). The minimum syringic acid ccontent of 0.024 µg g^{-1} was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.3.17 Ellagic Acid

Ellagic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 28).

Varikka extract had higher (0.022 µg g^{-1} DW) ellagic acid content compared to koozha (0.018 µg g^{-1} DW) extract.

The highest ellagic acid content of 0.027 µg 100 g^{-1} was recorded in extracts prepared from cabinet dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:50 ratio (0.019 µg g^{-1} DW)

Table 28. Phenolic acids (syringic acid, ellagic acid and chlorogenic acid) content (µg g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Syringic acid			Mean	Ellagic acid			Mean	Chlorogenic acid			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	0.048	0.046	0.067	0.054	0.0350	0.0150	0.0150	0.0220	0.003	0.003	0.002	0.003
Koozha (K)	0.037	0.024	0.055	0.039	0.0200	0.0110	0.0220	0.0180	0.014	0.003	0.013	0.010
Mean	0.042	0.035	0.061		0.0270	0.0130	0.0190		0.008	0.003	0.008	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.002	0.001			0.001	0			0.001	0		
E	0.002	0.001			0.001	0			0.001	0		
T x E	0.003	0.001			0.002	0.001			0.001	0.001		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Considering the combined effect of both the factors, it was observed that the extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio had significantly highest ellagic acid content of 0.035 µg g^{-1}, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (0.022 µg g^{-1}). The minimum ellagic acid content of 0.011µg g^{-1} was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.3.18 Chlorogenic Acid

Chlorogenic acid content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 28).

Koozha extract had higher (0.010 µg g^{-1} DW) chlorogenic acid content compared to varikka (0.003 µg g^{-1} DW) extract.

The highest chlorogenic acid content of 0.008 µg 100 g^{-1} was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio and from cabinet dried samples using 60% ethanol in 1:50 ratio.

Considering the combined effect of both the factors, it was observed that the extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio had significantly highest chlorogenic acid content of 0.014µg g^{-1}, which was on par with extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (0.013 µg g^{-1}). The minimum chlorogenic acid content of 0.002 µg g^{-1} was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio which was on par with extract from freeze dried varikka and koozha sample with ethanol at 1:40 ratio and cabinet dried varikka extracted with 60% ethanol at 1:50 (0.003 µg g^{-1}).

4.2.4 Flavonoids (ng g^{-1} DW)

Total fifteen individual flavonoids were identified and quantified from varikka and koozha extracts (Table). Flavonoid profile of the jackfruit extracts as influenced by type and extraction methods are shown in Tables from 29 to 33.

4.2.4.1 Myricetin

Myricetin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 29).

Varikka extract had higher (6,788.19 ng g-1 DW) myricetin content compared to koozha (1,943.71 ng g^{-1} DW) extract.

The highest myricetin content of 5,510.34 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (4,148.66 ng g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest myricietin content of 7,815.78 ng g^{-1} DW followed by extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio (7,137.85 ng g^{-1}). The minimum myricietin content of 1,159.47 ng g^{-1} DW was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.2.4.2 Catechin

Catechin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 29).

Varikka extract had higher (4,190.60 ng g-1 DW) catechin content compared to koozha (1,454.63 ng g^{-1} DW) extract.

The highest catechin content of 4,172.07ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (2,445.90 ng g^{-1} DW).

Table 29. Flavonoid (myricetin, catechinc acid and naringenin) content (ng g^{-1} DW) of extracts as influenced by extraction methods and jackfruit types

Type	Myricetin			Mean	Catechin			Mean	Naringenin			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	7,137.85	5,410.94	7,815.78	6,788.19	3,234.55	3,307.49	6,029.76	4,190.60	990.46	1,825.64	2,039.35	1,618.48
Koozha (K)	1,159.47	1,466.74	3,204.91	1,943.71	465.20	1,584.32	2,314.38	1,454.63	2,210.91	2,561.27	3,432.24	2,734.81
Mean	4,148.66	3,438.84	5,510.34		1,849.88	2,445.90	4,172.07		1,600.68	2,193.46	2,735.79	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	46.79	15.94			41.20	14.03			18.91	6.44		
E	57.31	19.52			50.46	17.19			23.16	7.89		
T x E	81.05	27.60			71.36	24.30			32.76	11.00		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest catechin content of 6,029.76 ng g^{-1} DW followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio (3,307.49 ng g^{-1} DW). The minimum catechin content of 465.20 ng g^{-1} DW was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.2.4.3 Naringenin

Naringenin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 29).

Koozha extract had higher naringenin content of 2,734.81 ng g^{-1} DW compared to varikka (1,618.48 ng g^{-1} DW) extract.

The highest (2,735.79 ng g^{-1} DW) naringenin content was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (2,193.46 ng g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest naringenin content of 3,432.24 ng g^{-1} DW followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (2,561.27 ng g^{-1} DW). The minimum naringenin content of 990.46 ng g^{-1} DW was observed in extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio.

4.2.4.4 Epicatechin

Epicatechin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 30).

Table 30. Flavonoid (epicatechin, quercetin and luteolin) content (ng g^{-1} DW) of extracts as influenced by jackfruit types and extraction methods

Type	Epicatechin			Mean	Quercetin			Mean	Luteolin			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	463.44	345.30	866.08	558.27	443.08	479.86	806.53	576.49	153.40	393.70	502.93	350.01
Koozha (K)	189.56	349.75	381.13	306.81	295.50	257.40	703.55	418.82	344.05	138.10	477.29	319.81
Mean	326.50	347.52	623.61		369.29	368.63	755.04		248.73	265.90	490.11	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	15.95	5.43			6.63	2.26			7.22	2.46		
E	19.54	6.65			8.12	2.77			8.84	3.01		
T x E	27.63	9.41			11.49	3.91			12.50	4.26		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Varikka extract had higher epicatechin content of 558.27 ng g^{-1} DW compared to koozha (306.81 ng g^{-1} DW) extract.

The highest (623.61ng g^{-1} DW) epicatechin content was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (347.52 ng g^{-1} DW)

Considering the interaction effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest epicatechin content of 866.08 ng g^{-1} DW followed by extracts prepared from cabinet dried varikka type using 60% ethanol in 1:50 ratio (463.44 ng g^{-1} DW). The minimum epicatechin content of 189.56 ng g^{-1} DW was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.2.4.5 Quercetin

Quercetin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 30).

Varikka extract had higher quercetin content of 576.49 ng g^{-1} DW compared to koozha (418.82 ng g^{-1} DW) extract.

The highest quercetin content of 755.04 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (369.29 ng g^{-1} DW), which was on par with extracts from freeze dried samples extracted using 60% ethanol in 1:40 ratio (368.63 ng g^{-1} DW).

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest quercetin content of 806.53 ng g^{-1} DW followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio

(703.55 ng g^{-1} DW). The minimum quercetin content of 257.40 ng g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.4.6 Luteolin

Luteolin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 30).

Varikka extract had higher (350.01 ng g^{-1} DW) luteolin content compared to koozha (319.81 ng g^{-1} DW) extract.

The luteolin content of 490.11 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (265.90 ng g^{-1} DW DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest luteolin content of 502.93 ng g^{-1} DW, followed by extracts extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (477.29 ng g^{-1} DW). The minimum luteolin content of 138.10 ng g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.4.7 Rutin

Rutin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 31).

Varikka extract had higher (226.88 ng g^{-1} DW) rutin content compared to koozha (195.95 ng g^{-1} DW) extract.

The rutin content of 261.36 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those

Table 31. Flavonoid (rutin, epigallocatechin and hesperetin) content (ng g^{-1} DW) of extracts as influenced by jackfruit types and extraction methods

Type	Rutin			Mean	Epigallocatechin			Mean	Hesperetin			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	189.20	173.98	317.46	226.88	247.94	210.39	325.50	261.28	63.98	71.43	143.64	93.02
Koozha (K)	195.35	187.26	205.25	195.95	279.85	300.38	405.83	328.69	65.03	61.05	114.36	80.15
Mean	192.28	180.62	261.36		263.90	255.39	365.66		64.50	66.24	129.00	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	4.83	1.65			3.68	1.25			1.47	0.50		
E	5.92	2.02			4.50	1.53			1.80	0.61		
T x E	8.37	2.85			6.37	2.17			2.54	0.87		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (192.28 ng g^{-1} DW)

Considering the combined effect of both the factors, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest rutin content of 317.46 ng g^{-1} DW, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (205.25 ng g^{-1} DW). The minimum rutin content of 173.98 ng g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.4.8 Epigallocatechin

Epigallocatechin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 31).

Koozha extract had higher (328.69 ng g^{-1} DW) epigallocatechin content compared to varikka (261.28 ng g^{-1} DW) extract.

The epigallocatechin content of 365.66 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio (E_3) followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (E_1) (263.90 ng g^{-1} DW DW)

Considering the combined effect of jackfruit type and extraction methods, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest epigallocatechin content of 405.83 ng g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (325.50 ng g^{-1} DW). The minimum epigallocatechin content of 210.39 ng g^{-1} DW was observed in extracts prepared from freeze dried varikka using 60% ethanol in 1:40 ratio.

4.2.4.9 Hesperetin

Hesperetin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 31).

Varikka extract had higher (93.02 ng g^{-1} DW) hesperetin content compared to koozha (80.15 ng g^{-1} DW) extract.

The hesperetin content of 129.00 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (66.24 ng g^{-1} DW) which was on par with extracts prepared from cabinet dried samples using 60% ethanol in 1:50 solid to solvent ratio (64.50 ng g^{-1} DW)

Considering the combined effect of jackfruit type and methods of extraction, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest hesperetin content of 143.64 ng g^{-1} DW, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (114.36 ng g^{-1} DW). The minimum hesperetin content of 61.05 ng g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.4.10 Apigenin

Apigenin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 32).

Koozha extract had higher (24.69 ng g^{-1} DW) apigenin content compared to varikka (11.67 ng g^{-1} DW) extract.

The apigenin content of 30.66 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (15.17 ng g^{-1} DW).

Table 32. Flavonoid (apigenin, fisetin and kaemperol) content (ng g^{-1} DW) of extracts as influenced by jackfruit types and extraction methods

Type	Apigenin			Mean	Fisetin			Mean	Kaemperol			Mean
	$D_1S_4R_3$	**$D_2S_4R_2$**	**$D_2S_4R_3$**		**$D_1S_4R_3$**	**$D_2S_4R_2$**	**$D_2S_4R_3$**		**$D_1S_4R_3$**	**$D_2S_4R_2$**	**$D_2S_4R_3$**	
Varikka (V)	12.50	9.74	12.76	11.67	3.74	4.26	11.05	6.35	4.50	5.60	5.83	5.31
Koozha (K)	4.89	20.61	48.57	24.69	4.53	9.01	9.36	7.64	0.86	4.89	7.53	4.42
Mean	8.70	15.17	30.66		4.14	6.64	10.21		2.68	5.24	6.68	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.49	0.17			0.17	0.06			0.11	0.04		
E	0.60	0.20			0.21	0.07			0.14	0.05		
T x E	0.84	0.29			0.30	0.10			0.20	0.07		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

Considering the combined effect of jackfruit type and methods of extraction, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest apigenin content of 48.57 ng g^{-1} DW, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (20.61 ng g^{-1} DW). The minimum apigenin content of 4.89 ng g^{-1} DW was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.2.4.11 Fisetin

Fisetin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 32).

Koozha extract had higher (7.64 ng g^{-1} DW) fisetin content compared to varikka (6.35 ng g^{-1} DW) extract.

The fisetin content of 10.21 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (6.64 ng g^{-1} DW).

Considering the combined effect of jackfruit type and method of extractions, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest fisetin content of 11.05 ng g^{-1} DW, followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio (9.36 ng g^{-1} DW). The minimum fisetin content of 3.74 ng g^{-1} DW was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.2.4.12 Kaemperol

Kaemperol content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 32).

Varikka extract had higher (5.31 ng g^{-1} DW) kaemperol content compared to koozha (4.42 ng g^{-1} DW) extract.

The kaemperol content of 6.68 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:40 ratio (5.24 ng g^{-1} DW).

Considering the combined effect of jackfruit type and method of extraction, it was observed that the extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio had significantly highest kaemperol content of 7.53 ng g^{-1} DW, followed by extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio (5.83 ng g^{-1} DW). The minimum kaemperol content of 0.86 ng g^{-1} DW was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.2.4.13 Galangin

Galangin content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 33).

Koozha extract had higher (4.07 ng g^{-1} DW) galangin content compared to koozha (2.95 ng g^{-1} DW) extract.

The highest galangin content of 4.46 ng g^{-1} DW was recorded in extracts prepared from cabinet dried samples using 60% ethanol in 1:50 ratio followed by those prepared from freeze dried samples using 60% ethanol in 1:50 ratio (3.49 ng g^{-1} DW).

Considering the combined effect of jackfruit type and method of extraction, it was observed that the extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio had significantly highest galangin content of 4.47 ng g^{-1} DW, which was found to be on par with extracts prepared from cabinet dried varikka extracted with 1:50 ratio (4.46 ng g^{-1} DW) followed by extracts

prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (4.14 ng g^{-1} DW). The minimum galangin content of 1.55 ng g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.4.14 Umbelliferone

Umbelliferone content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 33).

Varikka extract had higher (1.83 ng g^{-1} DW) umbelliferone content compared to koozha (1.64 ng g^{-1} DW) extract.

The umbelliferone content of 1.98 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (1.82 ng g^{-1} DW).

Considering the combined effect of jackfruit type and extraction methods, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest umbelliferone content of 2.05 ng g^{-1} DW followed by extracts prepared from freeze dried koozha using 60% ethanol in 1:50 ratio (1.91 ng g^{-1} DW) which was found to be on par with cabinet dried sample extracted with 60% ethanol in 1:50 ratio (1.89 ng g^{-1} DW). The minimum umbelliferone content of 1.27 ng g^{-1} DW was observed in extracts prepared from freeze dried koozha using 60% ethanol in 1:40 ratio.

4.2.4.15 Eriodictyol

Eriodictyol content of the extracts was significantly influenced by jackfruit types, extraction methods and their interaction (Table 33).

Varikka extract had higher (0.850 ng g^{-1} DW) eriodictyol content compared to koozha (0.252 ng g^{-1} DW) extract.

Table 33. Flavonoid (galangin, umbelliferone and eriodictyol) content (ng g^{-1} DW) of extracts as influenced by jackfruit types and extraction method

Type	Galangin			Mean	Umbelliferone			Mean	Eriodictyol			Mean
	$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$		$D_1S_4R_3$	$D_2S_4R_2$	$D_2S_4R_3$	
Varikka (V)	4.46	1.55	2.84	2.95	1.89	1.54	2.05	1.83	0.939	0.209	1.401	0.850
Koozha (K)	4.47	3.60	4.14	4.07	1.74	1.27	1.91	1.64	0.188	0.348	0.219	0.252
Mean	4.46	2.57	3.49		1.82	1.41	1.98		0.564	0.279	0.810	
Factors	C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±			C.D. (0.05)	SE(m) ±		
T	0.05	0.02			0.04	0.01			0.011	0.004		
E	0.06	0.02			0.05	0.02			0.014	0.005		
T x E	0.08	0.03			0.06	0.02			0.02	0.007		

$D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio; $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio; $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

The eriodictyol content of 0.810 ng g^{-1} DW was recorded in extracts prepared from freeze dried samples using 60% ethanol in 1:50 ratio followed by those prepared from cabinet dried samples using 60% ethanol in 1:50 ratio (0.564 ng g^{-1} DW).

Considering the combined effect of jackfruit type and extraction methods, it was observed that the extracts prepared from freeze dried varikka using 60% ethanol in 1:50 ratio had significantly highest eriodictyol content of 1.401 ng g^{-1} DW followed by extracts prepared from cabinet dried varikka using 60% ethanol in 1:50 ratio (0.939 ng g^{-1} DW). The minimum eriodictyol content of 0.188 ng g^{-1} DW was observed in extracts prepared from cabinet dried koozha using 60% ethanol in 1:50 ratio.

4.3 ENCAPSULATION OF EXTRACTS

The following three superior jackfruit extracts selected from Part-I were encapsulated independently by spray and freeze drying using maltodextrin as carrier.

1. $D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

2. $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio

3. $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

4.3. 1 Encapsulation by Spray Drying

Encapsulation of the three selected extracts was independently done for varikka and koozha by spray drying technique using two levels of maltodextrin (MD 10 and 20 DE), three levels of carrier to extract ratios (1:10, 1:15 and 1:20) at two temperatures (T_1 -Inlet 180° C and outlet 80° C and T_2 -Inlet 190° C and

outlet 90° C) of the spray drier as process variables. The resultant spray encapsulates were analysed for quality parameters, recovery percentage and moisture content is presented below.

4.3.1.1 Total Flavonoid Content (mg QE 100g^{-1}) (TFC)

4.3.1.1.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Total flavonoid content (TFC) of spray encapsulate of extract $D_1S_4R_3$ (cabinet dried sample extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence of maltodextrin (C), inlet and outlet temperature (T) and carrier to extract ratio (Cr) (Table 34).

Extract $D_1S_4R_3$ encapsulated with MD 20 DE (C_2) had higher total flavonoid content of 8.65 mg QE100 g^{-1} compared to those encapsulated with MD 10 DE (C_2) (8.23 mg QE100 g^{-1}).

The higher TFC of 8.63 mg QE 100 g^{-1} was recorded in extracts encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (8.25 mg QE100 g^{-1}).

Significantly highest TFC of 9.09 mg QE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 8.57 mg QE 100 g^{-1} TFC.

The interaction effect of all the three factors was found to be non-significant.

Koozha

Total flavonoid content (TFC) of spray encapsulated of extract $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio)

Table 34. Effect of process variables on total flavonoid content (mg QE 100 g^{-1}) of spray dried encapsulate of varikka extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	7.68	7.22	7.45	8.09	7.64	7.87	7.66
Cr_2 (1:15)	8.52	8.23	8.37	8.86	8.67	8.77	8.57
Cr_3 (1:20)	9.04	8.67	8.86	9.58	9.06	9.32	9.09
Mean	8.41	8.04		8.85	8.46		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.08	0.03		C_1	C_2	T_1	T_2
T	0.08	0.03		8.23	8.65	8.63	8.25
Cr	0.09	0.03					
C x T x Cr	NS	0.06					

T_1- 180°C Inlet and 80°C outlet temperature T_2- 190°C Inlet and 90°C outlet temperature

was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet and outlet temperature (T) and carrier to extract ratio (Cr) (Table 35).

Extract $D_1S_4R_3$ with MD 20 DE (C_2)had higher total flavonoid content of 7.93 mg QE100 g^{-1} compared to MD 10 DE (C_1) (7.49 mg QE100g^{-1}).

Higher TFC of 7.93 mg QE 100 g^{-1} was recorded in extracts encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (7.50 mg QE100g^{-1}).

Significantly, highest TFC of 8.29 mg QE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract volume (Cr_3) while the lowest was recoded in those prepared using 1:10 carrier to extract ratio (Cr_1) with 7.01 mg QE 100 g^{-1} TFC.

The interaction effects of all the three factors was found to be non-significant.

4.3.1.1.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

Total flavonoid content (TFC) of spray encapsulated extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet and outlet temperature (T) (Table 36).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher total flavonoid content of 9.04 mg QE100g^{-1} compared to those encapsulated with MD 10 DE (C_1) (8.50 mg QE100g^{-1}).

Higher TFC of 8.88 mg QE 100 g^{-1} was recorded in extracts encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (8.65 mg QE 100g^{-1}).

Table 35. Effect of process variables on total flavonoid content (mg QE 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	7.10	6.66	6.88	7.31	6.97	7.14	7.01
Cr_2 (1:15)	7.84	7.26	7.55	8.36	7.88	8.12	7.83
Cr_3 (1:20)	8.32	7.78	8.05	8.63	8.44	8.54	8.29
Mean	7.75	7.23		8.10	7.76		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.09	0.03		C_1	C_2	T_1	T_2
T	0.09	0.03		7.49	7.93	7.93	7.50
Cr	0.11	0.04					
C x T x Cr	NS	0.07					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Table 36. Effect of process variables on total flavonoid content (mg QE 100 g^{-1}) of spray dried encapsulate of varikka extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	7.95	7.61	7.78	8.28	8.11	8.20	7.99
Cr_2 (1:15)	8.85	8.48	8.66	9.31	9.33	9.32	8.99
Cr_3 (1:20)	9.31	8.81	9.06	9.60	9.58	9.59	9.33
Mean	8.70	8.30		9.07	9.01		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.10	0.03		C_1	C_2	T_1	T_2
T	0.10	0.04		8.50	9.04	8.88	8.65
Cr	0.12	0.04					
C x T x Cr	NS	0.08					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

Significantly highest TFC of 9.33 mg QE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3), followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 8.99 mg QE 100 g^{-1} TFC.

The interaction effects of all the three factors was found to be non-significant.

Koozha

Total flavonoid content (TFC) of spray encapsulate of extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr), inlet and outlet temperature (T) and their interaction (Table 37).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher total flavonoid content of 8.86 mg QE100g^{-1} compared to those encapsulated with MD 10 DE (C_1) (8.38 mg QE100g^{-1}).

Higher TFC of 8.88 mg QE 100 g^{-1} was recorded in extracts encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (8.36 mg QE100g^{-1}).

Significantly highest TFC of 9.24 mg QE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 8.79 mg QE 100 g^{-1} TFC.

The interaction effects across all the three factors revealed that, the extracts encapsulated using 20 DE MD at 1:20 carrier to extract volume (Cr_3) with inlet and out let temperature of 180 and 80º C ($C_2Cr_3T_1$) recorded the significantly highest TFC content of 9.78 mg QE 100g^{-1}. This was followed by extract encapsulated using 20 DE MD at carrier to extract ratio of 1: 15 (Cr_2) with inlet and outlet temperature of 180 and 80º C ($C_2Cr_2T_1$) (9.50 mg QE100 g^{-1}). The same was found to be on par with exact encapsulated with MD 20 DE at 1:20

Table 37. Effect of process variables on total flavonoid content (mg QE 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	7.68	7.66	7.67	8.26	7.70	7.98	7.83
Cr_2 (1:15)	8.79	8.21	8.50	9.50	8.67	9.09	8.79
Cr_3 (1:20)	9.27	8.67	8.97	9.78	9.25	9.51	9.24
Mean	8.58	8.18		9.18	8.54		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.09	0.03		C_1	C_2	T_1	T_2
T	0.09	0.03		8.38	8.86	8.88	8.36
Cr	0.12	0.04					
C x T x Cr	0.23	0.08					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

carrier to extract ratio at T_1 ((inlet-180; outlet-80º C) with 9.27 mg QE100 g^{-1} ($C_1Cr_3T_1$). The lowest total flavonoid content (7.66 mg QE 100 g^{-1}) was recorded in extracts encapsulated by using MD 10 DE at 1:10 carrier to extract ratio at inlet (190º C) and outlet temperature (90º C) ($C_1Cr_1T_2$). This was found to be on par with extracts encapsulated using MD 10 DE at 1:10 carrier to extract ratio at inlet (180º C) and outlet temperature (80º C) (7.68 mg QE100g^{-1}) ($C_1Cr_1T_1$). Extract encapsulated with MD 20 DE at 1:10 carrier to extract ratio at inlet (190º C) and outlet temperature (90º C) was also found to be on par with total flavonoid content of 7.70 mg QE100g^{-1} ($C_2Cr_1T_2$).

4.3.1.1.3 Freeze Dried Sample Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

Total flavonoid content (TFC) of spray encapsulated extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet and outlet temperature (T) (Table 38).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher total flavonoid content of 9.50 mg QE100g^{-1} compared to those encapsulated with MD 10 DE (C_1) (9.12 mg QE 100g^{-1})

Higher TFC of 9.56 mg QE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (9.07 mg QE 100g^{-1}).

Significantly highest TFC of 9.97 mg QE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 9.45 mg QE 100 g^{-1} TFC.

The interaction effects of all the three factors was found to be non-significant.

Table 38. Effect of process variables on total flavonoid content (mg QE 100 g^{-1}) of spray dried encapsulate of varikka extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	8.63	8.11	8.37	8.86	8.46	8.66	8.52
Cr_2 (1:15)	9.45	9.04	9.24	9.85	9.45	9.65	9.45
Cr_3 (1:20)	10.05	9.45	9.75	10.49	9.91	10.20	9.97
Mean	9.38	8.86		9.74	9.27		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.09	0.03		C_1	C_2	T_1	T_2
T	0.09	0.03		9.12	9.50	9.56	9.07
Cr	0.11	0.04					
C x T x Cr	NS	0.08					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Koozha

Total flavonoid content (TFC) of spray encapsulated extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet and outlet temperature (T) (Table 39).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher total flavonoid content of 9.73 mg QE100 g^{-1} compared to extract encapsulated with MD 10 DE (C_1) (9.36 mg QE100 g^{-1}).

Higher TFC of 9.76 mg QE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (9.32 mg QE 100g^{-1}).

Significantly highest TFC of 10.21 mg QE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 9.63 mg QE 100 g^{-1} TFC.

The interaction effects of all the three factors was found to be non-significant.

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

4.3.1.2.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Total phenolic content (TPC) of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet and outlet temperature (T) (Table 40).

Table 39. Effect of process variables on total flavonoid content (mg QE 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	8.88	8.32	8.60	9.19	8.79	8.99	8.80
Cr_2 (1:15)	9.60	9.31	9.46	9.93	9.66	9.80	9.63
Cr_3 (1:20)	10.26	9.76	10.01	10.71	10.11	10.41	10.21
Mean	9.58	9.13		9.94	9.52		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.10	0.03		C_1	C_2	T_1	T_2
T	0.10	0.03		9.36	9.73	9.76	9.32
Cr	0.12	0.04					
C x T x Cr	NS	0.08					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Table 40. Effect of process variables on total phenol content (mg GAE 100 g^{-1}) of Spray dried encapsulate of varikka extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	87.37	80.24	83.81	90.36	82.86	86.61	85.21
Cr_2 (1:15)	96.06	85.47	90.77	98.09	88.22	93.15	91.96
Cr_3 (1:20)	104.46	91.51	97.98	106.87	92.90	99.88	98.93
Mean	95.96	85.74		98.44	87.99		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.39	0.14		C_1	C_2	T_1	T_2
T	0.39	0.14		90.85	93.22	97.20	86.87
Cr	0.48	0.17					
C x T x Cr	NS	0.33					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Extract $D_1S_4R_3$ encapsulated with MD 20 DE (C_2) had higher total phenolic content of 93.22 mg GAE $100g^{-1}$ compared to those encapsulated with MD 10 DE (C_1)(90.85 mg GAE 100 g^{-1}).

Higher TPC of 97.20 mg GAE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (86.87 mg GAE 100 g^{-1}).

Significantly highest TPC of 98.93 mg GAE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 91.96 mg GAE 100 g^{-1} TPC.

The interaction effects of all the three factors was found to be non-significant.

Koozha

Total phenolic content (TPC) of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet and outlet temperature (T) (Table 41).

Extract $D_1S_4R_3$ encapsulated with MD 20 DE (C_2) had higher total phenolic content of 95.25 mg GAE $100g^{-1}$ compared to one encapsulated with MD 10 DE (C_1) (92.41 mg GAE 100 g^{-1}).

The higher TPC of 98.08 mg GAE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (89.58 mg GAE 100 g^{-1}).

Table 41. Effect of process variables on total phenol content (mg GAE 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	88.00	80.66	84.33	92.40	84.67	88.53	86.43
Cr_2 (1:15)	97.71	87.58	92.64	100.75	89.19	94.97	93.81
Cr_3 (1:20)	103.78	96.69	100.24	105.81	98.68	102.24	101.24
Mean	96.50	88.31		99.65	90.84		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.37	0.13		C_1	C_2	T_1	T_2
T	0.37	0.13		92.41	95.25	98.08	89.58
Cr	0.45	0.15					
C x T x Cr	NS	0.31					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Significantly highest TPC of 101.24 mg GAE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) while the lowest was recorded in those prepared using 1:10 carrier to extract ratio (Cr_1) with 86.43 mg GAE 100 g^{-1} TPC.

The interaction effects of all the three factors was found to be non-significant.

4.3.1.2.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

Total phenolic content (TPC) of spray encapsulated extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr), inlet-outlet temperature (T) and their interaction (Table 42).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher total phenolic content of 99.04 mg GAE 100g^{-1} compared to those encapsulated with MD 10 DE (C_1) (96.65 mg GAE 100g^{-1}).

Higher TPC of 102.67 mg GAE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (93.01 mg GAE 100 g^{-1}).

Significantly highest TPC of 105.96 mg GAE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 99.05 mg GAE 100 g^{-1} TPC.

Table 42. Effect of process variables on total phenol content (mg GAE 100 g^{-1}) of spray dried encapsulate of varikka , $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	92.31	82.94	87.63	92.94	85.89	89.42	88.52
Cr_2 (1:15)	102.90	92.69	97.79	105.47	95.14	100.30	99.05
Cr_3 (1:20)	109.61	99.44	104.52	112.81	101.97	107.39	105.96
Mean	101.60	91.69		103.74	94.33		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.36	0.12		C_1	C_2	T_1	T_2
T	0.36	0.12		96.65	99.04	102.67	93.01
Cr	0.44	0.15					
C x T x Cr	0.89	0.30					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

The highest TPC of all the three factors revealed that, the extract encapsulated using MD 20 DE at 1:20 carrier to extract ratio with inlet and out let temperature of 180 and 80º C had significantly highest TPC of 112.81 mg GAE 100 g^{-1}($C_2Cr_3T_1$). This was followed by extract encapsulated using 10 DE MD at 1: 20 carrier to extract ratio with inlet and outlet temperature of 180 and 80º C ($C_1Cr_3T_1$) (109.61 mg GAE 100 g^{-1}).The lowest total phenolic content of 82.94 mg GAE 100 g^{-1} was recorded in the extract encapsulated using 10 DE maltodextrin at 1: 10 carrier to extract ratio and spray dried at inlet (190º C) and outlet temperature (90º C) ($C_1Cr_1T_2$).

Koozha

Total phenolic content (TPC) of spray encapsulated extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet - outlet temperature (T) (Table 43).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher total phenolic content of 101.64 mg GAE 100g^{-1} compared to those encapsulated with MD 10 DE (C_1) (100.16 mg GAE 100g^{-1}).

Higher TPC of 104.49 mg GAE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (97.32 mg GAE 100 g^{-1}).

Significantly highest TPC of 110.72 mg GAE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 101.65 mg GAE 100 g^{-1} TPC.

The interaction effects of all the three factors was found to be non-significant.

Table 43. Effect of process variables on total phenol content (mg GAE 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	92.86	85.56	89.21	95.05	87.88	91.46	90.34
Cr_2 (1:15)	104.97	97.58	101.28	105.93	98.13	102.03	101.65
Cr_3 (1:20)	113.15	106.87	110.01	114.96	107.88	111.42	110.72
Mean	103.66	96.67		105.32	97.96		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.38	0.13		C_1	C_2	T_1	T_2
T	0.38	0.13		100.16	101.64	104.49	97.32
Cr	0.47	0.16					
C x T x Cr	NS	0.32					
T_1- 180°C Inlet and 80°C outlet temperature			T_2- 190°C Inlet and 90°C outlet temperature				

4.3.1. 2.3 Freeze Dried Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

Total phenolic content (TPC) of spray encapsulated extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) inlet - outlet temperature (T) and their interaction (Table 44).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher total phenolic content of 101.76 mg GAE $100g^{-1}$ compared to those encapsulated with MD 10 DE (C_1)(99.60 mg GAE $100g^{-1}$).

Higher TPC of 105.39 mg GAE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (95.97 mg GAE 100 g^{-1}).

Significantly highest TPC of 108.47 mg GAE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to volume of extract ratio (Cr_2) with 101.09 mg GAE 100 g^{-1} TPC.

The interaction effects of all the three factors revealed that, the extract encapsulated using MD 20 DE at 1:20 carrier to extract ratio ($Cr_{3)}$ at inlet - outlet temperature of 180 - 80º C ($C_2Cr_3T_1$) recorded significantly highest TPC of 115.47 mg GAE 100 g^{-1}. This was followed by extracts encapsulated using 10 DE MD at 1: 20 carrier to extract ratio (Cr_3) and with inlet - outlet temperature of 180 - 80º C ($C_1Cr_3T_1$) (112.65 mg GAE 100 g^{-1}). The lowest total phenolic content of 87.08 mg GAE 100 g^{-1} was recorded in extracts encapsulated using 10 DE at 1:10 carrier to extract ratio with inlet (190º C) and outlet temperature (90º C) ($C_1Cr_1T_2$).

Koozha

Table 44. Effect of process variables on total phenol content (mg GAE 100 g^{-1}) of spray dried encapsulate varikka extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	95.22	87.08	91.15	97.46	90.20	93.83	92.49
Cr_2 (1:15)	104.80	95.47	100.14	106.74	97.33	102.04	101.09
Cr_3 (1:20)	112.65	102.39	107.52	115.47	103.36	109.42	108.47
Mean	104.22	94.98		106.56	96.96		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.36	0.12		C_1	C_2	T_1	T_2
T	0.36	0.12		99.60	101.76	105.39	95.97
Cr	0.44	0.15					
C x T x Cr	0.89	0.30					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Table 45. Effect of process variables on total phenol content (mg GAE 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	97.41	87.58	92.50	100.03	92.31	96.17	94.33
Cr_2 (1:15)	105.64	97.92	101.78	107.37	100.66	104.02	102.90
Cr_3 (1:20)	114.46	109.39	111.93	117.92	111.17	114.55	113.24
Mean	105.84	98.30		108.44	101.38		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.44	0.15		C_1	C_2	T_1	T_2
T	0.44	0.15		102.07	104.91	107.14	99.84
Cr	0.54	0.19					
C x T x Cr	1.08	0.37					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Total phenolic content (TPC) of spray encapsulated extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) inlet - outlet temperature (T) and their interaction (Table 45).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher total phenolic content of 104.91 mg GAE $100g^{-1}$ compared to those encapsulated with MD 10 DE (C_1) (102.07mg GAE $100g^{-1}$).

Higher TPC of 107.14 mg GAE 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (99.84 mg GAE 100 g^{-1}).

Significantly highest TPC of 113.24 mg GAE 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to of extract ratio (Cr_2) with 102.90 mg GAE 100 g^{-1} TPC.

The extract encapsulated using MD 20 DE at 1:20 carrier to extract ratio ($Cr_{3)}$ at inlet - outlet temperature of 180 - 80º C ($C_2Cr_3T_1$) recorded significantly highest TPC of 117.92 mg GAE 100 g^{-1}. This was followed by extracts encapsulated using MD 10 DE at 1: 20 carrier to extract ratio (Cr_3) at inlet - outlet temperature of 180 - 80º C ($C_1Cr_3T_1$) (114.46 mg GAE 100 g^{-1}). The lowest total phenolic content of 87.58 mg GAE 100 g^{-1} was recorded in extracts encapsulated using 10DE at 1:10 carrier to extract ratio and spray dried at inlet (190º C) and outlet temperature (90º C) ($C_1Cr_1T_2$).

4.3.1. 3 Total Antioxidant (DPPH) Activity (%)

4.3.1.3.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Total antioxidant activity (DPPH scavenging) of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to

Table 46. Effect of process variables on total antioxidant activity (DPPH) activity (%) of spray dried encapsulate of varikka extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	51.44	50.54	50.99	53.72	51.51	52.62	51.80
Cr_2 (1:15)	53.29	51.30	52.29	55.45	54.29	54.87	53.58
Cr_3 (1:20)	57.35	56.35	56.85	59.56	57.74	58.65	57.75
Mean	54.03	52.73		56.24	54.51		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.27	0.09		C_1	C_2	T_1	T_2
T	0.27	0.09		53.38	55.38	55.13	53.62
Cr	0.33	0.11					
C x T x Cr	0.67	0.23					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) inlet - outlet temperature and their interaction (T) (Table 46).

Extract $D_1S_4R_3$ encapsulated with MD 20 DE (C_2) had higher scavenging activity with 55.38 per cent inhibition compared to those encapsulated with MD 10 DE (C_1) (53.38 %).

Higher scavenging activity of 55.13 per cent was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to T_2 (inlet- 190; outlet 90º C) (53.62%).

Significantly highest scavenging activity of 57.75 per cent was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3), while the lowest activity was recorded in extracts encapsulated using 1:10 carrier to extract ratio (Cr_1) (51.80%).

The interaction effect of all the three factors revealed that, the extract encapsulated using MD 20 DE at 1:20 carrier to extract ratio (Cr_3) at inlet (180 º C) and outlet (80º C) temperature recorded significantly highest scavenging activity of 59.56 per cent ($C_2Cr_3T_1$). This was followed by extract spray encapsulated using MD 20 DE at 1: 20 carrier to extract ratio (Cr_3) and inlet - out let temperature of 190 - 90º C ($C_2Cr_3T_2$) (57.74%). The same was found to be on par with extract encapsulated with 10 DE MD at 1:20 carrier to extract ratio and spray dried at T_1 (inlet-180; outlet-80º C) ($C_1Cr_3T_1$) (57.35%). The minimum scavenging activity of 50.54 per cent inhibition was observed when extracts were encapsulated with 10DE maltodextrin at 1: 10 carrier to extract ratio and spray dried at T_2 (inlet-190; outlet-90º C) ($C_1Cr_1T_2$).

Koozha

DPPH scavenging activity of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by carrier to extract ratio (Cr) and inlet - outlet temperature (T) (Table 47).

Table 47. Effect of process variables on total antioxidant activity (DPPH) activity (%) of spray dried encapsulate of koozha extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	53.43	51.44	52.44	55.14	51.61	53.38	52.91
Cr_2 (1:15)	56.55	55.31	55.93	57.42	55.59	56.51	56.22
Cr_3 (1:20)	61.73	58.08	59.90	62.51	55.08	58.80	59.35
Mean	57.24	54.94		58.36	54.09		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	NS	0.40		C_1	C_2	T_1	T_2
T	1.16	0.40		56.09	56.23	57.80	54.52
Cr	1.42	0.49					
C x T x Cr	NS	0.98					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Dextrose equivalence of maltodextrin did not significantly influence the antioxidant activity of the encapsulates.

Higher scavenging activity of 57.80 per cent was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to T_2 (inlet- 190; outlet 90º C) (54.52%).

Significantly highest scavenging activity of 59.35 per cent was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3), while the lowest activity was recorded in extracts encapsulated using 1:10 extract to volume ratio (Cr_1) (52.91%).

The interaction effect of all the factors did not influence the antioxidant activity of the encapsulates.

4.3.1.3.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

DPPH scavenging activity of spray encapsulated extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) inlet - outlet temperature (T) and their interaction (Table 48).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher scavenging activity with 59.34 per cent inhibition compared to those encapsulated with MD 10 DE (C_1) (57.52 %).

Higher scavenging activity of 59.33 per cent was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to T_2 (inlet- 190; outlet 90º C) (57.53%).

Table 48. Effect of process variables on total antioxidant activity (DPPH) activity (%) of spray dried encapsulate of varikka extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	54.70	53.32	54.01	56.59	54.46	55.52	54.77
Cr_2 (1:15)	57.53	55.61	56.57	60.53	58.45	59.49	58.03
Cr_3 (1:20)	62.17	61.77	61.97	64.46	61.58	63.02	62.49
Mean	58.13	56.90		60.53	58.16		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.23	0.08		C_1	C_2	T_1	T_2
T	0.23	0.08		57.52	59.34	59.33	57.53
Cr	0.29	0.10					
C x T x Cr	0.57	0.20					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

Significantly highest scavenging activity of 62.49 per cent was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3), followed by those prepared using 1:15 carrier to extract ratio (Cr_2) (58.03%).

The interaction effect of all the three factors revealed that, the extract encapsulated using MD 20 DE at 1:20 carrier to extract ratio and dried at inlet (180 ° C) and outlet (80° C) temperature recorded significantly highest scavenging activity of 64.46 per cent ($C_2Cr_3T_1$). This was followed by extract encapsulated using MD 10 DE at 1: 20 carrier to extract ratio and spray dried at inlet - out let temperature of 180 - 80° C ($C_1Cr_3T_1$) (62.17%).This was found to be on par with extract spray encapsulated with MD 10 DE at 1:20 carrier to extract ratio and dried at inlet 190 and outlet 90° C temperature ($C_1Cr_3T_2$) (61.77%). The minimum scavenging activity with 53.32 per cent inhibition was observed when extracts were spray encapsulated with 10DE maltodextrin at 1: 10 carrier to extract ratio and dried at T_2 (inlet-190; outlet-90° C) ($C_1Cr_1T_2$).

Koozha

DPPH scavenging activity of spray encapsulated extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) inlet - outlet temperature (T) and their interaction (Table 49).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher scavenging activity with 59.32 per cent inhibition compared to extract encapsulated with MD 10 DE (C_1) (57.70 %).

The higher scavenging activity of 60.14 per cent was recorded in samples encapsulated at T_1 (inlet-180; outlet-80° C) compared to T_2 (inlet- 190; outlet 90° C) (56.88%).

Significantly highest scavenging activity of 61.15 per cent was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3), while the

Table 49. Effect of process variables on total antioxidant activity (DPPH) activity (%) of spray dried encapsulate of koozha extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	56.60	53.15	54.87	57.68	53.47	55.57	55.22
Cr_2 (1:15)	57.98	56.55	57.27	64.57	57.53	61.05	59.16
Cr_3 (1:20)	61.60	60.35	60.97	62.42	60.24	61.33	61.15
Mean	58.73	56.68		61.56	57.08		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.38	0.13		C_1	C_2	T_1	T_2
T	0.38	0.13		57.70	59.32	60.14	56.88
Cr	0.47	0.16					
C x T x Cr	0.93	0.32					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

lowest activity was recorded in extracts encapsulated using 1:10 carrier to extract ratio (Cr_1) (55.22%).

Considering the interaction effect, it was observed that the extract encapsulated using MD 20 DE at 1:15 carrier to extract ratio at T_1 (inlet-180; outlet-80º C) recorded significantly highest scavenging activity of 64.57 per cent ($C_2Cr_2T_1$). This was followed by extracts encapsulated with MD 20 DE at 1: 20 carrier to extract ratio and spray dried at inlet (180º C) outlet (80º C) temperature (62.42%) ($C_2Cr_3T_1$). This was found to be on par with extract encapsulated using 10 DE maltodextrin at 1:20 carrier to extract ratio and spray dried at inlet (180º C) and outlet (80º C) temperature (61.60%) ($C_1Cr_3T_1$). The lowest scavenging activity of 53.15 per cent inhibition was observed when extracts were encapsulated with 10 DE maltodextrin at 1: 10 carrier to extract ratio and dried at T_2 (inlet-190; outlet-90º C). ($C_1Cr_1T_2$). This was found to be on par with extract encapsulated using MD 20 DE at 1:10 carrier to extract ratio and spray dried at inlet (190º C) and outlet (90º C) temperature ($C_2Cr_1T_2$) (53.47%).

4.3.1.3.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

DPPH scavenging activity of spray encapsulated extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet - outlet temperature (T) (Table 50).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher scavenging activity with 62.50 per cent inhibition compared to extract encapsulated with MD 10 DE (C_1) (60.34 %).

Higher scavenging activity of 62.27 per cent was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to T_2 (inlet- 190; outlet 90º C) (60.57%).

Table 50. Effect of process variables on total antioxidant (DPPH) activity (%) of spray dried encapsulate of varikka extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	57.43	54.42	55.93	58.56	59.02	58.79	57.36
Cr_2 (1:15)	60.60	57.49	59.04	62.40	60.61	61.50	60.27
Cr_3 (1:20)	67.55	64.56	66.06	67.10	67.30	67.20	66.63
Mean	61.86	58.83		62.69	62.31		
Factors	C.D. (0.05)	SE±(m)		**Overall mean**			
C	0.49	0.17		**C_1**	**C_2**	**T_1**	**T_2**
T	0.49	0.17		60.34	62.50	62.27	60.57
Cr	0.60	0.21					
C x T x Cr	NS	0.41					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

Significantly highest scavenging activity of 66.63 per cent was recorded when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3), followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 60.27 per cent inhibition.

The interaction effect of all the factors on the antioxidant activity of the encapsulates was found to be non-significant.

Koozha

DPPH scavenging activity of spray encapsulated extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr), inlet - outlet temperature (T) and their interaction (Table 51).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher scavenging activity with 61.89 per cent inhibition compared to extract encapsulated with MD 10 DE (60.71 %) (C_1).

Higher scavenging activity of 62.97 per cent was recorded in samples encapsulated at T_1 (inlet-180; outlet-80^o C) compared to T_2 (inlet- 190; outlet 90^o C) (59.63%).

Significantly highest scavenging activity of 65.89 per cent was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3), while the lowest activity was recorded in extracts encapsulated using 1:10 carrier to extract ratio (Cr_1) (56.76%).

Considering the interaction effect, it was observed that the extract spray encapsulated using MD 20 DE at 1:20 carrier to extract ratio and spray dried at T_1 (inlet-180; outlet-80^o C) recorded significantly highest scavenging activity of 68.47 per cent ($C_2Cr_3T_1$). This was followed by extracts encapsulated with MD 10

Table 51. Effect of process variables on total antioxidant (DPPH) activity (%) of spray dried encapsulate of koozha extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	57.50	54.94	56.22	59.40	55.20	57.30	56.76
Cr_2 (1:15)	61.53	59.52	60.53	64.57	59.35	61.96	61.24
Cr_3 (1:20)	66.33	64.43	65.38	68.47	64.32	66.40	65.89
Mean	61.79	59.63		64.15	59.63		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.24	0.08		C_1	C_2	T_1	T_2
T	0.24	0.08		60.71	61.89	62.97	59.63
Cr	0.29	0.10					
C x T x Cr	0.59	0.20					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

DE at 1: 20 carrier to extract ratio and spray dried at T_1 (inlet-180; outlet-80º C) (66.33%) ($C_1Cr_3T_1$). The minimum scavenging activity of 54.94 per cent inhibition was observed when extracts were encapsulated with 10DE maltodextrin at 1: 10 carrier to extract ratio and spray dried at T_2 (inlet-190; outlet-90º C) ($C_1Cr_1T_2$). This was found to be on par with extract encapsulated using MD 20 DE at 1:10 extract to volume ratio and spray dried at T_2 (inlet-190; outlet-90º C) (55.20%) ($C_2Cr_1T_2$).

4.3.1. 4 Ascorbic Acid Content (mg 100g^{-1})

4.3.1.4.1. Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Ascorbic acid content of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by carrier to extract ratio (Cr) and inlet and outlet temperature (T) (Table 52).

Ascorbic acid content of the spray encapsulated extract $D_1S_4R_3$, were not influenced by the levels of dextrose equivalence of mltodextrin.

Higher ascorbic acid content of 10.80 mg 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (9.16 mg 100 g^{-1}).

Significantly highest ascorbic acid content of 12.04 mg 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 10.33 mg 100 g^{-1} ascorbic acid content.

Table 52. Effect of process variables on ascorbic content (mg 100 g^{-1}) of spray dried encapsulate of varikka extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	7.73	6.54	7.13	8.62	7.43	8.02	7.58
Cr_2 (1:15)	11.00	9.51	10.25	11.59	9.21	10.40	10.33
Cr_3 (1:20)	13.08	11.29	12.19	12.78	11.00	11.89	12.04
Mean	10.60	9.11		11.00	9.21		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	NS	0.13		C_1	C_2	T_1	T_2
T	0.38	0.13		9.86	10.11	10.80	9.16
Cr	0.47	0.16					
C x T x Cr	NS	0.32					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

The interaction effect of all the factors on ascorbic acid content was found to be non-significant.

Koozha

Ascorbic acid content of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet - outlet temperature (T) (Table 53).

Extract $D_1S_4R_3$ encapsulated with MD 20 DE (C_2) had higher ascorbic acid content of 11.15 mg 100 g^{-1} compared to extract encapsulated with MD 10 DE (C_1) (10.75 mg 100 g^{-1}).

Higher ascorbic acid content of 12.04 mg 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80^o C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90^o C) (9.86 mg 100 g^{-1}).

Significantly highest ascorbic acid content of 14.71 mg 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 10.03 mg 100 g^{-1} ascorbic acid content.

The interaction effect of all the factors on the ascorbic acid content of the encapsulates was found to be non-significant.

4.3.1.4.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

Ascorbic acid content of spray encapsulated extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by carrier to extract ratio (Cr) and inlet and outlet temperature (T) (Table 54).

Table 53. Effect of process variables on ascorbic content (mg 100 g^{-1}) of spray dried encapsulate of koozha extract $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	8.32	6.84	7.58	9.51	7.73	8.62	8.10
Cr_2 (1:15)	11.00	8.62	9.81	11.29	9.21	10.25	10.03
Cr_3 (1:20)	15.75	13.97	14.86	16.35	12.78	14.56	14.71
Mean	11.69	9.81		12.38	9.91		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.40	0.14		C_1	C_2	T_1	T_2
T	0.40	0.14		10.75	11.15	12.04	9.86
Cr	0.49	0.17					
C x T x Cr	NS	0.33					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Table 54. Effect of process variables on ascorbic content (mg 100 g^{-1}) of spray dried encapsulate of varikka extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	12.78	11.29	12.04	12.78	11.00	11.89	11.96
Cr_2 (1:15)	15.75	14.56	15.16	17.54	14.56	16.05	15.60
Cr_3 (1:20)	21.99	20.80	21.40	22.29	18.72	20.51	20.95
Mean	16.84	15.55		17.54	14.76		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	NS	0.14		C_1	C_2	T_1	T_2
T	0.41	0.14		16.20	16.15	17.19	15.16
R	0.50	0.17					
C x T x Cr	NS	0.34					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Ascorbic acid content of the encapsulated extract, $D_2S_4R_2$ was not influenced by the levels of dextrose equivalence of mltodextrin.

Higher ascorbic acid content of 17.19 mg 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (15.16 mg 100 g^{-1}).

Significantly highest ascorbic acid content of 20.95 mg 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 15.60 mg 100 g^{-1} ascorbic acid content.

The interaction effect of all the factors on the antioxidant activity of the encapsulates was found to be non-significant.

Koozha

Ascorbic acid content of spray encapsulated extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (MD), carrier to extract ratio (Cr) and inlet - outlet temperature (T) (Table 55).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE had higher ascorbic acid content of 13.72 mg 100 g^{-1} compared to extract encapsulated with MD 10 DE (13.08 mg 100 g^{-1}).

Higher ascorbic acid content of 14.17 mg 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (12.63 mg 100 g^{-1}).

Significantly highest ascorbic acid content of 17.24 mg 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 13.97 mg 100 g^{-1} ascorbic acid content.

Table 55. Effect of process variables on ascorbic content (mg 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	9.21	8.32	8.77	9.81	8.62	9.21	8.99
Cr_2 (1:15)	13.97	12.78	13.37	15.16	13.97	14.56	13.97
Cr_3 (1:20)	18.43	15.75	17.09	18.43	16.35	17.39	17.24
Mean	13.87	12.28		14.46	12.98		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.41	0.14		C_1	C_2	T_1	T_2
T	0.41	0.14		13.08	13.72	14.17	12.63
Cr	0.50	0.17					
C x T x Cr	NS	0.35					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

The interaction effect of all the factors on ascorbic acid content of the encapsulate was found to be non-significant.

4.3.1.4.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

Ascorbic acid content of spray encapsulated extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr) and inlet - outlet temperature (T) (Table 56).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher ascorbic acid content of 17.68 mg 100 g^{-1} compared to extract encapsulated with MD 10 DE (C_1)(17.11 mg 100 g^{-1}).

The higher ascorbic acid content of 18.58 mg 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (16.22 mg 100 g^{-1}).

Significantly highest ascorbic acid content of 21.47 mg 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) while the lowest content was found in the encapsulates prepared using 1:10 carrier to extract ratio (Cr_1) with 13.23 mg 100 g^{-1} ascorbic acid content.

The interaction effect of all factors on the ascorbic acid content of the encapsulate was found to be non-significant.

Koozha

Ascorbic acid content of spray encapsulatrd extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by carrier to extract ratio (Cr) and inlet - outlet temperature (T) (Table 57).

Table 56. Effect of process variables on ascorbic content (mg 100 g^{-1}) of spray dried encapsulate of varikka extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	13.97	11.89	12.93	15.45	11.59	13.52	13.23
Cr_2 (1:15)	17.54	16.79	17.16	18.43	17.24	17.83	17.50
Cr_3 (1:20)	22.59	19.91	21.25	23.48	19.91	21.70	21.47
Mean	18.03	16.20		19.12	16.25		
Factors	C.D. (0.05)	SE±(m)		**Overall mean**			
C	0.45	0.15		**C_1**	**C_2**	**T_1**	**T_2**
T	0.45	0.15		17.11	17.68	18.58	16.22
Cr	0.55	0.19					
C x T x Cr	NS	0.38					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Table 57. Effect of process variables on ascorbic content (mg 100 g^{-1}) of spray dried encapsulate of koozha extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	11.00	9.51	10.25	11.00	8.62	9.81	10.03
Cr_2 (1:15)	13.97	12.78	13.37	13.97	12.48	13.23	13.30
Cr_3 (1:20)	19.91	18.43	19.17	19.91	18.43	19.17	19.17
Mean	14.96	13.57		14.96	13.18		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	NS	0.12		C_1	C_2	T_1	T_2
T	0.34	0.12		14.27	14.07	14.96	13.37
Cr	0.42	0.14					
C x T x Cr	NS	0.28					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Ascorbic acid content of the encapsulated extract, $D_2S_4R_3$ was not influenced by the levels of dextrose equivalence of mltodextrin.

Higher ascorbic acid content of 14.96 mg 100 g^{-1} was recorded in samples encapsulated at T_1 (inlet-180; outlet-80º C) compared to extracts encapsulated at T_2 (inlet- 190; outlet 90º C) (13.37 mg 100 g^{-1}).

Significantly highest ascorbic acid content of 19.17 mg 100 g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) while the lowest was found in the encapsulates prepared using 1:10 carrier to extract ratio (Cr_1) with 10.03 mg 100 g^{-1} ascorbic acid content.

The interaction effect of all the factors on ascorbic acid content of the encapsulate was found to be non-significant.

4.3.1.5 Recovery Percentage of Encapsulation

4.3.1.5.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Recovery of encapsulated (%) extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet - outlet temperature (T), carrier to extract ratio and their interaction (Cr) (Table 58).

Recovery was higher when extract $D_1S_4R_3$ was encapsulated with MD 20 DE (C_2) (76.77%) compared to MD 10 DE (C_1) (75.68%).

Higher recovery of 77.26 per cent was recorded when extracts were encapsulated at T_2 (inlet-190; outlet-90º C) compared encapsulation at T_1 (inlet-180; outlet 80º C) (75.19%).

Table 58. Effect of process variables on recovery percentage of spray dried encapsulate of varikka extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	76.94	78.82	77.88	77.30	79.64	78.47	78.17
Cr_2 (1:15)	75.74	76.71	76.22	75.88	78.66	77.27	76.75
Cr_3 (1:20)	72.20	73.70	72.95	73.11	76.05	74.58	73.77
Mean	74.96	76.41		75.43	78.12		
Factors	C.D. (0.05)	SE±(m)		**Overall mean**			
C	0.18	0.06		**C_1**	**C_2**	**T_1**	**T_2**
T	0.18	0.06		75.68	76.77	75.19	77.26
Cr	0.22	0.08					
C x T x Cr	0.44	0.15					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Significantly highest percent recovery of encapsulate (78.17%) was recorded, when encapsulated at 1:10 carrier to extract ratio (Cr_1) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) (76.75%).

Considering the interaction effect, it was observed that the extract encapsulated using MD 20 DE at 1:10 carrier to extract ratio and spray dried at T_2 (inlet-190; outlet-90º C) recorded significantly highest recovery of 79.64 per cent ($C_2Cr_1T_2$). This was followed by extracts encapsulated with MD 10 DE at 1: 10 carrier to extract ratio and spray dried at T_2 (inlet-190; outlet-90º C) (78.82) ($C_1Cr_1T_2$). This was found to be on par with extract encapsulated using MD 20 DE at 1:15 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90 º C ($C_2Cr_2T_2$) (78.66%). The minimum per cent recovery (72.20 per cent) was observed when extracts were encapsulated with 10DE maltodextrin at 1: 20 carrier to extract ratio and spray dried at T_1 (inlet-180; outlet-80º C) ($C_1Cr_3T_1$).

Koozha

Recovery of encapsulated (%) extract, $D_1S_4R_3$ (cabinet dried Koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet - outlet temperature (T), carrier to extract ratio (Cr) and their interaction (Table 59).

Extract $D_1S_4R_3$ encapsulated with MD 20 DE (C_2) had higher recovery (76.82 per cent) compared to extract encapsulated with MD 10 DE (C_1) (75.89%).

Higher recovery of 77.20 per cent was recorded in extracts encapsulated at T_2 (inlet-190; outlet-90º C) compared to extracts encapsulated at T_1 (inlet- 180; outlet 80º C) (75.51%).

Significantly highest percent recovery (78.23%) was recorded, when the extracts were encapsulated at 1:10 carrier to extract ratio (Cr_1) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) (77.82%).

Table 59. Effect of process variables on recovery percentage of spray dried encapsulate of koozha extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	77.40	78.72	78.06	77.77	79.01	78.39	78.23
Cr_2 (1:15)	76.80	78.17	77.48	77.34	78.95	78.15	77.82
Cr_3 (1:20)	71.50	72.73	72.12	72.22	75.64	73.93	73.02
Mean	75.23	76.54		75.78	77.87		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.19	0.06		C_1	C_2	T_1	T_2
T	0.19	0.06		75.89	76.82	75.51	77.20
Cr	0.23	0.08					
C x T x Cr	0.45	0.16					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

Considering the interaction effect, it was observed that the extract spray encapsulated using MD 20 DE at 1:10 carrier to extract ratio and dried at T_2 (inlet-190; outlet-90º C) recorded significantly highest recovery of 79.01 per cent ($C_2Cr_1T_2$). This was found to be on par with extracts encapsulated with MD 20 DE at 1: 15 carrier to extract ratio and spray dried at T_2 (inlet-190; outlet-90º C) (78.82) ($C_2Cr_2T_2$) and extract encapsulated using MD 10 DE at 1:10 carrier to extract ratio at inlet and outlet temperature of 190 and 90º C ($C_1Cr_1T_2$) (78.72%). The minimum per cent recovery (71.50 per cent) was observed when extracts were encapsulated with 10DE maltodextrin at 1: 20 carrier to extract ratio dried at T_1 (inlet-180; outlet-80º C) ($C_1Cr_3T_1$).

4.3.1.5.2. Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

Recovery of encapsulate (%) of extract $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet and outlet temperature (T), carrier to extract ratio (Cr) and their interaction (Table 60).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher recovery (77.01 per cent) compared to MD 10 DE (C_1) (75.18%).

Higher recovery of 77.67 per cent was recorded in extracts encapsulated at inlet - outlet temperature of 190 - 90º C (T_2) compared to extracts encapsulated at T_1 (inlet- 180; outlet 80º C) (74.52%).

Significantly highest percent recovery (77.39%) was recorded, when the extracts were encapsulated at 1:10 carrier to extract ratio (Cr_1) while the lowest recovery was recorded by those encapsulated at 1:20 carrier to extract ratio (Cr_3) (74.18%).

Table 60. Effect of process variables on recovery percentage of spray dried encapsulate of varikka extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	75.48	77.89	76.69	75.81	80.37	78.09	77.39
Cr_2 (1:15)	75.23	76.84	76.03	75.83	78.98	77.41	76.72
Cr_3 (1:20)	72.19	73.48	72.84	72.58	78.46	75.52	74.18
Mean	74.30	76.07		74.74	79.27		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.20	0.07		C_1	C_2	T_1	T_2
T	0.20	0.07		75.18	77.01	74.52	77.67
Cr	0.25	0.09					
C x T x Cr	0.50	0.17					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

The interaction effects of all the three factors revealed that, the extract encapsulated using MD 20 DE at 1:10 carrier to extract ratio by spray drying at inlet - outlet temperature of 190 - 90º C ($C_2Cr_1T_2$) produced significantly highest per cent recovery (80.37%) ($C_2Cr_1T_2$). This was followed by extracts encapsulated using 20 DE MD at 1: 15 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C ($C_2Cr_2T_2$) (78.98). The lowest recovery of 72.19 per cent was observed when extracts were encapsulated with 10DE maltodextrin at 1: 20 carrier to extract ratio followed by spray drying at inlet - outlet temperature of 180 - 80º C ($C_1Cr_3T_1$) This was found to be on par with extracts encapsulated using MD 20 DE at 1:20 carrier to extract ratio and spray dried at inlet - outlet temperature of 180 - 80º C ($C_2Cr_3T_1$) (72.58).

Koozha

Encapsulate recovery (%) of extract $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet - outlet temperature (T), carrier to extract ratio (Cr) and their interaction (Table 61).

Extract $D_2S_4R_2$ encapsulated with MD 20 DE (C_2) had higher recovery (76.56 per cent) compared to those encapsulated with MD 10 DE (C_1) (75.58%).

Higher recovery of 77.26 per cent was recorded for extracts encapsulated at inlet - outlet temperature of 190 - 90º C (T_2) compared to extracts encapsulated at T_1 (inlet- 180; outlet 80º C) (74.87%).

Significantly highest percent recovery (78.06%) was recorded, when the extracts were encapsulated at 1:10 carrier to extract ratio (Cr_1) while the lowest recovery was recorded by those encapsulated at 1:20 carrier to extract ratio (Cr_3) (73.42%).

The interaction effects of all the three factors revealed that, the extract spray encapsulated using MD 20 DE at 1:10 carrier to extract ratio and dried at

Table 61. Effect of process variables on recovery percentage of spray dried Encapsulate of koozha extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	76.63	78.85	77.74	77.44	79.34	78.39	78.06
Cr_2 (1:15)	74.75	78.26	76.51	75.87	78.01	76.94	76.72
Cr_3 (1:20)	72.18	72.79	72.49	72.36	76.33	74.35	73.42
Mean	74.52	76.63		75.22	77.89		
Factors	C.D. (0.05)	SE±(m)		**Overall mean**			
C	0.21	0.07		**C_1**	**C_2**	**T_1**	**T_2**
T	0.21	0.07		75.58	76.56	74.87	77.26
Cr	0.25	0.09					
C x T x Cr	0.50	0.17					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

inlet - outlet temperature of 190 -90º C ($C_2Cr_1T_2$) had significantly highest recovery (79.34%). This was on par with extracts encapsulated using 10 DE MD at 1: 10 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C ($C_1Cr_1T_2$) (78.85). The lowest per cent recovery of 72.18 per cent was observed when extracts were encapsulated with 10 DE maltodextrin at 1: 20 carrier to extract ratio and spray dried at inlet - outlet temperature of 180 - 80º C ($C_1Cr_3T_1$). This was found to be on par with extract encapsulated using MD 20 DE at 1:20 carrier to extract ratio and spray dried at inlet (180º C) and outlet temperature (80º C) with 72.36 per cent recovery ($C_2Cr_3T_1$).

4.3.1.5.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

Recovery of encapsulate (%) of extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet and outlet temperature (T), carrier to extract ratio and their interaction (Cr) (Table 62).

Extract $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher recovery of 79.16 per cent compared to extract encapsulated with MD 10 DE (C_1) (78.22%).

Higher recovery of 79.68 per cent was recorded when extracts were encapsulated at inlet - outlet temperature of 190 - 90º C (T_2) compared to extracts encapsulated at T_1 (inlet- 180; outlet 80º C) (77.70%).

Significantly highest percent recovery (81.58%) was recorded, when the extracts were encapsulated at 1:10 carrier to extract ratio (Cr_1) followed by those encapsulated at 1:15 carrier to extract ratio (Cr_2) (79.53%).

The interaction effects of all the three factors revealed that, the extract encapsulated using MD 20 DE at 1:10 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C ($C_2Cr_1T_2$) produced encapsulate with

Table 62. Effect of process variables on recovery percentage of spray dried encapsulates of varikka extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	79.77	82.39	81.08	80.40	83.77	82.08	81.58
Cr_2 (1:15)	77.55	79.68	78.61	79.97	80.93	80.45	79.53
Cr_3 (1:20)	73.95	76.01	74.98	74.56	75.31	74.94	74.96
Mean	77.09	79.36		78.31	80.00		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.29	0.10		C_1	C_2	T_1	T_2
T	0.29	0.10		78.22	79.16	77.70	79.68
Cr	0.36	0.12					
C x T x Cr	0.71	0.24					
T_1- 180°C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

significantly highest per cent recovery (83.77%). This was followed by extracts encapsulated using 10 DE MD at 1: 10 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C ($C_1Cr_1T_2$) (82.39%). The lowest recovery of 73.95 per cent was observed when extracts were encapsulated with 10 DE maltodextrin at 1: 20 carrier to extract ratio and spray dried at inlet - outlet temperature of 180 - 80º C ($C_1Cr_3T_1$). This was found to be on par with extract encapsulated using MD 20 DE at 1:20 carrier to extract ratio and spray dried at inlet (180º C) and outlet temperature (80º C) with 74.56 per cent recovery ($C_2Cr_3T_1$).

Koozha

Encapsulate recovery (%) of extract, $D_2S_4R_3$ (Freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet - outlet temperature (T), carrier to extract ratio (Cr) and their interaction (Table 63).

Extract, $D_2S_4R_3$ encapsulated with MD 20 DE (C_2) had higher recovery of 78.78 per cent compared to extract encapsulated with MD 10 DE (C_1) (78.28%).

Higher recovery of 79.21 per cent was recorded in extracts encapsulated at inlet - outlet temperature of 190 - 90º C (T_2) compared to extracts encapsulated at T_1 (inlet- 180; outlet 80º C) (77.84%).

Significantly highest recovery of encapsulate (80.79%) was recorded, when the extracts were encapsulated at 1:10 carrier to extract ratio (Cr_1) while the lowest recovery was recorded by those encapsulated at 1:15 carrier to extract ratio (Cr_3) (74.99%).

The interaction effects of all the three factors revealed that, the extract encapsulated using MD 20 DE at 1:10 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C ($C_2Cr_1T_2$) recorded highest recovery (82.09%). This was followed by extracts encapsulated using 10 DE MD at 1: 10

Table 63. Effect of process variables on recovery percentage of spray dried encapsulates of koozha extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	79.50	81.19	80.35	80.40	82.09	81.24	80.79
Cr_2 (1:15)	78.83	80.30	79.57	79.97	80.05	80.01	79.79
Cr_3 (1:20)	73.80	76.03	74.92	74.56	75.58	75.07	74.99
Mean	77.37	79.18		78.31	79.24		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.22	0.08		C_1	C_2	T_1	T_2
T	0.22	0.08		78.28	78.78	77.84	79.21
Cr	0.27	0.09					
C x T x Cr	0.54	0.19					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C ($C_1Cr_1T_2$) (81.19%). The lowest recovery of 73.80 per cent was observed when extracts were encapsulated with 10 DE maltodextrin at 1: 20 carrier to extract ratio and spray dried at inlet - outlet temperature of 180 - 80º C ($C_1Cr_3T_1$).

4.3.1.6 Moisture Content (%)

4.3.1.6.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Moisture content of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr), inlet - outlet temperature (T) and their interaction (Table 64).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) had minimum moisture content of 3.40 % compared to extracts encapsulated using 20 DE of MD (C_2) (4.54%).

The lower moisture content of 3.71 per cent was recorded in samples encapsulated at T_2 (inlet-190; outlet-90º C) compared to extracts encapsulated at T_1 (inlet- 190; outlet 90º C) (4.23%).

The extracts encapsulated at1:20 carrier to extract ratio (Cr_3) had significantly lowest moisture content (3.76 per cent) whereas, carrier to extract ratio of 1:10 (Cr_1) produced encapsulate with highest moisture content (4.19 per cent).

The interaction effects of all the three factors revealed that, the extracts encapsulated using MD 10 DE at 1:20 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C recorded significantly lowest moisture content of 2.84 per cent ($C_1Cr_3T_2$). This was followed by extracts encapsulated

Table 64. Effect of process variables on moisture content (%) of spray dried encapsulates of varikka extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	4.30	2.97	3.64	4.92	4.57	4.75	4.19
Cr_2 (1:15)	3.18	3.57	3.38	5.02	4.08	4.55	3.96
Cr_3 (1:20)	3.54	2.84	3.19	4.44	4.23	4.33	3.76
Mean	3.68	3.13		4.79	4.29		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.016	0.006		C_1	C_2	T_1	T_2
T	0.016	0.006		3.40	4.54	4.23	3.71
Cr	0.020	0.007					
C x T x Cr	0.04	0.014					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

with MD 10 DE at 1: 10 carrier to extract ratio and spray dried at inlet -outlet temperature of 190 - 90º C (2.97%)($C_1Cr_1T_2$). The highest moisture content of 5.02 per cent was observed when extracts were encapsulated with 20 DE maltodextrin at 1: 15 carrier to extract ratio and spray dried at inlet - outlet of 180 - 80º C ($C_2Cr_2T_1$).

Koozha

Moisture content of spray encapsulated extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (MD), carrier to extract ratio (Cr) inlet - outlet temperature (T) and their interaction (Table 65).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) was found to contain minimum moisture content of 3.80 per cent compared to extracts encapsulated using 20 DE (C_2) of MD (4.34%).

The lower moisture content of 3.65 per cent was recorded in samples encapsulated at T_2 (inlet-190; outlet-90º C) compared to extracts encapsulated at T_1 (inlet- 180; outlet 80º C) (4.49%).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly lowest moisture content of 3.79 per cent whereas, carrier to extract ratio of 1:10 (Cr_1) produced encapsulate with highest moisture content of 4.06 per cent.

The interaction effects of all the three factors revealed that, the extracts encapsulated using MD 10 DE at 1:20 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C recorded significantly lowest moisture content of 3.06 per cent ($C_1Cr_3T_2$). This was followed by extracts encapsulated with MD 10 DE at 1: 10 carrier to extract ratio and spray dried at inlet - outlet

Table 65. Effect of process variables on moisture content (%) of spray dried encapsulate of koozha extract, $D_1S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	3.82	3.26	3.54	4.78	4.37	4.58	4.06
Cr_2 (1:15)	4.86	3.78	4.32	5.05	3.77	4.41	4.37
Cr_3 (1:20)	4.03	3.06	3.55	4.41	3.67	4.04	3.79
Mean	4.24	3.37		4.75	3.93		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.033	0.011		C_1	C_2	T_1	T_2
T	0.033	0.011		3.80	4.34	4.49	3.65
Cr	0.041	0.014					
C x T x Cr	0.082	0.028					
T_1- 180° C Inlet and 80°C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

temperature of 190 - 90º C (3.26%)($C_1Cr_1T_2$). The highest moisture content of 5.05 per cent was observed when extracts were encapsulated with 20 DE maltodextrin at 1: 15 carrier to extract ratio and spray dried at T_1 (inlet-180; outlet-80º C) ($C_2Cr_2T_1$).

4.3.1.6.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

Moisture content of spray encapsulated of extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr), inlet - outlet temperature (T) and their interaction (Table 66).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) was found to contain minimum moisture content of 3.15 per cent compared to extracts encapsulated using 20 DE of MD (C_2) (4.02%).

The lower moisture content of 3.39 per cent was recorded in samples encapsulated at T_2 (inlet- 190; outlet 90º C) compared to extracts encapsulated at T_1 (inlet-180; outlet-80º C) (3.77%).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly lowest moisture content 3.40 per cent whereas, carrier to extract ratio of 1:10 (Cr_1) produced encapsulate with highest moisture content of 3.80%

When the interaction effects are considered, the extracts encapsulated using MD 10 DE at 1:10 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C recorded significantly lowest moisture content of 2.57 per cent ($C_1Cr_1T_2$). This was followed by extracts encapsulated with MD 10 DE at 1: 20 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C (2.84%) ($C_1Cr_3T_2$). The highest moisture content of 4.48 per cent was observed when extracts were encapsulated with 20 DE maltodextrin at 1: 10 carrier to extract ratio and spray dried at T_1 (inlet-180; outlet-80º C) ($C_2Cr_1T_1$).

Table 66. Effect of process variables on moisture content (%) of spray dried Encapsulate of varikka extract $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	3.83	2.57	3.20	4.48	4.32	4.40	3.80
Cr_2 (1:15)	2.91	3.25	3.08	4.18	3.85	4.02	3.55
Cr_3 (1:20)	3.49	2.84	3.17	3.75	3.54	3.64	3.40
Mean	3.41	2.89		4.14	3.90		
Factors	C.D. (0.05)	SE±(m)		**Overall mean**			
C	0.027	0.009		C_1	C_2	T_1	T_2
T	0.027	0.009		3.15	4.02	3.77	3.39
Cr	0.033	0.011					
C x T x Cr	0.067	0.023					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

Koozha

Moisture content of spray encapsulation of extract, $D_2S_4R_2$ (Freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), inlet - outlet temperature (T) and interaction (Table 67).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) was found to contain minimum moisture content of 3.18 per cent compared to extracts encapsulated using 20 DE of MD (C_2) (3.85%).

The lower moisture content of 3.17 per cent was recorded in samples encapsulated at T_2 (inlet- 190; outlet 90º C) compared to extracts encapsulated at T_1 (inlet-180; outlet-80º C) (3.85%).

The carrier to extract ratio did not influence the moisture content of encapsulates.

The interaction effects of all the three factors revealed that, the extract encapsulated using MD 10 DE at 1:15 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C recorded significantly lowest moisture content of 2.66 per cent ($C_1Cr_2T_2$). This was followed by extracts encapsulated with MD 10 DE at 1: 20 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C (2.75%) ($C_1Cr_3T_2$). The highest moisture content of 4.46 per cent was observed when extracts were encapsulated with 20 DE maltodextrin at 1: 15 carrier to extract ratio and spray dried at inlet - outlet temperature of 180 - 80º C ($C_2Cr_2T_1$).

4.3.1.6.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

Moisture content of spray encapsulated extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was

Table 67. Effect of process variables on moisture content (%) of spray dried Encapsulate of koozha extract, $D_2S_4R_2$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	3.11	3.31	3.21	3.94	3.67	3.80	3.51
Cr_2 (1:15)	3.72	2.66	3.19	4.46	3.30	3.88	3.54
Cr_3 (1:20)	3.55	2.75	3.15	4.36	3.35	3.85	3.50
Mean	3.46	2.91		4.25	3.44		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.025	0.009		C_1	C_2	T_1	T_2
T	0.025	0.009		3.18	3.85	3.85	3.17
Cr	NS	0.010					
C x T x Cr	0.061	0.021					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr), inlet - outlet temperature (T) and their interaction (Table 68).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) had minimum moisture content of 2.95 per cent compared to extracts encapsulated using 20 DE of MD (C_2) (3.80%).

The lower moisture content of 3.06 per cent was recorded in samples encapsulated at T_2 (inlet- 190; outlet 90º C) compared to extracts encapsulated at T_1 (inlet-180; outlet-80º C) (3.69%).

The extracts encapsulated at carrier to extract ratio of 1:15 (Cr_2) had significantly lowest moisture content 3.26 per cent which was found to be on par with extracts encapsulated at 1:20 extract to carrier ratio (Cr_2) (3.27%) whereas, carrier to extract ratio of 1:10 (Cr_1) produced encapsulate with highest moisture content of 3.58 per cent.

The interaction effects of all the three factors revealed that, the extract encapsulated using 10 DE MD at 1:20 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 and 90º C recorded significantly lowest moisture content of 2.46 per cent ($C_1Cr_3T_2$). This was followed by extracts encapsulated with MD 10 DE at 1: 15 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C (2.52%) ($C_1Cr_2T_2$). The highest moisture content of 4.33 per cent was observed when extracts were encapsulated with 20 DE maltodextrin at 1: 10 carrier to extract ratio and spray dried at T_1 (inlet-180; outlet-80º C) ($C_2Cr_1T_1$).

Koozha

Moisture content of spray encapsulated extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio (Cr), inlet - outlet temperature (T) and their interaction (Table 69).

Table 68. Effect of process variables on moisture content (%) of spray dried encapsulate of varikka extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	3.55	2.68	3.11	4.33	3.78	4.06	3.58
Cr_2 (1:15)	3.05	2.52	2.79	3.91	3.57	3.74	3.26
Cr_3 (1:20)	3.42	2.46	2.94	3.89	3.33	3.61	3.27
Mean	3.34	2.55		4.04	3.56		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.023	0.008		C_1	C_2	T_1	T_2
Cr	0.023	0.008		2.95	3.80	3.69	3.06
R	0.028	0.01					
C x T x Cr	0.057	0.019					
T_1- 180° C Inlet and 80° C outlet temperature				T_2- 190° C Inlet and 90° C outlet temperature			

Table 69. Effect of process variables on moisture content (%) of spray dried encapsulate of koozha extract, $D_2S_4R_3$

Carrier ratio (Cr)	Maltodextrin (C_1 -10DE)			Maltodextrin (C_2 -20DE)			Overall mean (Cr)
	T_1	T_2	Mean	T_1	T_2	Mean	
Cr_1 (1:10)	2.84	2.70	2.77	3.58	3.26	3.42	3.09
Cr_2 (1:15)	3.25	2.66	2.957	4.03	3.09	3.56	3.26
Cr_3 (1:20)	3.04	2.55	2.793	3.56	3.02	3.29	3.04
Mean	3.04	2.64		3.72	3.12		
Factors	C.D. (0.05)	SE±(m)		Overall mean			
C	0.022	0.008		C_1	C_2	T_1	T_2
T	0.022	0.008		2.84	3.42	3.38	2.88
Cr	0.027	0.009					
C x T x Cr	0.055	0.019					
T_1- 180° C Inlet and 80° C outlet temperature			T_2- 190° C Inlet and 90° C outlet temperature				

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) was found to contain minimum moisture content of 2.84 per cent compared to extracts encapsulated using 20 DE of MD (C_2) (3.42%).

The lower moisture content of 2.88 per cent was recorded in samples encapsulated at T_2 (inlet- 190; outlet 90º C) compared to extracts encapsulated at T_1 (inlet-180; outlet-80º C) (3.38%).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly lowest moisture content 3.04 per cent whereas, carrier to extract ratio of 1:15 (Cr_2) produced encapsulate with highest moisture content of 3.26 per cent.

The interaction effects of all the three factors revealed that, the extract encapsulated using 10 DE MD at 1:20 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C recorded significantly lowest moisture content recorded of 2.55 per cent ($C_1Cr_3T_2$). This was followed by extracts encapsulated with MD 10 DE at 1: 15 carrier to extract ratio and spray dried at inlet - outlet temperature of 190 - 90º C ($C_1Cr_2T_2$) (2.66%). This was found to be on par with extract encapsulated using MD 10 DE at 1:10 carrier to extract ratio and spray dried at T_2 (inlet-190; outlet-90º C) (2.70%) ($C_1Cr_1T_2$). The highest moisture content of 4.03 per cent was observed when extracts were encapsulated with 20 DE maltodextrin at 1: 15 carrier to extract ratio and spray dried at inlet - outlet temperature of 180 - 80º C ($C_2Cr_2T_1$).

4.3.2 Encapsulation by Freeze Drying

Encapsulation of the following three selected extracts (from part –I of the experiment) was independently carried out by freeze drying technique using two levels of carrier maltodextrin (10 and 20 dextrose equivalence) at 1:10, 1:15 and 1:20 carrier to extract ratio. The results of the analysis of the developed freeze encapsulates is presented below.

1. $D_1S_4R_3$- Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

2. $D_2S_4R_2$- Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio

3. $D_2S_4R_3$- Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio

4.3.2.1 Total Flavonoid Content (mg QE 100g^{-1}) (TFC)

4.3.2.1.1. Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Total flavonoid content of freeze encapsulated extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C) carrier to extract ratio and their interaction (Table 70).

Extracts encapsulated with maltodextrin (MD) of 20 dextrose equivalence (C_2) had higher total flavonoid content of 10.16 mg QE 100 g^{-1} compared to extracts encapsulated with MD 10 DE (C_1) (9.81 mg QE 100 g^{-1}).

Carrier to extract ratio at 1:20 (Cr_3) produced encapsulates with highest TFC of 10.47 mg QE 100g^{-1}, while the lowest TFC was recorded in extracts encapsulated at 1:10 (Cr_1) (9.34 mg QE 100g^{-1}).

Considering the interaction effect, it was observed that, extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly highest TFC of 10.63 mg QE 100 g^{-1}(C_2Cr_3). This was followed by extracts encapsulated with MD 10 DE at 1: 20 carrier to extract ratio (TFC of 10.32 mg QE 100 g^{-1}) which was found to be on par with extract encapsulated with MD 20

Table 70. Effect of dextrose equivalence and carrier to extract ratio on Total Flavonoid Content (mg QE 100 g^{-1}) of freeze dried encapsulate from the extract $D_1S_4R_3$

Total flavonoid content (mg QE 100 g^{-1})								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	9.04	10.07	10.32	9.81	8.30	8.92	9.39	8.87
C_2 (MD 20 DE)	9.64	10.20	10.63	10.16	8.34	9.17	9.52	9.01
Mean (Cr)	9.34	10.13	10.47		8.32	9.05	9.46	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.15	0.05			0.14	0.05		
Cr	0.18	0.06			0.18	0.06		
C x Cr	0.26	0.08			NS	0.08		

DE at carrier to extract ratio of 1:15 (10.20 mg QE 100 g^{-1}) and extract encapsulated with MD 10 DE at carrier to extract ratio of 1: 15 (10.07 mg QE 100 g^{-1}). The lowest total flavonoid content of 9.04 mg QE 100 g^{-1} was observed when extracts were encapsulated with 10DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

Koozha

Total flavonoid content of freeze encapsulated extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (MD) and carrier to extract ratio (Table 70).

Extracts encapsulated with maltodextrin (MD) of 20 dextrose equivalence (C_2) had higher total flavonoid content of 9.01 mg QE 100g^{-1} compared to extracts encapsulated with MD 10 DE (C_1) (8.87 mg QE 100g^{-1}).

Significantly highest TFC of 9.46 mg QE 100g^{-1} was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 9.05 mg QE 100g^{-1} TFC.

The interaction between dextrose equivalent of MD and carrier to extract ratio was found to be non-significant.

4.3.2.1.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

The total flavonoid content (TFC) of freeze encapsulated varikka extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) differed significantly with respect to dextrose equivalence (DE) of maltodextrin (MD) and carrier to extract ratio (Table 71).

Table 71. Effect of dextrose equivalence and carrier to extract ratio on Total Flavonoid Content (mg QE 100 g^{-1}) of freeze dried encapsulate from the extract $D_2S_4R_2$

Total flavonoid content (mg QE 100 g^{-1})								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	9.48	10.32	10.61	10.14	9.19	10.01	10.61	9.94
C_2 (MD 20 DE)	9.70	10.59	11.01	10.43	9.54	10.45	10.80	10.27
Mean (Cr)	9.59	10.45	10.81		9.37	10.23	10.71	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.18	0.06			0.13	0.04		
Cr	0.22	0.07			0.16	0.05		
C x Cr	NS	0.10			NS	0.07		

Extracts encapsulated with maltodextrin (MD) of 20 dextrose equivalence (20 DE) had higher total flavonoid content of 10.43 mg QE $100g^{-1}$ compared to extracts encapsulated with MD 10 DE (10.14 mg QE $100g^{-1}$).

Significantly highest TFC of 10.81 mg QE $100g^{-1}$ was recorded, when the extracts were encapsulated at 1:20 carrier to extract ratio (Cr_3) followed by those prepared using 1:15 carrier to extract ratio (Cr_2) with 10.45 mg QE $100g^{-1}$ TFC.

The interaction between dextrose equivalent of MD and carrier to extract ratio was found to be non-significant.

Koozha

The total flavonoid content (TFC) of freeze encapsulated koozha extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) showed significant difference and was influenced by levels of dextrose equivalence (DE) of maltodextrin (C) and extract to carrier ratio (Table 71).

Extracts encapsulated with maltodextrin (MD) of 20 dextrose equivalence (C_2) had higher total flavonoid content of 10.27 mg QE $100g^{-1}$ compared to extracts encapsulated with MD 10 DE (C_1) (9.94 mg QE $100g^{-1}$).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest TFC of 10.71 mg QE 100 g^{-1}, followed by extracts encapsulated with carrier to extract ratio of 1:15 (Cr_2) (10.23 mg QE 100 g^{-1} TFC).

The interaction between dextrose equivalent of MD and carrier to extract ratio was found to be non-significant.

4.3.2.1.3. Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

The total flavonoid content (TFC) of freeze encapsulated varikka extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent

ratio) showed significant difference and were influenced by levels of DE of MD (C), carrier to extract ratio and their interactions (Cr) (Table 72).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) was found to contain higher TFC of 10.95 mg QE 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (10.67 mg QE 100 g^{-1}).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest TFC of 11.40 mg QE 100 g^{-1} whereas, carrier to extract ratio of 1:10 ($Cr_{1)}$ produced encapsulate with lowest TFC content of 10.04 mg QE 100 g^{-1}.

Considering the interaction effect, it was observed that extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly highest TFC of 11.62 mg QE 100 g^{-1} (C_2Cr_3). This was followed by extract encapsulated with MD 20 DE at carrier to extract of 1:15 (11.21 mg QE 100 g^{-1}) (C_2Cr_2) which was on par with extract encapsulated with maltodextrin 10 DE at 1:20 carrier to extract ratio (11.19 mg QE 100 g^{-1}) (C_1Cr_3). The minimum total flavonoid content of 10.03 mg QE 100 g^{-1} was observed when extracts were encapsulated with 20DE maltodextrin at 1: 10 carrier to extract ratio (C_2Cr_1), which was on par with extract encapsulated with MD 10 DE at 1:10 extract to carrier ratio (10.05 mg QE 100 g^{-1}) (C_1Cr_1).

Koozha

The total flavonoid content (TFC) of freeze encapsulated varikka extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference and were influenced by carrier to extract ratio and interaction between dextrose equivalence (C) and carrier to extract ratio (Cr) (Table 72).

The levels of dextrose equivalence (C) of maltodextrin did not influence the TFC of the extract.

Table 72. Effect of dextrose equivalence and carrier to extract ratio on Total Flavonoid Content (mg QE 100 g^{-1}) of freeze dried encapsulate from the extract $D_2S_4R_3$

Total flavonoid content (mg QE 100 g^{-1})								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	10.05	10.78	11.19	10.67	10.03	10.88	11.75	10.89
C_2 (MD 20 DE)	10.03	11.21	11.62	10.95	10.30	10.92	11.60	10.94
Mean (Cr)	10.04	11.00	11.40		10.16	10.90	11.68	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.17	0.05			NS	0.04		
Cr	0.20	0.07			0.13	0.04		
C x Cr	0.29	0.09			0.19	0.06		

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest TFC of 11.68 mg QE 100 g^{-1}, followed by extracts encapsulated at carrier to extract ratio of 1:15 (Cr_2) with TFC of 10.90 mg QE 100 g^{-1}.

The interaction effect between the factors showed significantly highest TFC in extract encapsulated with MD 10 DE at 1:20 carrier to extract ratio (11.75 mg QE 100 g^{-1}) (C_1Cr_3).This was found to be on par with the extracts encapsulated with MD 20 DE at carrier to extract ratio of 1:20 (11.60 mg QE 100 g^{-1}) (C_2Cr_3). This was followed by extract encapsulated with maltodextrin 20 DE at 1:15 carrier to extract ratio (10.92 mg QE 100 g^{-1}) (C_2Cr_2) and was found to be on par with encapsulated extracts from MD 10 DE at 1:15 carrier to extract ratio (10.88 mg QE 100 g^{-1}) (C_1Cr_2). The minimum total flavonoid content of 10.03 mg QE 100 g^{-1} was observed when extracts were encapsulated with 10 DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

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

4.3.2.2.1 Cabinet Dried Sample Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Total phenolic content (TPC) of freeze encapsulated varikka extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by levels of DE of MD (C)carrier to extract ratio (Cr) (Table 73).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) was found to contain maximum TPC of 116.08 mg GAE 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (111.30 mg GAE 100 g^{-1}).

Table 73. Effect of dextrose equivalence and carrier to extract ratio on Total Phenolic Content (mg GAE 100 g^{-1}) of freeze dried encapsulate $D_1S_4R_3$

Total phenolic content (mg GAE 100 g^{-1})								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	106.61	111.93	115.34	111.30	110.54	114.08	117.79	114.14
C_2 (MD 20 DE)	111.46	116.66	120.11	116.08	115.22	121.13	123.32	119.89
Mean (Cr)	109.04	114.29	117.73		112.88	117.60	120.56	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.51	0.16			0.49	0.16		
Cr	0.62	0.20			0.60	0.19		
C x Cr	NS	0.28			0.86	0.27		

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest TPC of 117.73 mg 100 g^{-1} , followed by extracts encapsulated at carrier to extract ratio of 1:15 (Cr_2) with TPC of 114.29 mg QE 100 g^{-1}).

The interaction effect between the factors was found to be non-significant.

Koozha

The total phenolic content (TPC) of freeze encapsulated koozha extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference and with respect to levels of DE of MD (C), carrier ratio (Cr) and their interaction (Table 73).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) was found to contain maximum TPC of 119.89 mg GAE 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (114.14 mg GAE 100 g^{-1}).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest TPC of 120.56 mg GAE 100 g^{-1} whereas, carrier to extract ratio of 1:10 ($Cr_{1)}$ produced encapsulate with lowest of 112.88 mg GAE 100 g^{-1} TPC.

Considering the interaction effect, it was observed that extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly highest TPC of 123.32 mg GAE 100 g^{-1} (C_2Cr_3), followed by extracts encapsulated with MD 20 DE at carrier to extract ratio of 1:15 (121.13 mg GAE 100 g^{-1}) (C_2Cr_2). The minimum total phenolic content of 110.54 mg QE 100 g^{-1} was observed when extracts were encapsulated with 10DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

4.3.2.2.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

The total phenolic content (TPC) of freeze encapsulated varikka extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 74).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) was found to contain maximum TPC of 119.85 mg GAE 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (114.77 mg GAE 100 g^{-1}).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest TPC of 121.21 mg GAE 100 g^{-1} whereas, carrier to extract ratio of 1:10 ($Cr_{1)}$ produced encapsulate with lowest content of 112.94 mg GAE 100 g^{-1} TPC.

The interaction effect between the factors was found to be non-significant.

Koozha

The total phenolic content (TPC) of freeze encapsulated koozha extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by levels of DE of MD (C), carrier to extract ratio and their interaction (Cr) (Table 74).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had maximum TPC of 126.84 mg GAE 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (120.27 mg GAE 100 g^{-1}).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest TPC of 129.19 mg GAE 100 g^{-1} whereas, carrier to extract ratio of 1:10 ($Cr_{1)}$ produced encapsulate with lowest content of 118.05 mg GAE 100 g^{-1} TPC.

Table 74. Effect of dextrose equivalence and carrier to extract ratio on Total Phenolic Content (mg GAE 100 g^{-1}) of freeze dried encapsulate $D_2S_4R_2$

Total phenolic content (mg GAE 100 g^{-1})								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	110.12	115.39	118.80	114.77	113.87	121.42	125.52	120.27
C_2 (MD 20 DE)	115.77	120.16	123.62	119.85	122.23	125.43	132.86	126.84
Mean	112.94	117.77	121.21		118.05	123.43	129.19	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.62	0.20			0.52	0.17		
Cr	0.76	0.25			0.63	0.20		
C x Cr	NS	0.35			0.89	0.29		

Considering the interaction effect, it was observed that extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly highest TPC of 132.86 mg GAE 100 g^{-1} (C_2Cr_3), followed by extracts encapsulated with MD 10 DE at carrier to extract of 1:20 (125.52 mg GAE 100 g^{-1}) (C_1Cr_3), which was found to be on par with extract encapsulated using 20 DE of MD at 1:15 carrier to extract ratio (125.43 mg GAE 100 g^{-1}) (C_2Cr_2). The minimum total phenoilc content of 113.87 mg QE 100 g^{-1} was observed when extracts were encapsulated with 10DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

4.3.2.2.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

The total phenolic content (TPC) of freeze encapsulated varikka extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 75).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) was found to contain maximum TPC (122.20 mg GAE 100 g^{-1}) compared to extracts encapsulated using 10 DE of MD (C_1) (117.70 mg GAE 100 g^{-1}).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest TPC (124.36 mg GAE 100 g^{-1}) whereas, carrier to extract ratio of 1:10 ($Cr_{1)}$ produced encapsulate with lowest TPC of 114.97 mg GAE 100 g^{-1}.

The interaction effect between the factors was found to be non-significant.

Koozha

The Total Phenolic Content (TPC) of freeze encapsulated koozha extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent

Table 75. Effect of dextrose equivalence and carrier to extract ratio on Total Phenolic Content (mg GAE 100 g^{-1}) of freeze dried encapsulate $D_2S_4R_3$

Total phenolic content (mg GAE 100 g^{-1})								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	112.35	118.81	121.93	117.70	116.99	125.77	131.76	124.84
C_2 (MD 20 DE)	117.58	122.23	126.78	122.20	127.33	132.81	134.38	131.51
Mean	114.97	120.52	124.36		122.16	129.29	133.07	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.65	0.21			0.61	0.20		
Cr	0.79	0.25			0.75	0.24		
C x Cr	NS	0.36			1.05	0.34		

ratio) showed significant difference with respect to levels of DE of MD (C), carrier to extract ratio (Cr) and their interaction (Table 75).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) was found to contain maximum TPC of 131.51 mg GAE 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (124.84 mg GAE 100 g^{-1}).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest TPC of 133.07 mg GAE 100 g^{-1} whereas, carrier to extract ratio of 1:10 ($Cr_{1)}$ produced encapsulate with lowest TPC of 122.16 mg GAE 100 g^{-1}.

Considering the interaction effect, it was observed that extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly highest TPC of 134.38 mg GAE 100 g^{-1} (C_2Cr_3), followed by extracts encapsulated with MD 20 DE at carrier to extract ratio of 1:15 (132.81 mg GAE 100 g^{-1}) (C_2Cr_2) which was found to be on par with extract encapsulated using 10 DE of MD at 1:20 carrier to extract ratio (131.76 mg GAE 100 g^{-1}) (C_1Cr_3). The minimum total phenolic content of 116.99 mg GAE 100 g^{-1} was observed in extract encapsulated using MD of 10 DE at 1:10 carrier to extract ratio (C_1Cr_1).

4.3.2.3 Total Antioxidant (DPPH) Activity (%)

4.3.2.3.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

DPPH scavenging activity of freeze encapsulated varikka extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) carrier to extract ratio (Cr)and their interaction (Table 76).

Table 76. Effect of dextrose equivalence and carrier to extract ratio on total antioxidant activity (per cent inhibition) of freeze dried encapsulate from the extract $D_1S_4R_3$

Total antioxidant activity (per cent inhibition)								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	53.49	56.45	62.24	57.39	55.32	59.92	66.42	60.55
C_2 (MD 20 DE)	55.62	57.91	61.95	58.49	57.23	58.66	65.43	60.44
Mean (Cr)	54.55	57.18	62.09		56.28	59.29	65.93	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.40	0.13			NS	0.13		
Cr	0.49	0.16			0.48	0.15		
C x Cr	0.69	0.22			0.68	0.22		

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had higher scavenging activity with 58.49 per cent inhibition compared to extracts encapsulated using 10 DE of MD (C_1) (57.39 per cent).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest scavenging activity with 62.09 per cent inhibition, followed by extracts encapsulated at carrier to extract ratio of 1:15 (Cr_2) with 57.18 per cent inhibition.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:20 carrier to extract ratio had significantly highest scavenging activity of 62.24 per cent inhibition (C_1Cr_3), which was found to be on par with extract encapsulated with MD 20 DE at carrier to extract ratio of 1:20 (61.95 per cent) (C_2Cr_3). The lowest scavenging activity with per cent inhibition of 53.49 was observed in the extracts encapsulated with 10 DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

Koozha

DPPH scavenging activity of freeze encapsulated koozha extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) were significantly influenced by carrier to extract ratio (Cr) and interaction between DE of MD (C) and carrier to extract ratio (Table 76).

The effect of levels of dextrose equivalence (DE) of maltodexrin (MD) did not influence the DPPH scavenging activity of freeze encapsulated koozha extract.

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest scavenging activity with 65.93 per cent inhibition, followed by extracts encapsulated at carrier to extract ratio of 1:15 (Cr_2) with 59.29 per cent inhibition.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:20 carrier to extract ratio had significantly highest scavenging activity of 66.42 per cent inhibition (C_1Cr_3), which was followed by extract encapsulated with MD 20 DE at carrier to extract ratio of 1:20 (65.43 per cent) (C_2Cr_3). The lowest scavenging activity with per cent inhibition of 55.32 was observed in the extracts encapsulated with 10 DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

4.3.2.3.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

DPPH scavenging activity of of freeze encapsulated varikka extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) carrier to extract ratio (Cr) and their interaction (Table 77).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (MD) had higher scavenging activity with 63.81 per cent inhibition compared to extracts encapsulated using 10 DE of MD (62.75 per cent).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest scavenging activity with 66.60 per cent inhibition, followed by extracts encapsulated at 1:15 carrier to extract ratio (Cr_2) with 63.51 per cent inhibition.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:20 carrier to extract ratio had significantly highest scavenging activity of 67.76 per cent inhibition (C_1Cr_3), which was followed by extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio (65.44 per cent) (C_2Cr_3). The lowest scavenging activity with percent inhibition of 57.11 was observed in the extracts encapsulated with 10 DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

Table 77. Effect of dextrose equivalence and carrier to extract ratio on total antioxidant activity (per cent inhibition) of freeze dried encapsulate from the extract $D_2S_4R_2$

Total antioxidant activity (per cent inhibition)								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	57.11	63.38	67.76	62.75	58.65	64.37	70.22	64.41
C_2 (MD 20 DE)	62.35	63.65	65.44	63.81	61.40	65.00	71.20	65.87
Mean (Cr)	59.73	63.51	66.60		60.03	64.69	70.71	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.39	0.13			0.38	0.12		
Cr	0.48	0.15			0.47	0.15		
C x Cr	0.67	0.22			0.66	0.21		

Koozha

DPPH scavenging activity of freeze encapsulated koozha extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) showed significant difference with respect to (C) levels of DE of MD, carrier to extract ratio (Cr) and their interaction (Table 77).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had higher scavenging activity with 65.87 per cent inhibition compared to extracts encapsulated using 10 DE of MD (C_1) (64.41 per cent).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest scavenging activity with 70.71 per cent inhibition, followed by extracts encapsulated at 1:15 carrier to extract ratio (Cr_2) with 64.69 per cent inhibition.

Considering the interaction effect, the extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly highest scavenging activity of 71.20 per cent inhibition, which was followed by extract encapsulated with MD 10 DE at 1:20 carrier to extract ratio (70.22 per cent) (C_1Cr_3). The lowest scavenging activity with per cent inhibition of 58.65 was observed in the extracts encapsulated with 10 DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1).

4.3.2.3.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

DPPH scavenging activity of freeze encapsulated varikka extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to carrier to extract ratio (Cr) and interaction between DE of MD (C) and carrier to extract ratio (Table 78).

Table 78. Effect of dextrose equivalence and carrier to extract ratio on total antioxidant activity (per cent inhibition) of freeze dried encapsulate from the extract $D_2S_4R_3$

Total antioxidant activity (per cent inhibition)								
	Varikka (Cr)				Koozha (Cr)			
Maltodextrin (C)	Carrier to extract ratio			Mean (C)	Carrier to extract ratio			Mean (C)
	Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)		Cr_1	Cr_2	Cr_3	
C_1 (MD 10 DE)	61.89	66.24	71.66	66.60	63.56	67.61	75.37	68.84
C_2 (MD 20 DE)	63.84	64.67	70.73	66.42	63.53	67.77	77.48	69.59
Mean (Cr)	62.87	65.46	71.20		63.54	67.69	76.42	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	NS	0.15			0.32	0.10		
Cr	0.56	0.18			0.39	0.13		
C x Cr	0.79	0.26			0.56	0.18		

The two levels of dextrose equivalence of maltodexrin (C) did not influence the DPPH scavenging activity significantly.

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest scavenging activity with 71.20 per cent inhibition, followed by extract encapsulated at 1:15 carrier to extract ratio (Cr_2) with 65.46 per cent inhibition.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:20 carrier to extract ratio had significantly highest scavenging activity of 71.66 per cent inhibition (C_1Cr_3), which was followed by extract encapsulated with MD 20 DE at carrier to extract ratio of 1:20 (70.73 per cent) (C_2Cr_3). The lowest scavenging activity with per cent inhibition of 61.89 per cent was observed in the extracts encapsulated with 10 DE maltodextrin at 1: 10 carrier to extract ratio (C_1Cr_1),

Koozha

DPPH scavenging activity of freeze encapsulated koozha extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by by levels of DE of MD (C), carrier to extract ratio (Cr) and their interaction (Table 78).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had higher scavenging activity with 69.59 per cent inhibition compared to extracts encapsulated using 10 DE of MD (C_1) (68.84 per cent).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest scavenging activity with 76.42 per cent inhibition, followed by extracts encapsulated at 1:15 carrier to extract ratio (Cr_2) with 67.69 per cent inhibition.

Considering the interaction effect, it was observed that extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly

highest scavenging activity of 77.48 per cent inhibition (C_2Cr_3), which was followed by extract encapsulated with MD 10 DE at 1:20 carrier to extract ratio (75.37 per cent) (C_1Cr_3). The lowest scavenging activity with per cent inhibition of 63.53 per cent was observed in the extract was encapsulated with 20 DE maltodextrin at 1: 10 carrier to extract ratio (C_2Cr_1) which was found to be on par with extract encapsulated with MD 10 DE at 1:10 carrier to extract ratio (63.53%) (C_1Cr_1).

4.3.2.4 Ascorbic Acid Content ((mg 100g^{-1})

4.3.2.4.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Ascorbic acid content of freeze encapsulated varikka extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 79).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_1) had maximum ascorbic acid content of 20.12 mg 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_2) (18.34 mg 100 g^{-1}).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest TAC value of 20.80 mg 100 g^{-1} which was found to be on par with extract produced at 1:15 carrier to extract ratio ($Cr_{2)}$ (20.21 mg 100 g^{-1}).

The interaction effect between the factors was found to be non significant.

Koozha

Ascorbic acid content of freeze encapsulate from the koozha extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 79).

Table 79. Effect of dextrose equivalence and carrier to extract ratio on ascorbic acid content (mg 100 g^{-1}) of freeze dried encapsulate from the extract $D_1S_4R_3$

Ascorbic acid content (mg 100 g^{-1})								
Maltodextrin (C)	**Varikka (Cr)**				**Koozha (Cr)**			
	Carrier to extract ratio			**Mean (C)**	**Carrier to extract ratio**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	16.08	19.32	19.62	18.34	17.44	20.80	22.19	20.14
C_2 (MD 20 DE)	17.27	21.10	21.99	20.12	18.43	21.70	21.99	20.71
Mean	16.67	20.21	20.80		17.93	21.25	22.09	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.68	0.22			0.48	0.16		
Cr	0.83	0.27			0.59	0.19		
C x Cr	NS	0.38			NS	0.27		

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had maximum ascorbic acid content of 20.71 mg 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (20.14 mg 100 g^{-1}).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest ascorbic acid of 22.09 mg 100 g^{-1} whereas, 1:10 carrier to extract ratio (Cr_1) produced encapsulate with lowest ascorbic acid content of 17.93 mg 100 g^{-1}.

The interaction between dextrose equivalent levels and carrier to extract ratio was found to be non-significant

4.3.2.4.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

Ascorbic acid content of freeze encapsulated varikka extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 80).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had maximum ascorbic acid content of 30.02 mg 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (28.33 mg 100 g^{-1}).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest ascorbic acid of 32.10 mg 100 g^{-1} while the lowest was recorded in the extracts encapsulated at 1:10 (Cr_1) carrier to extract ratio (26.01 mg 100 g^{-1}).

The interaction effect between the factors was found to be non-significant.

Table 80. Effect of dextrose equivalence and carrier to extract ratio on ascorbic acid content (mg 100 g^{-1}) of freeze dried encapsulate from the extract $D_2S_4R_2$

Ascorbic acid content (mg 100 g^{-1})								
	Varikka (Cr)				Koozha (Cr)			
Maltodextrin (C)	Carrier to extract ratio			Mean (C)	Carrier to extract ratio			Mean (C)
	Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)		Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)	
C_1 (MD 10 DE)	24.96	28.83	31.21	28.33	27.14	30.22	32.49	29.95
C_2 (MD 20 DE)	27.05	30.02	32.99	30.02	28.23	32.69	35.07	32.00
Mean	26.01	29.42	32.10		27.69	31.45	33.78	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.76	0.24			0.60	0.19		
Cr	0.93	0.30			0.74	0.24		
C x Cr	NS	0.42			NS	0.34		

Koozha

Ascorbic acid content of freeze encapsulated koozha extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 80).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had maximum ascorbic acid content of 32.00 mg 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (29.95 mg 100 g^{-1}).

The extracts encapsulated at 1:20 carrier to extract ratio of (Cr_3) had significantly highest ascorbic acid content of 33.78 mg 100 g^{-1} whereas, 1:10 carrier to extract ratio of ($Cr_{1)}$ produced encapsulate with lowest ascorbic acid content of 27.69 mg 100 g^{-1}.

The interaction between levels of dextrose equivalence and carrier to extract ratio was found to be non-significant.

4.3.2.4.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

Ascorbic acid content of freeze encapsulated varikka extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 81).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had maximum ascorbic acid content of 32.39 mg 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (30.22 mg 100 g^{-1}).

Table 81. Effect of dextrose equivalence and carrier to extract ratio on Ascorbic acid content (mg 100 g^{-1}) of freeze dried encapsulate from the extract $D_2S_4R_3$

Ascorbic acid content (mg 100 g^{-1})								
Maltodextrin (C)	**Varikka (Cr)**				**Koozha (Cr)**			
	Carrier to extract ratio			**Mean (C)**	**Carrier to extract ratio**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	27.05	31.21	32.39	30.22	28.53	32.10	34.48	31.70
C_2 (MD 20 DE)	28.23	33.29	35.66	32.39	30.31	33.29	36.26	33.29
Mean	27.64	32.25	34.03		29.42	32.69	35.37	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.79	0.25			0.76	0.24		
Cr	0.96	0.31			0.93	0.30		
C x Cr	NS	0.44			NS	0.42		

The extracts encapsulated at 1:20 carrier to extract ratio of (Cr_3) had significantly highest ascorbic acid content of 34.03 mg 100 g^{-1} followed by, extract produced at 1:15 carrier to extract ratio ($Cr_{2)}$ (32.25 mg 100 g^{-1}).

The interaction effect between the factors was found to be non-significant.

Koozha

Ascorbic acid content of freeze encapsulated koozha extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) and carrier to extract ratio (Cr) (Table 81).

The extract encapsulated with 20 dextrose equivalence (DE) maltodexrin (C_2) had maximum ascorbic acid content of 33.29 mg 100 g^{-1} compared to extracts encapsulated using 10 DE of MD (C_1) (31.70 mg 100 g^{-1}).

The extracts encapsulated at 1:20 carrier to extract ratio of (Cr_3) had significantly highest ascorbic acid content of 35.37 mg 100 g^{-1} followed by extract produced at 1:15 carrier to extract ratio of ($Cr_{2)}$ (32.69 mg 100 g^{-1}).

The interaction effect between the factors was found to be non significant.

4.3.2.5. Recovery Percentage of Encapsulation (%)

4.3.2.5.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

Recovery of encapsulate (%) of extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C) and carrier to extract ratio (Cr) (Table 82).

Table 82. Effect of dextrose equivalence and carrier to extract ratio on recovery (per cent) of encapsulation of freeze dried encapsulate from the extract $D_1S_4R_3$

Recovery percentage of encapsulation (%)								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	96.16	97.54	97.48	97.06	95.84	96.77	96.70	96.44
C_2 (MD 20 DE)	97.22	98.31	98.08	97.87	96.79	97.50	98.67	97.65
Mean	96.69	97.93	97.78		96.32	97.14	97.69	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.40	0.13			0.35	0.11		
Cr	0.50	0.16			0.43	0.14		
C x Cr	NS	0.21			0.61	0.20		

The extract encapsulated with MD 20 DE (C_2)had higher recovery 97.87 per cent compared to extract encapsulated using MD 10 DE (C_1) (97.06%).

The extracts encapsulated at carrier to extract ratio of 1:15 (Cr_2) had significantly highest recovery (97.93%) which was found to be on par with extract encapsulated at 1:20 (Cr_3) carrier to extract ratio (97.78%). The lowest encapsulate recovery was observed in extracts encapsulated at 1:10(Cr_1) carrier to extract ratio (96.69%).

The interaction effect between the factors was found to be non-significant.

Koozha

Recovery of encapsulate (%) of extract $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C), carrier to extract ratio and their interaction (Cr) (Table 82).

The extract encapsulated with MD 20 DE (C_2) had higher recovery of encapsulate 97.65 per cent compared to extract encapsulated using MD 10 DE (C_1) (96.44%).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest recovery of encapsulate (97.69%) followed by extract encapsulated at 1:15 (Cr_2) carrier to extract ratio (97.14).

Considering the interaction effect, it was observed that extract encapsulated with MD 20 DE at 1:20 carrier to extract ratio had significantly highest encapsulate recovery of 98.67 per cent (C_2Cr_3), followed by extract encapsulated with MD 20 DE at 1:15 carrier to extract ratio (C_2Cr_2) (97.50%).

The minimum per cent recovery was observed when extract was encapsulated with MD 10 DE at 1:10 carrier to extract ratio (C_1Cr_1) (95.84%).

4.3.2.5.2 Freeze Dried Samples Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

Recovery of encapsulate (%) of extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C) and carrier to extract ratio (Cr) (Table 83).

The extract encapsulated with MD 20 DE (C_2) had higher recovery (98.01 per cent) compared to extract encapsulated using MD 10 DE (C_1) (97.44%).

The extracts encapsulated at 1:20 carrier to extract ratio of (Cr_3) had significantly highest recovery of encapsulate (98.37%) whereas, carrier to extract ratio of 1:15 (Cr_2) produced encapsulate with recovery of 97.82 per cent.

The interaction effect between the factors was found to be non-significant.

Koozha

Recovery of encapsulate (%) of extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C) and carrier to extract ratio (Cr) (Table 83).

The extract encapsulated with maltodextrin (MD) 20 dextrose equivalence (C_2) had higher recovery (97.88%) compared to extract encapsulated using MD 10 DE (C_1) (96.69%).

The extracts encapsulated at 1:20 carrier to extract ratio (Cr_3) had significantly highest recovery (97.93%) which was found to be on par with extract encapsulated at 1:15 (Cr_2) carrier to extract ratio (97.52%). The lowest encapsulate recovery was observed in extracts encapsulated at 1:10(Cr_1) carrier to extract ratio (96.40%).

Table 83. Effect of dextrose equivalence and carrier to extract ratio on recovery (per cent) of encapsulation of freeze dried encapsulate from the extract $D_2S_4R_2$

Recovery percentage of encapsulation (%)								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	96.51	97.74	98.08	97.44	95.86	97.15	97.04	96.69
C_2 (MD 20 DE)	97.46	97.91	98.65	98.01	96.94	97.88	98.82	97.88
Mean	96.98	97.82	98.37		96.40	97.52	97.93	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.33	0.11			0.37	0.12		
Cr	0.41	0.13			0.45	0.14		
C x Cr	NS	0.19			NS	0.20		

The interaction effect between the factors was found to be non-significant.

4.3.2.5.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

Recovery of encapsulate (%) of extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C) and carrier to extract ratio (Cr) (Table 84).

The extract encapsulated with MD 20 DE (C_2) had higher recovery of encapsulate 98.90 per cent compared to extract encapsulated using MD 10 DE (C_1) (97.86%).

The extracts encapsulated at carrier to extract ratio of 1:20 (Cr_3) had significantly highest recovery of encapsulate (98.66%) which was found to be on par with extract encapsulated at 1:15 (Cr_2) carrier to extract ratio (98.51%). The lowest encapsulate recovery was observed in extracts encapsulated at 1:10(Cr_1) carrier to extract ratio (97.98%).

The interaction effect between the factors was found to be non-significant.

Koozha

Recovery of encapsulate (%) of extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) was significantly influenced by dextrose equivalence (DE) of maltodextrin (C) and carrier to extract ratio (Cr) (Table 84).

The extract encapsulated with MD 20 DE (C_2) had higher recovery (98.03 per cent) compared to extract encapsulated using MD 10 DE (C_1) (96.88%).

Table 84. Effect of dextrose equivalence and carrier to extract ratio on recovery (per cent) of encapsulation of freeze dried encapsulate from the extract $D_2S_4R_3$

Recovery percentage of encapsulation (%)								
	Varikka				Koozha			
Maltodextrin (C)	Carrier to extract ratio (Cr)			Mean (C)	Carrier to extract ratio (Cr)			Mean (C)
	Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)		Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)	
C_1 (MD 10 DE)	97.63	97.78	98.19	97.86	95.99	97.06	97.59	96.88
C_2 (MD 20 DE)	98.34	99.24	99.13	98.90	97.14	98.12	98.85	98.03
Mean	97.98	98.51	98.66		96.56	97.59	98.22	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.43	0.14			0.41	0.13		
Cr	0.52	0.17			0.50	0.16		
C x Cr	NS	0.24			NS	0.23		

The extracts encapsulated at 1:20 carrier to extract ratio of (Cr_3) had significantly highest recovery (98.22%) whereas, 1:15 carrier to extract ratio (Cr_2) produced encapsulate recovery of 97.59 per cent.

The interaction effect between the factors was found to be non-significant.

4.3.2.6 Moisture Content (%)

4.3.2.6.1 Cabinet Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_1S_4R_3$)

Varikka

The moisture content (%) of freeze encapsulated varikka extract, $D_1S_4R_3$ (cabinet dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) carrier to extract ratio (Cr) and their interaction (Table 85).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) had minimum moisture content of 3.40 % compared to extracts encapsulated using 20 DE of MD (C_2) (3.87%).

The extracts encapsulated at 1:10 carrier to extract ratio of (Cr_1) had significantly lowest moisture content of 3.20 % whereas, carrier to extract ratio of 1:20 (Cr_3) produced encapsulate with highest moisture content (4.03%).

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:10 carrier to extract ratio had significantly lowest moisture content of 2.88% (C_1Cr_1), followed by extract encapsulated with MD 20 DE at carrier to extract ratio of 1:10 (3.53%) (C_2Cr_1), which was found to be on par with extract encapsulated with MD 10 DE 1:15 at carrier to extract ratio of (3.53%) (C_1Cr_2). The maximum moisture content of 4.26% was observed in the extracts encapsulated with 20 DE maltodextrin at 1: 20 carrier to extract ratio (C_2Cr_3).

Table 85. Effect of dextrose equivalence and carrier to extract ratio on moisture content (mg 100 g^{-1}) of freeze dried encapsulate from the extract $D_1S_4R_3$

Moisture content (%)								
Maltodextrin (C)	Varikka				Koozha			
	Carrier to extract ratio (Cr)			Mean (C)	Carrier to extract ratio (Cr)			Mean (C)
	Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)		Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)	
C_1 (MD 10 DE)	2.88	3.53	3.79	3.40	2.70	3.45	4.26	3.47
C_2 (MD 20 DE)	3.51	3.85	4.26	3.87	3.82	4.44	4.83	4.36
Mean	3.20	3.69	4.03		3.26	3.95	4.54	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.05	0.02			0.05	0.02		
Cr	0.06	0.02			0.06	0.02		
C x Cr	0.08	0.03			0.09	0.03		

Koozha

The moisture content (%) of freeze encapsulated koozha extract, $D_1S_4R_3$ (cabinet dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) showed significant difference with respect to levels of DE of MD (C) carrier to extract ratio (Cr) and their interaction (Table 85).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) had minimum moisture content of 3.47 % compared to extracts encapsulated using 20 DE of MD (C_2) (4.36%).

The extracts encapsulated at carrier to extract ratio of 1:10 (Cr_1) had significantly lowest moisture content 3.26 % whereas, carrier to extract ratio of 1:20 (Cr_3) produced encapsulate with highest moisture content of 4.54%.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:10 carrier to extract ratio had significantly lowest moisture content of 2.70% (C_1Cr_1), followed by extract encapsulated with MD 10 DE at extract to carrier ratio of 1:15 (3.45%) (C_1Cr_2). The maximum moisture content of (4.83%) was observed in the extracts encapsulated with 20 DE maltodextrin at 1: 20 carrier to extract ratio (C_2Cr_3).

4.3.2.6.2 Freeze Dried Sample Extracted Using 60% Ethanol at 1:40 Solid to Solvent Ratio ($D_2S_4R_2$)

Varikka

The moisture content of freeze encapsulated varikka extract, $D_2S_4R_2$ (freeze dried varikka extracted using 60% ethanol at 1:40 solid to solvent ratio) differed significantly and were influenced by levels of DE of MD (C), carrier to extract ratio (Cr) and their interaction (Table 86).

Table 86. Effect of dextrose equivalence and carrier to extract ratio on moisture content (mg 100 g^{-1}) of freeze dried encapsulate from the extract $D_2S_4R_2$

Moisture content (%)								
Maltodextrin (C)	Varikka				Koozha			
	Carrier to extract ratio (Cr)			Mean (C)	Carrier to extract ratio (Cr)			Mean (C)
	Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)		Cr_1 (1:10)	Cr_2 (1:15)	Cr_3 (1:20)	
C_1 (MD 10 DE)	2.28	3.65	3.91	3.28	2.45	2.66	3.15	2.75
C_2 (MD 20 DE)	3.30	4.11	4.37	3.93	3.39	3.90	4.69	3.99
Mean	2.79	3.88	4.14		2.92	3.28	3.92	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.042	0.014			0.04	0.01		
Cr	0.052	0.017			0.04	0.01		
C x Cr	0.073	0.023			0.06	0.02		

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) was found to contain minimum moisture content (3.28 %) compared to extracts encapsulated using 20 DE of MD (C_2) (3.93%).

The extracts encapsulated at 1:10 carrier to extract ratio of (Cr_1) had significantly lowest moisture content (2.79 %) whereas, carrier to extract ratio of 1:20 (Cr_3) produced encapsulate with highest moisture content of 4.14%.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:10 carrier to extract ratio had significantly lowest moisture content of 2.28% (C_1Cr_1), followed by extract encapsulated with MD 20 DE at ratio of 1:10 (3.30%) (C_1Cr_1). The maximum moisture content of 4.37% was observed in the extracts encapsulated with 20 DE maltodextrin at 1: 20 carrier to extract ratio (C_2Cr_3).

Koozha

The moisture content of freeze encapsulated koozha extract, $D_2S_4R_2$ (freeze dried koozha extracted using 60% ethanol at 1:40 solid to solvent ratio) differed with respect to levels of DE of MD (C), carrier to extract ratio (Cr) and their interaction (Table 86).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) had minimum moisture content (2.75 %) compared to extracts encapsulated using 20 DE of MD (C_2) (3.99%).

The extracts encapsulated at 1:10 carrier to extract ratio (Cr_1) had significantly lowest moisture content 2.92 % followed by extract encapsulated at 1:15 carrier to extract ratio (Cr_3) with moisture content of 3.28%.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:10 carrier to extract ratio had significantly lowest moisture content of 2.45% (C_1Cr_1), followed by extract encapsulated with

MD 10 DE at carrier to extract ratio of 1:15 (2.66%) (C_1Cr_2). The maximum moisture content of 4.69% was observed in the extracts encapsulated with 20 DE maltodextrin at 1: 20 carrier to extract ratio (C_2Cr_3).

4.3.2.6.3 Freeze Dried Samples Extracted Using 60% Ethanol at 1:50 Solid to Solvent Ratio ($D_2S_4R_3$)

Varikka

The moisture content of freeze encapsulated varikka extract, $D_2S_4R_3$ (freeze dried varikka extracted using 60% ethanol at 1:50 solid to solvent ratio) differed significantly and were influenced by levels of DE of MD (C), carrier ratio (Cr) and their interaction (Table 87).

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) was found to contain minimum moisture content of 3.13 % compared to extracts encapsulated using 20 DE of MD (C_2) (3.73%).

The extracts encapsulated at 1:10 carrier to extract ratio of (Cr_1) had significantly lowest moisture content 2.67 % whereas, carrier to extract ratio of 1:20 (Cr_3) produced encapsulate with highest moisture content of 3.97%

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:10 carrier to extract ratio had significantly lowest moisture content of 2.22% (C_1Cr_1), followed by extract encapsulated with MD 20 DE at 1:10 carrier to extract ratio of 1:10 (3.12%) (C_2Cr_1). The maximum moisture content of 4.15% was observed in the extracts encapsulated with 20 DE maltodextrin at 1: 20 carrier to extract ratio (C_2Cr_3).

Koozha

The moisture content of freeze encapsulated koozha extract, $D_2S_4R_3$ (freeze dried koozha extracted using 60% ethanol at 1:50 solid to solvent ratio) differed significantly for moisture content with respect to levels of DE of MD (C), carrier to extract ratio) and their interaction (Table 87).

Table 87. Effect of dextrose equivalence and carrier to extract ratio on moisture content (%) of freeze dried encapsulate from the extract $D_2S_4R_3$

Moisture content (%)								
Maltodextrin (C)	**Varikka**				**Koozha**			
	Carrier to extract ratio (Cr)			**Mean (C)**	**Carrier to extract ratio (Cr)**			**Mean (C)**
	Cr_1 (1:10)	**Cr_2 (1:15)**	**Cr_3 (1:20)**		**Cr_1 (1:10)**	**Cr_2 (1:15)**	**Cr_3 (1:20)**	
C_1 (MD 10 DE)	2.22	3.39	3.79	3.13	2.51	2.99	3.19	2.90
C_2 (MD 20 DE)	3.12	3.91	4.15	3.73	3.25	3.75	4.54	3.85
Mean	2.67	3.65	3.97		2.88	3.37	3.86	
Factors	C.D. (0.05)	SE(m)±			C.D. (0.05)	SE(m)±		
C	0.04	0.01			0.04	0.01		
Cr	0.05	0.02			0.05	0.01		
C x Cr	0.07	0.02			0.06	0.02		

The extract encapsulated with 10 dextrose equivalence (DE) maltodexrin (C_1) had minimum moisture content (2.90 %) compared to extracts encapsulated using 20 DE of MD (C_2) (3.85%).

The extracts encapsulated at 1:10 carrier to extract ratio (Cr_1) had significantly lowest moisture content 2.88 % whereas, 1:20 carrier to extract ratio (Cr_3) produced encapsulate with highest moisture content of 3.86%.

Considering the interaction effect, it was observed that extract encapsulated with MD 10 DE at 1:10 carrier to extract ratio had significantly lowest moisture content of 2.51% ((C_1Cr_1), followed by extract encapsulated with MD 10 DE carrier to extract ratio of 1:15 (2.99%) (C_1Cr_2). The maximum moisture content of 4.54% was observed in the extracts encapsulated with 20 DE maltodextrin at 1: 20 carrier to extract ratio (C_2Cr_3).

4.4 COMMERCIAL APPLICATION OF ENCAPSULATED EXTRACT

Based on superior biochemical properties the following treatments were selected from Part-III of the experiment for further studies. Experiment was conducted for varikka and koozha separately.

T_1- Freeze dried sample extracted using 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) and further spray encapsulated using 20 dextrose matodextrin at 1:20 extract to carrier ratio at 180 - 80º C inlet - out let temperature ($C_2Cr_3T_1$).

T_2- Freeze dried sample extracted using 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) and further freeze encapsulated using 20 dextrose matodextrin at 1:20 extract to carrier ratio (C_2Cr_3).

The selected encapsulates were incorporated in to fortified mango RTS beverages as per FSSAI standards and compared with a commercial fortified beverage available in the market. A preliminary study was conducted to know the quantity of encapsulates to be dissolved in mango RTS beverage. The

encapsulates were incorporated to RTS beverages in varied concentration (10-100 mg100 mL^{-1}) and organoleptic evaluation was conducted on nine point hedonic scale (enclosed in appendix).

4.4.1 Organoleptic Evaluation of Mango RTS Beverage Enriched with Spray Encapsulates ($C_2Cr_3T_1$ of $D_2S_4R_3$)

Organoleptic evaluation of the mango RTS beverage was conducted and the results of the study are presented in Table 88.

4.4.1.1 Color and Appearance

Organoleptic scores for color and appearance of mango RTS beverage enriched with spray dried encapsulate did not differ significantly (Table 88).

4.4.1.2 Consistency (Mouthfeel)

Consistency of mango RTS beverage enriched with spray encapsulate differed significantly (Table 88). The highest score for consistency was recorded for mango RTS beverage with 20 mg 100 mL^{-1} encapsulate spray encapsulate (8.80), which was found to be on par with mango RTS with 10 mg 100 mL^{-1} spray encapsulate (8.60), mango RTS with 30 mg 100 mL^{-1} spray encapsulate (8.40) and mango RTS beverage with 40 mg 100 mL^{-1} spray encapsulate (8.30). Significantly lowest score was received for mango RTS beverage enriched with 90 mg 100 mL^{-1} spray encapsulate (7.16) which was found to be on par with mango RTS beverage with 100 mg 100 mL^{-1} spray encapsulate (7.30), mango RTS beverage with 60 mg 100 mL^{-1} spray encapsulate (7.60) and mango RTS beverage with 80 mg 100 mL^{-1} spray encapsulate (7.70).

4.4.1.3 Flavor

Organoleptic scores for flavor of mango RTS beverage enriched with spray encapsulate were found to be non-significant (Table 88).

Table 88. Organoleptic evaluation of mango RTS beverage enriched with spray encapsulate of varikka

Treatments	Color and appearance	Consistency (mouth feel)	Flavor	Taste	Overall acceptability
T_1- Mango RTS +10 mg 100 mL^{-1} spray encapsulate	8.83	8.60	8.50	8.80	8.80
T_2- Mango RTS +20 mg 100 mL^{-} spray encapsulate	8.83	8.80	8.60	8.40	8.90
T_3- Mango RTS+30 mg 100 mL^{-1} spray encapsulate	9.00	8.40	8.60	8.50	8.50
T_4 - Mango RTS+40 mg 100 mL^{-1} spray encapsulate	9.00	8.30	8.80	8.10	8.10
T_5- Mango RTS+50 mg 100 mL^{-1} spray encapsulate	8.67	8.20	8.60	8.00	8.30
T_6- Mango RTS+60 mg 100 mL^{-1} spray encapsulate	8.50	7.60	8.70	6.10	7.30
T_7- Mango RTS+70 mg 100 mL^{-1} spray encapsulate	8.75	7.90	8.60	6.00	6.10
T_8- Mango RTS+80 mg 100 mL^{-1} spray encapsulate	8.42	7.70	8.50	5.50	6.10
T_9- Mango RTS+90 mg 100 mL^{-1} spray encapsulate	8.67	7.16	8.40	5.00	4.90
T_{10}- Mango RTS+100 mg 100 mL^{-1} spray encapsulate	8.33	7.30	8.30	4.10	4.60
C.D. (0.05)	NS	0.56	NS	0.58	0.44
SE±(m)	0.15	0.19	0.16	0.20	0.15

4.4.1.4 Taste

Organoleptic scores of mango RTS beverage differed significantly for taste (Table 88). Significantly highest score for taste (8.80) was received for the RTS beverage enriched with 10 mg100 mL^{-1} spray encapsulate which was found to be on par with mango RTS with 30 mg 100 mL^{-1} spray encapsulate (8.50) and mango RTS beverage with 20 mg 100mL^{-1} spray encapsulate (8.40). Significantly, lowest score was obtained for RTS beverage enriched with 100 mg 100 mL^{-1} spray encapsulate (4.10).

4.4.1.5 Overall Acceptability

Overall acceptability scores of mango RTS beverage enriched with spray encapsulate differed significantly (Table 88). The highest overall acceptability scores was received for mango RTS beverage enriched with 20 mg 100mL^{-1} spray encapsulate (8.90) which was found to be on par with mango RTS beverage with 10 mg 100mL^{-1} spray encapsulate (8.80) and T_3 mango RTS beverage with 30 mg 100mL^{-1} spray encapsulate (8.50). Significantly lowest score for overall acceptability was recorded by RTS beverage enriched with 100 mg 100 mL^{-1} spray encapsulate (4.60) which was found to be on par with mango RTS beverage with 90 mg 100mL^{-1} spray encapsulate (4.90).

4.4.2 Organoleptic Evaluation of Mango RTS Beverage Enriched with Freeze Encapsulate (C_2Cr_3 of $D_2S_4R_3$)

4.4.2.1 Color and Appearance

Organoleptic scores for color and appearance of mango RTS beverages enriched with freeze dried encapsulate did not differ significantly (Table 89).

4.4.2.2 Consistency (Mouthfeel)

Consistency of mango RTS beverage enriched with freeze encapsulate differed significantly (Table 90). The highest scores for consistency was recorded

Table 89. Organoleptic evaluation of mango RTS beverage enriched with freeze encapsulate of varikka

Treatments	Color and appearance	Consistency (mouth feel)	Flavor	Taste	Overall acceptability
T_1- Mango RTS +10 mg 100 mL^{-1} freeze encapsulate	8.70	8.60	8.40	8.90	8.70
T_2- Mango RTS +20 mg 100 mL^{-1} freeze encapsulate	8.70	8.70	8.70	8.60	8.80
T_3- Mango RTS+30 mg 100 mL^{-1} freeze encapsulate	8.70	8.60	8.40	8.30	8.30
T_4 - Mango RTS+40 mg 100 mL^{-1} freeze encapsulate	8.60	8.20	8.50	8.10	8.10
T_5- Mango RTS+50 mg 100 mL^{-1} freeze encapsulate	8.60	8.05	8.60	8.00	8.20
T_6- Mango RTS+60 mg 100 mL^{-1} freeze encapsulate	8.70	7.70	8.40	6.00	6.10
T_7- Mango RTS+70 mg 100 mL^{-1} freeze encapsulate	8.60	7.30	8.30	5.90	6.00
T_8- Mango RTS+80 mg 100 mL^{-1} freeze encapsulate	8.60	7.30	8.10	5.70	5.90
T_9- Mango RTS+90 mg 100 mL^{-1} freeze encapsulate	8.50	7.10	8.30	5.40	4.90
T_{10}- Mango RTS+100 mg 100 mL^{-1} freeze encapsulate	8.40	6.80	8.10	4.40	4.50
C.D. (0.05)	NS	0.40	NS	0.53	0.50
SE±(m)	0.14	0.14	0.15	0.18	0.17

for mango RTS+20 mg 100 mL^{-1} freeze encapsulate (8.70), which was found to be on par with mango RTS with10 mg 100 mL^{-1} freeze encapsulate and mango RTS with 30 mg 100 mL^{-1} freeze encapsulate (8.60). Significantly lowest score was received for mango RTS beverage enriched with 100 mg 100 mL^{-1} freeze encapsulate (6.80) which was found to be on par with mango RTS with 90 mg 100 mL^{-1} freeze encapsulate (7.10).

4.4.2.3 Flavour

Organoleptic scores for flavor of mango RTS beverages enriched with freeze encapsulate were found to be non-significant (Table 89).

4.4.2.4 Taste

Organoleptic scores of mango RTS beverage enriched with freeze encapsulate differed significantly for taste (Table 89). The highest score for taste was obtained for the RTS beverage enriched with 10 mg100 mL^{-1} freeze encapsulate (8.90) which was found to be on par with T_2 mango RTS with 20 mg 100mL^{-1} freeze encapsulate (8.60). Significantly lowest score was recorded for mango RTS enriched with 100 mg 100 mL^{-1} spray encapsulate (4.40).

4.4.2.5 Overall Acceptability

Mango RTS beverage enriched with freeze encapsulate differed significantly for overall acceptability scores (Table 89). The highest overall acceptability score was received for mango RTS beverage enriched with 20 mg 100 mL^{-1} freeze encapsulate (8.80) which was found to be on par with mango RTS beverage with 10 mg 100mL^{-1} freeze encapsulate (8.70) and mango RTS beverage with 30 mg 100 mL^{-1} freeze encapsulate (8.30). The lowest score for overall acceptability was recorded for RTS beverage enriched with 100 mg 100 mL^{-1} freeze encapsulate (4.50) which was found to be on par with mango RTS beverage with 90 mg 100mL^{-1} freeze encapsulate (4.90).

Considering the organoleptic scores of mango RTS beverage enriched with spray and freeze encapsulate, quantity of encapsulate to be dissolved was finalized. The overall acceptability scores for mango RTS beverage enriched with both spray and freeze encapsulate were between 9 (like extremely) and 8 (like very much) for beverages prepared by dissolving 10-50 mg 100 mL^{-1} (0.05%) concentration. Based on these scores, the limit for enrichment of mango RTS beverage was fixed as 50 mg 100 mL^{-1}.

4.4.3 Analysis of Mango RTS Beverage Enriched with Encapsulates

Qualitative analysis of the prepared beverages were conducted to assess the possibility and extent of fortification with the encapsulates. The results of the qualitative parameters as influenced by quantity of encapsulates used for enrichment of the mango RTS beverage are presented below.

4.4.3.1 Varikka

4.4.3.1.1 Total Soluble Solids (° Brix)

Mango RTS beverage enriched with encapsulates differed significantly for total soluble solid content (TSS) (Table 90). Significantly highest TSS content of 15.28 was recorded in mango RTS beverage enriched with 50 mg 100 mL^{-1} freeze encapsulate which was found to be on par with mango RTS beverage with 50 mg 100 mL^{-1} spray encapsulate (15.25) and T_4 (Commercial fortified beverage) (15.18). The lowest TSS content of 14.97was recorded for control (T_3) sample.

4.4.3.1.2 Total Sugar Content (g 100mL^{-1})

Mango RTS beverage enriched with encapsulates differed significantly for total sugar content ((Table 90). Significantly highest total sugar content of 13.19 g 100 mL^{-1} was recorded in mango RTS with 50 mg 100 mL^{-1} freeze encapsulate which was found to be on par with mango RTS with 50 mg 100 mL^{-1} spray

Table 90. Effect of encapsulate concentration on quality parameters of mango RTS beverage enriched with (spray and freeze) encapsulate of varikka extract, $D_2S_4R_3$

Treatments	Total soluble solids (° Brix)	Sugars g 100 mL^{-1}	Acidity (%)	Total phenolic content (mg 100 mL^{-1})	Antioxidant activity (%)
T_1- Mango RTS+50 mg 100 mL^{-1} spray encapsulate	15.25	13.10	0.30	40.90	73.21
T_2- Mango RTS+50 mg 100 mL^{-1} freeze encapsulate	15.28	13.19	0.31	41.05	76.29
T_3- Control sample (with no encapsulates)	14.96	12.13	0.27	38.23	55.19
T_4-Commercial fortified beverage	15.20	13.05	0.27	38.48	63.17
C.D. (0.05)	0.08	0.35	0.02	0.54	0.86
SE±(m)	0.024	0.11	0.007	0.17	0.28

encapsulate (13.10 g 100 mL^{-1}) and commercial fortified beverage (13.05 g 100 mL^{-1}). Significantly lowest TSS content of 12.13 g 100 mL^{-1} was recorded in control sample.

4.4.3.1.3 Acidity (%)

Mango RTS beverage enriched with encapsulates differed significantly for acidity content (%) (Table 90). Significantly lowest acidity content of 0.27 per cent was recorded in control sample and commercial fortified beverage. The highest acidity of 0.31 per cent was recorded in mango RTS enriched with 50 mg 100 mL^{-1} freeze encapsulate which was found to be on par with mango RTS with 50 mg spray encapsulate 100 mL^{-1}.

4.4.3.1.4 Total Phenolic Content (mg 100mL^{-1})

Total phenolic content (TPC) (mg GAE 100 mL^{-1}) of mango RTS beverage enriched with the encapsulates is presented in Table (90). Total phenolic content of mango RTS beverage was significantly influenced by the encapsulate added. The highest TPC of 41.05 mg GAE 100 mL^{-1} was recorded in mango RTS enriched with 50 mg 100 mL^{-1} freeze encapsulate which was found to be on par with mango RTS with 50 mg spray encapsulate 100 mL^{-1} (40.90 mg GAE 100 mL^{-1}). Significantly lowest TPC of 38.23 mg 100 mL^{-1} was recorded in control sample which was found to be on par with commercial fortified beverage (38.48 mg GAE 100 mL^{-1}).

4.4.3.1.5 Antioxidant Activity (%)

DPPH scavenging activity of mango RTS enriched the extracts is presented in Table 90. DPPH scavenging activity of the enriched mango RTS beverage was significantly influenced by the encapsulate dissolved. Significantly highest scavenging activity with 76.29 per cent inhibition was noticed in RTS beverage enriched with 50 mg 100 mL^{-1} freeze encapsulate, followed by mango

RTS with 50 mg 100 mL^{-1} spray encapsulate (73.21%). The lowest scavenging activity with per cent inhibition of 55.19 per cent was observed in control sample.

4.4.3.1.6 Organoleptic Evaluation

Scores for organoleptic properties of RTS beverages enriched with encapsulates is presented in Table (92). Organoleptic parameters viz., color and appearance, consistency, flavor, taste and overall acceptability of RTS beverages enriched with spray and freeze encapsulates ($C_2Cr_3T_1$ and C_2Cr_3) of varikka extracts $D_2S_4R_3$ were not significantly affected by the of encapsulates added to the beverage.

4.4.3.2 Koozha

4.4.3.2.1 Total Soluble Solids (° Brix)

Mango RTS beverage enriched with encapsulates differed significantly for total soluble solid content (TSS) (Table 91). The highest TSS content of 15.24 was recorded in mango RTS enriched with 50 mg 100 mL^{-1} freeze encapsulate which was found to be on par with commercial fortified beverage (15.21). Significantly lowest TSS content of 14.96 was recorded in control sample.

4.4.3.2.2 Total Sugar Content (g 100mL^{-1})

Mango RTS beverage enriched with freeze dried encapsulate differed significantly for total sugar content (Table 91). Significantly highest total sugar content of 13.41 g 100 mL^{-1} was recorded in mango RTS with 50 mg 100 mL^{-1} freeze encapsulate which was found to be on par with mango RTS with 50 mg 100 mL^{-1} spray encapsulate (13.10 g 100 mL^{-1}) and commercial fortified beverage (13.05 g 100 mL^{-1}). Significantly lowest TSS content of 12.13 g 100 mL^{-1} recorded in control sample.

Table 91. Effect of encapsulate concentration on quality parameters of mango RTS beverage enriched with (spray and freeze) encapsulate of koozha extract, D_2S4R_3

Treatments	Total soluble solids (° Brix)	Sugars g 100 mL^{-1}	Acidity (%)	Total phenolic content (mg 100 mL^{-1})	Antioxidant activity (%)
T_1- Mango RTS+50 mg 100 mL^{-1} spray encapsulate	15.16	13.10	0.31	41.07	74.25
T_2- Mango RTS+50 mg 100 mL^{-1} freeze encapsulate	15.24	13.41	0.31	41.12	78.07
T_3- Control	14.96	12.13	0.27	38.23	55.31
T_4-Commercial fortified beverage	15.21	13.05	0.27	38.48	63.18
C.D. (0.05)	0.07	0.44	0.02	0.57	0.82
SE±(m)	0.02	0.14	0.008	0.18	0.26

4.4.3.2.3 Acidity (%)

Mango RTS beverage enriched with encapsulates differed significantly for acidity content (%) (Table 91). Significantly lowest acidity content of 0.27 per cent was recorded in control sample and commercial fortified beverage. The highest acidity of 0.31 per cent was recorded in mango RTS enriched with 50 mg 100 mL^{-1} spray/ freeze encapsulate 100 mL^{-1}.

4.4.3.2.4 Total Phenolic Content (mg 100mL^{-1})

Total phenolic content (TPC) (mg GAE 100 $mL^{-1)}$ of mango RTS beverage enriched with encapsulates from koozha extract is presented in Table 91. Total phenolic content of mango RTS beverage was significantly influenced by freeze encapsulates added. Significantly highest TPC of 41.12 mg GAE 100 mL^{-1} was recorded in mango RTS enriched with 50 mg 100 mL^{-1} freeze encapsulate which was found to be on par with mango RTS with 50 mg 100 mL^{-1} spray encapsulate. Significantly lowest TPC of 38.23 mg 100 mL^{-1} was recorded in control sample which was found to be on par with commercial fortified beverage (38.48 mg GAE 100 mL^{-1}).

4.4.3.2.5 Antioxidant activity (%)

DPPH scavenging activity of mango RTS enriched with spray encapsulate from koozha extract is presented in Table 91. DPPH scavenging activity of the enriched mango RTS beverage was significantly influenced by encapsulate dissolved. Significantly highest scavenging activity with 78.07 per cent inhibition was noticed in RTS beverage enriched with 50 mg 100 mL^{-1} freeze encapsulate, followed by mango RTS with 50 mg 100 mL^{-1} spray encapsulate (74.25%). The lowest scavenging activity with per cent inhibition of 55.19 per cent was observed in control sample.

Table 92. Organoleptic evaluation of mango RTS beverage enriched with spray and freeze encapsulate (from varikka extract $D_2S_4R_3$)

Treatments	Color and appearance	Consistency (mouth feel)	Flavor	Taste	Overall acceptability
T_1- Mango RTS+50 mg 100 mL^{-1} spray encapsulate	8.63	8.44	8.50	8.38	8.25
T_2- Mango RTS+50 mg 100 mL^{-1} freeze encapsulate	8.63	8.38	8.50	8.25	8.25
T_3- Control	8.25	8.38	8.25	8.63	8.50
T_4-Commercial fortified beverage	8.38	8.50	8.63	8.38	8.63
C.D. (0.05)	NS	NS	NS	NS	NS
SE±(m)	0.13	0.17	0.18	0.17	0.12

4.4.3.2.6 Organoleptic Evaluation

Scores for organoleptic properties of RTS beverages enriched with encapsulates from koozha extract is presented in Table (93). Organoleptic parameters *viz*., color and appearance, consistency, flavor, taste and overall acceptability of RTS beverage enriched with encapsulates of koozha extract $D_2S_4R_3$ were not significantly affected by the encapsulate added to the beverage.

Table 93. Organoleptic evaluation of mango RTS beverage enriched with spray and freeze encapsulate (from koozha extract $D_2S_4R_3$)

Treatments	Color and appearance	Consistency (mouth feel)	Flavor	Taste	Overall acceptability
T_1- Mango RTS+50 mg 100 mL^{-1} spray encapsulate	8.63	8.38	8.38	8.25	8.25
T_2- Mango RTS+50 mg 100 mL^{-1} freeze encapsulate	8.50	8.25	8.50	8.38	8.50
T_3- Control	8.38	8.25	8.25	8.50	8.38
T_4-Commercial fortified beverage	8.38	8.25	8.63	8.63	8.63
C.D. (0.05)	NS	NS	NS	NS	NS
SE±(m)	0.11	0.14	0.15	0.21	0.11

5. DISCUSSION

The present investigation was undertaken to standardize the extraction procedure for maximizing the antioxidant, anti-hyperglycemic and anti-proliferative properties of fruit wastes (except bulb, seed and peel without horny portion, all other parts) from varikka and koozha jackfruit types, phytochemical profiling, encapsulation and commercial exploitation of encapsulated extracts for fortification of fruit juice beverages. Extraction of the cabinet and freeze dried samples was carried out with different solvents in different solid to solvent ratios. HPLC analysis of the superior crude extracts was carried out for better understanding of the constituents present. The extracts were spray and freeze encapsulated for stability and for incorporation in RTS beverages. The data generated from the studies conducted on crude extracts, phytochemical profiling of encapsulates and application of encapsulates in mango RTS beverages are discussed in detail in this chapter as four parts. The whole experiment was conducted independently for varikka and koozha types.

1. Standardization of extraction procedure

2. Phytochemical profiling

3. Encapsulation of extracts

4. Commercial application of encapsulated extract

5.1 STANDARDIZATION OF EXTRACTION PROCEDURE

The samples constituted except bulb, seed and peel without horny portion, all other parts which were dried in cabinet drier (50^{o} C) and freeze dried at (-45 to -50^{o} C) at pressure up to 0.05 mbar. The samples were dried until it reached a moisture content of 12-15 percentage pulverized to fine powders and extracts were prepared using solvents *viz*., methanol at 90 %, 80 %, 50% (S_3) and ethanol at 60 %, 80 % with solid to solvent ratios of 1:30, 1:40 and 1:50. The extracts were analysed after concentration and drying (Plate 8).

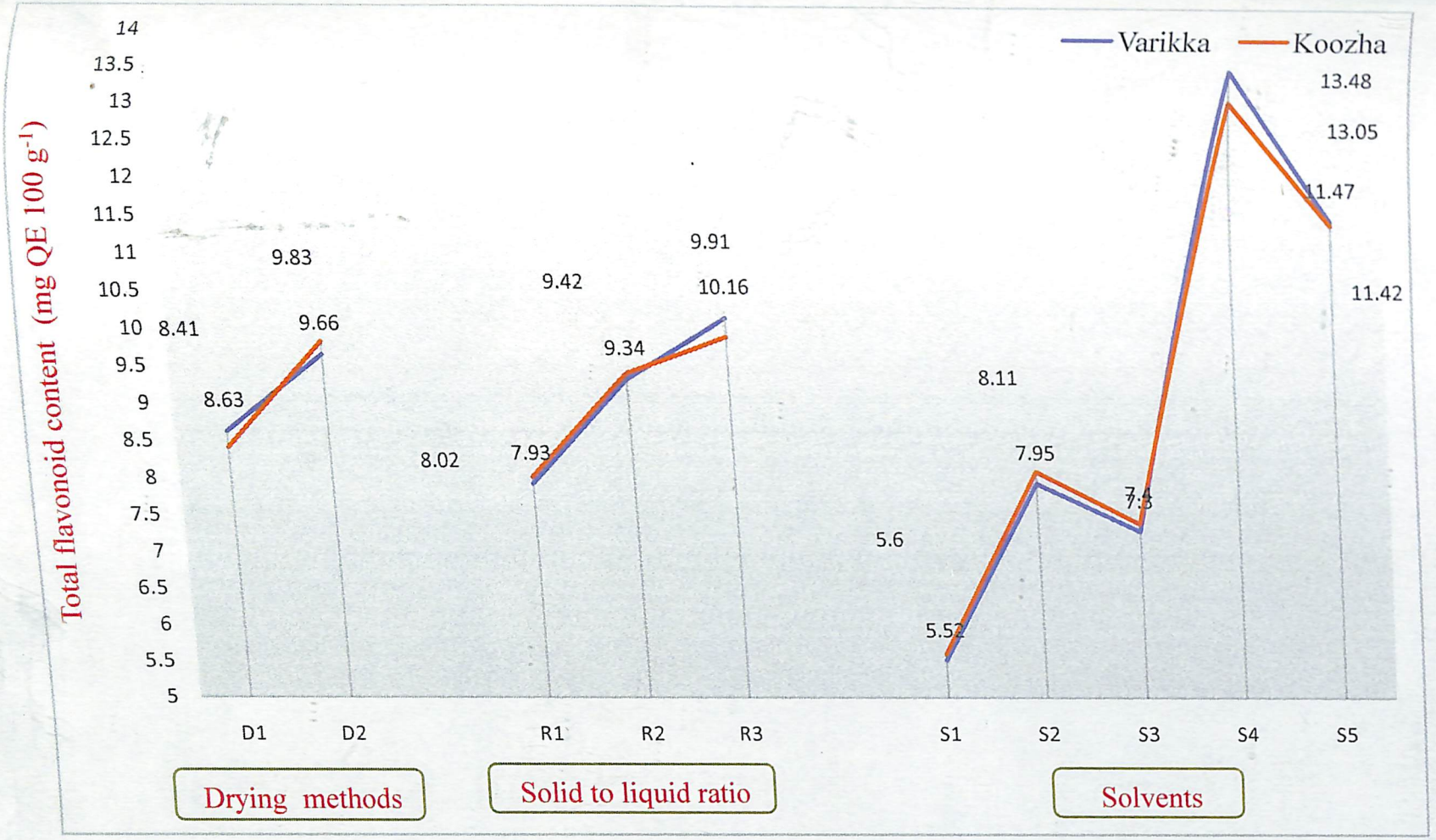
The data on preliminary study conducted to decide the optimum temperature for cabinet drying revealed that, samples dried at 50º C in cabinet drier were superior with highest total flavonoid, phenol and ascorbic acid contents for varikka and koozha samples. Increase in temperature from 50 to 70º C resulted in decrease in TFC and TPC of the samples from 110 to 98.85 mg GAE $100g^{-1}$ and 9.52 to 7.61 mg QE $100g^{-1}$ respectively. Vega-Gálvez *et al*. (2012) observed that an increase in drying temperature caused degradation of total phenolic content in apple (var. Granny Smith) slices dried using air convective drier and reported significantly highest TPC retention at 40º C compared to 60 and 80º C. Prolonged drying time did not necessarily produce the strongest degradation instead a rise in temperature causes a degradation of total phenolic content.

Increase in drying temperature reduced the ascorbic acid content of sample dried in cabinet drier. Varikka and koozha samples dried at 50º C retained 24.25% and 27.61% more ascorbic than those dried at 70º C. In a study on dehydration of whole persimmons, Nicoleti *et al.* (2007) observed ascorbic acid degradation during convective drying and found higher degradation rates at higher drying temperatures, independent of the time required to attain the desired moisture content in the final product.

The extracts were evaluated for antioxidant and anti-hyperglycemic properties for selection of superior three treatments. Anti-oxidant activity of the extract was assessed by evaluating Total Flavonoid content (TFC), Total Phenolic Content (TPC), Ascorbic Acid Content and Total Antioxidant Activity (TAC).

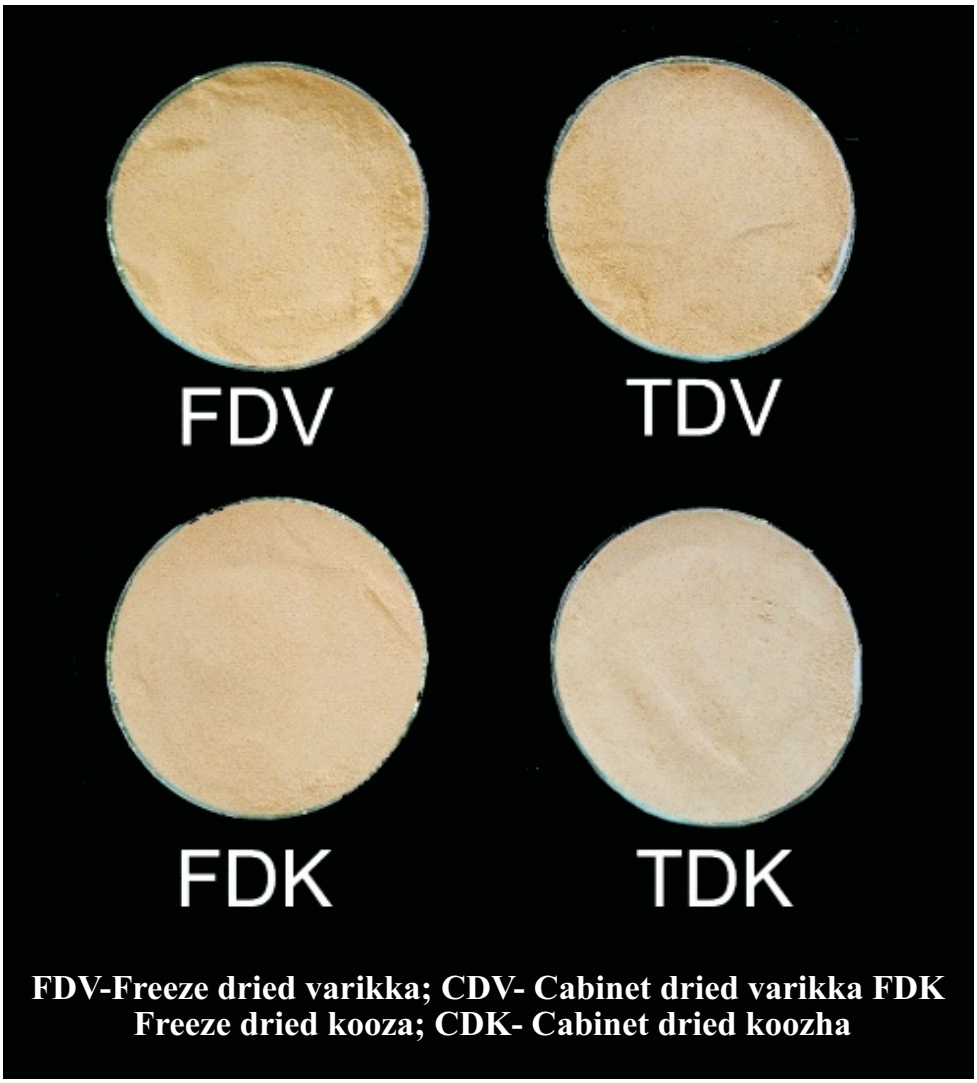
5.1.1 Total Flavonoid Content (mg QE 100 g^{-1})

Total flavonoid content of the extracts from varikka and koozha were found to be significantly highest in extracts from freeze-dried samples (Fig. 1). As discussed by Rafiq *et al*. (2019), extracts from freeze dried kinnow fruit peels were found to contain significantly highest TFC compared to their tray and vacuum dried counterparts. The difference in the TFC observed in drying techniques seemed to have significant effect on flavonoid content. The reduced



Drying methods-D_1-Cabinet drying, D_2-Freeze drying; Solid to liquid ratio- R_1-1:30, R_2-1:40, R_3-1:50 Solvents-S_1-Methanol-90%, S_2-Methanol-80%, S_3-Methanol-50%, S_4-Ethanol-60%, S_5-Ethanol-80%

Figure 1. Influence of drying methods (D), solid to liquid ratio (R) and solvents (S) on Total Flavonoid Content of jackfruit extract



FDV-Freeze dried varikka; CDV- Cabinet dried varikka FDK Freeze dried kooza; CDK- Cabinet dried koozha

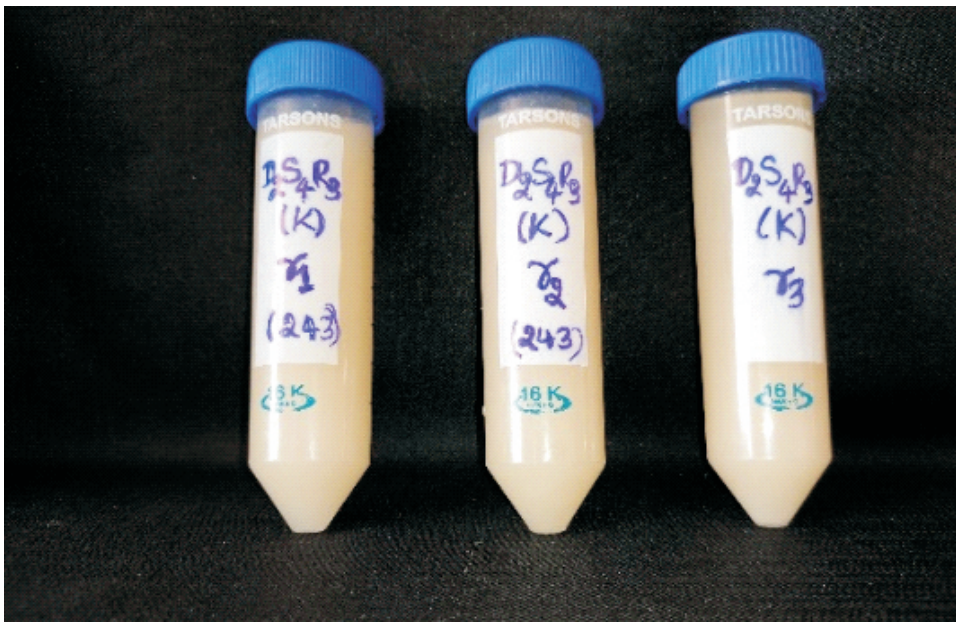


Plate 8. Pulverized Freeze and cabinet dried samples

level of flavonoid content in cabinet dried peels might be due to chemical, enzymatic or thermal decomposition of the compounds. In a similar study conducted by Sun *et al*. (2015) on physiologically immature citrus fruits, extracts from freeze dried samples were found to contain individual flavonoids in higher quantities.

Solvents used in the study had significantly influenced TFC of extracts (Figure 1). Ethanolic extracts had more TFC than methanolic extracts from varikka and koozha. TFC of extracts prepared using 60 per cent ethanol was found to be 13.48 and 13.05 mg QE 100 g^{-1} in varikka and koozha respectively while the lowest TFC was found in 90 per cent methanol extract (varikka -5.52 and koozha-5.60 mg QE 100g^{-1}). Daud *et al*., 2017 reported highest total flavonoid content in extract obtained from maceration of jackfruit rind with 70 per cent ethanol compared to percolation and soxhlet extraction with the same solvent. Nobosse *et al*. (2018) reported highest content of TFC in ethanolic extracts of *Moring oleifera* leaves compared to methanolic. The results are in line with the present study.

TFC of the extracts was found to increase with increase in solid to liquid ratio (Fig. 1). Among the solid to solvent ratios, R_3 (1:50) showed the highest flavonoid content while, the lowest was found in 1:30 solid to solvent ratio. The increase in flavonoid content was observed with increase in the volume of solvent to the extent of 21.95 and 19.07 per cent in varikka and koozha respectively. The results obtained in the study are consistent with mass transfer principles where the driving force for mass transfer is considered as the concentration gradient between the solid and the solvent. Higher solid-to-solvent ratio increases the concentration gradient, leading to an increased diffusion rate of the compounds from the extracted solid material into the solvent, but also determines the increase in the necessary period to achieve equilibrium. Predescu *et al*. (2016) reported similar results in ethanolic extracts of dog rosehips, sea buckthorn fruits and hawthorn.

The interaction effect of methods of drying, type of solvent and solid to solvent ratio produced extracts that differed 3.24 times and 3.49 times in TFC in

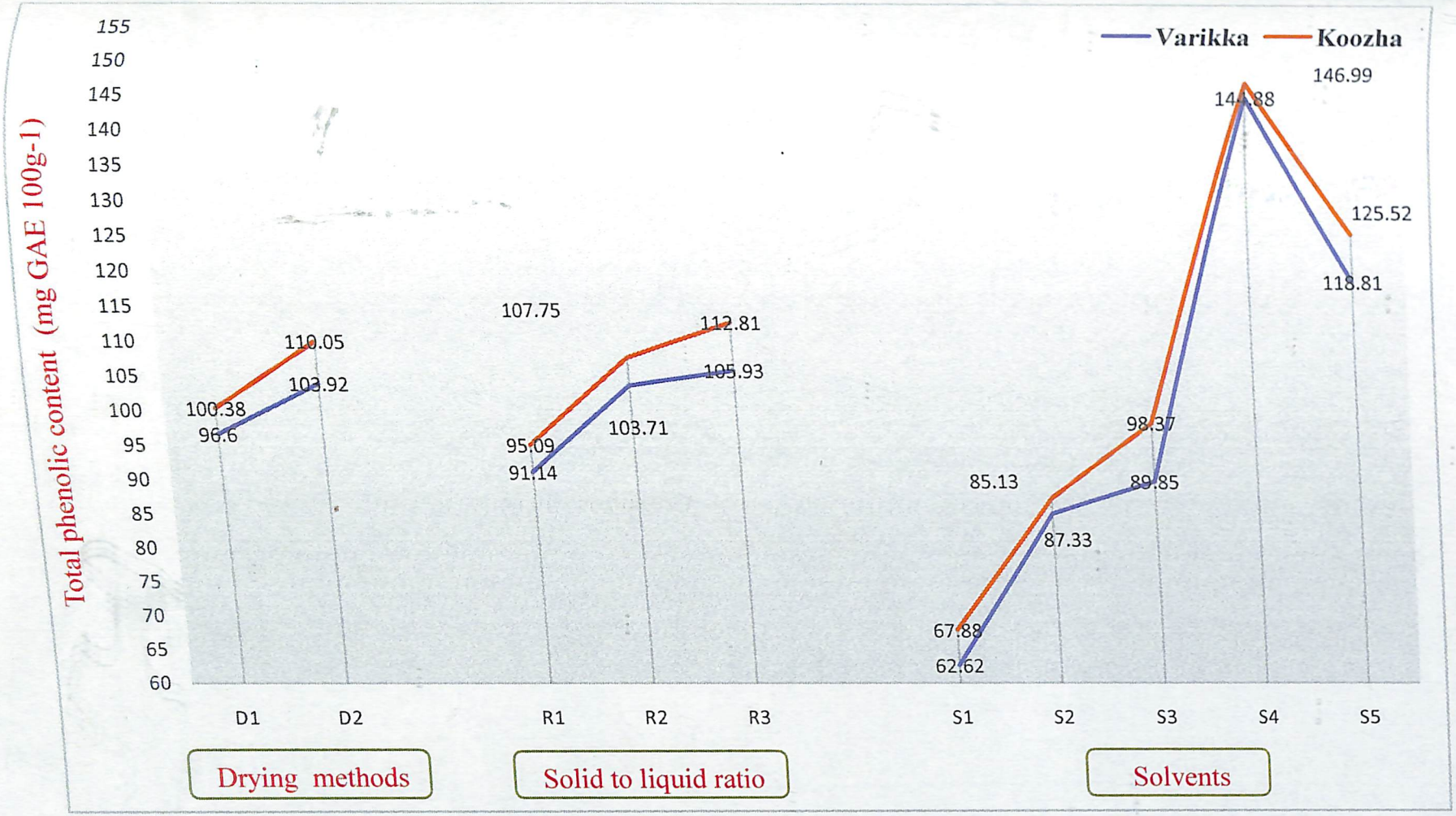
varikka and koozha respectively from the extreme end. The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest TFC content of 15.66 and 15.88 mg QE 100 g^{-1} in varikka and koozha respectively.

5.1.2 Total Phenolic Content (mg GAE 100 g^{-1})

Total phenolic content (TPC) was influenced by the drying methods, solvent used and solid to solvent ratios (Fig. 2). The phenolic content of sample was very much influenced by the drying method employed. TPC was found significantly highest in the extracts obtained from freeze dried samples. In a similar study conducted on marionberry, strawberry, and corns, freeze-drying preserved higher TPC and ascorbic acid content in comparison with air-drying (Asami *et al*., 2003). Sub atmospheric drying conditions coupled with drying at -45 to-50º C by means of sublimation are the factors responsible for retention of highest TPC.

TPC of the extracts were also influenced by solvent used in the study (Fig 2). As reported by Jagatap *et al*. (2010), phenolic content of jackfruit pulp was found to be highest in ethanolic extracts compared to extracts prepared methanol, water and acetone. This confirms the results of the current study. Ningappa *et al*. (2008), reported that TPC of extracts of dried curry leaves was highest in the extract, ethanol + water in 1:1 ratio compared to absolute ethanol. Turkmen *et al*. (2006) while testing the influence of solvents, ethanol and methanol at 50, 80 and 100 per cent concentration on TPC of black and black mate tea reported highest TPC in ethanolic extract compared to methanolic extract. Higher TPC recovery was found in 50% ethanol and decrease in TPC was reported with corresponding increase in concertation of solvent.

The same trends were also observed in TPC of varikka and koozha extracts in the current study as TPC decreased with in the concentration of ethanol from 60 to 80 per cent. The same trend of decreased TPC with increase in



Drying methods-D_1-Cabinet drying, D_2-Freeze drying; Solid to liquid ratio- R_1-1:30, R_2-1:40, R_3-1:50 Solvents-S_1-Methanol-90%, S_2-Methanol-80%, S_3-Methanol-50%, S_4-Ethanol-60%, S_5-Ethanol-80%

Figure 2. Influence of drying methods (D), solid to liquid ratio (R) and solvents (S) on Total phenolic content of jackfruit extract

concentration of ethanol from 60 to 80 per cent was observed in TPC of varikka and koozha extract.

As the solid to liquid ratio increased, there was significant increase in the TPC from 91.14 to 105.93 for varikka and 95.09 to 112.81 mg GAE $100g^{-1}$ in koozha (Fig. 2). The results obtained in the study are consistent with mass transfer principles.

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest TPC of 156.10 and 164.63 mg GAE 100 g^{-1} in varikka and koozha respectively.

5.1.3 Total Antioxidant (DPPH) Activity (%)

The DPPH scavenging activity of crude extracts of varikka and koozha was influenced by drying methods, solvent used and solid to solvent ratio (Fig. 3). The scavenging activity was highest (15 per cent) in extracts from freeze dried samples. In a study conducted on roselle (*Hibiscus sabdariffa* L.), all the extracts prepared from the freeze dried leaves showed higher DPPH scavenging activity compared to those prepared using room, sun, oven, microwave, crossflow, infrared dried samples. Increased DPPH activity is mainly attributed to the higher phenolic and flavonoid content retained by freeze drying compared to spray drying. Strong positive correlation existed between TPC and TFC and scavenging activity (Kumar *et al*., 2015).

Ethanolic extracts showed scavenging activity in the range of 52.37 to 59.04 in varikka and 52.24 to 58.69 per cent in koozha respectively. For methanolic extract, the scavenging activity ranged between 46.22 to 49.26 per cent for varikka and 44.17 to 52.76 per cent in koozha (Fig. 3). Scavenging activity observed was significantly high for 60 per cent ethanol followed by 80 per cent ethanol. Munir *et al*. (2018) studied antioxidant potential of onion waste and reported higher scavenging activity for ethanol extracts, compared to that of

methanol. Prasad *et al*. (2009) reported that, 50 per cent ethanol extract of litchi seeds showed highest DPPH radical scavenging activity, compared to the extracts *viz*., pure ethanol extract, methanol extract, 50% methanol extract and water extract.

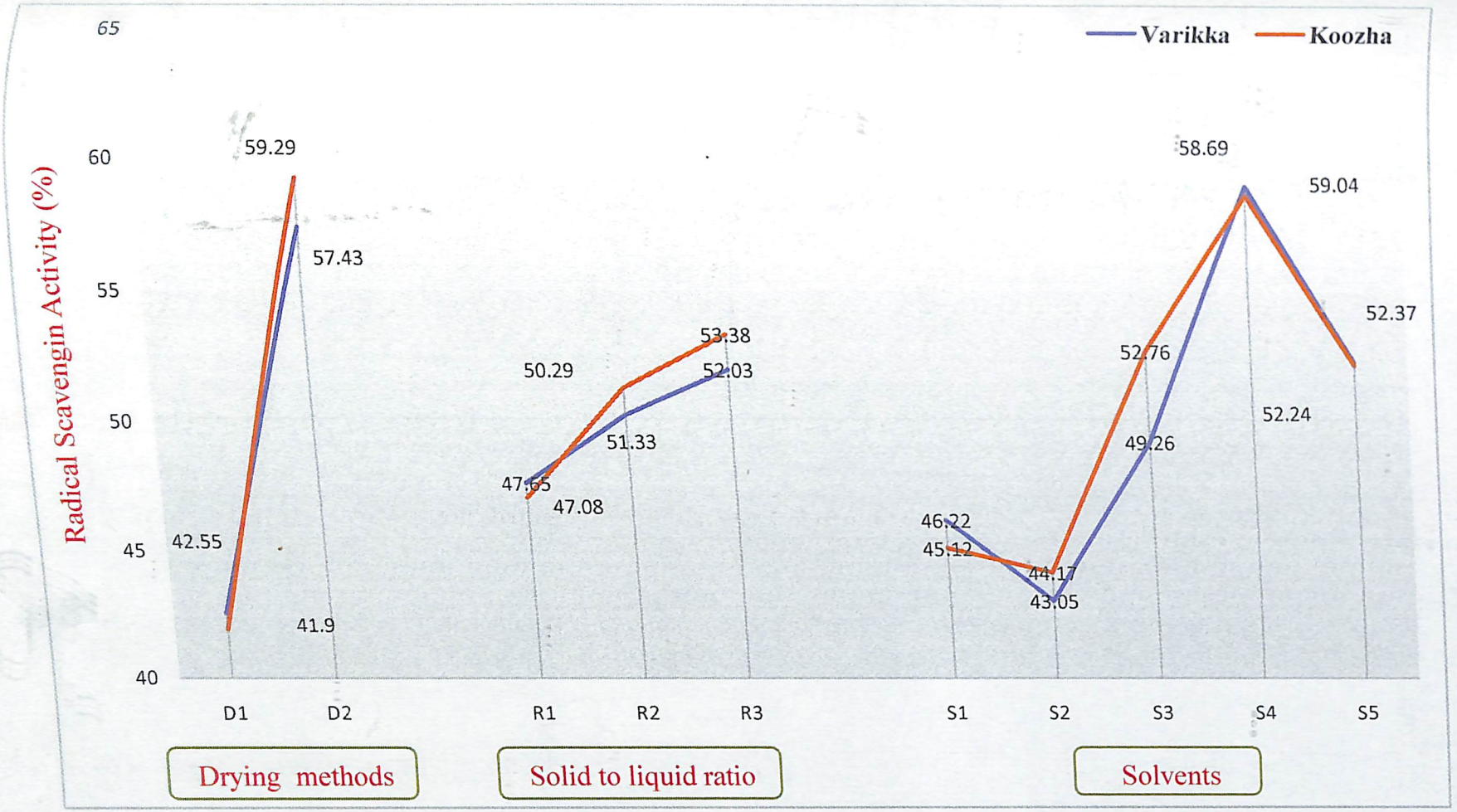
Increase in the sloid to liquid ratio from 1:30 to 1:50 showed enhancement in the DPPH scavenging activity in both varikka and koozha extracts from 47.65 to 52.03% and 47.08 to 53.38% respectively (Fig. 3). Increased antioxidant activity is mainly attributed to the higher TPC and TFC.).

Extract of freeze dried varikka and koozha samples using 60 per cent ethanol at 1:50 solid to solvent ratio had highest DPPH scavenging activity with per cent inhibition of of 69.29 and 68.64 respectively. Kumar *et al*. (2015) reported a strong positive correlation between antioxidant activity (DPPH) and phenolic compounds. Similar trend was noticed in the present study, where DPPH scavenging activity was highest in the extracts containing higher TPC and TFC.

5.1.4 Ascorbic Acid Content (mg $100g^{-1}$)

Freeze drying enhanced ascorbic acid content of extracts 1.50 to 1.52 times in varikka and koozha compared to cabinet drying (Fig. 4). Sogi *et al*. (2015) reported higher ascorbic acid content in freeze dried mango powders compared to the cabinet, vacuum, and infra-red dried powders. Nicoleti *et al*. (2007) observed ascorbic acid degradation during convective drying and found higher degradation rates at higher drying temperatures which suggests degenerative effect of temperature on ascorbic acid content.

Ascorbic acid content increased with increase in solid to liquid ratio both in varikka and koozha samples (Fig. 4). Ascorbic acid content of 35.43 and 35.80 mg 100 g^{-1} were recorded when solid to solvent ratio was 1:50 in both varikka and koozha respectively which was on par with 1:40 (35.34 mg $100g^{-1}$).



Drying methods-D_1-Cabinet drying, D_2-Freeze drying; Solid to liquid ratio- R_1-1:30, R_2-1:40, R_3-1:50 Solvents-S_1-Methanol-90%, S_2-Methanol-80%, S_3-Methanol-50%, S_4-Ethanol-60%, S_5-Ethanol-80%

Figure 3. Influence of drying methods (D), solid to liquid ratio (R) and solvents (S) on Antioxidant (DPPH) activity of jackfruit extracts

Drying methods-D_1-Cabinet drying, D_2-Freeze drying; Solid to liquid ratio- R_1-1:30, R_2-1:40, R_3-1:50 Solvents-S_1-Methanol-90%, S_2-Methanol-80%, S_3-Methanol-50%, S_4-Ethanol-60%, S_5-Ethanol-80%

Figure 4. Influence of drying methods (D), solid to liquid ratio (R) and solvents (S) on Ascorbic acid content (mg $100g^{-1}$) of jackfruit extracts

Extracts prepared using 90 per cent methanol contained highest ascorbic acid content compared to other extracts (Fg. 4). Freeze dried varikka samples extracted using 90 per cent methanol at 1:50 solid solvent ratio ($D_2S_1R_3$) recorded the highest (45.88 mg $100g^{-1}$) ascorbic acid content and freeze dried koozha samples extracted using 90% methanol at 1:40 solid solvent ratio ($D_2S_1R_2$) had the highest ascorbic acid content of 47.37 mg $100g^{-1}$.

5.1.5 α-glucosidase Inhibition

α- glucosidase inhibition activity of crude extracts of varikka and koozha were influenced by drying methods, solvents used and solid to solvent ratio (Table 11 and 12). Extract from freeze dried samples of varikka and koozha inhibited 66.95 and 70.49 per cent respectively (Fig. 5). Increased enzyme inhibition activity observed in the freeze dried extracts is mainly attributed to the higher content of TPC and TFC retained in the freeze dried samples.

Solvents used in the study also showed significant difference in enzyme activity (Fig 5). Ethanolic extract (60%) from varikka and koozha samples inhibited enzyme activity 1.75 and 1.70 times more compared to extracts obtained using 90% methanol. Ivanov *et al*. (2022) reported that, extract of *Salvia nemorosa* using ethanol : water 50:50 had highest α-glucosidase inhibition activity with lowest $IC_{50,}$ compared to ethanol 100%, ethanol : water 90:10 and 70:30. In the current study also, the enzyme inhibition activity was higher in 60% ethanol (varikka-82.73 and koozha-83.01%), compared to 80% ethanol (varikka- 76.57 and koozha78.63).

Solid to solvent ratio also influenced the α- glucosidase inhibition activity significantly. Increase in the enzyme inhibition activity found at higher solid to solvent ratio of 1:50 is mainly attributed to higher TPC and TFC of the extract.

The interaction effects across all the three factors revealed that, the freeze dried samples extracted using 60% ethanol at 1:50 solid liquid ratio ($D_2S_4R_3$) recorded the significantly highest α- glucosidase inhibition activity of 90.24 and

92.28 per cent in varikka and koozha respectively. Correlation between the IC_{50} value of extrcts $D_1S_4R_3$, $D_2S_4R_2$, and $D_2S_4R_3$ from varikka and koozha revealed, a very strong negative correlation between TFC (varikka-0.906 koozha-0.99) and TPC (varikka-0.968 koozha-0.985) of the extracts (Table 94).

5.1.6 Anti-cancerous Properties

Based on the efficiency and economics, extraction of freeze dried samples using 60% ethanol at 1:40 solid to solvent ratio ($D_2S_4R_2$), similar samples using 60% ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) and cabinet dried samples with 60% ethanol at 1:50 solid to solvent ratio ($D_1S_4R_3$) were selected as three superior extraction methods.

The three selected extracts (based on TPC, TFC, DPPH activity and α-glucosidase inhibition activity) were tested on HeLa cell lines with Doxorubicin as control (Fig. 6). Freeze dried varikka and koozha samples extracted in 60 percent ethanol at 1:50 solid to solvent ratio had lowest IC_{50} value of 129.30 and 157.58 µg/mL respectively (Table 13). Negative correlations were found between higher TPC (varikka-0.693 and koozha-0.648) and TFC (varikka-0.993 of extracts and koozha-0.785) lower IC_{50} values (Table 94). Though the IC_{50} value for Doxorubicin is comparatively low (18.85 µg/mL), plant based anti-proliferative agents are preferred over synthetic drugs owing to their safety and lower side effects. In a study conducted with peel extracts of five varieties of mango, significant inhibition in the growth of HeLa cells, and a decrease in the number of viable cells in a dose-dependent manner was reported (Ali *et al.*, 2012). The growth inhibition in HeLa cells and decrease in the number of viable cells by the cytotoxicity caused by the different extracts can be seen in the plates (Plates 9 to 12).

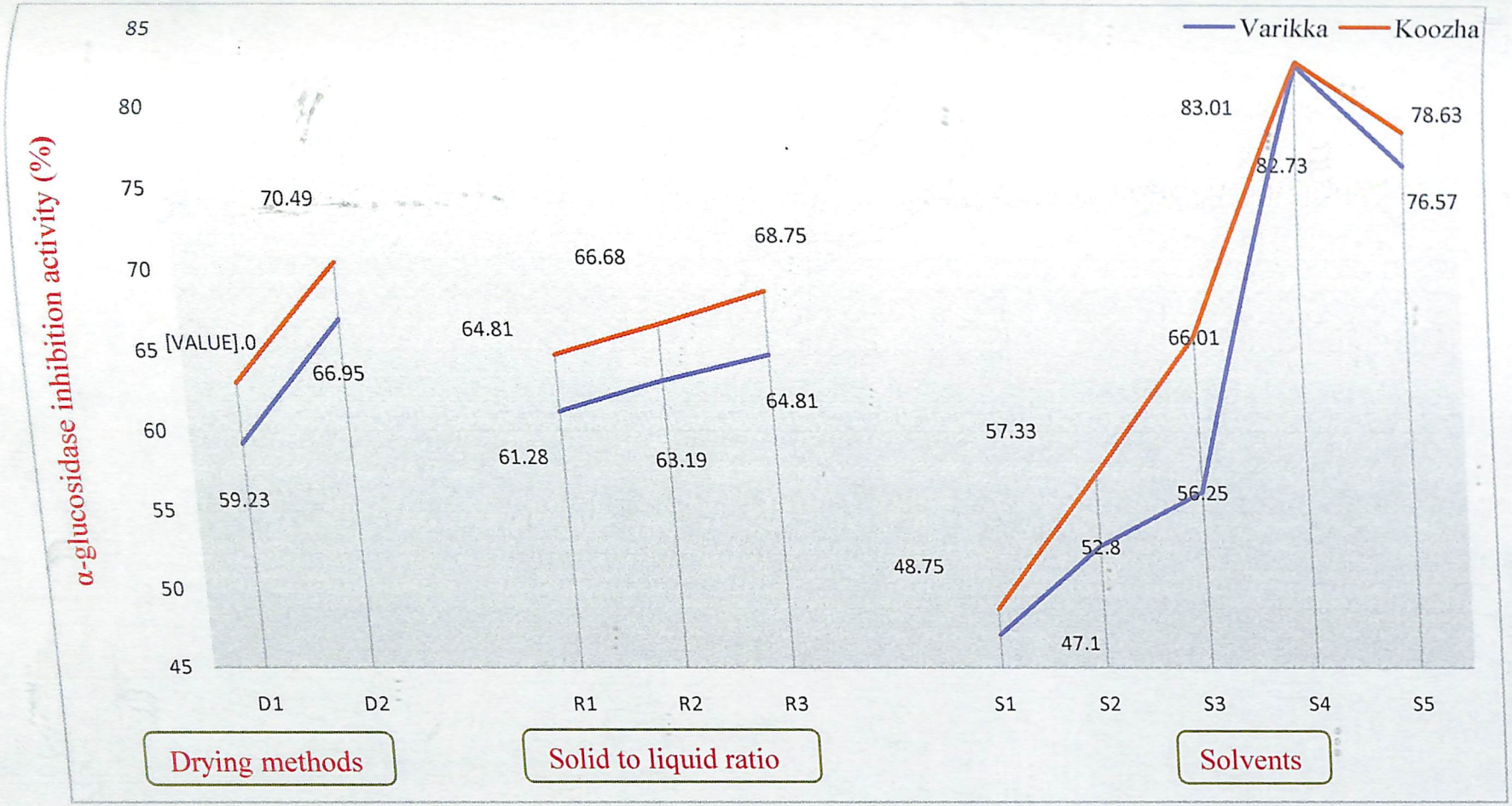
5.2 PHYTOCHEMICAL PROFILING

The phytochemical profile of varikka and koozha extracts was characterized by using LCMS/MS (Waters UPLC H class system fitted with TQD

Table 94. Correlation between TFC and TPC of extracts with α-glucosidase and MTT assay

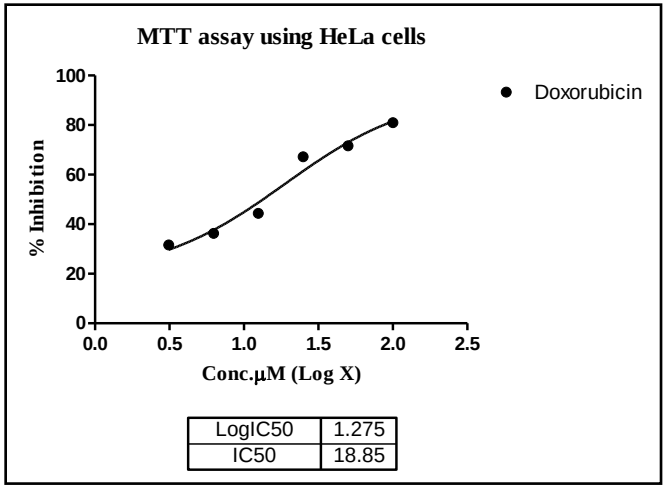
Extracts	IC_{50} value of α-glucosidase ($mg\ mL^{-1}$)		Extracts	IC_{50} value of MTT assay on HeLa cell line ($\mu g\ mL^{-1}$)	
	Varikka	Koozha		Varikka	Koozha
$D_1S_4R_3$	1.00	0.97	$D_1S_4R_3$	901.8	501.65
$D_2S_4R_2$	0.83	0.81	$D_2S_4R_2$	861.2	539.35
$D_2S_4R_3$	0.70	0.73	$D_2S_4R_3$	129.3	157.58
Acarbose	0.64	0.64	Doxorubicin	18.85	18.85
CD (0.05)	0.01	0.02		3.27	8.71
Pearsón TFC	-0.906	-0.99		-0.993	-0.785
Pearson TPC	-0.968	-0.985		-0.693	-0.648

Pearson's correlation coefficient strength value: Weak = 0.2–0.39; moderate = 0.4–0.59; Strong = 0.6–0.79; Very strong = 0.8–1.0.

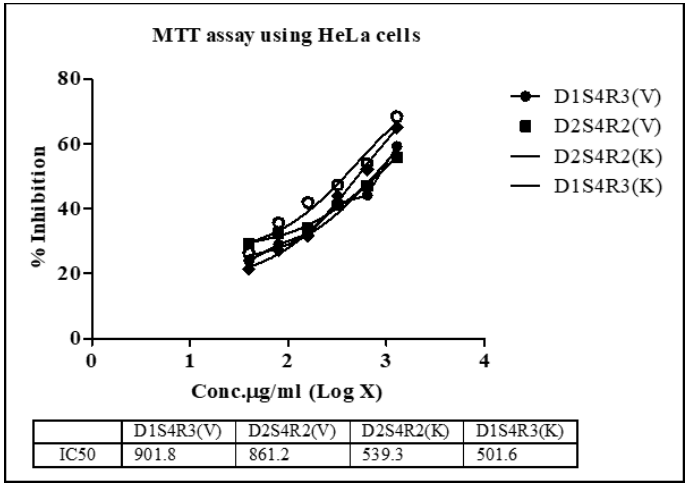


Drying methods-D_1-Cabinet drying, D_2-Freeze drying; Solid to liquid ratio- R_1-1:30, R_2-1:40, R_3-1:50 Solvents-S_1-Methanol-90%, S_2-Methanol-80%, S_3-Methanol-50%, S_4-Ethanol-60%, S_5-Ethanol-80%

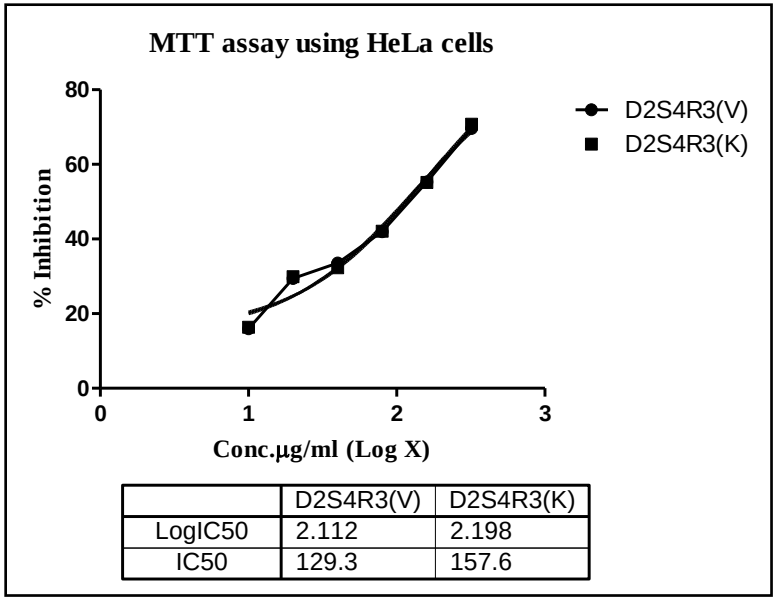
Figure 5. Influence of drying methods (D), solid to liquid ratio (R) and solvents (S) on α- glucosidase enzyme inhibition (AGI) activity (%) of jackfruit extracts



LogIC50	1.275
IC50	18.85

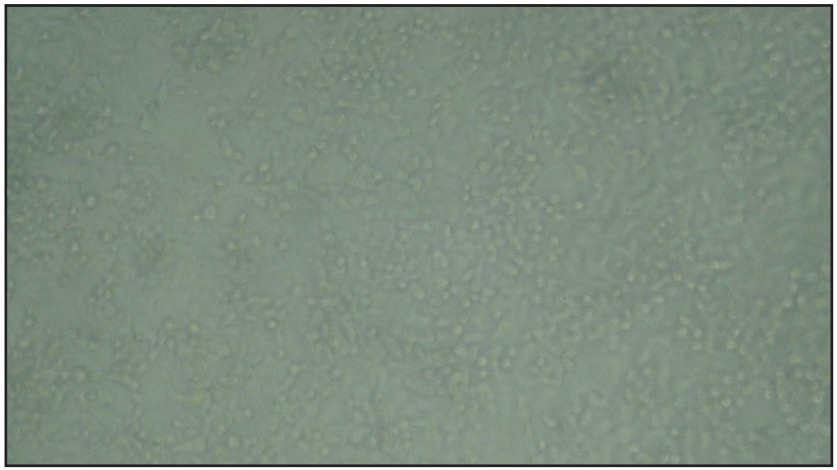


	D1S4R3(V)	D2S4R2(V)	D2S4R2(K)	D1S4R3(K)
IC50	901.8	861.2	539.3	501.6

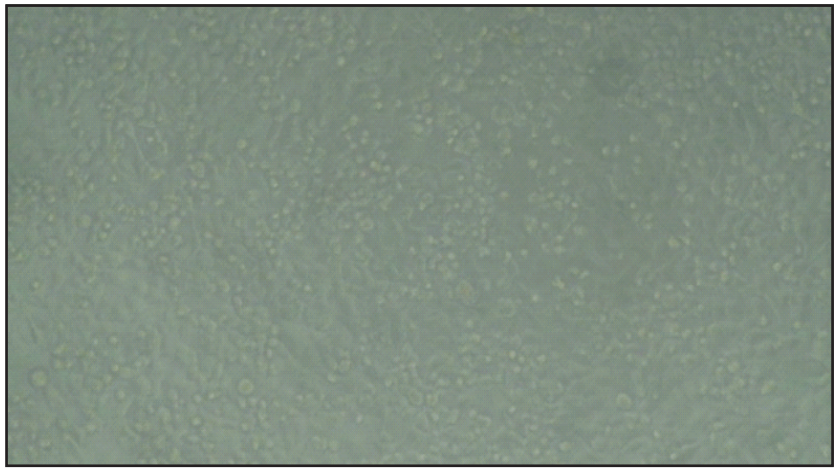


	D2S4R3(V)	D2S4R3(K)
LogIC50	2.112	2.198
IC50	129.3	157.6

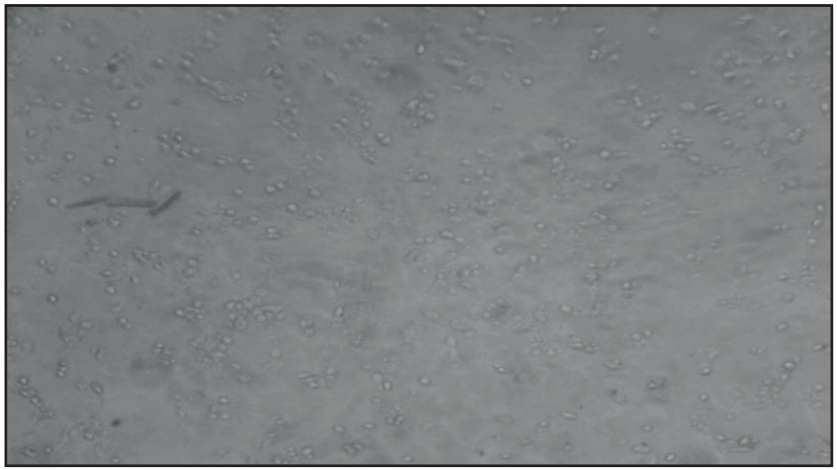
Figure6. Per cent inhibition of HeLa cell lines as influenced by jackfruit extracts



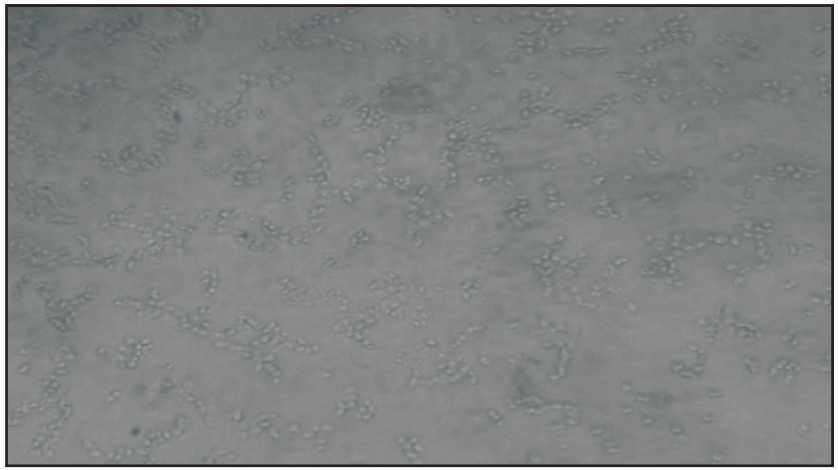
Control (IC_{50} 18.85 µg/mL)



Extract $D_1S_4R_3$ (IC_{50} 901.80 µg/mL)



Extract $D_2S_4R_2$ (IC_{50} 861.20 µg/mL)



Extract $D_2S_4R_3$(IC_{50} 129.30 µg/mL)

Plate 9. Cytotoxicity effect of selected jackfruit (varikka) extracts on HeLa cell lines

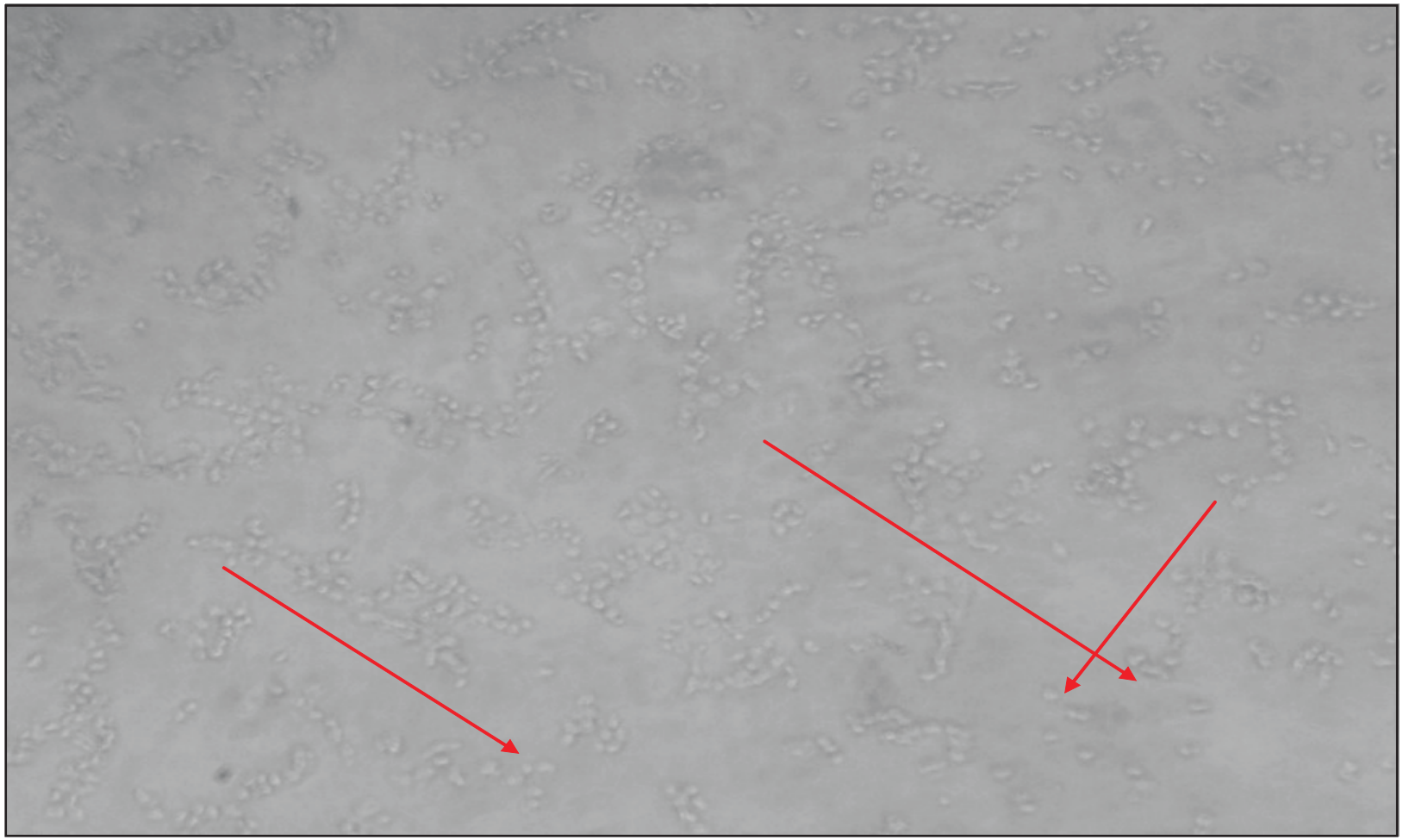
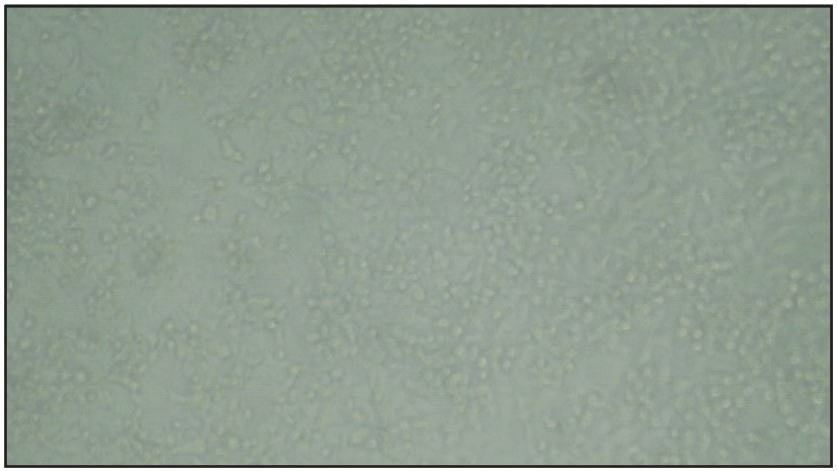
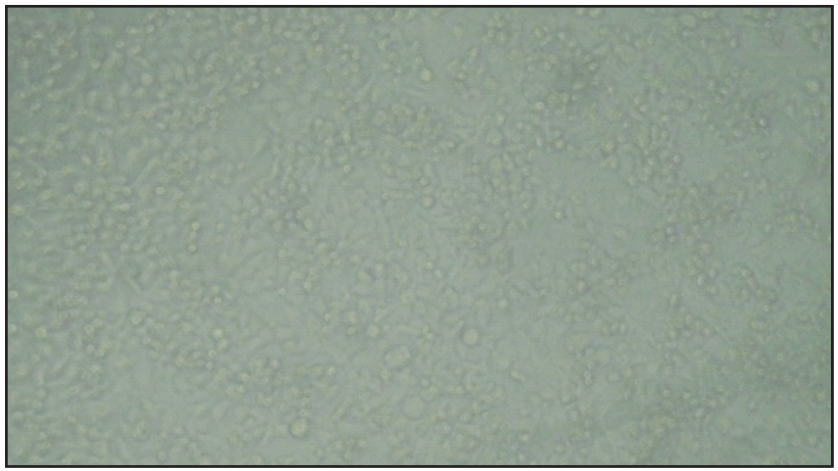


Plate 10. Cytotoxicity effect of varikka extract $D_2S_4R_3$ on HeLa cell lines



Control (IC_{50} 18.85 µg/mL)



Extract $D_1S_4R_3$ (IC_{50} 501.60 µg/mL)

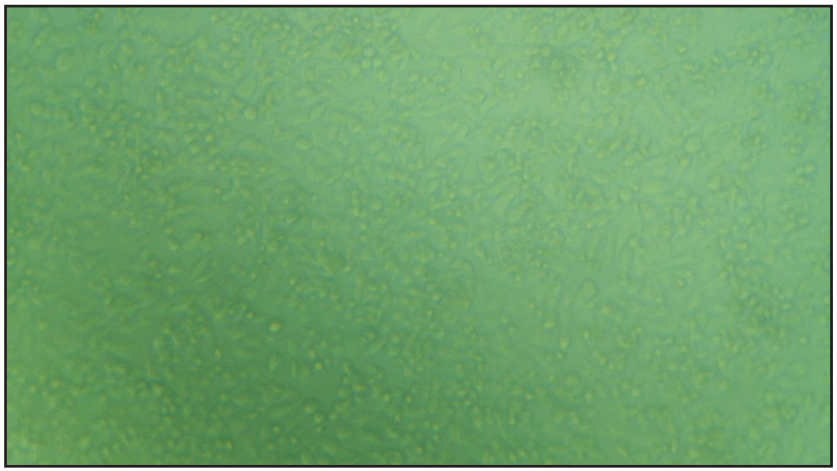
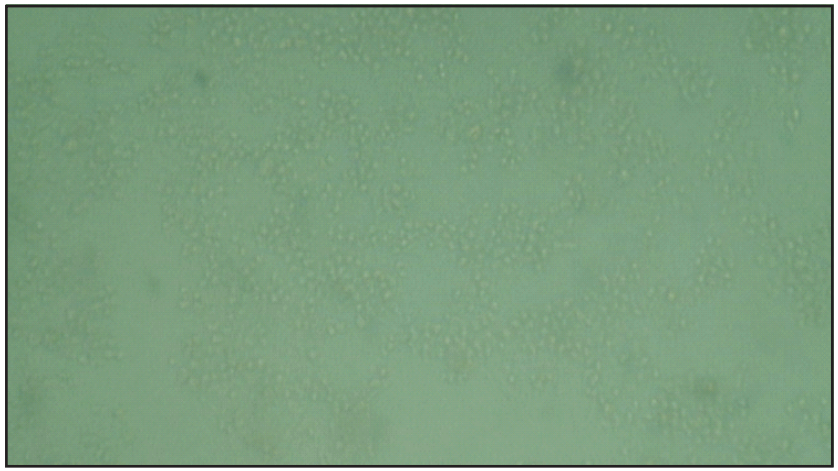


Plate 3. Extract $D_2S_4R_2$ (IC_{50} 861.20 µg/mL)



Extract $D_2S_4R_3$ (IC_{50} 157.60 µg/mL)

Plate. 11 Cytotoxicity effect of selected jackfruit (koozha) extracts on HeLa cell lines

Plate. 12 Cytotoxicity effect of koozha extract $D_2S_4R_3$ on HeLa cell lines

MS/MS system) to explore the presence of possible functional compounds. Three superior extracts selected from part-I of the experiment *viz*., $D_1S_4R_3$ (Cabinet dried samples extracted with 60% ethanol at 1:50 solid to solvent ratio) $D_2S_4R_2$ (Freeze dried samples extracted with 60% ethanol at 1:40 solid to solvent ratio) and $D_2S_4R_3$ (Freeze dried samples extracted with 60% ethanol at 1:50 solid to solvent ratio) were analysed for sugars, organic acids, phenolic acids and flavonoids.

5.2.1. Profiling of Sugars (mg g^{-1} DW)

Sugars were extracted by following the methods by Steppuhn and Wackers, (2004) with suitable modifications. Total fifteen sugars were fractionated and identified. Though the individual sugar content differed with respect to types of jackfruit (varikka and koozha) and extracts, all the identified sugars were present in all the extracts. Major sugars identified were fructose, glucose, mannose, sorbitol and sucrose. Sugars which were found in comparatively small quantities were xylose, lactose, trehalose, fucose and rhamnose (Fig. 7 and 8).

Jackfruit types differed significantly for their individual sugar content. Extract from varikka recorded higher glucose and sucrose content compared to koozha extract, whereas all the other sugars were high in koozha extract compared to varikka extracts.

All the sugars were found in highest quantities in the extract, $D_2S_4R_3$. Varikka extract $D_2S_4R_3$ contained highest fructose, while sucrose content was highest in varikka extract $D_1S_4R_3$. All the remaining sugars were highest in the koozha extract $D_2S_4R_3$. Among the extracts of varikka, $D_1S_4R_3$ contained highest maltose and lactose whereas other sugars were highest in the extract $D_2S_4R_3$. For koozha extract all the sugars were found highest in the extract $D_2S_4R_3$.

5.2.2 Profiling of Organic Acids (mg g^{-1} DW)

Organic acids are natural compounds in fruits and vegetables. The nature and concentration of the organic acids in fruits are of interest because of their

influence on the organoleptic properties and stability of fruit juices. The extraction procedure for organic acids was followed as per Ribeiro *et al*. (2007) and were fractionated and identified by TQD-MS/MS (Waters, USA) system. Ten organic acids were fractionated and identified from both the jackfruit types and all the organic acids were present in all the three extracts.

Citric acid, malic acid, shikimic acid, succinic acid, hydroxycitric acid, malonic acid and pyruvic acid were found in higher quantity in varikka extracts, whereas tartaric acid, fumaric acid and maleic acid were present in koozha extracts. All the organic acids were highest in $D_2S_4R_3$ (Fig. 9 and 10).

$D_2S_4R_3$ of varikka recorded highest citric acid, succinic acid, malonic acid and pyruvic acid. Malic acid, tartaric acid and fumaric acid were highest in $D_2S_4R_3$ of koozha.

Zhang *et al*. (2017) fractionated peel extract of jackfruit and identified 8 organic acids *viz*., naphthalenedicarboxylic acid, quinic acid, malic acid, quinic acid isomers, citric acid, [5-glucopyranosyloxy-2- oxo-2,3-dihydro-1H-indol-3-yl]acetic acid, resorcylic acid-O-hexosid, hydroxycaproic acid-O-hexoside. In the current study, in all the extracts from varikka and koozha malic acid and citric acid were also identified.

5.2.3 Phenolic Compounds (µg g^{-1} DW)

Phenolic compounds are the secondary metabolites which are widely found in plants and plant derived foods. Several analytical methods are available for detection of the phenolic compounds. Most of the times, these phenolic compounds are analyzed by High Performance Liquid Chromatography (HPLC) (Giusti *et al*., 1999; Vagiri *et al*., 2012), coupled with diode array detector and mass spectrometer (Revilla *et al*., 1999).

In the present investigation, eighteen phenolic compounds were identified by comparing their retention times and mass spectra with respective standards. It

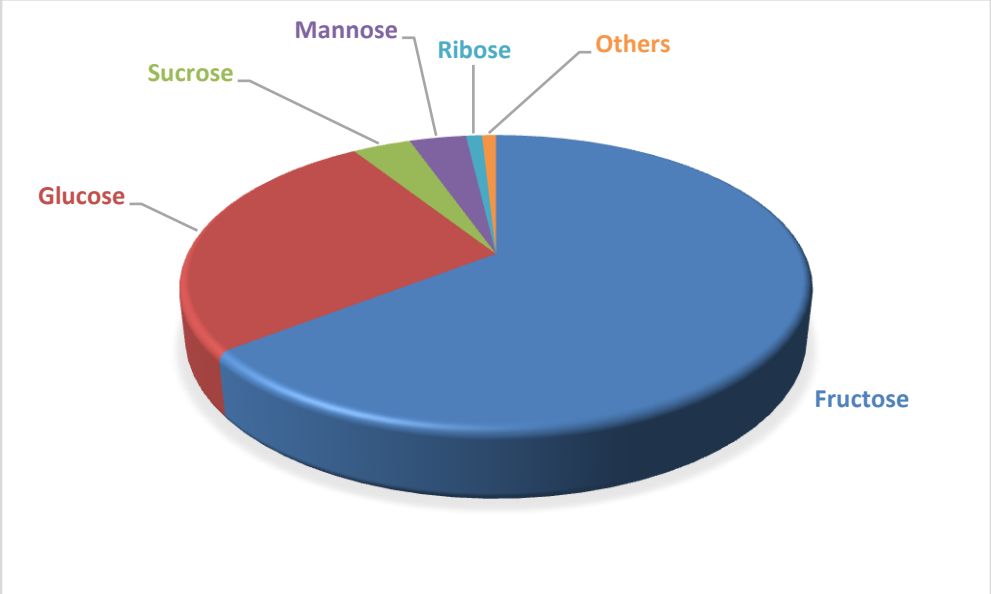


Figure 7. Profiling of sugars of varikka extracts

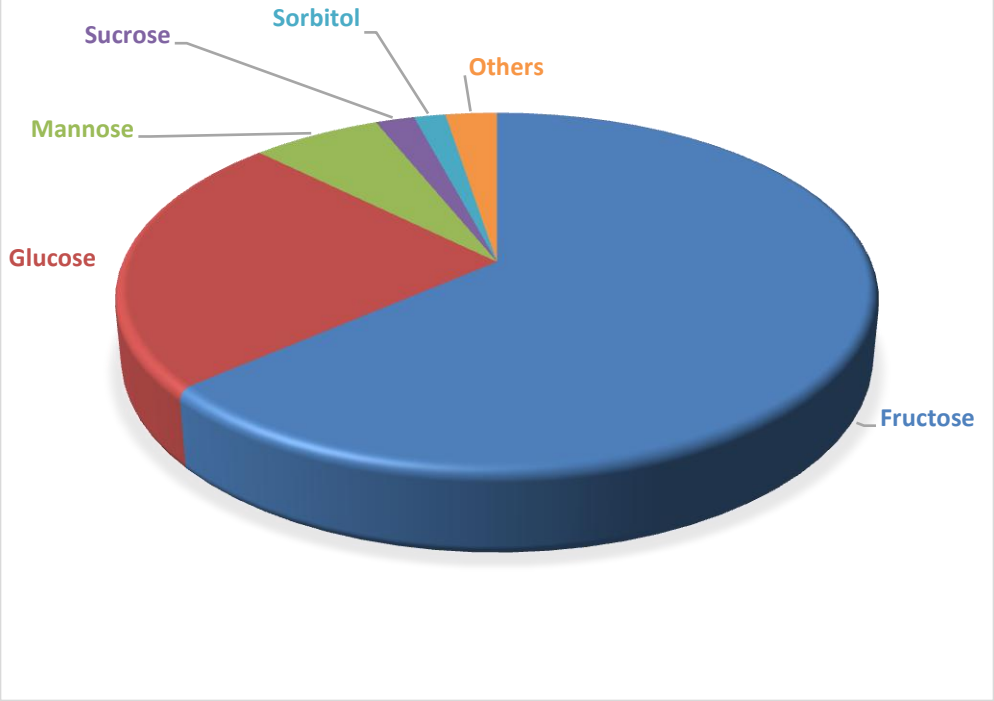


Figure 8. Profiling of sugars of koozha extracts

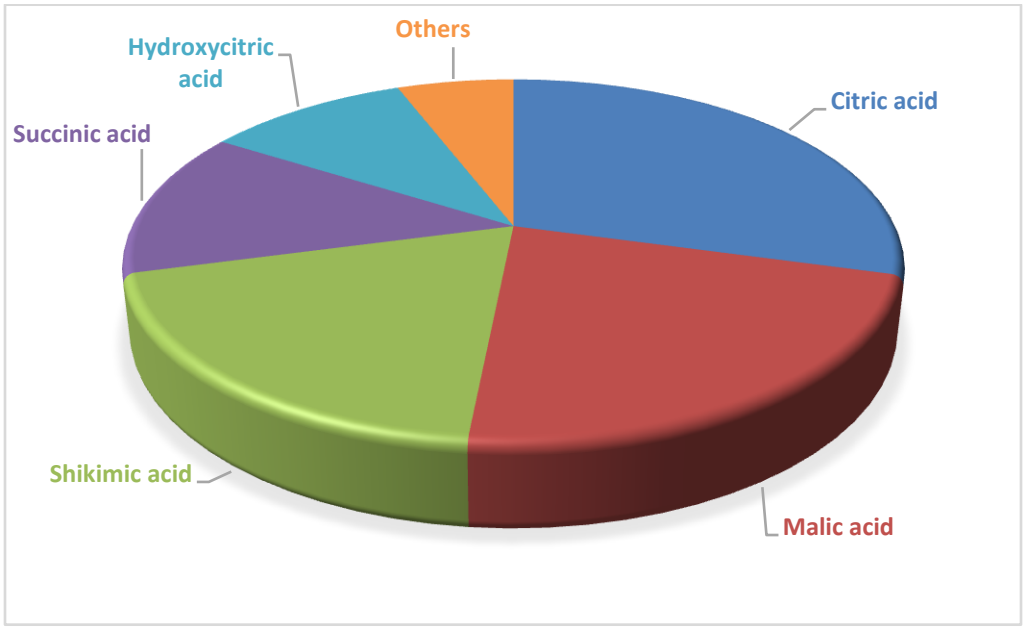


Figure 9. Profiling of organic acids of varikka extracts

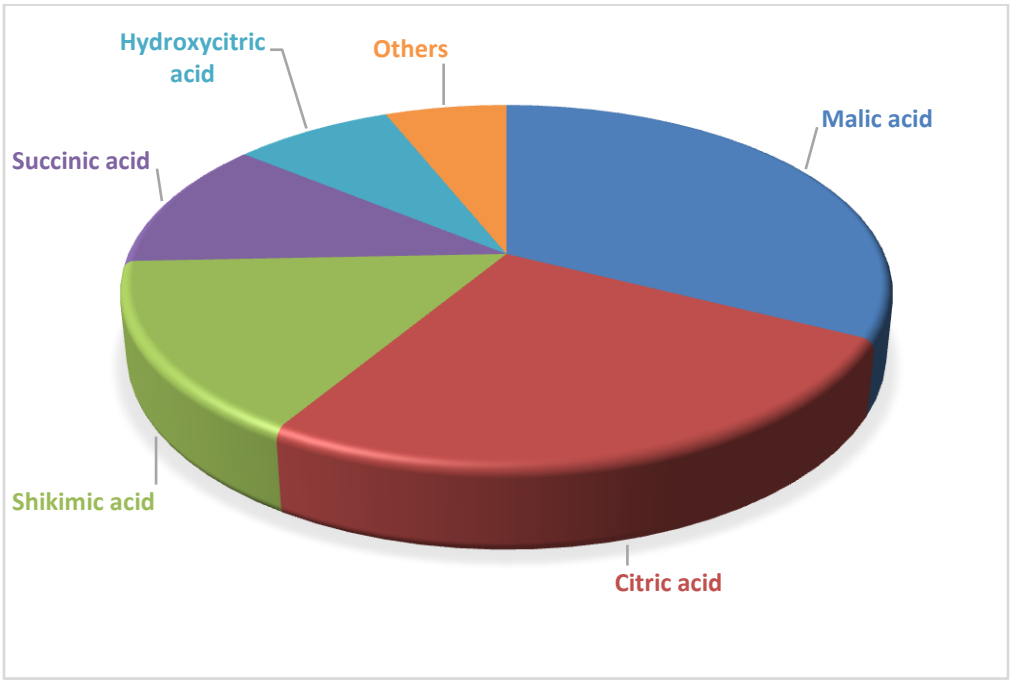


Figure10. Profiling of organic acids of koozha extracts

is apparent from mean values that phenolic acids *viz.,* ferulic acid, gentisic acid, p-Coumaric acid, 2,4-dihydroxybenzoic acid, caffeic acid, and *o*-coumaric acid, benzoic acid were abundant in varikka extract while p-Hydroxy benzoic acid, sinapic acid, syringic acid, ellagic acid and chlorogenic acid were limited (Table 24 to 29). In the extracts from koozha, ferulic acid, *p*-coumaric acid, benzoic acid, o-coumaric acid, 2,4-dihydroxybenzoic acid were found in higher concentration, whereas p-Hydroxy benzoic acid, sinapic acid, syringic acid, ellagic acid and chlorogenic acid were found in meagre quantity (Fig. 11 and 12).

Two types of jackfruits used in the study differed significantly for the quantity of individual phenolic acid contents in the extracts. Varikka extracts contained highest ferulic acid, 2,4-dihydroxybenzoic acid, Gentisic acid, Gallic acid, t-Cinnamic acid, 3-Hydroxy benzoic acid, Sinapic acid, Syringic acid and Ellagic acid while koozha extracts contained highest p-Coumaric acid, Caffeic acid, Benzoic acid, o-Coumaric acid, Vanillic acid, Salicylic acid, Protocatechuic acid and Chlorogenic acid.

It is clear from the HPLC-MS/MS analysis that individual phenolic acids were positively correlated with total phenolic contents of the extracts. Extracts prepared from freeze dried sample with 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) had highest total phenolic content, with highest ferulic acid, p-oumaric acid, caffeic acid, benzoic acid, 2,4-dihydroxy benzoic acid, gentisic acid, vanillic acid, etc. Salicylic acid was highest in the extract prepared from freeze dried samples extracted with 60 per cent ethanol at 1:40 solid to solvent ratio ($D_2S_4R_2$) and extract prepared using cabinet dried ample with 60 per cent ethanol at 1:50 solid to solvent ratio ($D_1S_4R_3$) contained higher ellagic acid. Chlorogenic acid was found to be equal in the extracts $D_2S_4R_3$ and $D_1S_4R_3$.

The individual phenolic acid content was significantly different among the extracts and between the types of jackfruit (varikka and koozha) and is depicted in Table 24 to 29. Ferulic acid, gentisic acid, 2,4-dihydroxybenzoic acid, t-Cinnamic acid, Protocatechuic acid, sinapic acid, syringic acid, 3-Hydroxy benzoic acid and

p-Hydroxy benzoic acid were found highest in the varikka extract $D_2S_4R_3$, while p-Coumaric acid, caffeic acid, benzoic acid, o-Coumaric acid, vanillic acid gallic acid were found highest in koozha extract $D_2S_4R_3$. Salicylic acid was highest in the varikka extract of $D_2S_4R_2$, ellagic acid content in varikka extract of $D_1S_4R_3$ and chlorogenic acid in the koozha extract of $D_1S_4R_3$.

In a study conducted by Zhang *et al*. (2017), the phytochemical profile of jackfruit peel extract was characterized using HPLC-QTOF-MS/MS. A total of 9 hydroxycinnamic acids and 3 hydroxycoumarins were detected in sample, including 6 caffeoylquinic acid (CQA) isomers , a 3,4-dihydroxybenzoic acid methyl ester-C-dihexoside, a feruloylglucose , a caffeoylglucose and 3 esculetin glycosides. In the current study also, in all the extracts p-Coumaric acid, o-Coumaric acid, t-Cinnamic acid, 2,4-dihydroxybenzoic acid, 3-Hydroxy benzoic acid, and benzoic acid were fractionated and identified. Daud *et al.* (2017) conducted phytochemical profiling of jackfruit rind and rachis extracts by LCMS in the negative mode. Gluconic acid, vaccihein A, stachyose hydrate were identified in peak a, quinic acid (peak b), pyromeconic acid and comenic acid (peak c), protocatechuic acid (peak d), quincic acid and chlorogenic acid in peak e. In the current study also protocatechuic acid and chlorogenic acid were identified apart from other phenolic compounds.

Daud *et al.* (2017) reported difference in the antioxidant activity of the crude extracts of different inedible parts *viz*., rind and rachis which differed with respect to extraction methods and solvents. Apart from total phenolic content, quantity of protocatechuic acid and chlorogenic acid in the extracts influenced the DPPH scavenging activity. These compounds are known as natural antioxidant agents that scavenges free radical with an IC_{50} of 1.88 lg/ml, as reported by Li *et al*. (2019). Apart from higher protocatechuic acid, extract $D_2S_4R_3$ from varikka and koozha, also contained higher ferulic acid, p-Coumaric acid and caffeic acid showing highest scavenging activity with per cent inhibition of 69.29 and 68.64 respectively. Between the types, extract from varikka showed higher DPPH scavenging

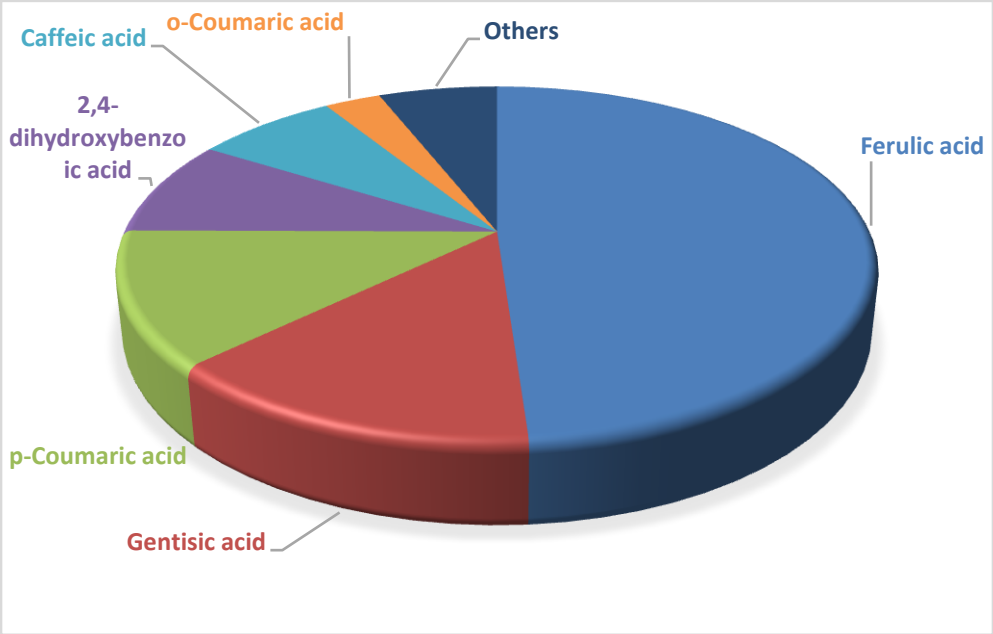


Figure11. Profiling of phenolic acids of varikka extracts

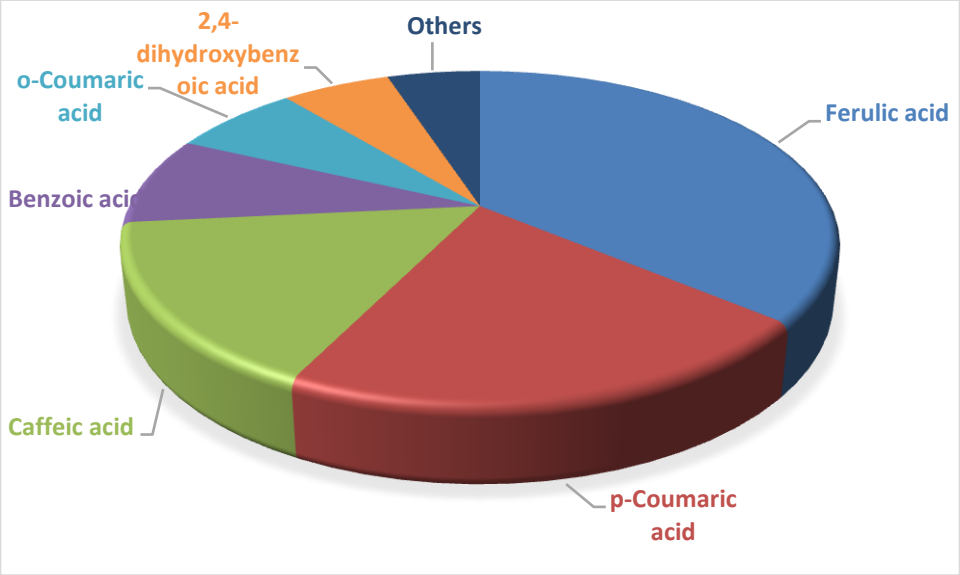


Figure12. Profiling of phenolic acids of koozha extracts

activity compared to koozha which may be attributed to higher content of protocatechuic acid and ferulic acid compared to koozha.

Benalla *et al*. (2010) reported, gallic acid and methyl gallate extracted from *Terminalia superba* had higher α glucosidase inhibition activity compared to other phenolic compounds. They had also studied extracts of 11 known compounds obtained from methanolic extracts of *Cichorium intybus* and reported that cichoridiol, intybusoloid and vanillic acid had higher glucosidase inhibition activity. Koozha extract $D_2S_4R_3$ recorded highest α glucosidase inhibition activity compared to varikka extract. Koozha extract $D_2S_4R_3$ contained highest vanillic acid and gallic acid (apart from highest TPC) compared to varikka extract. This confirms higher α glucosidase inhibition activity of koozha ($D_2S_4R_3$) compared to varikka extract $D_2S_4R_3$ and other extracts.

The extracts *viz.,* $D_1S_4R_3$, $D_2S_4R_2$ and $D_2S_4R_3$ from varikka and koozha were tested on HeLa cell lines to assess the cytotoxicity effect. The extracts exhibited a dose dependent inhibition against the cell viability and proliferation. Significantly highest anti proliferative activity was exerted by the extract $D_2S_4R_3$ compared to $D_2S_4R_2$ and $D_1S_4R_3$. The extracts $D_2S_4R_3$ from varikka and koozha had the lowest IC_{50} value of 129.30 and 157.58 µg mL^{-1} compared to $D_2S_4R_2$ and $D_1S_4R_3$. Anti-proliferative property of the extract was found to be significantly highest in the extracts with highest TPC. However, koozha extract $D_2S_4R_3$ in spite of having highest TPC, had higher IC_{50} value compared to varikka extract. The difference in the cytotoxicity level between the varikka and koozha extract $D_2S_4R_3$ may be mainly attributed to presence of particular phenol in the extract. Ferulic acid content of the varikka extract $D_2S_4R_3$ was significantly highest, compared to koozha extract. Presence of higher ferulic acid might have contributed to the higher cytotoxicity effect, which in turn is responsible for lower IC_{50} values. LCMS MS/MS analysis of the extract showed presence of ferulic and caffeic acid in the extract which is attributed mainly to the enhanced anti proliferative effect on HeLa cell lines. The koozha extract $D_1S_4R_3$ (501.65 µg/ml) had lower IC_{50} value compared to the extract $D_2S_4R_2$ (539.35 µg/ml), even though the latter

contained higher TPC (154.09 mg GAE 100 $g^{-1)}$ compared to the former (164.63 mg GAE 100 $g^{-1)}$. Presence of higher ferulic acid content in the extract $D_1S_4R_3$ might have contributed to the higher cytotoxicity effect on HeLa cell lines. Gao *et al*. (2018) reported inhibitory effect of ferulic acid on human Hela and Caski cervical cancer cells and recommended that it might act as an anti-cancer drug through inhibiting the autophagy and inducing cell cycle arrest in human cervical carcinoma cells. The research findings provides a theoretical basis for the treatment of human cervical cancer using ferulic acid. This study confirms the findings of our study conducted on HeLa cell lines.

5.2.4 Flavonoids (µg g^{-1} FW)

In the present investigation, flavonoids were recorded in very small amounts compared to individual phenolic compounds. The perusal of mean values indicated that major flavonoids found in both varikka and koozha extrcts were myricetin, catechin, naringenin, epicatechin, quercetin and luteolin, whereas fisetin, kaemperol, galangin, umbelliferone and eriodictyol were found in meagre quantity. Fractionation and identification of flavonoid revealed that both the extracts from varikka and koozha contained all the fifteen flavonoids and identified but the quantity of individual flavonoids differed with respect to types. Extract from varikka contained higher content of myricetin, catechin, Epicatechin, quercetin, luteolin, rutin, hesperetin, kaemperol umbelliferone and eriodictyol compared to koozha, whereas koozha extract contained higher naringenin, epigallocatechin, apigenin, fisetin, and galangin (Fig. 13 and 14).

Considering the mean values of extracts, it was observed that, $D_2S_4R_3$ was found to contain highest individual flavonoids, except for galangin which was found highest in the extract, $D_1S_4R_3$.

Varikka extract $D_2S_4R_3$ was found to contain highest myricetin, catechin, epicatechin, quercetin, luteolin, rutin, fisetin, umbelliferone, eriodictyol. Extract $D_2S_4R_3$ of koozha had highest naringenin, epigallocatechin, hesperetin, apigenin and kaemperol. Galangin was highest in the koozha extract $D_1S_4R_3$. Zhang *et al*.,

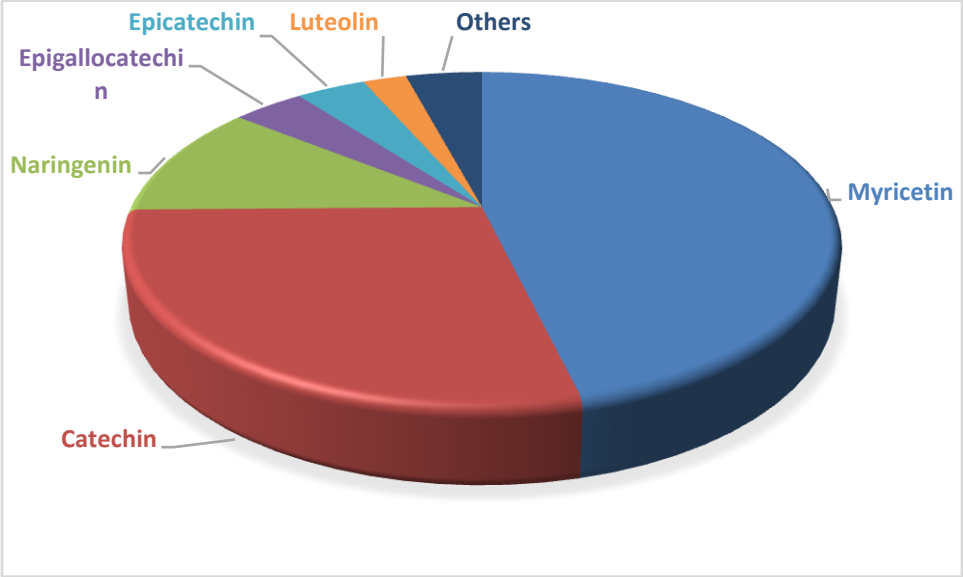


Figure13. Profiling of flavonoid of varikka extracts

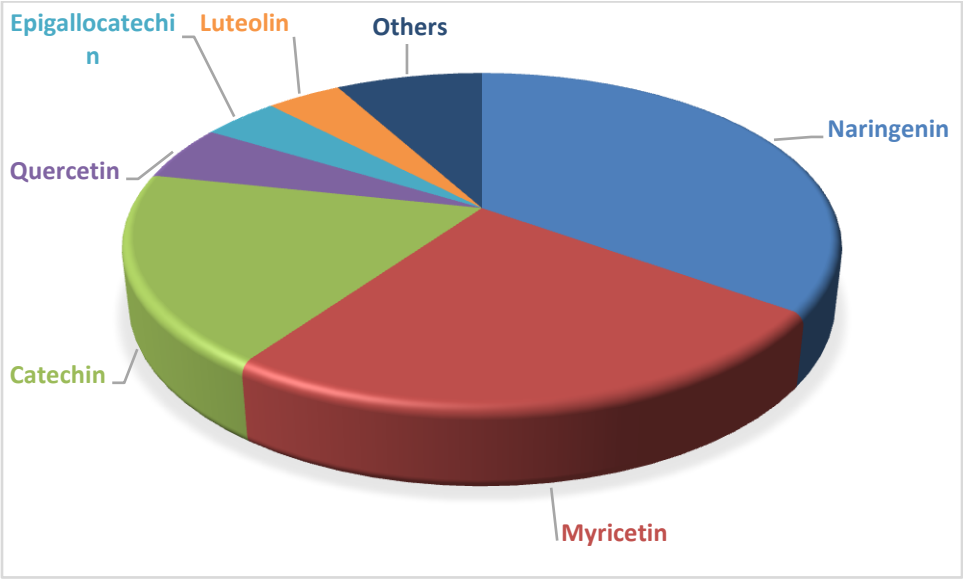


Figure14. Profiling of flavonoid of koozha extracts

(2017), identified eighteen individual flavonoids by HPLC-QTOF-MS/MS among which, epicatechin, catechin, quercetin and naringein were reported in all the three extracts of both varikka and koozha.

The crude extracts of jackfruit differed significantly for DPPH scavenging activity. The scavenging activity of the extract $D_2S_4R_3$ was found to be highest among all the extracts which also contained highest TFC. Extract $D_2S_4R_3$ which contained higher TFC also showed higher antioxidant activity (contained also highest TPC) compared to other extracts. Hidalgo *et al*. (2010) studied Flavonoid–flavonoid (individual) interaction and its effect on their antioxidant activity and concluded that, there were both synergistic and antagonistic interactions between flavonoids that may explain the results obtained when measuring the antioxidant effect of whole food/extracts. Presence of individual higher flavonoids itself is not sufficient, instead their interaction with other flavonoids whether, synergetic or antagonistic, is also going to influence the DPPH scavenging activity. This explains why the DPPH scavenging activity of the extracts did not increase in proportion to the content of individual flavonoids. Hidalgo *et al*. (2010) also reported synergistic interactions between myricetin and kaempferol. In the current study, higher DPPH scavenging activity noticed in the varikka extract $D_2S_4R_3$, contained higher myricetin content compared to koozha, explaining a higher scavenging activity of the extract.

Li *et al*. (2019) studied the influence of three novel flavonoids and ten analogues obtained from *Hippophae rhamnoides* subsp. *sinensis* seed extract on α glucosidase inhibition activity and reported kaempferol and 70 per cent ethanolic elution fraction showed prominent α-glucosidase inhibitory activities. In the current study also koozha extract $D_2S_4R_3$ which contained a higher kaempferol content had recorded highest α-glucosidase inhibition activity.

Extract $D_2S_4R_3$ of varikka, which contained higher quercetin content, had recorded lower IC_{50} value compared to koozha extract $D_2S_4R_3$ and other extracts. This confirms lower IC_{50} value recorded for cytotoxicity on HeLa cell lines as

compared to koozha extract $D_2S_4R_3$ even though the latter had higher TFC. Wang *et al*. (2016) reported, quercetin can induce apoptosis and protective autophagy in HeLa cells at low concentrations.

5.3 ENCAPSULATION OF EXTRACTS

Encapsulation of the following three superior jackfruit extracts was done independently by spray and freeze drying using maltodextrin as carrier (Plate 13).

Cabinet dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio ($D_1S_4R_3$)

Freeze dried samples extracted with 60% ethanol in 1:40 solid to solvent ratio ($D_2S_4R_2$)

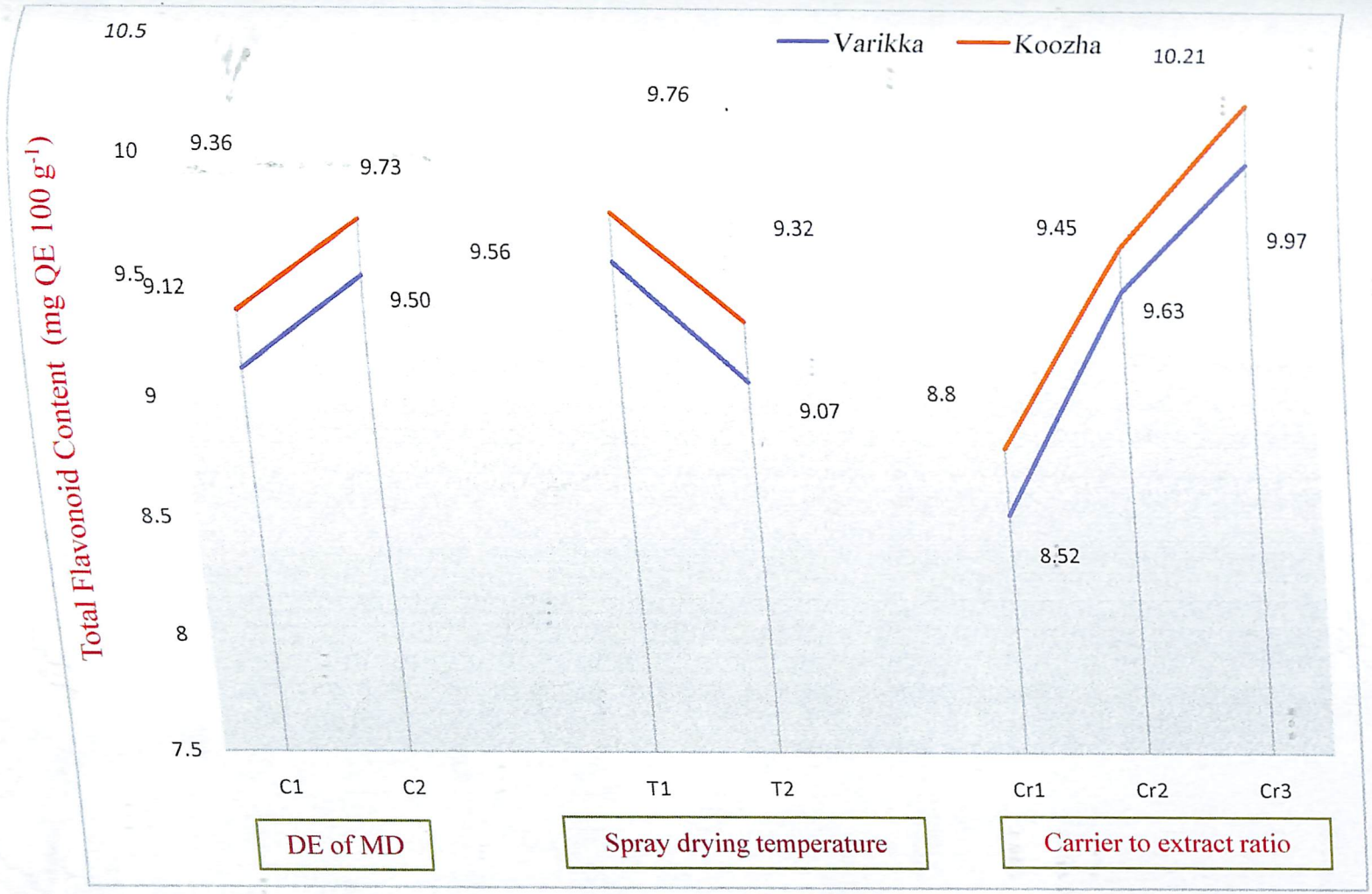
Freeze dried samples extracted with 60% ethanol in 1:50 solid to solvent ratio ($D_2S_4R_3$)

5.3.1 Encapsulation of Extracts by Spray Drying

The extracts were encapsulated with two levels of maltodextrin (MD 10 and 20 DE), three levels of carrier to extract ratios (1:10, 1:15 and 1:20) with two temperatures of spray drying (Inlet 180° C - outlet 80°C and Inlet 190°C - outlet 90° C). The influence of DE of MD, carrier to extract ratio and spray drying temperature on physicochemical properties of the spray encapsulates is discussed below.

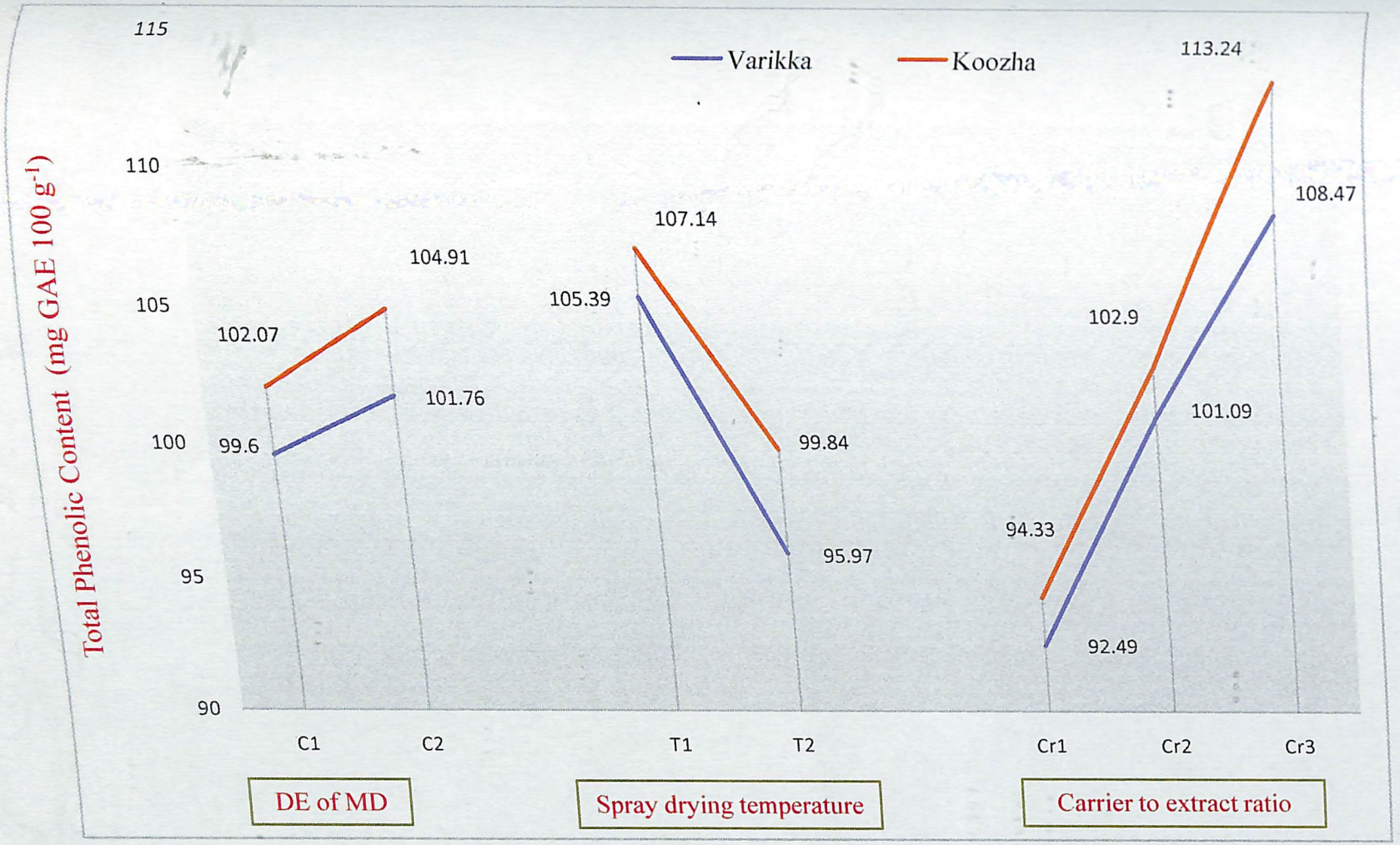
Total flavonoid content (TFC), total phenolic content (TPC), antioxidant activity (DPPH) and ascorbic acid content of varikka and koozha encapsulates were influenced by all the process variables (Fig.15).

Physicochemical properties of both the extracts encapsulated with 20 DE MD were superior compared to those encapsulated with 10 DE MD (Fig. 15 to 18). Bazaria and Kumar (2017) studied influence of levels of DE of MD for encapsulating beetroot juice *viz*., MD 10DE, MD 20 DE, MD 10+20DE, MD 10



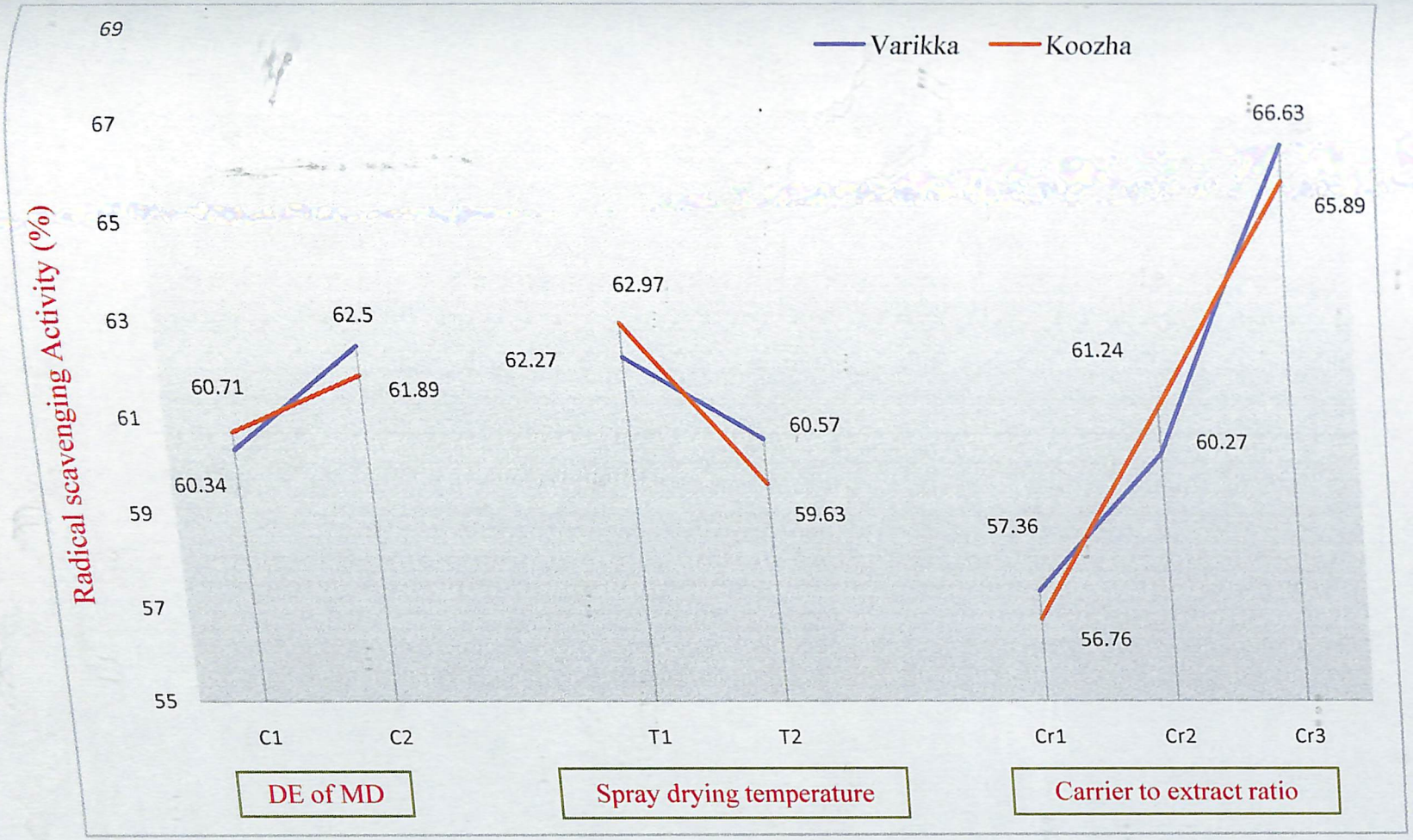
C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin20 Dextrose Equivalence; T_1-180°C Inlet - 80°C outlet; T_2-190°C Inlet - 90°C outlet;Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 15. Influence of process variables on Total Flavonoid Content ofspray dried encapsulate of extract $D_2S_4R_3$



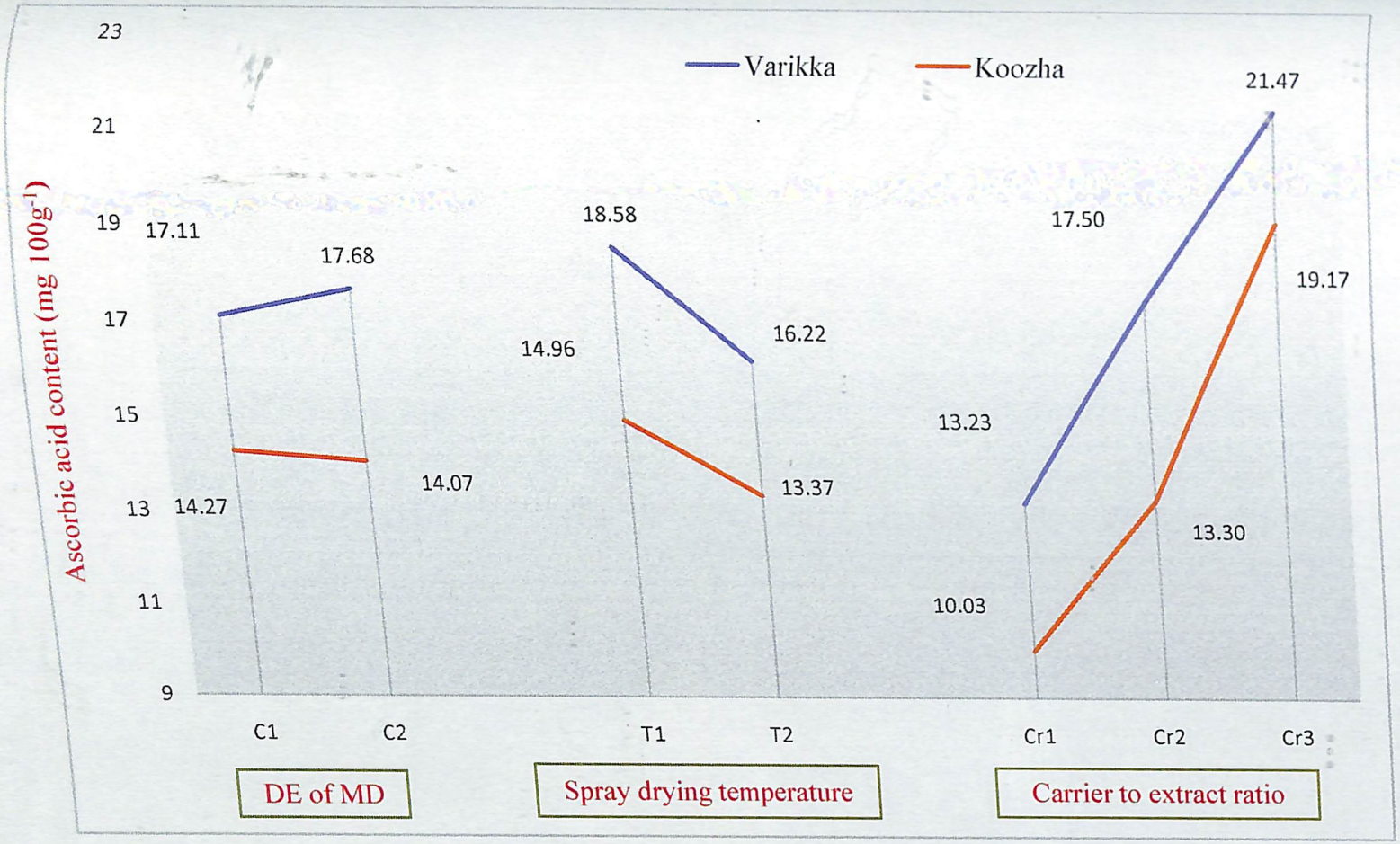
C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin20 Dextrose Equivalence; T_1-180°C Inlet - 80°C outlet; T_2-190°C Inlet - 90°C outlet; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 16. Influence of process variables on Total Phenolic Content ofspray dried encapsulate of extract $D_2S_4R_3$



C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin20 Dextrose Equivalence; T_1-180°C Inlet - 80°C outlet; T_2-190°C Inlet - 90°C outlet; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 17. Influence of process variables on total antioxidant (DPPH) activityofspray dried encapsulate of extract $D_2S_4R_3$

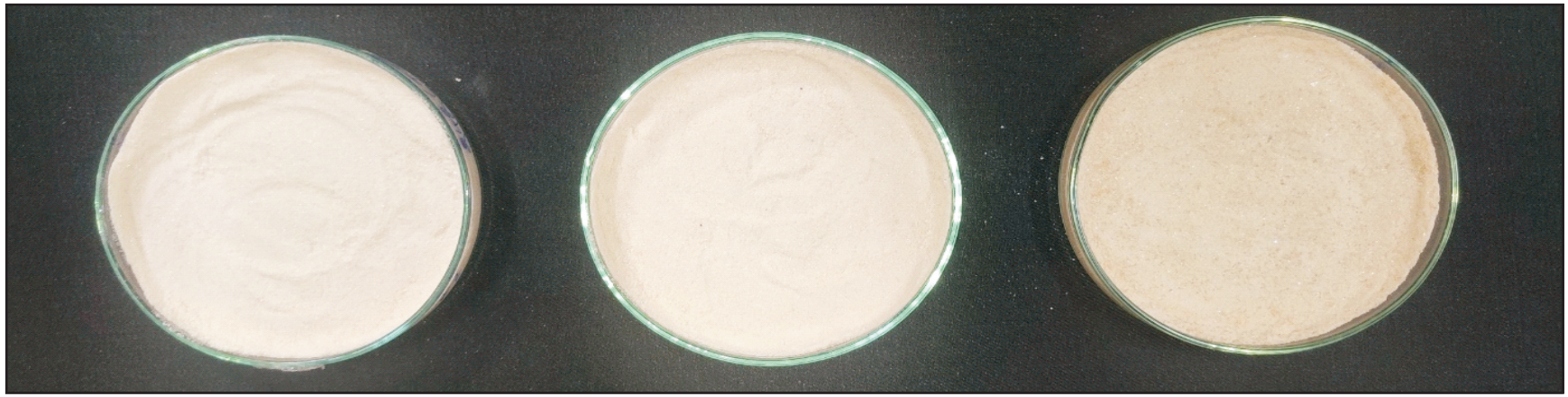


C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin20 Dextrose Equivalence; T_1-180°C Inlet - 80°C outlet; T_2-190°C Inlet - 90°C outlet; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 18. Influence of process variables on Ascorbic acid content of spray dried encapsulate of extract $D_2S_4R_3$

$C_2Cr_1T_1$ $C_2Cr_2T_1$ $C_2Cr_3T_1$

Cr_1-1:10; Cr_2-1:15; Cr_3-1:20; C_1 -MD 10 DE; C_2-MD; T_1-180°C Inlet - 80°C outlet temperature



C_2Cr_1 C_2Cr_2 C_2Cr_3

Cr_1-1:10; Cr_2-1:15; Cr_3-1:20; C_1 -MD 10 DE; C_2-MD

Plate 13. Spray and freeze dried encapsulates of jackfruit extracts

DE + Gum Arabica and MD 20 DE + AG and reported higher retention of TPC in microencapsulates spray dried with MD 20 DE or in combination with other carriers. Anandaraman and Reineccius (1986) reported increase in TFC and TPC of the encapsulates obtained using MD 20 DE compared to 10 DE. Increased DE of maltodextrins helps in formation of a more dense matrix, which makes it more impermeable to oxygen and provides better retention of TFC and TPC in the encapsulates.

Extracts encapsulated with 20 DE MD recorded highest ascorbic acid content and DPPH scavenging activity in both types compared to those encapsulated with 10 DE MD (Fig. 18). Increased ascorbic acid content might have attributed to the higher scavenging activity of both varikka and koozha encapsulates prepared with 20 DE MD. The result is in agreement with the findings of (Campelo *et al*., 2017) who had observed increased lime essential oil properties with increase in dextrose equivalence of maltodextrin from 5 to 20 DE. In a study on encapsulation of beetroot juice, Bazaria and Kumar (2017) reported higher DPPH scavenging activity in the encapsulates prepared with 20 DE MD compared to 10 DE.

The increased carrier concentration from 1:10 to 1:20 resulted in significantly increased TFC, TPC and DPPH scavenging activity of the encapsulates from varikka and koozha extracts. For varikka encapsulates prepared from the extract $D_2S_4R_3$, with the increase in carrier to extract ratio from 1:10 to 1:20 the corresponding radical scavenging activity increased from 57.76 to 66.03% and for koozha it was 56.76 to 65.89 % respectively (Fig. 17). Increase in TPC and DPPH scavenging activity with increase in core to carrier material (maltodextrin) from 1:1 to 1:4 were observed in the extracts of Indian Mulberry fruit (*Morinda citrifolia* L.) encapsulated with maltodextrin. Radical scavenging activity of the encapsulates increased with increase in carrier to extract ratio from 1:10 to 1:20 in all the spray encapsulates (Krishnaiah *et al*., 2012). The increased TFC, TPC and DPPH scavenging activity in the spray encapsulates by increasing the concentration of wall materials might be due to the interference of

maltodextrin and increased stability of compounds under higher concentration of carrier material. In general, the higher amount of maltodextrin retained higher TFC than the lower amount of MD, showing the ability of MD to bind with the compounds. Saikia *et al*. (2015) reported increase in retention of TPC in core of spray encapsulates of carambola pomace with maltodextrin with increase in core to coating material ratios from 1:10 to 1:20.

Increase in carrier to extract ratio from 1:10 to 1:20 helped in higher retention of ascorbic acid (Fig 18). This trend in increased ascorbic acid content of the encapsulates was observed in all the extracts of varikka and koozha. Ho *et al*.(2015) conducted an experiment to know the effect of carrier material concentration on the antioxidant compounds of spray dried sim (*Rhodomyrtus tomentosa*) juice and reported higher retention of ascorbic acid and phenolic compounds with increase in core to carrier material ratio from 1:1 to 1:4. Increase in core: wall ratio from led to better formation of the shell layer that protected antioxidant compounds including ascorbic acid from high temperature and oxidation reactions during the spray drying process. This explanation was supported by the fact that the powder samples with higher core:wall ratio were more stable against degradation during the accelerated storage than those with lower core: wall ratio. This confirms the higher content of ascorbic acid retention observed in the encapsulates produced with higher carrier to extract ratio in the current study conducted on spray dried encapsulates of jackfruit extract.

Spray drying temperature also influenced phytochemical properties of encapsulates obtained from both varikka and koozha extracts. Decrease in the TFC, TPC and antioxidant activity of the extracts was noticed with increase in spray drying temperature from 180° C to 190°C inlet and 80°C to 90° C outlet irrespective of carrier to extract ratio (Fig 15, 16 and 17). Krishnaiah *et al*. (2012) reported decrease in the TFC, TPC and antioxidant activity of the Indian Mulberry encapsulates with maltodextrin with increase in the spray drying temperature (from 90 to 140º C) at all the core to wall material ratios. Vu *et al*. (2020) studied influence of spray drying temperature on TPC of banana peel extract encapsulated

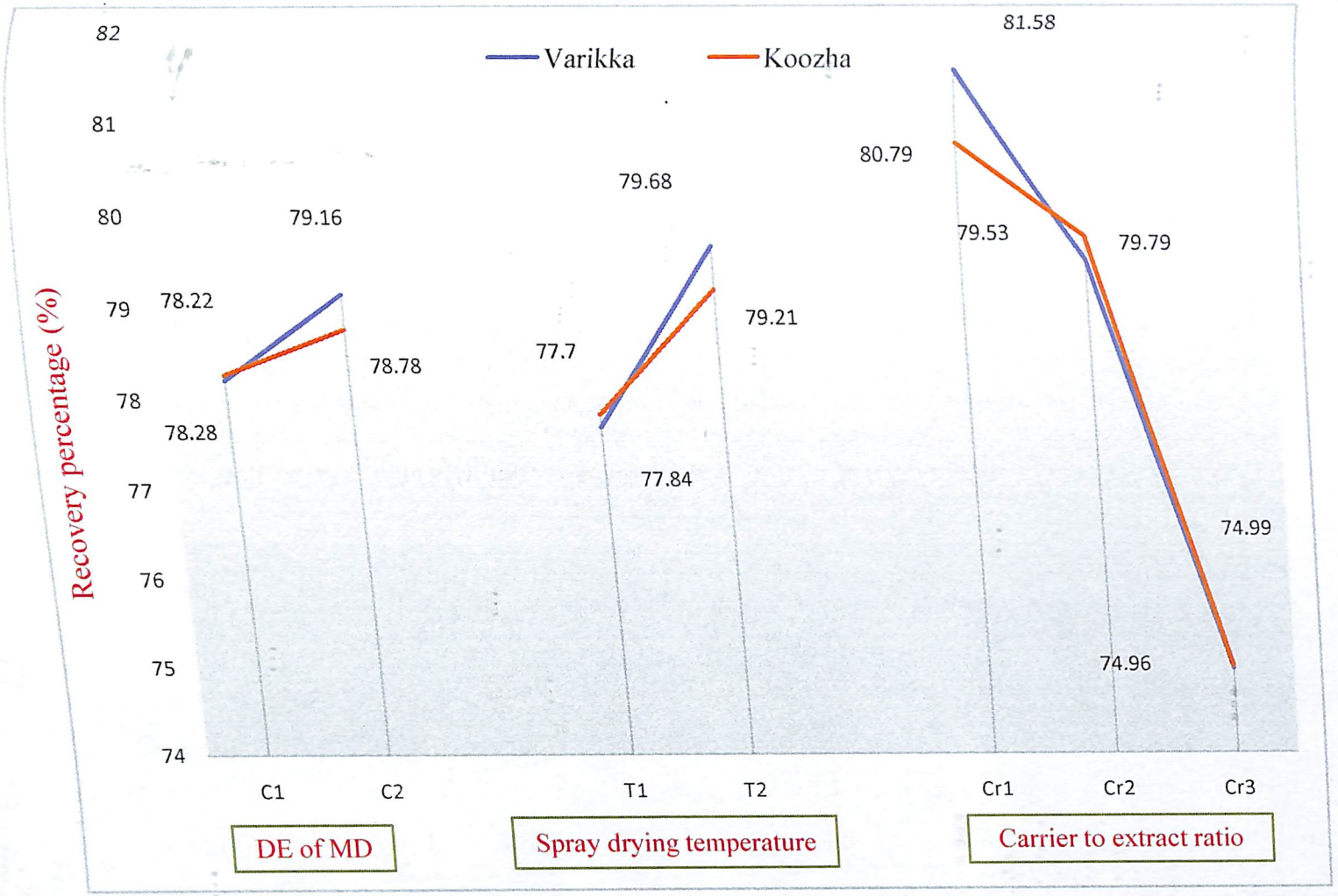
with maltodextrin (MD), gum arabica and combination of MD with gum arabica and reported decrease in TPC of the encapsulates with increase in inlet temperature from 160 to 180º C.

Ascorbic acid losses occur mainly due to processing and storage temperature; the longer the processing time and storage time, higher the increase in ascorbic acid degradation. Spray drying temperature influenced the ascorbic acid content of the encapsulates (Fig. 18). With increase in the inlet temperature from 180 to 190º C, decrease in ascorbic acid content was noticed in all the encapsulates from varikka and koozha extracts. This is inconformity with the results of Ho *et al*. (2015) who had observed reduced ascorbic acid content with increased inlet temperature from 180 to 190º C probably due to the thermolability of ascorbic acid. Higher drying temperature enhances degradation rate of ascorbic acid. Mishra *et al*. (2014) while spray drying of amla juice with maltodextrin as wall material, also observed a significant decrease in ascorbic acid content of the encapsulates when the inlet temperature was higher than 175º C. Murali *et al*. (2015) encapsulated black carrot juice using 20 DE Maltodexrin at different spray drying temperature from 150 to 225º C and reported decrease in total anthocyanin content of the encapsulates with increase in spray drying temperature.

Recovery percentage of the encapsulate was found to be influenced by the dextrose equivalence of maltodextrin, carrier to extract ratio and temperature of spray drying (Fig. 19). All the encapsulates prepared using 20 DE MD recorded higher recovery percentage compared to those encapsulated with 10 DE (Fig. 19). Increase in the recovery percentage of encapsulate with increase in the DE of MD is also reported by Vu *et al*. (2020) in banana (*Musa cavendish*) peel extract spray encapsulated with maltodextrin. Increase in DE of MD from 4 to 7 (M040) to 16.5 to 19.99 (M180) had increased the yield of spray encapsulates. In the current study also, encapsulates prepared from 20 DE MD had higher recovery compared to those encapsulates prepared with 10 DE MD irrespective of type of extract and jackfruit types used.

When the carrier to extract ratio was increased from 1:10 to 1:20 powder recovery was increased (Fig. 19) while the moisture content of the powder was reduced (Table 65 to 70). It can be explained that higher the carrier to extract ratio, the higher the amount of maltodextrin added to the extracts (prior to spray drying) resulting increase in the total solid content of the feed solution. Quek *et al*. (2007) reported that increase in total solid content of the feed solution in encapsulation of watermelon juice, reduced the amount of water for evaporation and decreased the moisture content of the powder. As powder became drier, its stickiness to the wall of the drying chamber decreases and more powder can be collected at the cyclone. Similar results were recorded in guava juice encapsulation by spray drying (Patil *et al*., 2014) and in spray drying of gac (*Momordica cochinchinensis*) fruit aril (Tuyen *et al*., 2010).

Spray drying temperature also influenced the percent recovery of all the encapsulates prepared from varikka and koozha extracts (Fig. 19). Recovery was higher in the extracts encapsulated at 190 inlet - 90º C outlet temperature, compared to 180 and 80 º C. Vu *et al*., (2020), based on the studies conducted on encapsulation of banana peel extract with maltodextrin alone and in combination with other carrier materials reported increased encapsulate recovery with increase inlet temperature from 150 to 180º. In a similar study conducted on spray dried sim (*Rhodomyrtus tomentosa* (Ait.) Hassk) juice encapsulates prepared with maltodextrin, increased recovery was reported with increase inlet temperature from 150 to 190º C (Ho *et al*., 2015). Similar results were also reported by Krishnaiah *et al*. (2012) in the spray encapsulates of *Morinda citrifolia* L. Increase in inlet temperature from 180 to 190º C enhanced the powder recovery due to decrease in powder moisture content. As the moisture content of the encapsulates decreased, the stickiness of the encapsulates was reduced, which in turn reduces the encapsulates sticking to the wall of the drying chamber resulting in collection of more powder at the cyclone. Samborska *et al*. (2005) reported a decrease in powder moisture content with increase in inlet temperature of spray drying.



C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin20 Dextrose Equivalence; T_1-180°C Inlet - 80°C outlet; T_2-190°C Inlet - 90°C outlet; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 19. Influence of process variables on recovery percent (%) of spray dried encapsulate of extract $D_2S_4R_3$

Moisture content is one of the important factors that influences recovery, stability and storage life of encapsulates. Moisture content of the encapsulate was influenced by DE of MD, carrier to extract ratio and temperature of spray drying (Fig. 20).

Encapsulates prepared from the varikka and koozha extracts with10 DE MD had lower moisture content compared to those with 20 DE MD (Fig. 20). Vu *et al*. (2020) reported lowest moisture content in the encapsulates prepared from banana peel extract with the DE of 4 to 7 (M040) of MD compared to 16.5 to 19.99 (M180).

Moisture content of the encapsulates prepared at 1:20 carrier to extract ratio was lower compared to those with 1:10 carrier to extract ratio (Fig. 20). This is in accordance with the findings of Saikia *et al*. (2015) who had observed lowest moisture content in the *Averrhoa carambola* pomace encapsulates prepared with maltodexrin at 1:20 core to carrier material ratio compared to 1:10. Krishnaiah *et al*. (2012) also reported lowest moisture content of the encapsulates at 1:4 core to wall material ratio compared to 1:1. Vu *et al*. (2020) reported decrease in the moisture content of the encapsulates prepared from banana peel extracts with maltodextrin with increase in the dry matter to carrier ratio. Moisture content of the spray dried encapsulates was decreased with increase in core to wall material ratio. The moisture content of the spray-dried powder decreased when the amount of maltodextrin added was increased. In a spray-drying system, water content of the feed has an effect on the final moisture content of the powder produced (Abadio *et al*., 2004). The addition of maltodextrin to the feed prior to spray-drying increases the total solid content and reduces the amount of water available for evaporation there by decreasing the moisture content of the powder.

Moisture content of the encapsulates was influenced by the spray drying temperature (Fig. 20). Lower moisture content was recorded by the all the encapsulates prepared at higher inlet - out let temperature of 190 - 90º C compared 180 - 80 º C. Decreased moisture content was noticed when spray

drying temperature was enhanced from 130º C to 180º C (Vu *et al*., 2020) and 90-140º C (Krishnaiah *et al*., 2012). At higher inlet air temperatures, the rate of heat transfer to the particle is greater, providing a greater driving force for moisture evaporation resulting in powders with reduced moisture content.

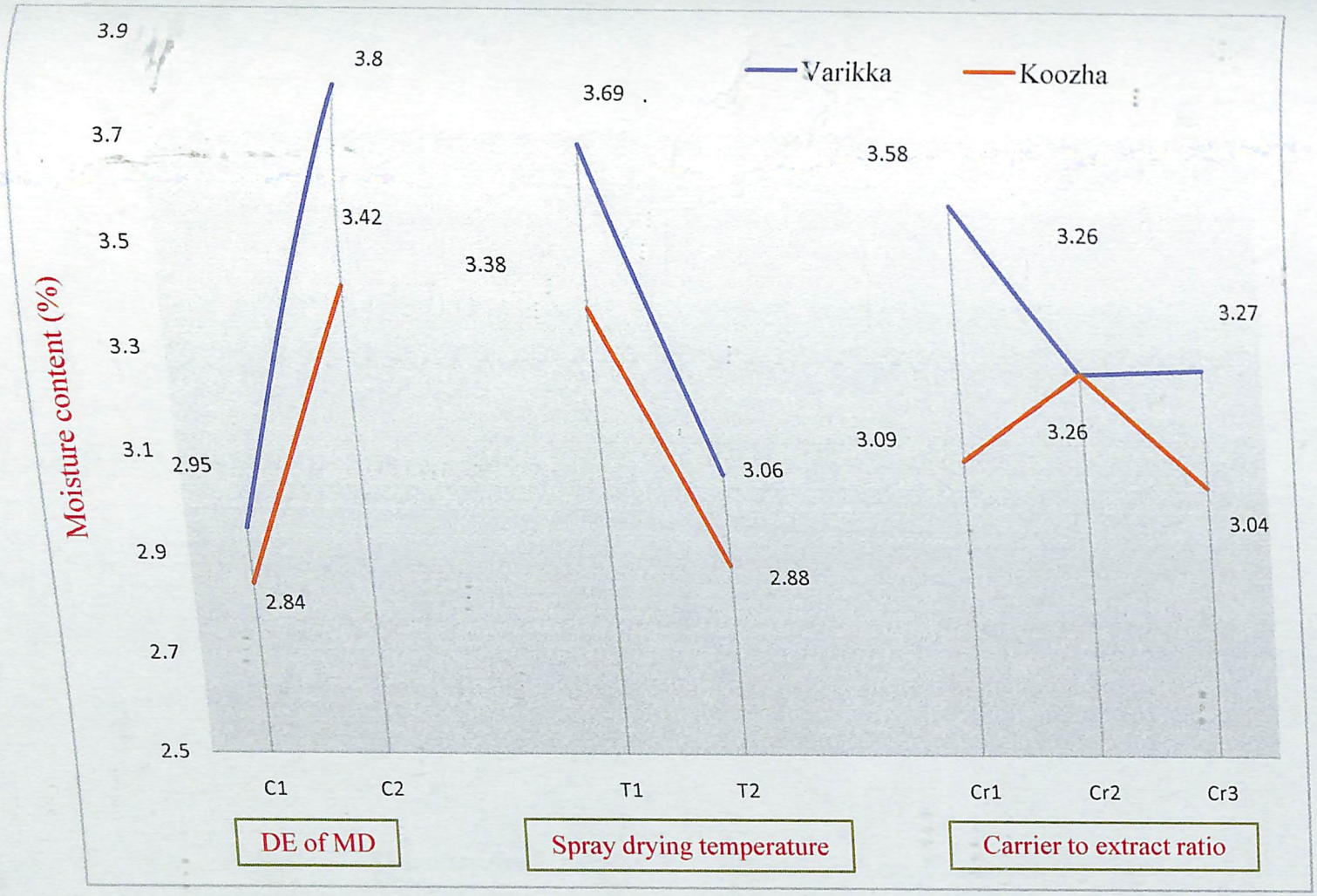
5.3.2 Encapsulation of Extracts by Freeze Drying

Encapsulation of the three superior extracts was conducted by freeze drying technique using two levels of carrier maltodextrin (10 and 20 dextrose equivalence) at 1:10, 1:15 and 1:20 carrier to extract ratio (Plate 14). The influence of DE of MD and carrier to extract ratio on the physicochemical properties of the freeze encapsulates is discussed below.

Total flavonoid content, total phenolic content, DPPH scavenging activity and ascorbic acid content of freeze encapsulates of varikka and koozha extracts were influenced by two levels of DE of MD and carrier to extract ratio (Table 21 to 24).

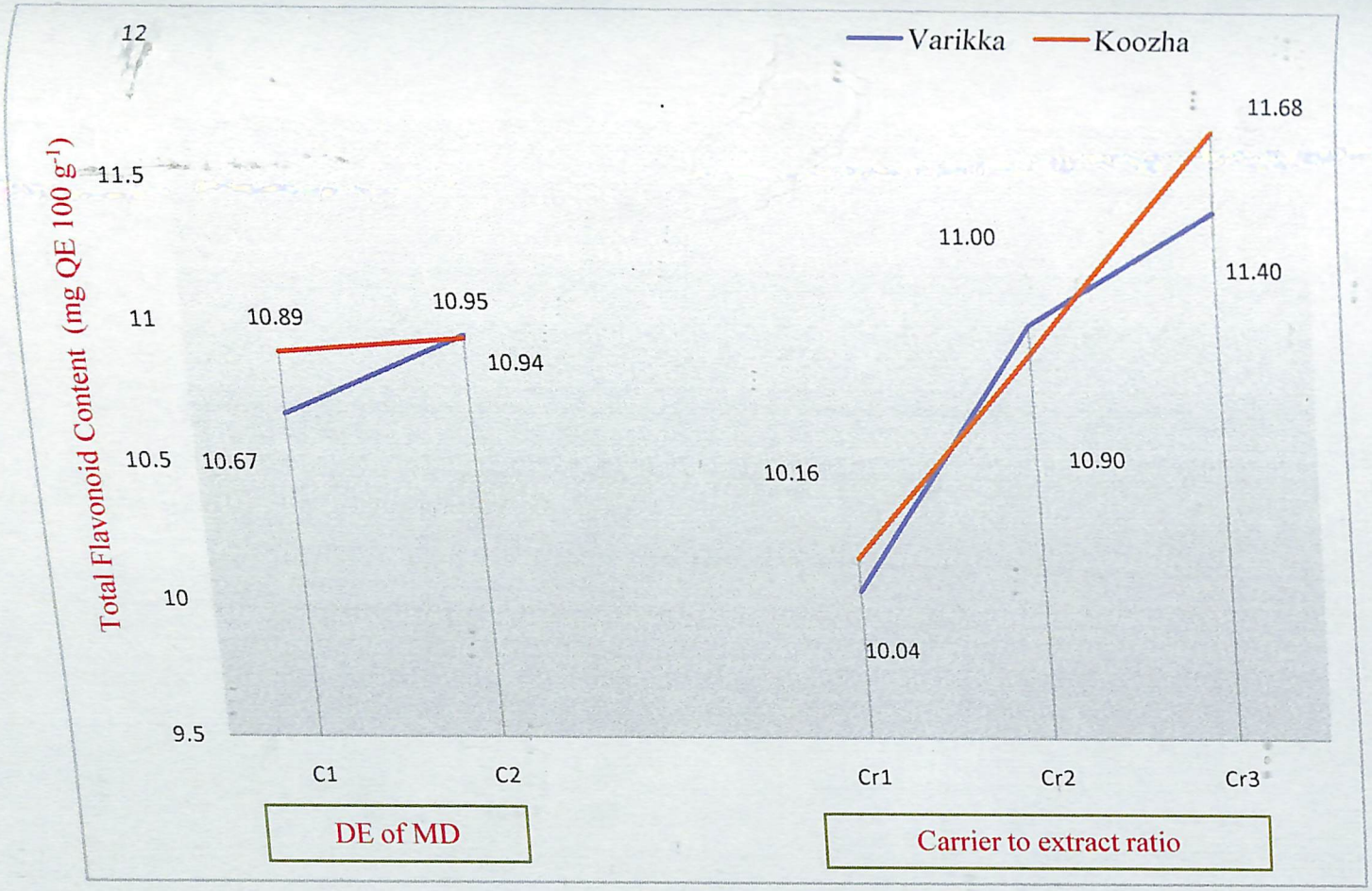
TFC, TPC, DPPH scavenging activity (except for varikka extract) and ascorbic acid content of all the varikka and koozha extracts prepared with 20 DE were found to be higher compared to 10 DE (Fig. 21, 22,23 and 24). Higher DE maltodextrins form a more dense, more oxygen impermeable matrix providing better retention and longer shelf life of encapsulates (Anandaraman and Reineccius, 1986).

Increase in carrier to extract ratio from 1:10 to 1:20 showed increased retention of TFC, TPC, ascorbic acid content and DPPH scavenging activity in all the freeze dried encapsulates (Fig. 21, 22,23 and 24). Suravanichnirachorn *et al*. (2018) studied freeze encapsulation of mao [*Antidesma bunius* (L.) juice with maltodextrin at 25 to 35 per cent concentration and reported increase in DPPH scavenging activity and higher retention of total anthocyanin content with increase in MD concentration. Sikia *et al*. (2015) reported higher retention of TPC in the core of *Averrhoa carambola* pomace encapsulate with increase in core to wall



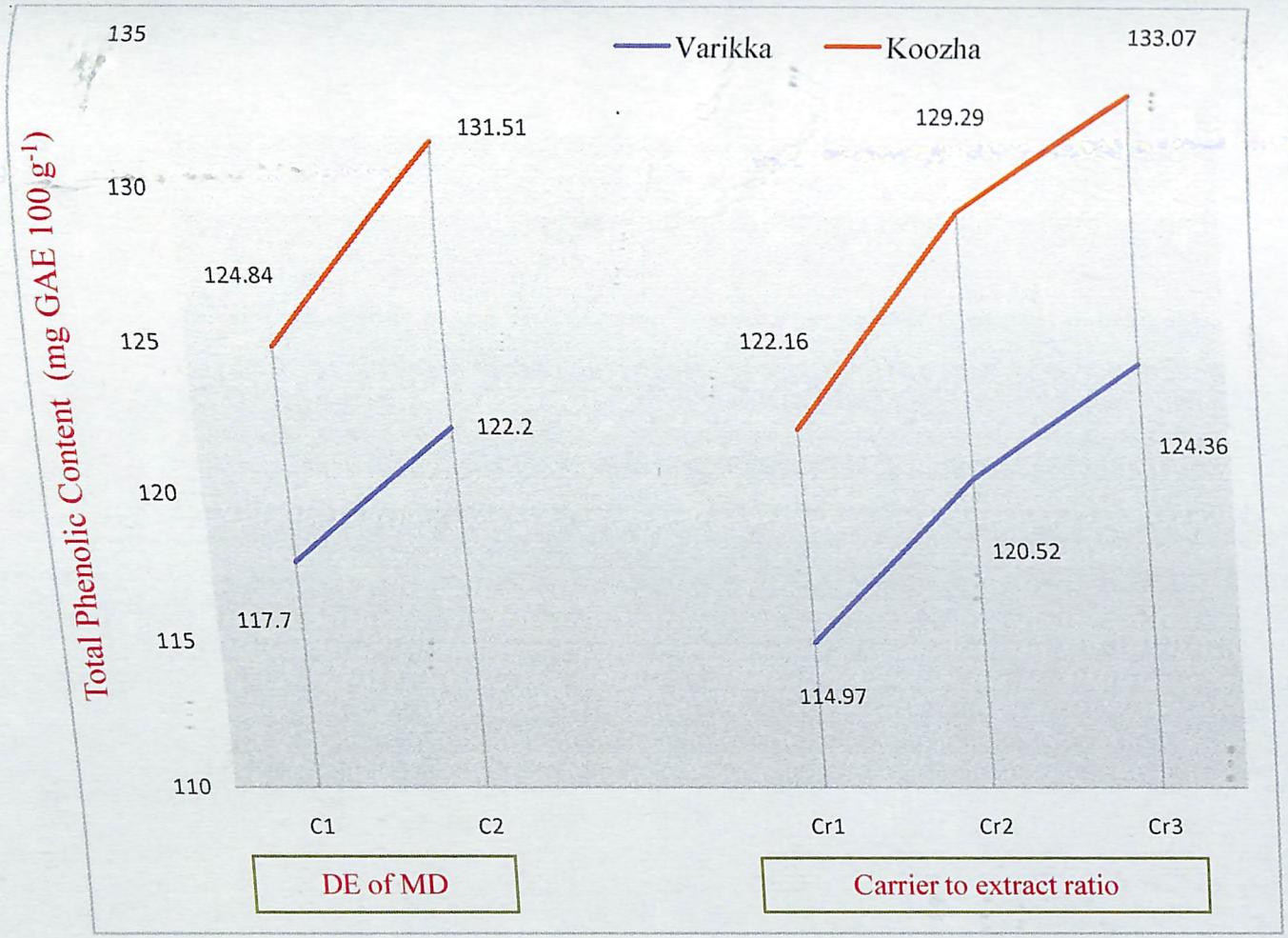
C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin20 Dextrose Equivalence; T_1-180°C Inlet - 80°C outlet; T_2-190°C Inlet - 90°C outlet; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 20. Influence of process variables on Moisture content (%) of spray dried encapsulate of extract $D_2S_4R_3$



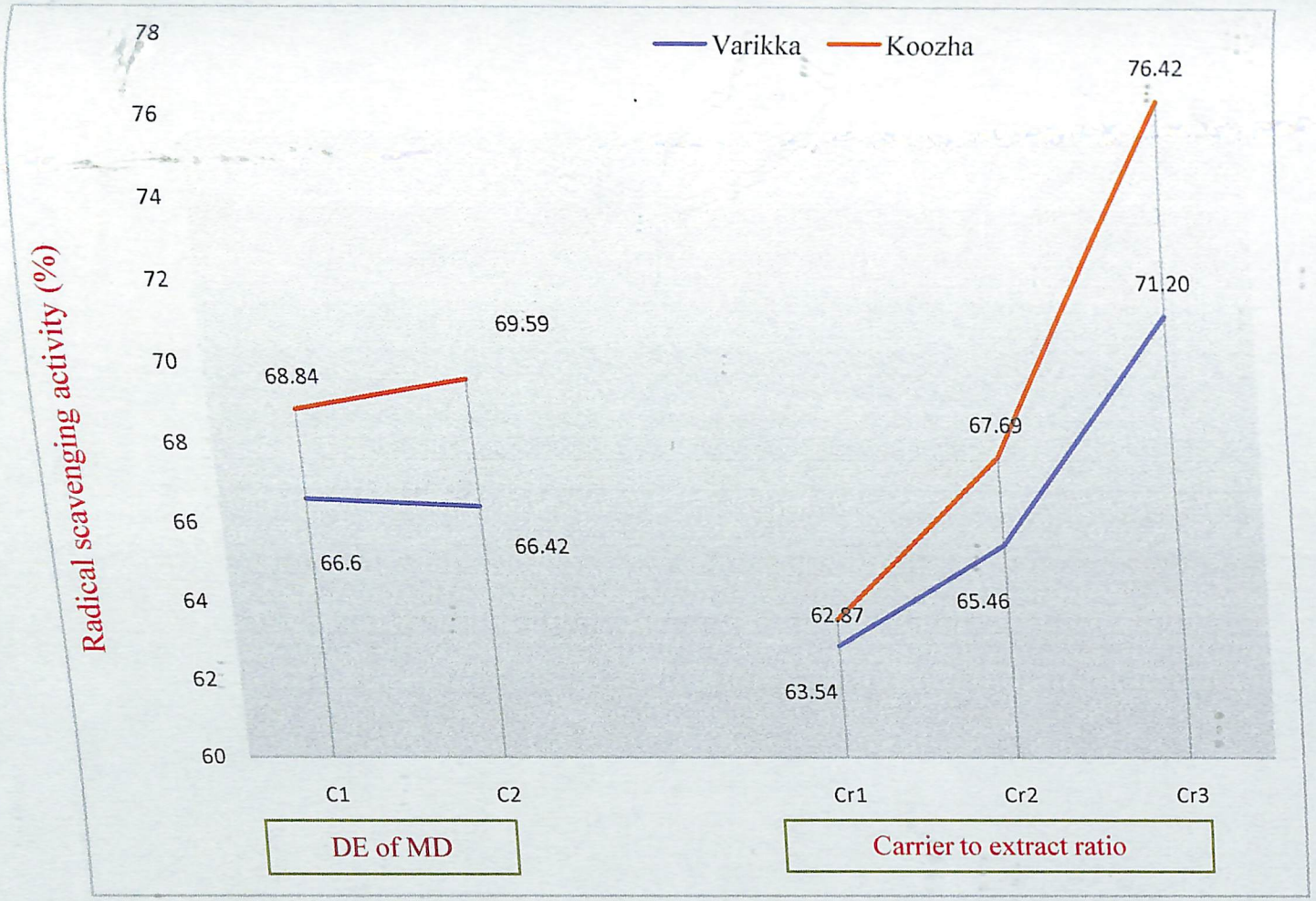
C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin 20 Dextrose Equivalence; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 21. Influence of process variables on Total flavonoid content offreeze dried encapsulates of extract $D_2S_4R_3$



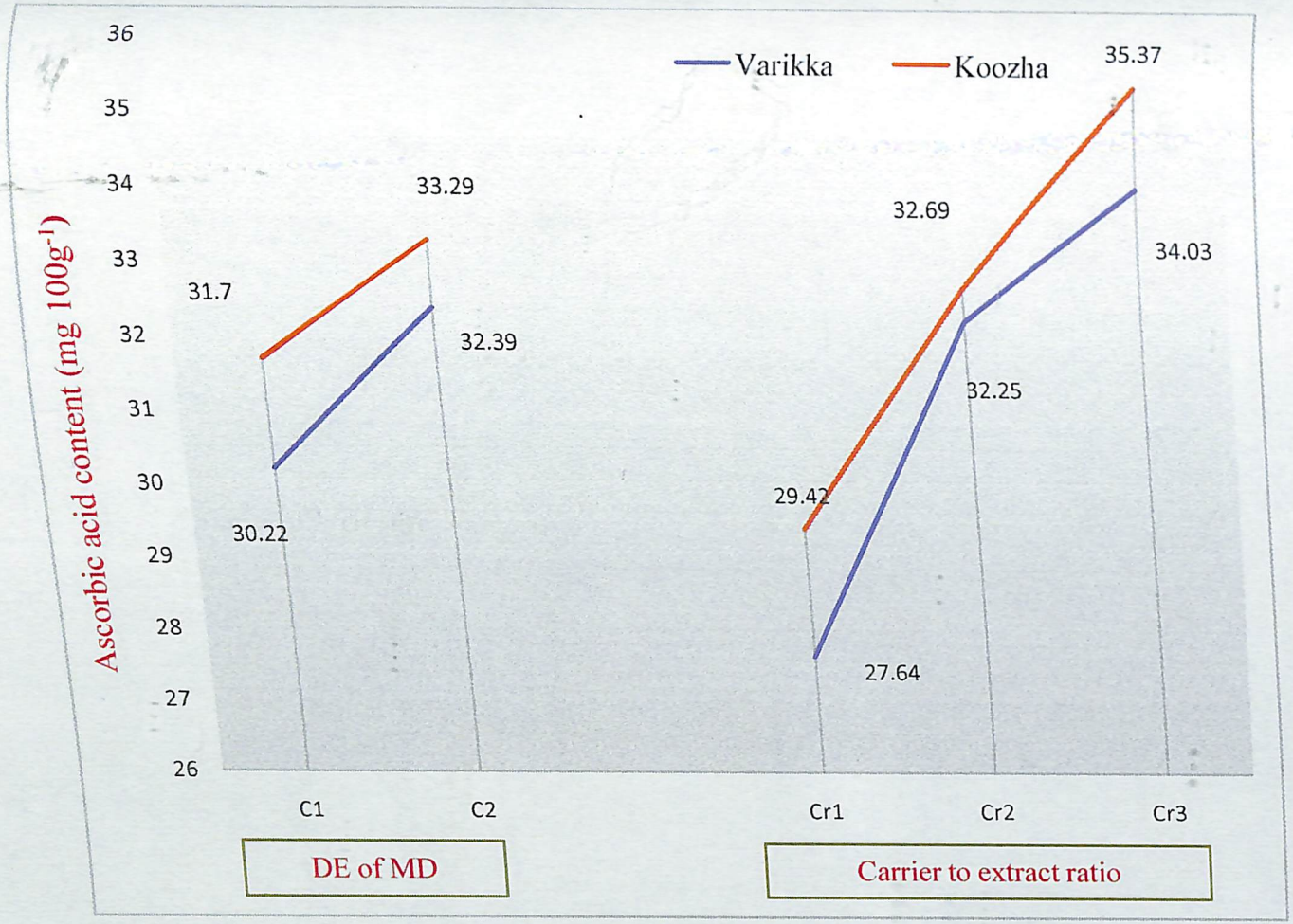
C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin 20 Dextrose Equivalence; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 22. Influence of process variables on Total Phenolic Content offreeze driedencapsulates of extract $D_2S_4R_3$



C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin 20 Dextrose Equivalence; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 23. Influence of process variables ontotal antioxidant (DPPH) activity offreeze dried encapsulates of extract $D_2S_4R_3$

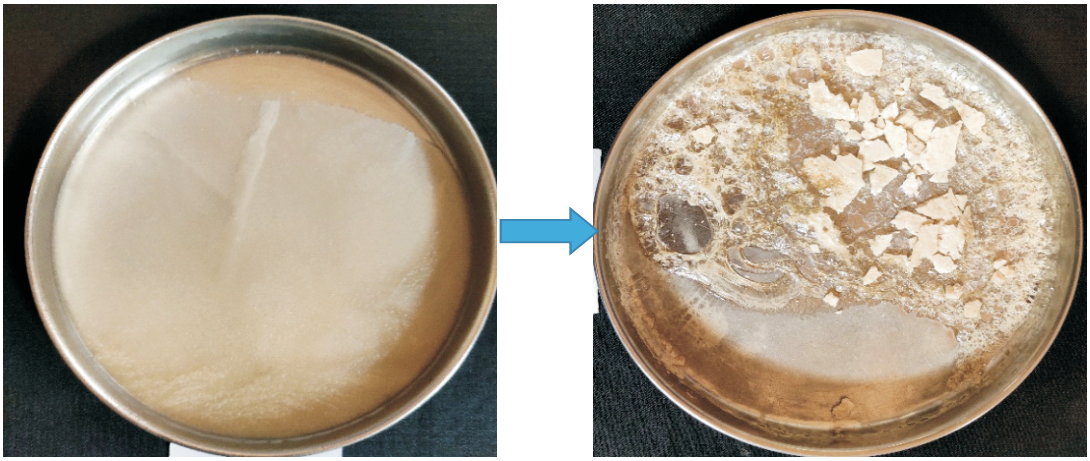


C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin 20 Dextrose Equivalence; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 24. Influence of process variables onAscorbic acid content offreeze dried encapsulates of extract $D_2S_4R_3$

MD Cr-III

MD Cr-II



MD Cr-I

Plate 14. Pre freed homogenized extract in different carrier to extract ratio and final product

material ratio from 1:10 to 1:20. These results are in line with the current study. Azarpazhooh *et al*. (2019) prepared encapsulates from ethanolic pomegranate peel extract using MD (DE=16.5–19.5) at extract to carrier ratio (weight/weight) 1:5, 1:10 and 1:15. The anthocyanin, TPC and DPPH scavenging activity of the encapsulates were reported to be higher in the encapsulates prepared at 1:15 extract to carrier ratio compared to 1:10.

Recovery of encapsulate (%) of varikka and koozha extracts was influenced by dextrose equivalence of maltodextrin and carrier to extract ratio (Fig. 25). The extracts encapsulated with MD 20 DE had higher recovery of encapsulates compared to extract encapsulated using MD 10 DE. The extracts encapsulated at carrier to extract ratio of 1:20 had highest recovery of encapsulates (except varikka $D_1S_4R_3$), while the lowest recovery of the encapsulates was observed in extracts encapsulated at 1:10 carrier to extract ratio (Fig. 25). Azarpazhooh *et al*. (2019) obtained higher yield of encapsulates by freeze drying of pomegranate peel extract with maltodextrin at 1:15 carrier to extract ratio compared to 1:10.

Moisture content of the freeze encapsulates prepared from all the varikka and koozha extracts was influenced by the dextrose equivalence of maltodextrin and carrier to extract ratio (Fig. 26). Encapsulates prepared with 10 DE MD had lowest moisture content compared to those with 20 DE (Fig. 26). This is in conformity with the results of Azarpazhooh *et al*., (2019), who had recorded lower moisture content in pomegranate peel extracts encapsulated with maltodexrin at 5 percent, compared to those encapsulated at 15 per cent. The encapsulates with higher moisture content also recorded higher recovery percentage of encapsulation.

In general, the extract prepared from freeze dried samples with 60% ethanol in 1:50 solid to solvent ratio ($D_2S_4R_3$) which had highest TPC, TFC and ascorbic acid compared to the oter two extracts, $D_2S_4R_2$ and $D_1S_4R_3$, produced the encapsulates with higher contents for the same parameters. Freeze encapsulation

of the extracts $D_2S_4R_3$ also produced similar results. The extract $D_2S_4R_3$ also could produce spray and freeze encapsulates with highest DPPH scavenging activity compared to other two extracts selected for encapsulation.

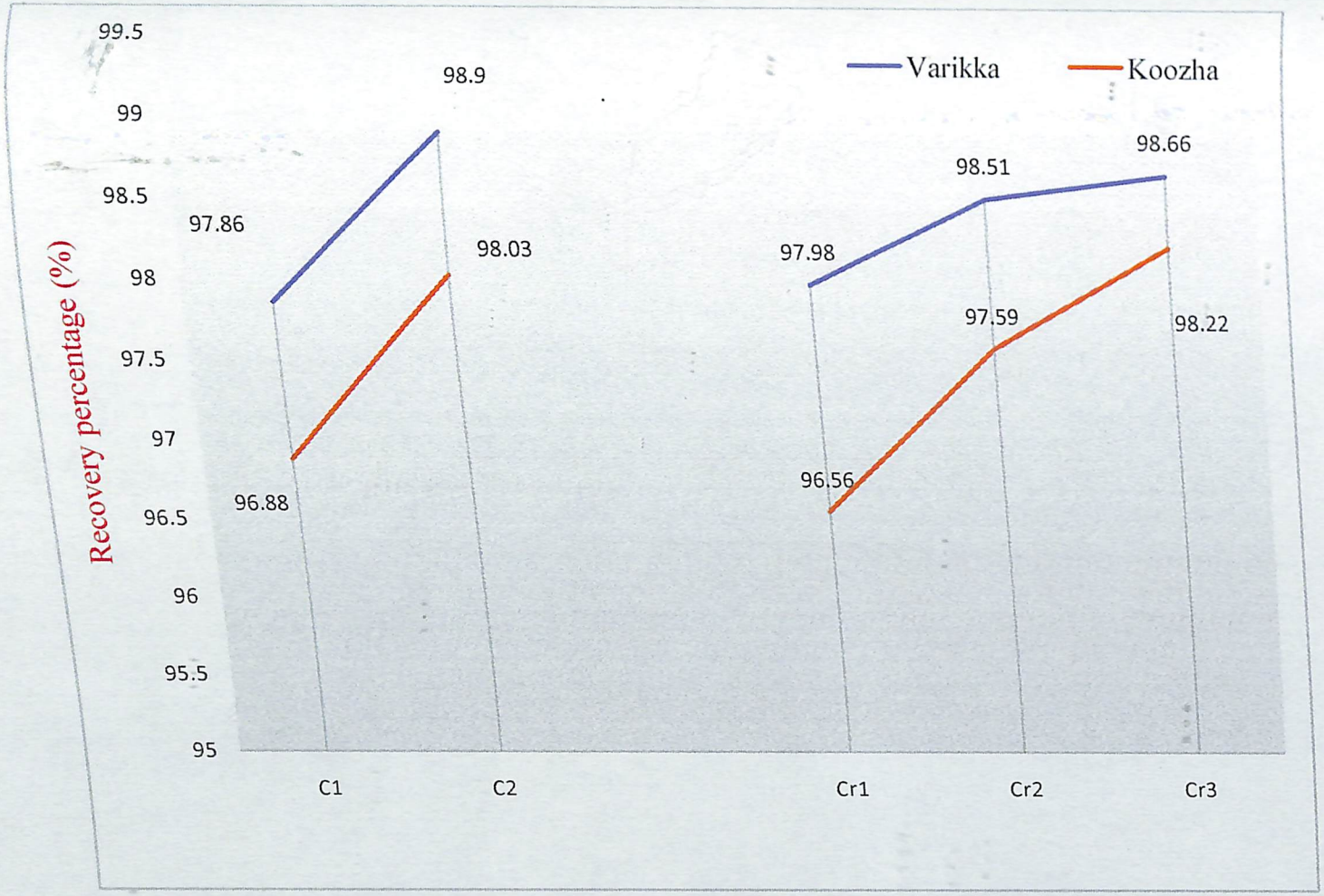
Based on the results of the biochemical properties, spray encapsulate from the extract from freeze dried varikka and koozha with 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) spray dried using 20 DE maltodextrin at 1:20 carrier to extract ratio with inlet and outlet temperature of 180 and 80° C ($C_2T_1Cr_3$) was found to be superior. On the same lines, among the freeze encapsulate extract encapsulated using 20 dextrose equivalence maltodextrin at 1:20 carrier to extract ratio (C_2Cr_3) from the extract $D_2S_4R_3$ (varikka and koozha) was found to be superior with respect to biochemical properties. These two encapsulates were further utilized for preparation of fortified mango RTS beverage.

5.4 COMMERCIAL APPLICATION OF ENCAPSULATED EXTRACT

Extraction of freeze dried varikka and koozha samples was done using 60 per cent ethanol at 1:50soid to solvent ratio. This extract was further spray encapsulated using 20 dextrose equivalent matodextrin (20 DE MD) at 1:20 extract to carrier ratio at inlet and out let temperature of 180 and 80º C ($C_2Cr_3T_1$) and freeze encapsulated using 20 dextrose matodextrin at 1:20 extract to carrier ratio (C_2Cr_3).

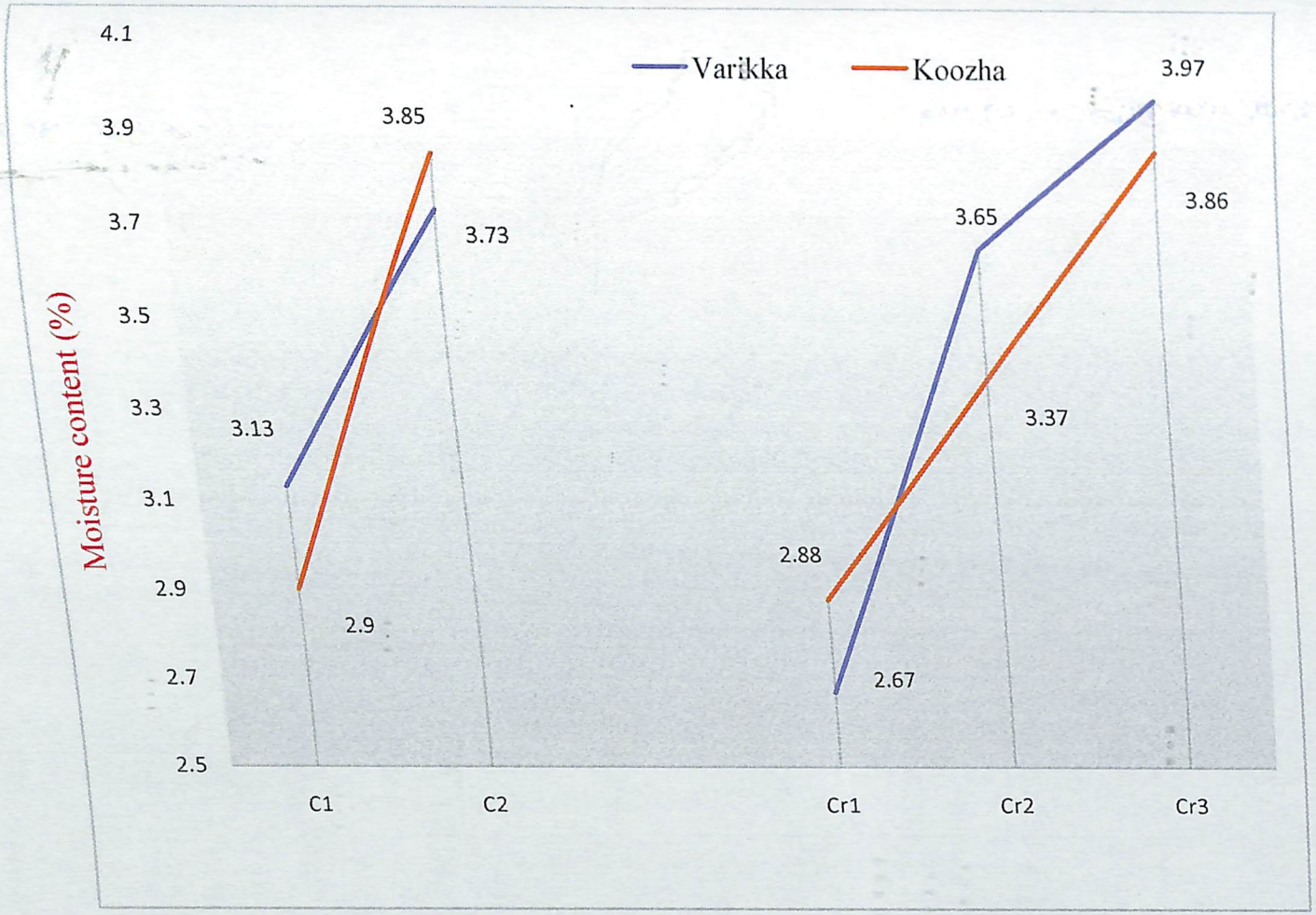
The selected encapsulates developed in part III of the experiment were utilized for preparation of fortified mango RTS beverages as per FSSAI standards and compared with commercial fortified beverage (Plate 15). Influence of encapsulates used for enrichment on the physicochemical and sensory properties of the mango RTS beverage is discussed in this chapter.

Preliminary study was conducted to decide the quantity of encapsulates to be dissolved for fortification. It was carried out using spray and freeze and encapsulates of varikka. Mango RTS beverage was prepared as per FSSAI



C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin 20 Dextrose Equivalence; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 25. Influence of process variables onRecovery percent (%) offreeze dried encapsulates of extract $D_2S_4R_3$



C_1 -Maltodextrin 10 Dextrose Equivalence, C_2-Maltodextrin 20 Dextrose Equivalence; Cr_1-1:10; Cr_2-1:15; Cr_3-1:20

Figure 26. Influence of process variables onMoisture content (%) offreeze dried encapsulates of extract $D_2S_4R_3$

Plate 15. Mango RTS enriched with spray and freeze encapsulates

standards and enriched with encapsulates at 0.01 to 0.1 per cent concentration. Sensory scores for the enriched RTS beverage influenced scores for mouth feel, taste and overall acceptability and the scores for color and appearance and flavor were found to be non significant. The scores for mouth feel, taste and overall acceptability were found to be between 9 (like extremely) and 8 (like very much) for beverages prepared by dissolving 0.01 to 0.05 per cent encapsulate (for spray and freeze encapsulates). As the concentration of the encapsulates had increased from 0.06 to 0.1 per cent the sensory properties of the mango RTS beverage were found to alter. Based on this quantity of encapsulates to be dissolved in the mango RTS beverage was decided as 0.05 per cent. Mango RTS beverage were prepared by dissolving both freeze and spray encapsulates of varikka and koozha at 0.05 per cent concentration and were analysed for physicochemical and sensory evaluation.

Analysis of mango RTS beverage enriched with (varikka and koozha) encapsulates $C_2Cr_3T_1$ and C_2Cr_3 of extract $D_2S_4R_3$

Though varikka and koozha encapsulates utilized for enrichment had influenced TSS of mango RTS beverage, the increase in TSS compared to control sample was meagre and it was 0.32 and 0.28° Brix in varikka and koozha respectively. Sakhale *et al*. (2012) reported increased TSS in whey protein based mango RTS beverage.

The encapsulates added altered the sugar content of the RTS beverage. The increase in the sugar content was very scanty compared to the control.

Acidity of the mango RTS beverage was found to be lowest in control and commercial sample compared to the beverages enriched with encapsulates. Though the acidity of the enriched beverages was slightly high, it did not alter the sensory properties.

Encapsulates added to the mango RTS beverage had enhanced the TPC of the beverage. Sawale *et al*. (2017) conducted a study to know the effect of

incorporation of encapsulated and free *Terminalia arjuna* herb extract on stability of chocolate vanilla dairy drink. Addition of *Terminalia arjuna* herb extract encapsulate increased TPC content of beverage compared with control. In the present study also, addition of both spray and freeze encapsulates to mango RTS beverage resulted in increase in the TPC compared to control and the commercial fortified mango RTS beverage.

Addition of encapsulates to the mango RTS beverage had enhanced the DPPH scavenging activity to 13-16%, compared to commercial fortified mango RTS beverage. This increased scavenging activity is mainly attributed to the higher TPC along with other antioxidant agents present in the beverage. Owczarek *et al*. (2004) prepared juices of cranberry, raspberry and black currant enriched with tea leaf and elder berry fruit extracts and reported increase in TPC of these juices. The antioxidant capacity of the fruit-herbal beverages was correlated with their total phenolic content ($r=0.85$; $p\leq0.02$). This establishes an increase in TPC coupled with enhanced DPPH scavenging activity of the enriched mango RTS beverages.

Sensory evaluation of mango RTS beverages enriched with spray or freeze encapsulate of varikka and koozha extracts revealed that color and appearance, consistency, taste, flavor and overall acceptability scores were not influenced by quantity of spray dried encapsulate used for enrichment. The RTS beverages enriched with both freeze and spray encapsulate @ 0.05per cent concentration were similar to commercial fortified beverage with respect to sensory parameters and no negative effect of encapsulation was noticed on the sensory properties of the beverage. These spray and freeze encapsulates could be utilized for fortifying mango RTS beverage @ 50 mg 100 ml^{-1} without affecting the sensory parameters with an enhanced antioxidant activity of 13-16% compared to commercial fortified mango RTS beverage.

6. SUMMARY

An investigation on "Jackfruit (*Artocarpus heterophyllus* Lam.) as a potential source of bioactive compounds" was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani from 2017-2020 with the objectives to standardize the extraction procedure for maximizing the antioxidant, anti-cancerous and anti-hyperglycemic properties of fruit wastes from varikka and koozha jackfruit types, phytochemical profiling, encapsulation and commercial exploitation of encapsulated extracts for fortification of fruit juice beverages. Major findings of the study are summarised below.

The samples *viz*., all parts of fruits, except bulb, seed and peel without horny portion, were dried in cabinet drier (50^{o} C) and freeze dried drier at (-45 to -50^{o} C at pressure up to 0.05 mbar). The samples were dried until it reached a moisture content of 12-15 percentage, pulverized to fine powders and extracts were prepared using solvents *viz*., methanol at 90 %, 80 %, 50% (S_3) and ethanol at 60 %, 80 % with solid to solvent ratios of 1:30, 1:40 and 1:50. The extracts were analysed after concentration and drying.

Total flavonoid content, total phenolic content, DPPH scavenging activity, ascorbic acid content and α-glucosidase inhibition activity of extracts from varikka and koozha were found to be significantly highest in extracts from freeze-dried samples.

Ethanolic extracts had more TFC, TPC, DPPH scavenging activity and α-glucosidase inhibition activity than methanolic extracts from varikka and koozha and the increase in DPPH scavenging and α-glucosidase inhibition activity in 60 per cent ethanol is mainly attributed higher content of TFC and TPC of those extracts. Decrease in TFC and TPC in the extracts was noticed with increase in concentration of ethanol from 60 to 80 per cent.

As the solid to solvent ratio increased from 1:30 to 1:50 there was significant increase in the TFC, TPC, DPPH scavenging activity, ascorbic acid

and α-glucosidase inhibition activity in all the varikka and koozha extracts. Increase in TFC and TPC with increase in solid to solvent ratio are inconsistent with mass transfer principles where the driving force for mass transfer is considered as the concentration gradient between the solid and the solvent.

Extract of freeze dried varikka samples using 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) had highest Total flavonoid content (TFC) (15.66 mg QE $100g^{-1}$), Total phenolic content (TPC) (156.10 mg GAE 100g), DPPH scavenging activity (69.29 per cent inhibition) and α-glucosidase inhibition activity (90.24 per cent). The same extract, $D_2S_4R_3$ from koozha also exhibited highest TFC (15.88 mg QE 100 g^{-1}), TPC (164.63 mg GAE 100g), DPPH scavenging activity (68.64 per cent inhibition) and α-glucosidase inhibition activity (92.28 per cent). Increased DPPH activity is mainly attributed to the higher phenolic and flavonoid content retained by freeze drying compared to spray drying. Strong positive correlation existed between TPC and TFC and scavenging activity.

Freeze dried varikka samples extracted using 90 per cent methanol at 1:50 solid solvent ratio recorded the highest (45.88 mg $100g^{-1}$) ascorbic acid content and freeze dried koozha samples extracted using 90% methanol at 1:40 solid solvent ratio had the highest ascorbic acid content of 47.37 mg $100g^{-1}$.

Based on the efficiency and economics, extraction of freeze dried samples using 60% ethanol at 1:40 solid to solvent ratio ($D_2S_4R_2$), extraction of freeze dried samples using 60% ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) and cabinet dried samples with 60% ethanol at 1:50 solid to solvent ratio ($D_1S_4R_3$) were selected as three superior extraction methods.

The three selected extracts were tested on HeLa cell lines with Doxorubicin as control. Freeze dried varikka and koozha samples extracted in 60 percent ethanol at 1:50 solid to solvent ratio had lowest IC_{50} value of 129.30 and 157.58 µg/mL respectively. Negative correlations were found between higher

TPC (varikka-0.693 and koozha-0.648) and TFC (varikka-0.993 of extracts and koozha-0.785) lower IC_{50} values.

The phytochemical profiling of the three superior varikka and koozha extracts was done by using LCMS/MS (Waters UPLC H class system fitted with TQD MS/MS system) to explore the presence of possible functional compounds. Total fifteen sugars were fractionated and identified. Though the individual sugar content differed with respect to types of jackfruit and extracts, the sugars were common in all the extracts. Major sugars identified were fructose, glucose, mannose, sorbitol and sucrose. Sugars which were found in comparatively small quantities were xylose, lactose, trehalose, fucose and rhamnose.

Extract from varikka recorded higher glucose and sucrose content compared to koozha extract, whereas all the other sugars were high in koozha extract compared to varikka extracts. Varikka extract,$D_2S_4R_3$ had highest fructose, while sucrose content was highest in varikka extract $D_1S_4R_3$. All the remaining sugars were highest in the koozha extract $D_2S_4R_3$. Among the extracts of varikka, $D_1S_4R_3$ contained highest maltose and lactose whereas other sugars were highest in the extract $D_2S_4R_3$. For koozha extract all the sugars were found highest in the extract $D_2S_4R_3$.

Ten organic acids were fractionated and identified from both the jackfruit types and all the organic acids were present in all the three extracts.

Citric acid, malic acid, shikimic acid, succinic acid, hydroxycitric acid, malonic acid and pyruvic acid were higher in varikka extracts, whereas tartaric acid, fumaric acid and maleic acid were present in koozha extracts. All the organic acids were highest in $D_2S_4R_3$. $D_2S_4R_3$ of varikka recorded highest citric acid, succinic acid, malonic acid and pyruvic acid. Malic acid, tartaric acid and fumaric acid were highest in $D_2S_4R_3$ of koozha.

Eighteen phenolic compounds were identified by comparing their retention times and mass spectra with respective standards. Extracts prepared from freeze

dried sample with 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) had highest total phenolic content, with highest ferulic acid, p- oumaric acid, caffeic acid, benzoic acid, 2,4-dihydroxy benzoic acid, gentisic acid, vanillic acid, etc. Salicylic acid was highest in the extract prepared from freeze dried samples extracted with 60 per cent ethanol at 1:40 solid to solvent ratio ($D_2S_4R_2$) and extract prepared using cabinet dried ample with 60 per cent ethanol at 1:50 solid to solvent ratio ($D_1S_4R_3$) contained higher ellagic acid. Chlorogenic acid content was found to be equal in the extracts $D_2S_4R_3$ and $D_1S_4R_3$.

Anti-proliferative property of the extract was significantly highest in the extracts with highest TPC. However, koozha extract $D_2S_4R_3$, in spite of having highest TPC, had higher IC_{50} value compared to varikka extract. Correlation was noticed between higher ferulic acid content and lower IC_{50} values

Fractionation and identification of flavonoid revealed the presence of all the fifteen flavonoids in the extracts from varikka and koozha, but the quantity of individual flavonoids differed with respect to types. Extract $D_2S_4R_3$ had highest individual flavonoids, except for galangin which was found highest in the extract, $D_1S_4R_3$. Varikka extract $D_2S_4R_3$ was found to contain highest myricetin, catechin, epicatechin, quercetin, luteolin, rutin, fisetin, umbelliferone, eriodictyol. Extract $D_2S_4R_3$ of koozha had highest naringenin, epigallocatechin, hesperetin, apigenin and kaemperol. Galangin was highest in the koozha extract $D_1S_4R_3$.

Encapsulation of the three superior jackfruit extracts *viz*., $D_1S_4R_3$, $D_2S_4R_2$, $D_2S_4R_3$ was done independently by spray drying with two levels of maltodextrin (MD 10 and 20 DE), three levels of carrier to extract ratios (1:10, 1:15 and 1:20) with two temperatures of spray drying (Inlet 180° C - outlet 80°C and Inlet 190°C - outlet 90° C).

Total flavonoid content (TFC), total phenolic content (TPC), antioxidant activity (DPPH) and ascorbic acid content of varikka and koozha encapsulates were influenced by all the process variables.

Physicochemical properties of both the extracts encapsulated with 20 DE MD were superior compared to those encapsulated with 10 DE MD. The increased carrier concentration from 1:10 to 1:20 resulted in significantly increased TFC, TPC, ascorbic acid content and DPPH scavenging activity of the encapsulates from varikka and koozha extracts.

Spray drying temperature also influenced phytochemical properties of encapsulates obtained from both varikka and koozha extracts. Decrease in the TFC, TPC, ascorbic acid content and antioxidant activity of the extracts was noticed with increase in spray drying temperature from 180° C to 190°C inlet and 80°C to 90° C outlet irrespective of carrier to extract ratio.

All the encapsulates prepared using 20 DE MD recorded higher recovery percentage compared to those encapsulated with 10 DE. When the carrier to extract ratio was increased from 1:10 to 1:20 powder recovery was increased while the moisture content of the powder was reduced.

Recovery was higher in the extracts encapsulated at 190 inlet - 90º C outlet temperature, compared to 180 and 80 º C.

Encapsulates prepared from the varikka and koozha extracts with10 DE MD had lower moisture content compared to those with 20 DE MD. Moisture content of the encapsulates prepared at 1:20 carrier to extract ratio was lower compared to those with 1:10 carrier to extract ratio. The addition of maltodextrin to the feed prior to spray-drying increases the total solid content and reduces the amount of water available for evaporation there by decreasing the moisture content of the powder.

Lower moisture content was recorded by the all the encapsulates prepared at higher inlet - out let temperature of 190 - 90º C compared 180 - 80 º C. At higher inlet air temperatures, the rate of heat transfer to the particle is greater, providing a greater driving force for moisture evaporation resulting in powders with reduced moisture content.

TFC, TPC, ascorbic acid and DPPH scavenging activity of both varikka and koozha extracts spray encapsulated with 20 DE MD, 1:20 carrier concentration at temperature of 180° C inlet - 80°C outlet were superior. All the encapsulates prepared using 20 DE MD recorded higher recovery percentage and lower moisture content. When the carrier to extract ratio was increased from 1:10 to 1:20 powder recovery was increased while the moisture content of the powder was reduced. Recovery was higher and moisture content was lower in the extracts encapsulated at 190 inlet - 90º C outlet temperature.

Encapsulation of the three superior extracts was conducted by freeze drying technique using two levels of carrier maltodextrin (10 and 20 dextrose equivalence) at 1:10, 1:15 and 1:20 carrier to extract ratio.

TFC, TPC, DPPH scavenging activity and ascorbic acid content of all the varikka and koozha extracts prepared with 20 DE were found to be higher compared to 10 DE. Higher DE maltodextrins form a more dense, more oxygen impermeable matrix providing better retention and longer shelf life of encapsulates.

Increase in carrier to extract ratio from 1:10 to 1:20 showed increased retention of TFC, TPC, ascorbic acid content and DPPH scavenging activity in all the freeze dried encapsulates.

The extracts encapsulated with MD 20 DE had higher recovery of encapsulates compared to extract encapsulated using MD 10 DE. The extracts encapsulated at carrier to extract ratio of 1:20 had highest recovery of encapsulates (except varikka $D_1S_4R_3$), while the lowest recovery of the encapsulates was observed in extracts encapsulated at 1:10 carrier to extract ratio.

Encapsulates prepared with 10 DE MD had lowest moisture content compared to those with 20 DE.

TFC, TPC, DPPH scavenging activity and ascorbic acid content of all the extracts prepared with 20 DE and carrier to extract ratio of 1:20 were superior. The extracts encapsulated with MD 20 DE had higher recovery of encapsulates. The extracts encapsulated at carrier to extract ratio of 1:20 had highest recovery of encapsulates (except varikka $D_1S_4R_3$), while the lowest recovery was observed in extracts encapsulated at 1:10 carrier to extract ratio. Encapsulates prepared with 10 DE MD had lowest moisture content compared to those with 20 DE.

The extract prepared from freeze dried samples with 60% ethanol in 1:50 solid to solvent ratio ($D_2S_4R_3$) which had highest TPC, TFC and ascorbic acid, produced spray and freeze encapsulates with higher phytochemical compounds. The extract $D_2S_4R_3$ also could produce spray and freeze encapsulates with highest DPPH scavenging activity compared to other two extracts selected for encapsulation.

Spray encapsulate of the extract prepared from freeze dried varikka and koozha with 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) using 20 DE maltodextrin at 1:20 carrier to extract ratio with inlet and outlet temperature of 180 and 80° C ($C_2T_1Cr_3$) was found to be superior. Freeze encapsulation of the same extract($D_2S_4R_3$)using 20 dextrose equivalence maltodextrin at 1:20 carrier to extract ratio (C_2Cr_3) produced superior encapsulates with respect to biochemical properties. These two encapsulates were further utilized for preparation of fortified mango RTS beverage.

The selected encapsulates were utilized for preparation of fortified mango RTS beverages as per FSSAI standards and compared with a commercial fortified beverage.

Quantity of spray / freeze encapsulates to be dissolved in mango RTS beverage was decided as 0.05 per cent and the prepared beverages were analysed for physicochemical and sensory quality parameters.

Though encapsulates utilized for enrichment had influenced TSS of mango RTS beverage, the increase in TSS compared to control sample was only 0.32 and 0.28° Brix in varikka and koozha respectively. The encapsulates added altered the sugar content of the RTS beverage. Acidity of the mango RTS beverage was found to be lowest in control and commercial sample compared to the beverages enriched with encapsulates. Though the acidity of the enriched beverages was slightly high, it did not alter the sensory properties.

Addition of both spray and freeze encapsulates to mango RTS beverage resulted in increase in the TPC compared to control and the commercial fortified mango RTS beverage. Addition of encapsulates to the mango RTS beverage had enhanced the DPPH scavenging activity to 13-16%, compared to commercial fortified mango RTS beverage.

Sensory evaluation of mango RTS beverages enriched with spray or freeze encapsulate of varikka and koozha extracts revealed that color and appearance, consistency, taste, flavor and overall acceptability scores were not influenced by quantity of spray dried encapsulate used for enrichment. The RTS beverages enriched with both freeze and spray encapsulate @ 0.05per cent concentration were similar to commercial fortified beverage with respect to sensory parameters and no negative effect of encapsulation was noticed on the sensory properties of the beverage. These spray and freeze encapsulates could be utilized for fortifying mango RTS beverage @ 50 mg 100 ml^{-1} without affecting the sensory parameters with an enhanced antioxidant activity of 13-16% compared to commercial fortified mango RTS beverage.

7. REFERENCES

A.O.A.C. (2000) Official methods of analysis (17th Ed.) Association of Official Analytical Chemists, Gaithersburg, MD.

Abadio, F.D.B., Domingues, A.M., Borges, S.V., and Oliveira, V.M. 2004. Physical properties of powdered pineapple (*Ananas comosus*) juice—effect of malt dextrin concentration and atomization speed. *J. Food Eng*. 64(3): 285-287.

Adan, A.A., Ojwang, R.A., Muge, E.K., Mwanza, B.K., and Nyaboga, E.N. 2020. Phytochemical composition and essential mineral profile, antioxidant and antimicrobial potential of unutilized parts of jackfruit. *Food Res*. 4(4): 1125-1134.

Agada, R., Thagriki, D., Lydia, D.E., Khusro, A., Alkahtani, J., Al Shaqha, M.M., Alwahibi, M.S., and Elshikh, M.S. 2021. Antioxidant and anti-diabetic activities of bioactive fractions of *Carica papaya* seeds extract. *J. King Saud Univ. Sci.* 33(2): 101342.

Ahmed, N., Siddiqui, S., Gehlot, R. and Arora, S., 2018. Effect of phyto-protein enrichment on organoleptic evaluation of mango RTS beverages. *J. Pharmacogn. Phytochemistry* 7(6): 36-39.

Ali, M.R., Yong, M.J., Gyawali, R., Mosaddik, A., Ryu, Y.C., and Cho, S.K. 2012. Mango (*Mangifera indica* L.) peel extracts inhibit proliferation of HeLa human cervical carcinoma cell via induction of apoptosis. *J. Korean Soc. Appl. Biol. Chem. 55*(3): 397-405.

Anandaraman, S. and Reineccius, G.A., 1986. Stability of encapsulated orange peel oil. *Food technology (USA).*

Ang, Y.K., Sia, W.C., Khoo, H.E., and Yim, H.S. 2012. Antioxidant potential of *Carica papaya* peel and seed. *Focus. modern food ind*. 1(1): 11-16.

Arun, K.B., Jayamurthy, P., Anusha, C.V., Mahesh, S.K., and Nisha, P. 2017. Studies on activity guided fractionation of pomegranate peel extracts and its effect on antidiabetic and cardiovascular protection properties. *J. Food Process. Preserv***.** 41(1): 13108.

Arung, T., Shimizu, K., Tanaka, H., and Kondo, R. 2010a. 3-Prenyl luteolin, a new prenylated flavone with melanin biosynthesis inhibitory activity from wood of *Artocarpus heterophyllus*. Fitoterapia. 81: 640−643.

Arung, E. T., Wicaksono, B. D., Handoko, Y. A., Kusuma, I. W., Shimizu, K., Yulia, D., and Sandra, F. 2010. Cytotoxic effect of artocarpin on T47D cells. *J. Nat. Med*. 64: 423−429.

Arung, E.T., Shimizu, K., and Kondo, R. 2007. Structure–activity relationship of prenyl‐substituted polyphenols from *Artocarpus heterophyllus* as inhibitors of melanin biosynthesis in cultured melanoma cells. *Chem. Biodivers*. *4*(9): 2166-2171.

Asami, D.K., Hong, Y.J., Barrett, D.M., and Mitchell, A.E. 2003. Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *J. Agric. Food Chem*. *51*(5): 1237-1241.

Azarpazhooh, E., Sharayei, P., Zomorodi, S., and Ramaswamy, H.S. 2019. Physicochemical and phytochemical characterization and storage stability of freeze-dried encapsulated pomegranate peel anthocyanin and in vitro evaluation of its antioxidant activity. *Food Bioproc Tech*. 12(2): 199-210.

Ballesteros, L.F., Ramirez, M.J., Orrego, C.E., Teixeira, J.A., and Mussatto, S.I. 2017. Encapsulation of antioxidant phenolic compounds extracted from spent coffee grounds by freeze-drying and spray-drying using different coating materials. *Food Chem.* 237: 623-631.

Baron A.D. 1998. Postprandial hyperglycaemia and α-glucosidase inhibitors. Diabetes Research and Clinical Practice. 40: S51-55. https://doi.org/10. 1016/ S0140-6736 (02)08905-5.

Bazaria, B. and Kumar, P. 2017. Effect of dextrose equivalency of maltodextrin together with Arabic gum on properties of encapsulated beetroot juice. *J. Food Meas. Charact*. 11(1): 156-163.

Begum, S. and Srivalli, P. 2019. Antidiabetic Potential of *Mangifera Indica* L. cv. Anwar Ratol Leaves Medicinal Application of Food Wastes. *J. Pharm. Innov*. 3(2):18-22.

Benalla, W., Bellahcen, S., and Bnouham, M. 2010. Antidiabetic medicinal plants as a source of alpha glucosidase inhibitors. *Curr. Diabetes Rev*. *6*(4): 247-254.

Biworo, A., Tanjung, E., Iskandar, K., and Suhartono, E. 2015. Antidiabetic and antioxidant activity of jackfruit (*Artocarpus heterophyllus*) extract. *J. Med. Biol. Eng*. 4(4).

Cammack, R. 2006. *Oxford Dictionary of Biochemistry and Molecular Biology* (2nd Ed). Oxford University Press, 2006: 74-75.

Campelo, P.H., do Carmo, E.L., Zacarias, R.D., Yoshida, M.I., Ferraz, V.P., de Barros Fernandes, R.V., Botrel, D.A., and Borges, S.V. 2017. Effect of dextrose equivalent on physical and chemical properties of lime essential oil microparticles. *Ind Crops Prod*. *102*: 105-114.

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. A. 913*(1-2): 387-395.

Chiasson, J.L., Josse, R.G., Gomis, R., Hanefeld, M., Karasik, A., Laakso, M., and STOP-NIDDM Trial Research Group. 2002. Acarbose for prevention of type 2 diabetes mellitus: the STOP-NIDDM randomised trial. *Lancet*. 359(9323): 2072-2077.

Chranioti, C., Nikoloudaki, A., and Tzia, C. 2015. Saffron and beetroot extracts encapsulated in maltodextrin, gum Arabic, modified starch and chitosan: Incorporation in a chewing gum system. *Carbohydr. Polym.* 127: 252-263.

Chun, O.K., Kim, D.O., Moon, H.Y., Kang, H.G., and Lee, C.Y. 2003. Contribution of individual polyphenolics to total antioxidant capacity of plums. *J. Agric. Food Chem. 51*(25): 7240-7245.

Cortés-Rojas, D.F., Souza, C.R., and Oliveira, W.P. 2014. Encapsulation of eugenol rich clove extract in solid lipid carriers. *J. Food Eng***.** 127: 34-42.

Cos, P., Vlietinck, A.J., Berghe, D.V., and Maes, L. 2006. Anti-infective potential of natural products: how to develop a stronger in vitro 'proof-of-concept'. *J. Ethnopharmacology*. 106(3): 290-302.

Crouch, S.P.M., Kozlowski, R., Slater, K.J. and Fletcher, J. 1993. The use of ATP bioluminescence as a measure of cell proliferation and cytotoxicity. *J. Immunol. Meth. 160*(1): 81-88.

da Fonseca Machado, A.P., Rezende, C.A., Rodrigues, R.A., Barbero, G.F., e Rosa, P.D.T.V., and Martínez, J. 2018. Encapsulation of anthocyanin-rich extract from blackberry residues by spray-drying, freeze-drying and supercritical antisolvent. *Powder Technol*. 340: 553-562.

Daud, M.N.H., Fatanah, D.N., Abdullah, N., and Ahmad, R. 2017. Evaluation of antioxidant potential of *Artocarpus heterophyllus* L. J33 variety fruit waste from different extraction methods and identification of phenolic constituents by LCMS. *Food chem. 232*: 621-632.

De Castro, M.L. and Garcıa-Ayuso, L.E. 1998. Soxhlet extraction of solid materials: an outdated technique with a promising innovative future. *Anal. Chim. Acta*. 369(1-2): 1-10.

De Oliveira, W.Q., Wurlitzer, N.J., de Oliveira Araújo, A.W., Comunian, T.A., Bastos, M.D.S.R., de Oliveira, A.L., Magalhães, H.C.R., Ribeiro, H.L., de Figueiredo, R.W., and de Sousa, P.H.M. 2020. Complex coacervates of cashew gum and gelatin as carriers of green coffee oil: The effect of microcapsule application on the rheological and sensorial quality of a fruit juice. *Int. Food Res. J*. 131: 109047.

Dorta, E., Lobo, M.G., and González, M. 2012. Using drying treatments to stabilise mango peel and seed: Effect on antioxidant activity. *Lwt -food sci technol*. *45*(2): 261-2680.

Ezhilarasi, P.N., Indrani, D., Jena, B.S., and Anandharama krishnan, C. 2013. Freeze drying technique for microencapsulation of Garcinia fruit extract and its effect on bread quality. *J. Food Eng***.** 117(4): 513-520.

Fatemeh, S.R., Saifullah, R., Abbas, F.M.A., and Azhar, M.E. 2012. Total phenolics, flavonoids and antioxidant activity of banana pulp and peel flours: influence of variety and stage of ripeness. *Int. Food Res. J*. 19(3): 1041.

Ferlay J, Soerjomataram I, Dikshit R, Eser S, Mathers C, Rebelo M, Parkin DM, Forman D, Bray F (2015) Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. International Journal of Cancer 136(5): E359-386.

Gao, J., Yu, H., Guo, W., Kong, Y., Li, Q., Yang, S., Zhang, Y., and Wang, Y. 2018. The anticancer effects of ferulic acid is associated with induction of cell cycle arrest and autophagy in cervical cancer cells. *Cancer Cell Int***.** *18*(1): 1-9.

Giusti, M., Rodriguez-Saona, L., Griffin, D., and Wrolstad, R. 1999. Electrospray and tanden mass spectroscopy as tools for anthocyanin characterization. *J. Agric. Food Chem*. 47(12): 4657-4664.

GOK [Government of Kerala] 2019. Agricultural statistics 2019-20 pp130 wwwecostat.kerala.gov.in http://www.ecostat.kerala.gov.in/images/pdf/publications/Agriculture/data/2019-20/after220920/agristat2019-20.pdf

Gupta, D., Mann, S., Sood, A., and Gupta, R.K. 2011. Phytochemical, nutritional and antioxidant activity evaluation of seeds of jackfruit (*Artocarpus heterophyllus* Lam.). *Int. J. Pharma Bio Sci.* 2(4): 336-345.

Hidalgo, M., Sánchez-Moreno, C., and de Pascual-Teresa, S. 2010. Flavonoid–flavonoid interaction and its effect on their antioxidant activity. *Food chem*. 121(3): 691-696.

Ho, L.P., Pham, A.H., and Le, V.V.M. 2015. Effects of Core/Wall Ratio and Inlet Temperature on the Retention of Antioxidant Compounds during the Spray Drying of Sim (*Rhodomyrtus tomentosa*) Juice. *J. Food Process. Preserv*. 39(6): 2088-2095.

Hossain, M.A., Evan, M.S.S., Moazzem, M.S., Roy, M., and Zzaman, W., 2020. Response Surface Optimization for Antioxidant Extraction from Jackfruit (*Artocarpus heterophyllus* Lam.) Seed and Pulp. *J. Sci. Res*. 12(3): 397-409.

Ivanov, M., Božunović, J., Gašić, U., Drakulić, D., Stevanović, M., Rajčević, N., and Stojković, D. 2022. Bioactivities of *Salvia nemorosa* L. inflorescences are influenced by the extraction solvents. *Ind Crops Prod*. 175: 114260.

Jagadeesh, S.L., Reddy, B.S., Swamy, G.S.K., Gorbal, K., Hegde, L., and Raghavan, G.S.V. 2007. Chemical composition of jackfruit (*Artocarpus heterophyllus* Lam.) selections of Western Ghats of India. *Food Chem*. *102*(1): 361-365

Jagtap, U.B., Panaskar, S.N., and Bapat, V.A. 2010. Evaluation of antioxidant capacity and phenol content in jackfruit (*Artocarpus heterophyllus* Lam.) fruit pulp. *Plant Foods Hum. Nutr*. 65(2): 99-104.

Jiang, Z., Shi, R., Chen, H., and Wang, Y. 2019. Ultrasonic microwave-assisted extraction coupled with macroporous resin chromatography for the purification of antioxidant phenolics from waste jackfruit (*Artocarpus heterophyllus* Lam.) peels. *J. Food Sci. Technol*. 56(8): 3877-3886.

Kalra, S., 2014. Alpha glucosidase inhibitors. *J. Pak. Med. Assoc.* 64(4): 474-476.

Kang, H.M. and Saltveit, M.E. 2002. Antioxidant capacity of lettuce leaf tissue increases after wounding. *J. Agric. Food Chem*. 50(26): 7536 -7541.

Kato-Schwartz, C.G., Corrêa, R.C.G., de Souza Lima, D., de Sá-Nakanishi, A.B., de Almeida Gonçalves, G., Seixas, F.A.V., Haminiuk, C.W., Barros, L., Ferreira, I.C., Bracht, A., and Peralta, R.M. 2020. Potential anti-diabetic properties of Merlot grape pomace extract: An in vitro, in silico and in vivo study of α-amylase and α-glucosidase inhibition. *Int. Food Res. J.* 137: 109462.

Kaushik, V. and Roos, Y.H. 2007. Limonene encapsulation in freeze-drying of gum Arabic–sucrose–gelatin systems. , *Food Sci. Technol.* 40(8): 1381-1391.

Khan, M.R., Omoloso, A.D., and Kihara, M. 2003. Antibacterial activity of *Artocarpus heterophyllus*. *Fitoterapia*, 74(5): 501-505.

Kotowaroo, M.I., Mahomoodally, M.F., Gurib‐Fakim, A., and Subratty, A.H. 2006. Screening of traditional antidiabetic medicinal plants of mauritius for possible α‐amylase inhibitory effects in vitro. *Phytother Res***.** 20(3): 228-231.

Krishnaiah, D., Sarbatly, R., and Nithyanandam, R. 2012. Microencapsulation of Morinda citrifolia L. extract by spray-drying. *Chem. Eng. Res. Des*. 90(5): 622-632.

Kuck, L.S. and Noreña, C.P.Z. 2016. Microencapsulation of grape (*Vitislabrusca* var. Bordo) skin phenolic extract using gum Arabic, polydextrose, and partially hydrolyzed guar gum as encapsulating agents. *Food Chem*. 194: 569-576.

Kumar, S.S., Manoj, P., Shetty, N.P., and Giridhar, P. 2015. Effect of different drying methods on chlorophyll, ascorbic acid and antioxidant compounds retention of leaves of Hibiscus sabdariffa L. *J. Sci. Food Agric*. 95(9): 1812-1820.

Leal, Y.A., Fernández-Garrote, L.M., Mohar-Betancourt, A., and Meneses-García, A. 2016. The importance of registries in cancer control. *Salud Publica Mex*. 58: 309-316.

Li, R., Wang, Q., Zhao, M., Yang, P., Hu, X., and Ouyang, D. 2019. Flavonoid glycosides from seeds of *Hippophae rhamnoides* subsp. Sinensis with α-glucosidase inhibition activity. *Fitoterapia*, *137*, p.104248.

Loizzo, M.R., Tundis, R., Chandrika, U.G., Abeysekera, A.M., Menichini, F., and Frega, N.G. 2010. Antioxidant and antibacterial activities on foodborne pathogens of *Artocarpus heterophyllus* Lam.(Moraceae) leaves extracts. *J. Food Sci*. 75(5): M291-M295.

Luo, F., Fu, Y., Xiang, Y., Yan, S., Hu, G., Huang, X., Huang, G., Sun, C., Li, X., and Chen, K. 2014. Identification and quantification of gallotannins in mango (*Mangifera indica* L.) kernel and peel and their antiproliferative activities**.** *J. Funct. Foods*. 8: 282-291.

Miller-Keane, O.T.M. and O'Toole, M.T. 2003. Miller-Keane encyclopedia and dictionary of medicine, nursing, and allied health (7th Ed.) Philadelphia: Saunders.

Mishra, B.B., Patel, A.S., and Kar, A. 2019. Storage stability of encapsulated anthocyanin-rich extract from black carrot (*Daucuscarota* ssp. *Sativus*) using different coating materials. *Curr. Agric. Res. J.* 7(1): 53.

Mishra, P., Mishra, S., and Mahanta, C.L. 2014. Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of amla (*Emblica officinalis*) juice powder. *Food Bioprod. Process*. 92(3): 252-258.

Motaal, A. A. and Shaker, S.2011. Anticancer and antioxidant activities of standardized whole fruit, pulp, and peel extracts of Egyptian pomegranate. *Open. Conf. Proc. J.* (2) 1.

Munir, A., Sultana, B., Bashir, A., Ghaffar, A., Munir, B., Shar, G.A., Nazir, A., and Iqbal, M. 2018. Evaluation of Antioxidant Potential of Vegetables Waste. *Pol. J. Environ. Stud.* 27(2).

Murali, S., Kar, A., Mohapatra, D., and Kalia, P. 2015. Encapsulation of black carrot juice using spray and freeze drying. *Food Sci Technol Int.* 21(8): 604-612.

Mustafa, H.M., Amin, N.A.M., Zakaria, R., Anuar, M.S., Baharuddin, A.S., Hafid, H.S., and Omar, F.N. 2020. Dual impact of different drying treatments and ethanol/water ratios on antioxidant properties and colour attribute of jackfruit leaves (*Artocarpus heterophyllus* Lam.) Mastura Variety (J35). *Bio Resources*. 15(3): 5122-5140.

NHB (National Horticulture Board).2018 Horticulture at a Glance 2018 [online]. Available: hb.gov.in/StatisticsViewer.aspx?enc=CaSOU6CTRN/Ty9tOdH8Lkgol2QGWss6940QLGSpy2T0m6tZbw4/y0R84pftyqIGN[20January 2022]

Nicoleti, J.F., Silveira Jr, V., Telis-Romero, J., and Telis, V.R. 2007. Influence of drying conditions on ascorbic acid during convective drying of whole persimmons. *Dry. Technol*. 25(5): 891-899.

Ningappa, M.B., Dinesha, R., and Srinivas, L. 2008. Antioxidant and free radical scavenging activities of polyphenol-enriched curry leaf (*Murraya koenigii* L.) extracts. *Food Chem*. *106*(2): 720-728.

Nobossé, P., Fombang, E.N., and Mbofung, C.M. 2018. Effects of age and extraction solvent on phytochemical content and antioxidant activity of fresh *Moringa oleifera* L. leaves. *Food Sci. Nutr*. *6*(8): 2188-2198.

Olalere, O.A., Gan, C.Y., Abdurahman, H.N., Adeyi, O., and Ahmad, M.M. 2020. Holistic approach to microwave-reflux extraction and thermo-analytical fingerprints of under-utilized *Artocarpus heterophyllus* seed wastes. *Heliyon*. 6(8): 04770.

Oleksii, P., Francisco, J. B., Nabil. G., Nikolai, L., and Eugène, V. 2014. Impact of pulsed electric fields and high voltage electrical discharges on extraction of high-added value compounds from papaya peels. *Food Res. Int*. 65: 337-343.

Ong, B.T., Nazimah, S. A. H., Osman, A., Quek, S.Y., Voon, Y.Y., Hashim, D., Chew, P.M., and Kong, Y.W. 2006. Chemical and flavour changes in jackfruit (*Artocarpus heterophyllus Lam*.) cultivar J3 during ripening. *Postharvest Biol. Technol*. 40(3): 279-286.

Osmani, O.H., Dhanasekar, S.S., Kumar, K.S., Sahu, R.K., and Roy, A. 2009. In vivo antidiabetic potential of *Artocarpusheterophyllus* plant seeds in streptozotocin-induced-diabetic rats. *Biomed. Pharmacol*. J. 2(2): 339.

Owczarek, L., Jasiñska, U., Osiñska, M., and Skapska, S. 2004. Juices and beverages with a controlled phenolic content and antioxidant capacity. *Polish J. Food Nutr. Sci*. 13(3): 261-268.

Paini, M., Aliakbarian, B., Casazza, A.A., Lagazzo, A., Botter, R., and Perego, P. 2015. Microencapsulation of phenolic compounds from olive pomace using spray drying: A study of operative parameters. *LWT-Food Sci and Technol*. *62*(1): 177-186.

Pandey, S. and Ojha, P. 2020. Preparation and Quality Evaluation of Mango based Whey Beverage. *J. Food Sci. Technol.* 12(12): 59-61.

Papoutsis, K., Golding, J.B., Vuong, Q., Pristijono, P., Stathopoulos, C.E., Scarlett, C.J., and Bowyer, M. 2018. Encapsulation of citrus by-product extracts by spray-drying and freeze-drying using combinations of maltodextrin with soybean protein and ι-Carrageenan. Foods, 7(7): 115.

Patil, V., Chauhan, A.K., and Singh, R.P. 2014. Optimization of the spray-drying process for developing guava powder using response surface methodology. *Powder Technol*. 253: 230-236.

Prakash, O., Kumar, R., Mishra, A., and Gupta, R. 2009. *Artocarpus heterophyllus* (Jackfruit): An overview. Pharmacogn. Rev. 3: 353−358.

Prasad, K.N., Yang, B., Yang, S., Chen, Y., Zhao, M., Ashraf, M., and Jiang, Y. 2009. Identification of phenolic compounds and appraisal of antioxidant and antityrosinase activities from litchi (*Litchi sinensis* Sonn.) seeds. *Food Chem*. *116*(1): 1-7.

Predescu, N.C., Papuc, C., Nicorescu, V., Gajaila, I.U.L.I.A.N.A., Goran, G.V., Petcu, C.D., and Stefan, G.E.O.R.G.E.T.A. 2016. The influence of solid-to-solvent ratio and extraction method on total phenolic content, flavonoid content and antioxidant properties of some ethanolic plant extracts. *Rev. Chim*. (67): 1922-1927.

Quek, S.Y., Chok, N.K., and Swedlund, P. 2007. The physicochemical properties of spray-dried watermelon powders. *Chem. Eng. Process*. 46(5): 386-392.

Rafiq, S., Singh, B., and Gat, Y. 2019. Effect of different drying techniques on chemical composition, color and antioxidant properties of kinnow (*Citrus reticulata*) peel. *J. Food Sci. Technol*. 56(5): 2458-2466.

Ranganna, S., 1986, Hand book of analysis and quality control for fruit and vegetable products. Tata Mc-Graw-Hill Publ. Co. Ltd., New Delhi.

Ray, S., Raychaudhuri, U., and Chakraborty, R. 2016. An overview of encapsulation of active compounds used in food products by drying technology. *Food Biosci*. 13: 76-83.

Revilla, I., Magarino, S. P., Gonzalez-SanJose, M. L., and Beltran, S. 1999. Identification of anthocyanin derivatives in grape skin extracts and red wines by liquid chromatography with diode array and mass spectrometric detection. *J. Chromatogr*. 847(9): 83-90.

Ribeiro, B., Rangel, J., Valentão, P., Andrade, P.B., Pereira, J.A., Bölke, H., and Seabra, R.M. 2007. Organic acids in two Portuguese chestnut (*Castanea sativa* Miller) varieties. *Food Chem*. *100*(2): 504-508.

Robert, P., Gorena, T., Romero, N., Sepulveda, E., Chavez, J., and Saenz, C. 2010. Encapsulation of polyphenols and anthocyanins from pomegranate (*Punica granatum*) by spray drying. *Int. J. Food Sci.* 45(7): 1386-1394.

Ruiz-Montanez, G., Burgos-Hernandez, A., Calderón-Santoyo, M., Lopez-Saiz, C.M., Velazquez-Contreras, C.A., Navarro-Ocana, A., and Ragazzo-Sánchez, J.A. 2015. Screening antimutagenic and antiproliferative properties of extracts isolated from Jackfruit pulp (*Artocarpus heterophyllus* Lam). *Food Chem*. 175: 409-416.

Ruiz-Montañez, G., Calderón-Santoyo, M., Chevalier-Lucia, D., Picart-Palmade, L., Jimenez-Sánchez, D.E., and Ragazzo-Sánchez, J.A. 2019. Ultrasound-assisted microencapsulation of jackfruit extract in eco-friendly powder particles: characterization and antiproliferative activity. *J. Dispers Sci Technol*. 40(10): 1507-1515.

Ruiz-Montañez, G., Ragazzo-Sanchez, J.A., Picart-Palmade, L., Calderón-Santoyo, M., and Chevalier-Lucia, D. 2017. Optimization of nanoemulsions processed by high-pressure homogenization to protect a bioactive extract of jackfruit (*Artocarpus heterophyllus* Lam*). Innov. Food Sc.i Emerg. Technol , 40*: 35-41.

Sadasivam, S. and Manickam, A. 1992. Biochemical methods for agricultural sciences. *Wiley Eastern Limited and Tamil Nadu Agricultural University*, Coimbatore, India.

Saikia, S., Mahnot, N.K., and Mahanta, C.L. 2015. Optimisation of phenolic extraction from *Averrhoa carambola* pomace by response surface methodology and its microencapsulation by spray and freeze drying. *Food chem*, 171: 144-152.

Sakhale, B.K., Pawar, V.N., and Ranveer, R.C. 2012. Studies on the development and storage of whey based RTS beverage from mango cv. Kesar. *Food Bioproc Tech*. 3(3).

Samborska, K., Witrowa-Rajchert, D. and Gonçalves, A. 2005. Spray-drying of α-amylase. The effect of process variables on the enzyme inactivation. *Drying Technol*. *23*(4), pp.941-953.

Saraswaty, V., Risdian, C., Primadona, I., Andriyani, R., Andayani, D.G.S. and Mozef, T. Pineapple peel wastes as a potential source of antioxidant compounds. In: *IOP conference series: earth and environmental science,* March 2017 Tangerang, Indonesia. IOP Publishing (60) pp. 12-13.

Šavikin, K., Živković, J., Alimpić, A., Zdunić, G., Janković, T., Duletić-Laušević, S., and Menković, N. 2018. Activity guided fractionation of pomegranate extract and its antioxidant, antidiabetic and antineurodegenerative properties. *Ind Crops Prod.* 113: 142-149.

Sawale, P.D., Patil, G.R., Hussain, S.A., Singh, A.K., and Singh, R.R.B. 2017. Effect of incorporation of encapsulated and free Arjuna herb on storage stability of chocolate vanilla dairy drink. *Food Biosci*. 19: 142-148.

Saxena, A., Bawa, A.S., and Raju, P.S. 2009. Phytochemical changes in fresh-cut jackfruit (*Artocarpus heterophyllus* L.) bulbs during modified atmosphere storage. *Food Chem.* 115(4): 1443-1449.

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

Singleton, V. L. and Rossi, J. A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Amer. J. Enol. Vitic*. 16(3): 144-158.

Škerget, M., Kotnik, P., Hadolin, M., Hraš, A.R., Simonič, M., and Knez, Ž. 2005. Phenols, proanthocyanidins, flavones and flavonols in some plant materials and their antioxidant activities. *Food Chem*. *89*(2): 191-198.

Sogi, D.S., Siddiq, M., and Dolan, K.D. 2015. Total phenolics, carotenoids and antioxidant properties of Tommy Atkin mango cubes as affected by drying techniques. *LWT-Food Sci Technol. 62*(1): 564-568.

Steppuhn, A. and Wackers, F. L. 2004. HPLC sugar analysis reveals the nutritional state and the feeding history of parasitoids. *Funct. Ecol*. 18: 812-819.

Subburamu, K., Singaravelu, M., Nazar, A., and Irulappan, I. 1992. A study on the utilization of jack fruit waste. *Bioresour. Technol*. *40*(1): 85-86.

Sun, Y., Shen, Y., Liu, D., and Ye, X. 2015. Effects of drying methods on phytochemical compounds and antioxidant activity of physiologically dropped un-matured citrus fruits. *LWT-Food Sci and Technol*. *60*(2): 1269-1275.

Sundarraj, A.A. and Ranganathan, T.V. 2018. Phytochemical constituents and thin-layer chromatography evaluation of the ethanolic extract of jackfruit (*Artocarpus integer*) peel. *J. Pharm Res*. 12(5): 717.

Suravanichnirachorn, W., Haruthaithanasan, V., Suwonsichon, S., Sukatta, U., Maneeboon, T., and Chantrapornchai, W. 2018. Effect of carrier type and concentration on the properties, anthocyanins and antioxidant activity of freeze-dried mao (*Antidesma bunius* (L.) Spreng) powders. *Agric. Nat. Resour*. *52*(4): 354-360.

Tejpal, A. and Amrita, P. 2016. Jackfruit: A health boon. *Int. J. Res. Ayurveda. Pharm.* 7(3): 59-64.

Tiwari, A.K. and Rao, J.M. 2002. Diabetes mellitus and multiple therapeutic approaches of phytochemicals: present status and future prospects. *Curr. Sci*. 30-38.

Trindade, M.B., Lopes, J.L., Soares-Costa, A., Monteiro-Moreira, A.C., Moreira, R.A., Oliva, M.L.V., and Beltramini, L.M. 2006. Structural characterization of novel chitin-binding lectins from the genus Artocarpus and their antifungal activity. *Biochim Biophys Acta Proteins Proteom BBA-PROTEINS PROTEOM*. 1764(1): 146-152.

Turkmen, N., Sari, F., and Velioglu, Y.S. 2006. Effects of extraction solvents on concentration and antioxidant activity of black and black mate tea polyphenols determined by ferrous tartrate and Folin–Ciocalteu methods. *Food Chem*. 99(4): 835-841.

Tuyen, C.K., Nguyen, M.H., and Roach, P.D. 2010. Effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac (*Momordica cochinchinensis*) fruit aril powder. *J. Food Eng*. *98*(3): 385-392.

Vagiri, M., Ekholm, A. Andersson, S. C., Johansson, E., and Rumpunen, K. 2012. An optimized method for analysis of phenolic compounds in buds, leaves, and fruits of black currant (*Ribes nigrum* L.). *J. Agric. Food Chem.* 60(7): 105-110.

Vázquez-González, Y., Ragazzo-Sánchez, J.A., and Calderón-Santoyo, M. 2020. Characterization and antifungal activity of jackfruit (*Artocarpus heterophyllus* Lam.) leaf extract obtained using conventional and emerging technologies. *Food Chem.* 127211.

Vega-Gálvez, A., Ah-Hen, K., Chacana, M., Vergara, J., Martínez-Monzó, J., García-Segovia, P., Lemus-Mondaca, R., and Di Scala, K. 2012. Effect of temperature and air velocity on drying kinetics, antioxidant capacity, total phenolic content, colour, texture and microstructure of apple (var. Granny Smith) slices. *Food Chem*. 132(1): 51-59.

Vu, H.T., Scarlett, C.J., and Vuong, Q.V. 2020. Encapsulation of phenolic-rich extract from banana (*Musa cavendish*) peel. *J. Food Sci. Technol*. 57(6): 2089-2098.

Wang, Y., Zhang, W., Lv, Q., Zhang, J., and Zhu, D. 2016. The critical role of quercetin in autophagy and apoptosis in HeLa cells. *Tumor Biol*. *37*(1): 925-929.

Weidner, S., Amarowicz, R., Karamać, M., and Frączek, E. 2000. Changes in endogenous phenolic acids during development of Secale cereale caryopses and after dehydration treatment of unripe rye grains. *Plant Physiol. Biochem*. *38*(7-8): 595-602.

Whiting, D.R., Guariguata, L., Weil, C., and Shaw, J. 2011. IDF diabetes atlas: global estimates of the prevalence of diabetes for 2011 and 2030. *Diabetes Res. Clin. Pract*. 94(3): 311-321.

Wong, C.W. and Tan, H.H. 2017. Production of spray-dried honey jackfruit (*Artocarpus heterophyllus*) powder from enzymatic liquefied puree. *J. Food Sci. Technol***.** 54(2): 564-571.

Xu, S.Y., Liu, J.P., Huang, X., Du, L.P., Shi, F.L., Dong, R., Huang, X.T., Zheng, K., Liu, Y., and Cheong, K. L. 2018. Ultrasonic-microwave assisted extraction, characterization and biological activity of pectin from jackfruit peel. *LWT*. 90577-582.

Yadav, D.N., Vishwakarma, R.K., Borad, S., Bansal, S., Jaiswal, A.K., and Sharma, M. 2016. Development of protein fortified mango based ready-to-serve beverage. *J. Food Sci. Technol*. 53(10): 3844-3852.

Yadav, N., Parveen, S., and Banerjee, M. 2020. Potential of nano-phytochemicals in cervical cancer therapy. *Clin. Chim. Acta*. 505: 60-72.

Zengin, G. 2016. A study on in vitro enzyme inhibitory properties of *Asphodeline anatolica*: New sources of natural inhibitors for public health problems. *Ind. Crop Prod*. 83: 39-43.

Zhang, L., Tu, Z.C., Xie, X., Wang, H., Wang, H., Wang, Z.X., Sha, X.M., and Lu, Y. 2017. Jackfruit (*Artocarpus heterophyllus* Lam.) peel: A better source of antioxidants and a-glucosidase inhibitors than pulp, flake and seed, and phytochemical profile by HPLC-QTOF-MS/MS. *Food Chem*. 234: 303-313.

Zhishen, J., Mengcheng, T., and Jianming, W. 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chem. 64*(4): 555-559.

Zhu, K., Zhang, Y., Nie, S., Xu, F., He, S., Gong, D., Wu, G., and Tan, L. 2017. Physicochemical properties and in vitro antioxidant activities of polysaccharide from *Artocarpus heterophyllus* Lam. pulp. *Carbohydr. Polym*. 155: 354-361.

Appendices

APPENDIX I

Average temperature and relative humidity data recorded during the extraction (2.07.2019 to 31.12.2019) of jackfruit extracts

Sl. No.	Month	Temperature (°C)		Relative Humidity (%)	
		Minimum	Maximum	Minimum	Maximum
1.	July	22.1	30.2	50.7	65.1
2.	August	21.9	31.7	50.9	61.8
3.	September	24.4	31.8	51.9	64.9
4.	October	21.9	31.7	50.9	61.8
5.	November	24.4	30.1	50.6	69.7
6.	December	21.9	31.7	50.9	61.8

APPENDIX II

Sensory evaluation score sheet

Name of the product:

Name of the evaluator: Date:

Sl no	Sample code	Colour	Consistency (mouthfeel)	Taste	Flavour	Overall acceptability
1						
2						
3						
4						

Remarks.....

Signature of the evaluator

9-Point Hedonic Scale

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

APPENDIX III

Cost of production of spray encapsulates

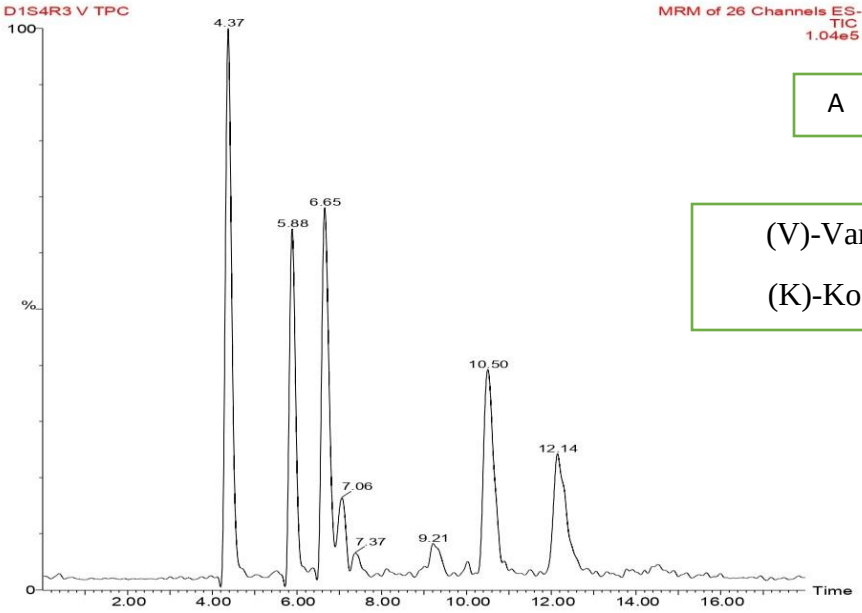
Sl no	Item	Quantity	Rate	Amount (Rs)
1.	Jackfruit waste sample	2g	30rs/100g	00.60
2.	Ethanol	180 mL	500/lit	90.00
3.	Freeze drying cost of sample	2g	150 KW/120g	02.50
4.	Maltodextrin	20g	670/kg	13.50
5.	Spray encapsulation cost	15g	2.5 KW/2 hour	15.00
For encapsulate of 15g of spray encapsulate				**121.60**
Cost for enrichment of 100ml RTS beverage				**Rs. 0.40**

APPENDIX-IV

Cost of production of freeze encapsulates

Sl no	Item	Quantity	Rate	Amount(Rs)
1.	Jackfruit waste sample	2g	30rs/100g	00.60
2.	Ethanol	180 mL	500/lit	90.00
3.	Freeze drying cost of sample	2g	150 KW/120g	02.50
4.	Maltodextrin	20g	670/kg	13.50
5.	Freeze encapsulation cost	20g	250 KW/100g	30.00
For encapsulate of 20g of freeze encapsulate				**136.60**
For enrichment of 100ml RTS beverage				**Rs. 0.35**

Appendix - V



A

(V)-Varikka

(K)-Koozha

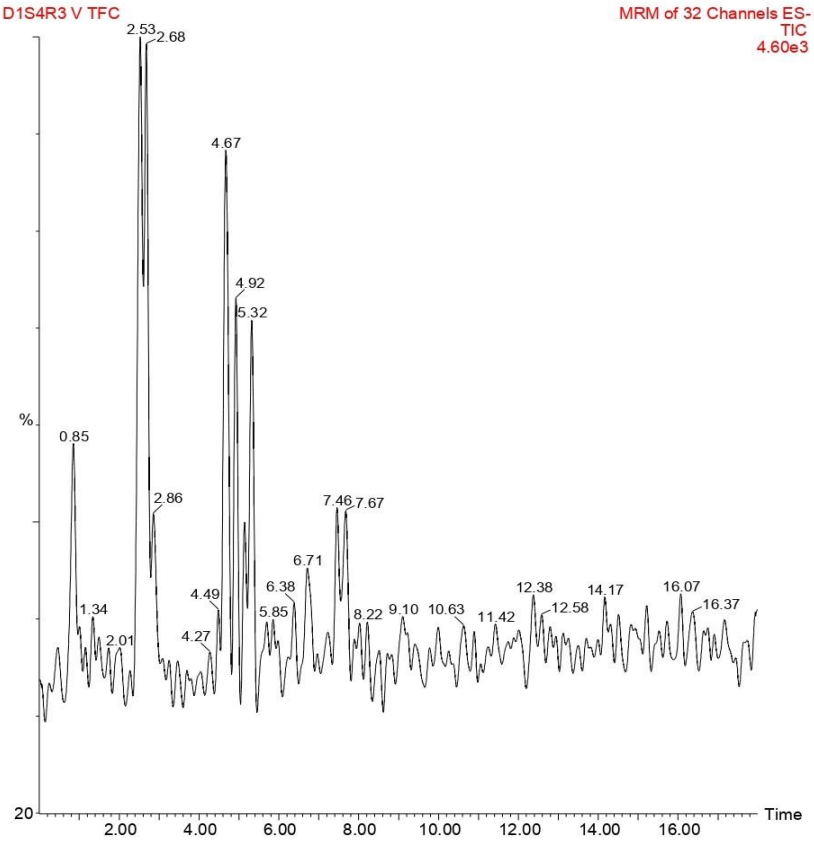
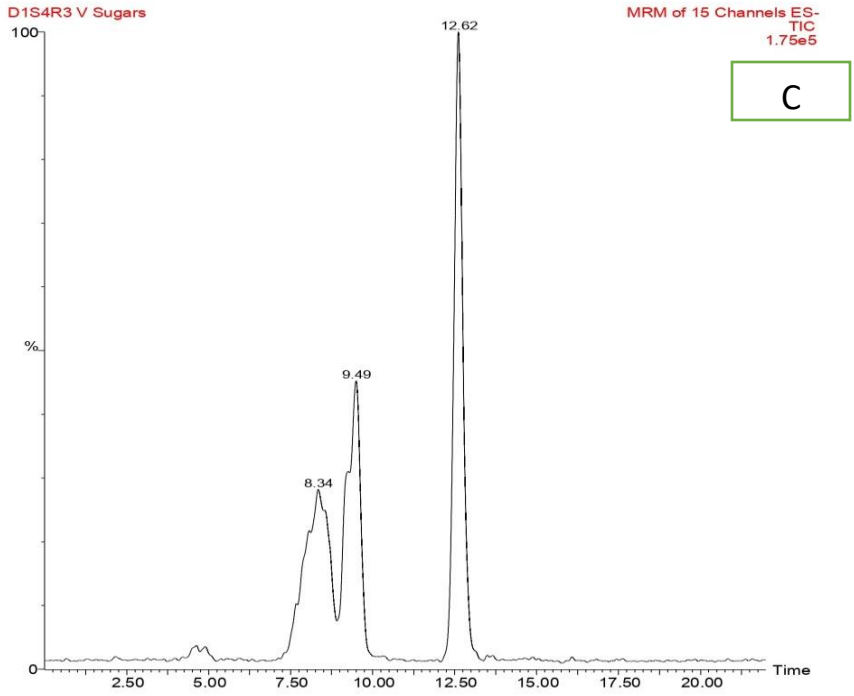
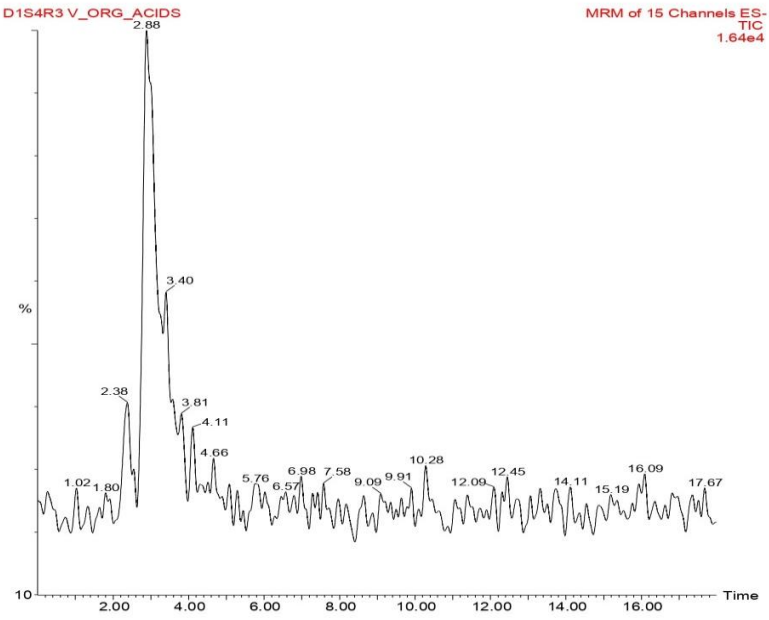


Plate 1: Chromatograms TPC (A) and TFC (B) profiling of the extract $D_1S_4R_3$ (V)

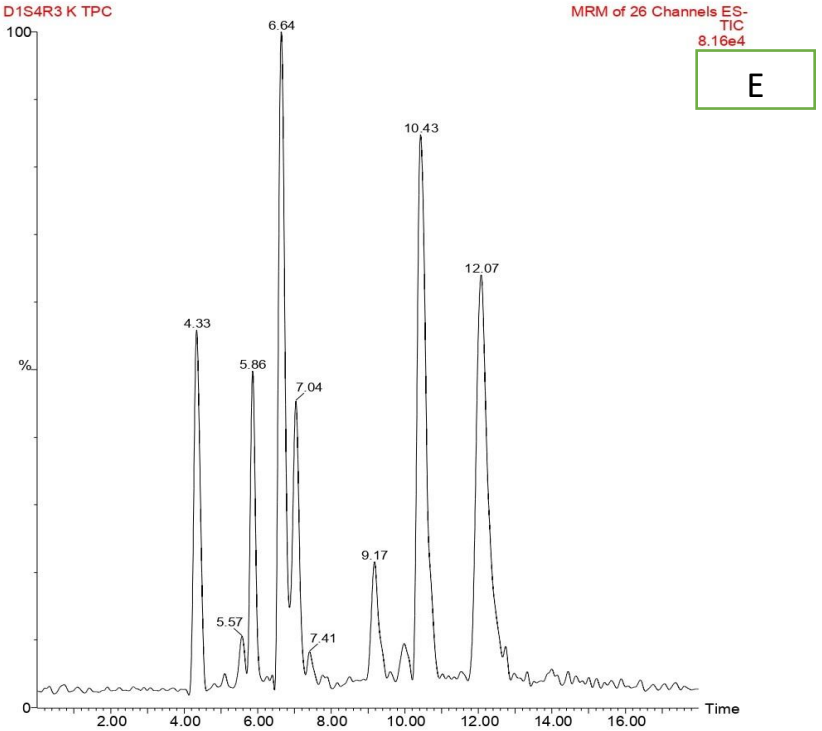


C



D

Plate 2: Chromatograms sugars (C) and organic acids (D) profiling of the extract $D_1S_4R_3$ (V)



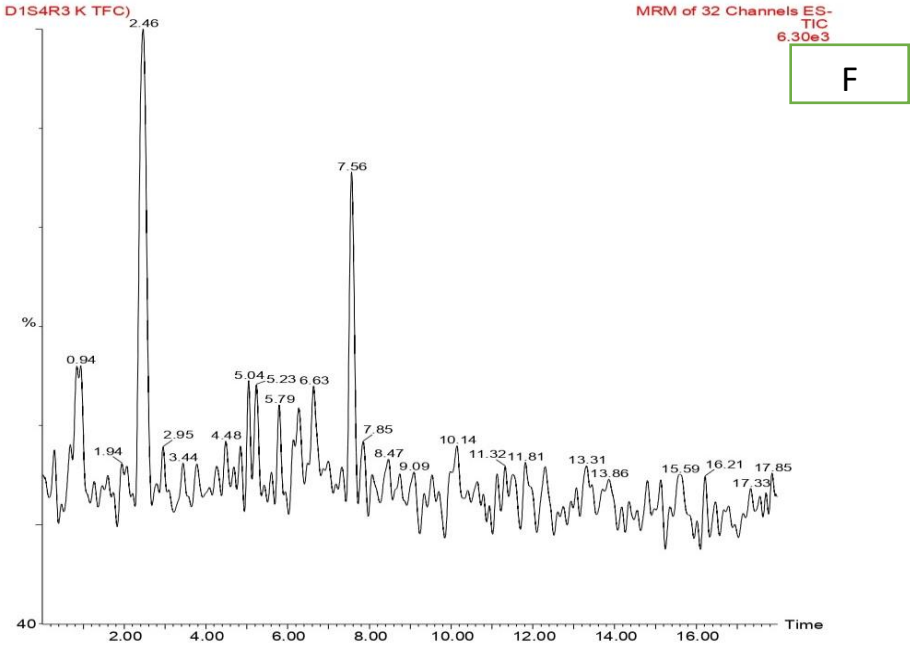


Plate 3: Chromatograms TPC (E) and TFC (F) profiling of the extract $D_1S_4R_3$ (K)

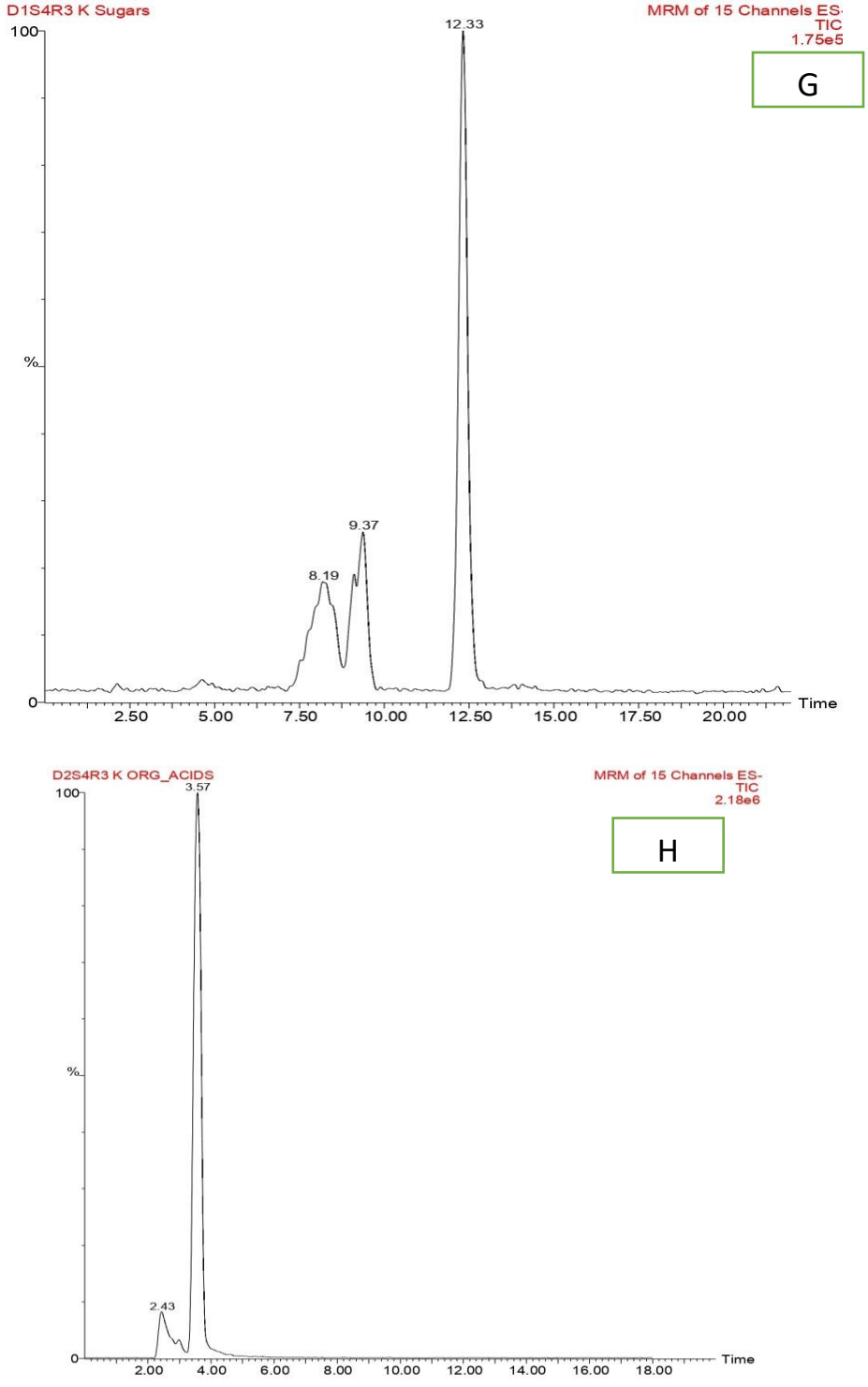
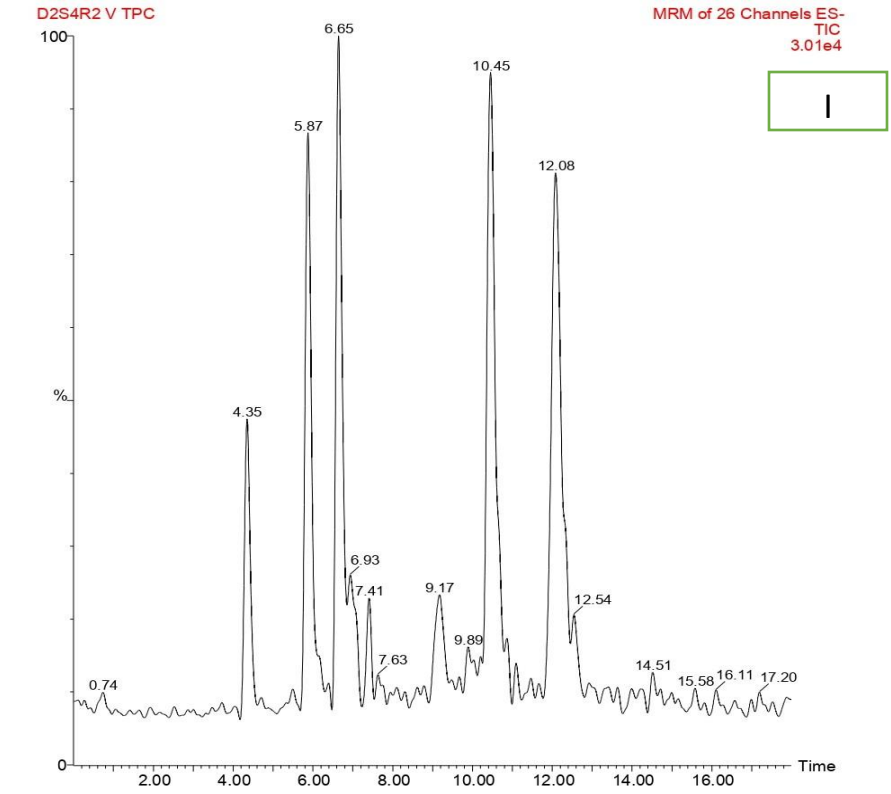


Plate 4: Chromatograms sugars (G) and organic acids (H) profiling of the extract $D_1S_4R_3$ (K)



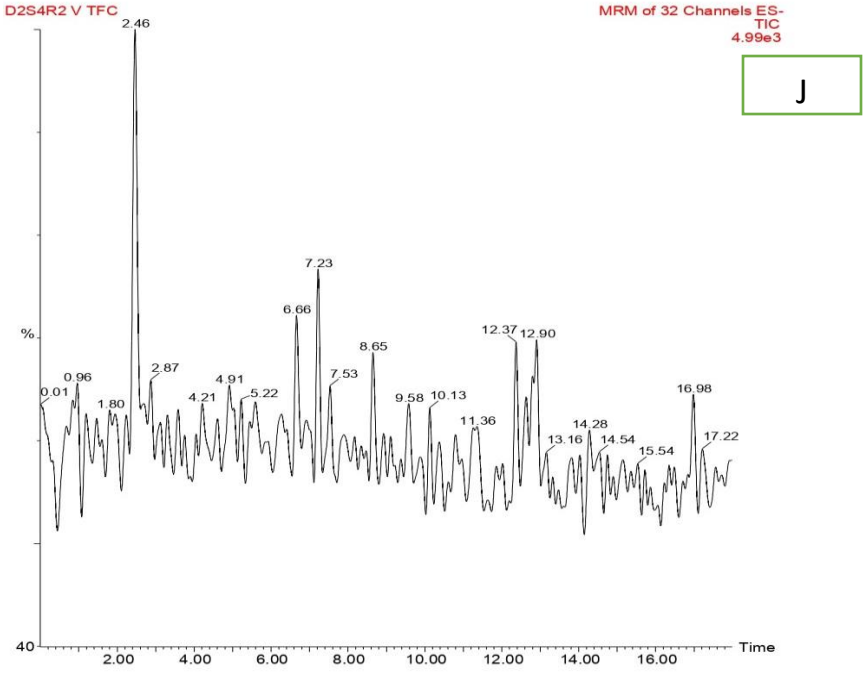


Plate 5: Chromatograms TPC (I) and TFC (J) profiling of the extract $D_2S_4R_2$ (V)

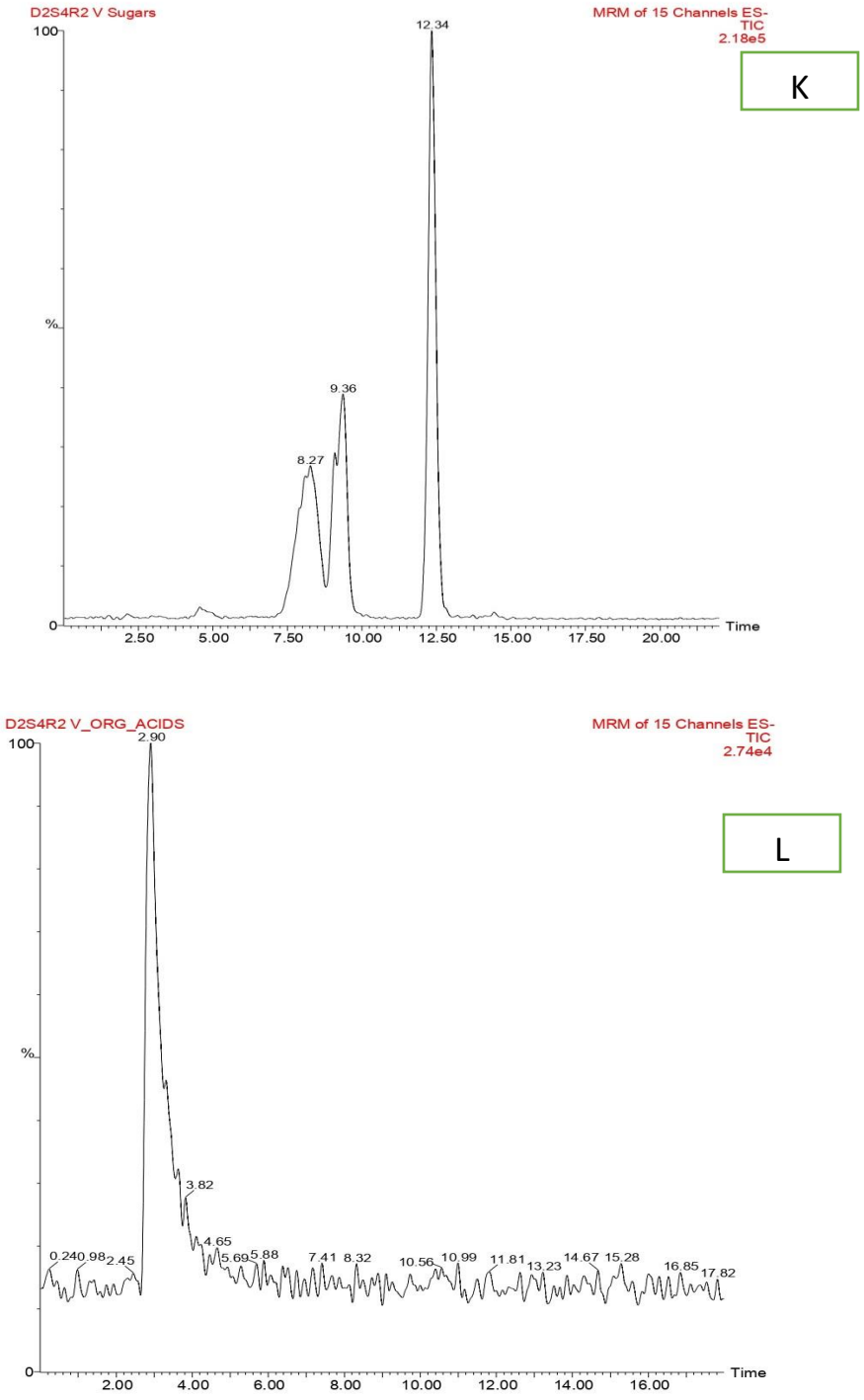
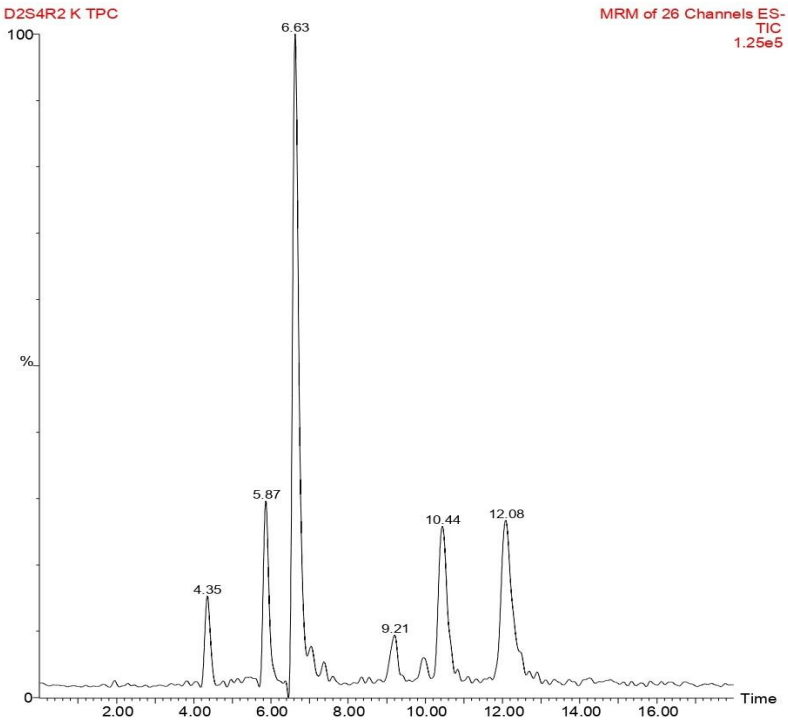
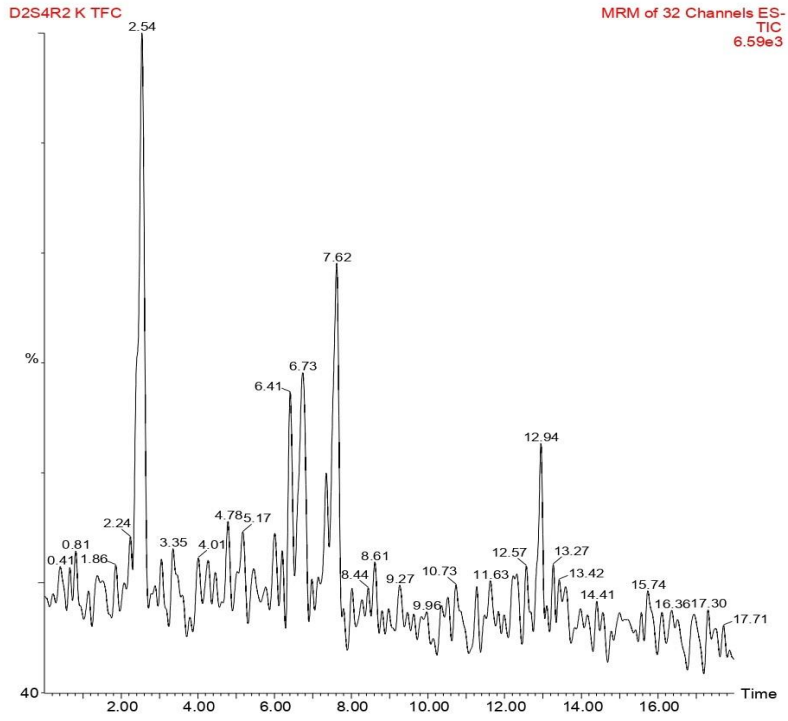


Plate 6: Chromatograms sugars (K) and organic acids (L) profiling of the extract $D_2S_4R_2$ (V)



M



N

Plate 7: Chromatograms TPC (M) and TFC (N) profiling of the extract $D_1S_4R_3$ (K)

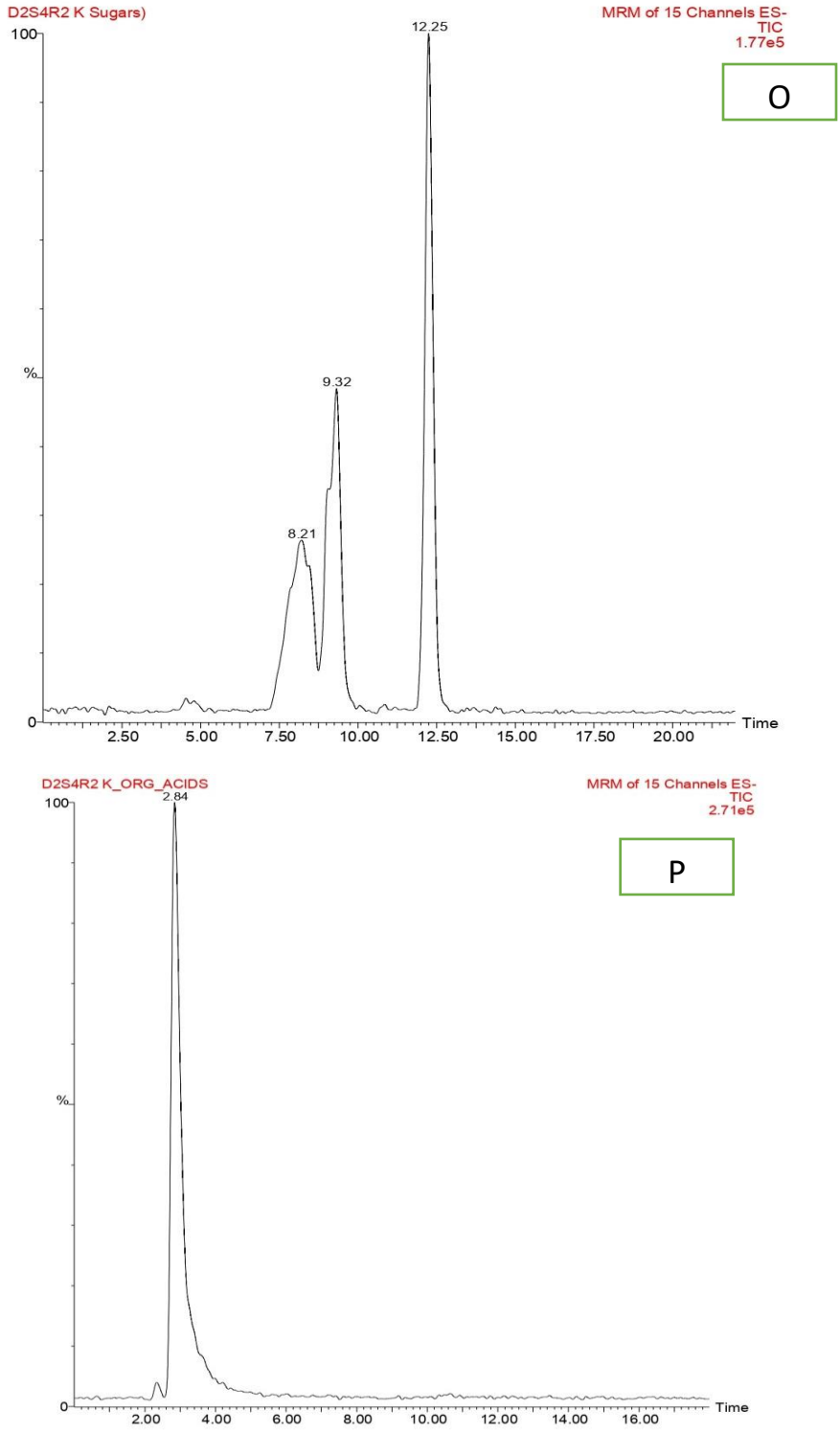
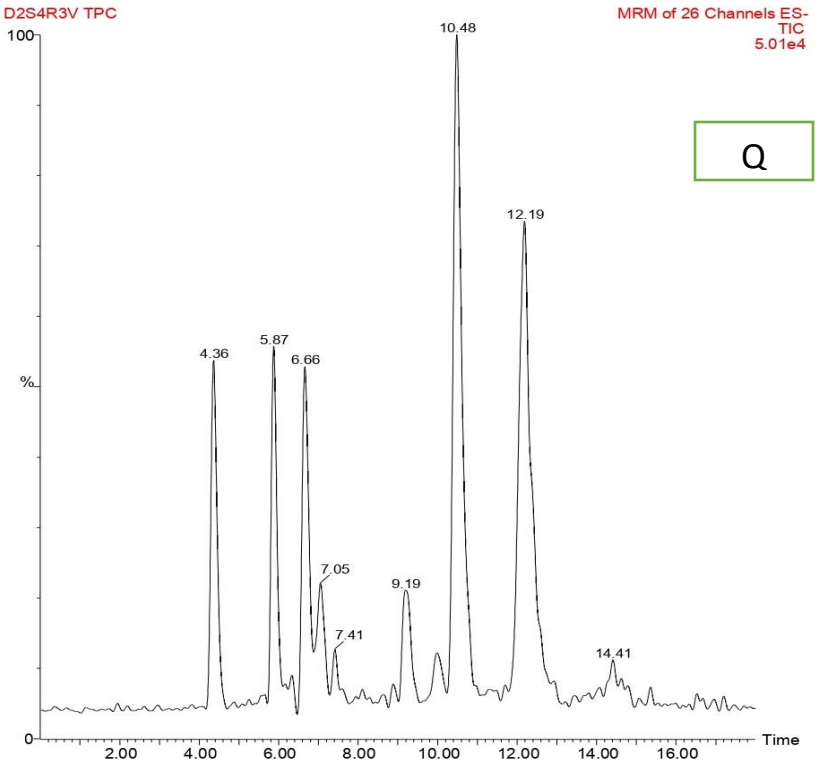


Plate 8: Chromatograms sugars (O) and organic acids (P) profiling of the extract $D_2S_4R_2$ (K)



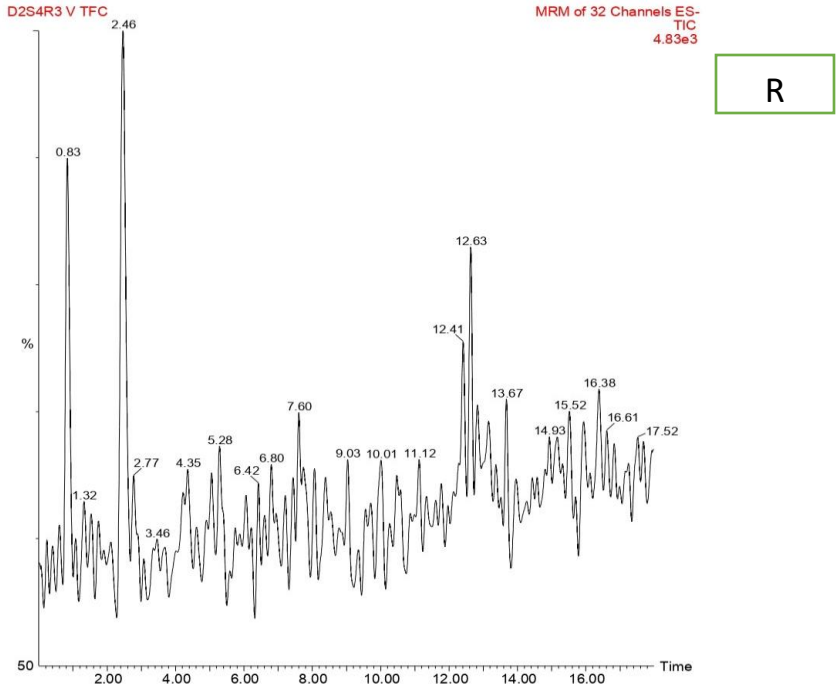
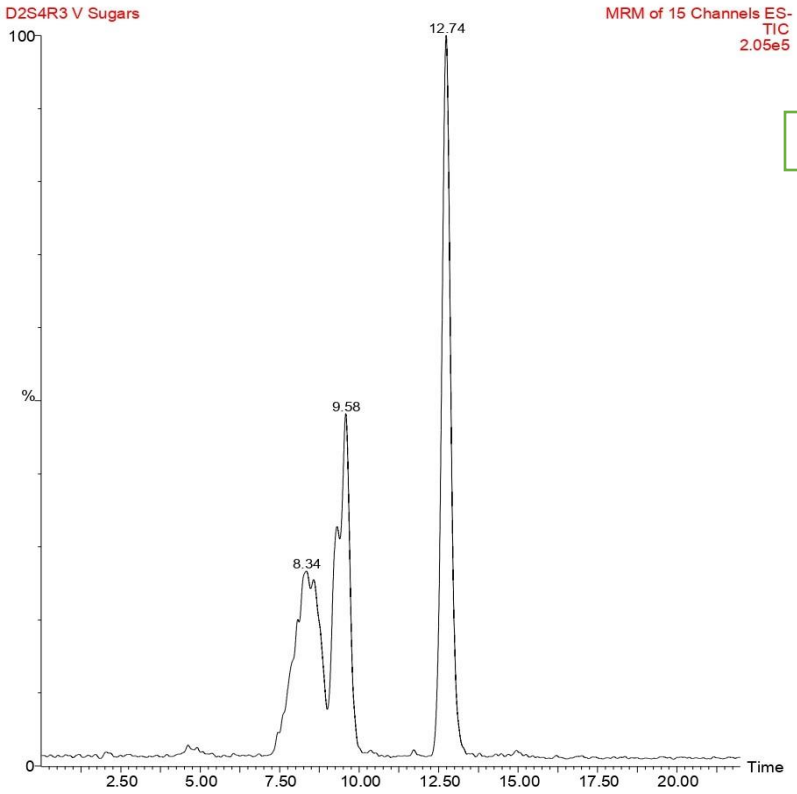
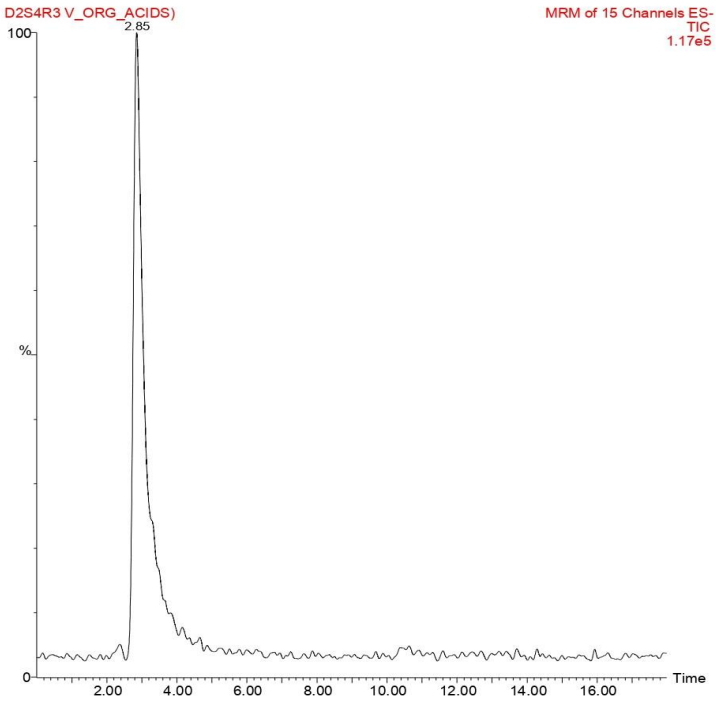


Plate 9: Chromatograms TPC (Q) and TFC (R) profiling of the extract $D_2S_4R_3$ (V)

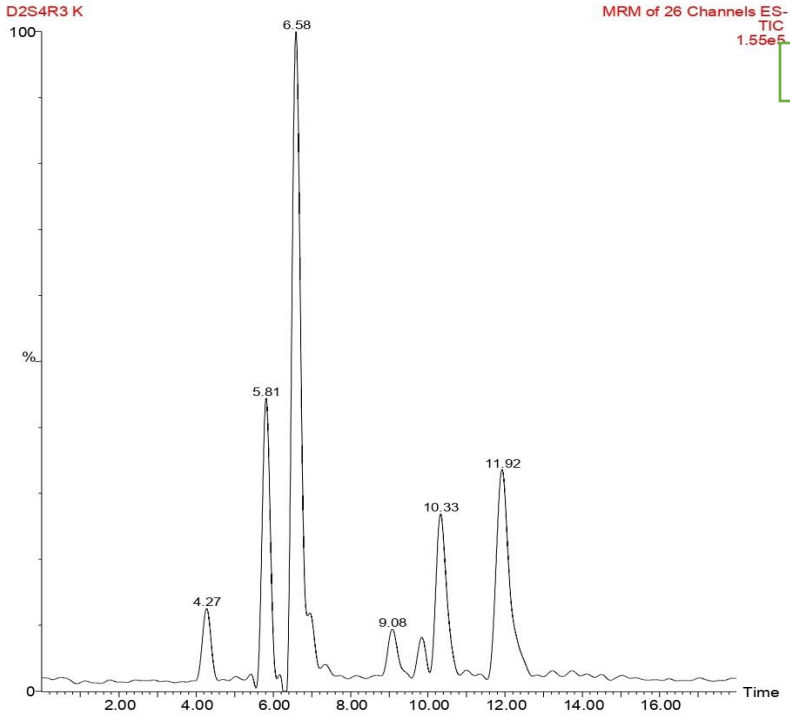


S

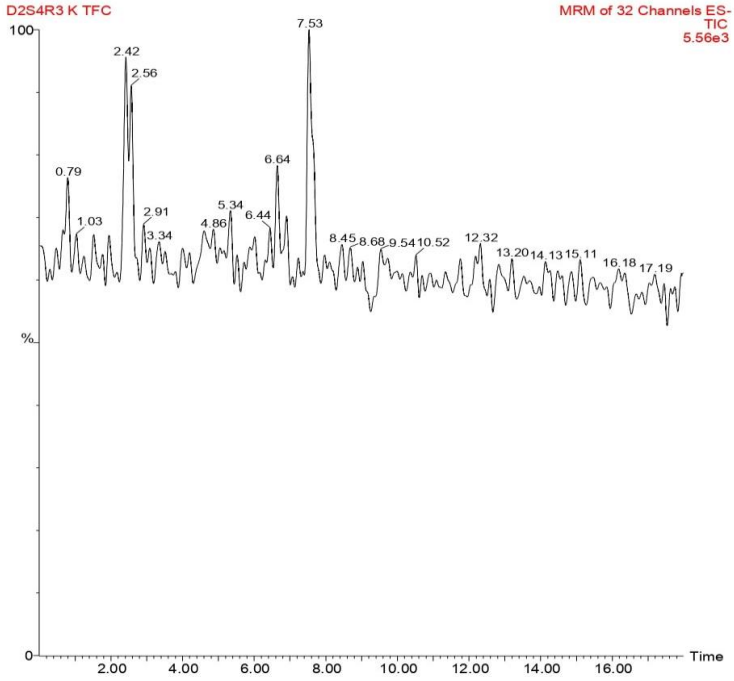


T

Plate 10: Chromatograms sugars (S) and organic acids (T) profiling of the extract $D_2S_4R_3$ (V)



U



V

Plate 11: Chromatograms TPC (U) and TFC (V) profiling of the extract $D_2S_4R_3$ (Koozha)

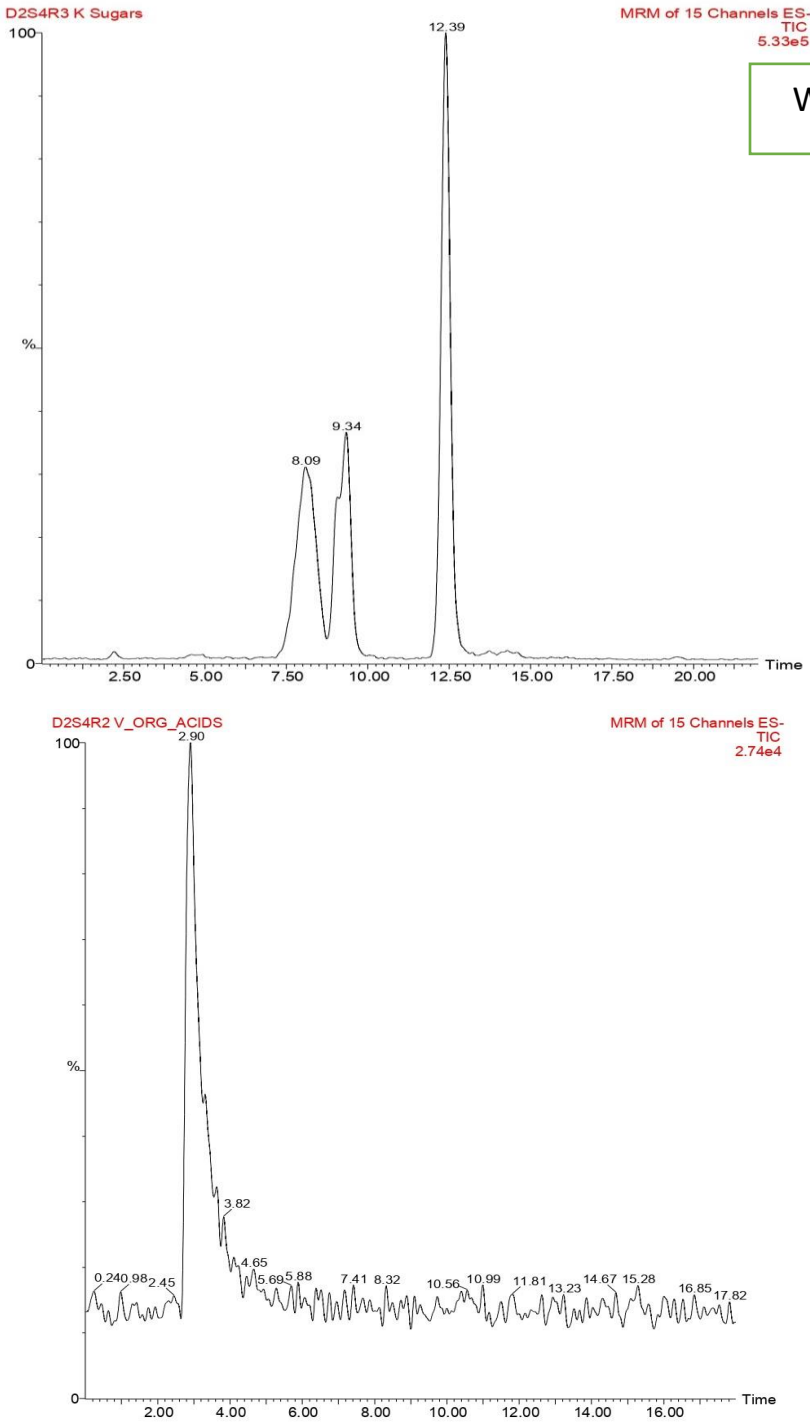


Plate 12: Chromatograms Sugars (W) and Organic acids (X) profiling of the extract $D_2S_4R_3$ (Koozha)

JACKFRUIT (*Artocarpus heterophyllus* Lam.) AS A POTENTIAL SOUCE OF BIOACTIVE COMPOUNDS

by

VIRESH

(2017-22-003)

ABSTRACT

Submitted in partial fulfilment of the

requirements for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2022

ABSTRACT

An investigation on "Jackfruit (*Artocarpus heterophyllus* Lam.) as a potential source of bioactive compounds" was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani from 2017-2020 with the objective**s** to standardize the extraction procedure for maximizing the antioxidant, anti-cancerous and anti-hyperglycemic properties of fruit wastes from varikka and koozha jackfruit types, phytochemical profiling, encapsulation and commercial exploitation of encapsulated extracts for fortification of fruit juice beverages. Experiments were carried out in four parts.

Standardization of extraction procedure was carried out in the first part by evaluating the extracts for antioxidant, anti-hyperglycemic and anti-cancerous properties. Both varikka and koozha types were harvested at optimum maturity and were utilized at ripe stage independently. Except bulb, seed and peel without horny portion, all other parts were dried in cabinet (D_1) and freeze (D_2) driers, pulverized to fine powders and extracts were prepared using solvents *viz*., methanol at 90 (S_1), 80 (S_2), 50% (S_3) and ethanol at 60 (S_4), 80 % (S_5) with solid to solvent ratios of 1:30 (R_1), 1:40 (R_2) and 1:50 (R_3). Extract of freeze dried varikka samples using 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) had highest Total flavonoid content (TFC) (15.66 mg QE $100g^{-1}$), Total phenolic content (TPC) (156.10 mg GAE 100g), DPPH scavenging activity (69.29 per cent inhibition) and α-glucosidase inhibition activity (90.24 per cent). The same extract, $D_2S_4R_3$ from koozha also exhibited highest TFC (15.88 mg QE 100 g^{-1}), TPC (164.63 mg GAE 100g), DPPH scavenging activity (68.64 per cent inhibition) and α-glucosidase inhibition activity (92.28 per cent).

Freeze dried varikka samples extracted using 90 per cent methanol at 1:50 solid solvent ratio ($D_2S_1R_3$) recorded the highest (45.88 mg $100g^{-1}$) ascorbic acid content and freeze dried koozha samples extracted using 90% methanol at 1:40 solid solvent ratio ($D_2S_1R_2$) had the highest ascorbic acid content of 47.37 mg $100g^{-1}$.

Based on the efficiency and economics, extraction of freeze dried samples using 60% ethanol at 1:40 solid to solvent ratio ($D_2S_4R_2$), similar samples using 60% ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) and cabinet dried samples with 60% ethanol at 1:50 solid to solvent ratio ($D_1S_4R_3$) were selected as three superior extraction methods .

The MTT system which is a simple, reproducible and accurate means of measuring the activity of living cells via mitochondrial dehydrogenases was utilized to assess the anti-cancerous properties of the selected three extracts viz., $D_2S_4R_2$, $D_2S_4R_3$ and $D_1S_4R_3$ on HeLa cell lines with doxorubicin as control. Freeze dried varikka and koozha samples extracted in 60 percent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$) had the lowest IC_{50} value of 129.30 and 157.60 µg mL^{-1} respectively whereas the IC_{50} value for doxorubicin (positive control) was18.85 µg mL^{-1}.

When the three superior extracts were subjected to phytochemical profiling in the second part of the experiment using LCMS/MS (Waters UPLC H class system fitted with TQD MS/MS system) for sugars, organic acids, phenolic acids and flavonoids, they were significantly influenced by extraction methods and jack fruit types. Fifteen sugars, ten organic acids, eighteen phenolic acids and fifteen flavonoids were fractionated and identified from the extracts. Extract of freeze dried sample using 60% ethanol in 1:50 solid to solvent ratio ($D_2S_4R_3$) had highest sugars, organic acids, phenolic acids and flavonoid content. The major sugars identified were fructose, glucose, mannose, sucrose and sorbitol and; organic acids were citric acid, malic acid, shikimic acid, succinic and hydroxycitric acid; phenolic acids were ferulic acid, p-coumaric acid, caffeic acid, benzoic acid, o - coumaric acid; myricetin, catechin, naringenin, quercetin and epicatechin were the major flavonoids.

The three superior extracts selected were encapsulated independently by spray and freeze drying in the third part of the study. Two maltodextrin (MD) levels (10 and 20 dextrose equivalence, DE), three carrier to extract ratio (1:10, 1:15 and 1:20), two inlet- outlet temperature of spray drier (180 - 80º C inlet -

outlet and 190 - 90º C inlet - outlet) were the process variables for spray encapsulation, whereas for freeze encapsulation, maltodextrin (MD) levels and carrier ratio were selected as process variables.

The extract $D_2S_4R_3$ from varikka and koozha, spray encapsulated using MD 20 DE at 1:20 carrier to extract ratio (Cr_3) at inlet and outlet temperature of 180 and 80º C (T_1) recorded highest TPC of 115.47 and 117.92 mg GAE 100 g^{-1} respectively. Varikka and koozha extracts spray encapsulated using MD 20 DE at 1:10 carrier to extract ratio at 190 - 90ºC inlet - outlet temperature ($C_2Cr_1T_2$) produced encapsulate with highest per cent recovery (83.77 and 82.09 % respectively). Lowest moisture content of 2.46 and 2.55 per cent were recorded by the extracts spray encapsulated using 10 DE MD at 1:20 carrier to extract ratio at inlet - outlet temperature of 190 - 90º C ($C_1Cr_3T_2$) from varikka and koozha respectively. Based on the superior physico-chemical properties, spray encapsulate of freeze dried varikka and koozha extracts prepared using 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$), using 20 DE maltodextrin at 1:20 carrier to extract ratio with 180 - 80°C inlet - outlet temperature ($C_2T_1Cr_3$), was selected for Part 4 of the experiment.

$D_2S_4R_3$ extract from varikka and koozha, when freeze encapsulated with MD 20 DE at 1:20 carrier to extract ratio had highest TFC of 11.62 and 11.75 mg QE 100 g^{-1} respectively. Koozha extract, freeze encapsulated with MD 20 DE at 1:20 carrier to extract ratio had highest TPC of 134.38 mg GAE 100 g^{-1} DPPH scavenging activity of varikka and koozha extracts were highest when freeze encapsulated with MD 20 DE at 1:20 carrier to extract ratio (per cent inhibition of 71.66 and 77.48 respectively). Ascorbic acid content and per cent recovery of encapsulates were not influenced by levels of MD or carrier to extract ratio. The extracts freeze encapsulated with MD 10 DE at 1:10 carrier to extract ratio had lowest moisture content of 2.22 and 2.51% respectively. Based on the superior physico-chemical properties, freeze encapsulate of the freeze dried varikka and koozha extract prepared with 60 per cent ethanol at 1:50 solid to solvent ratio ($D_2S_4R_3$), using 20 DE maltodextrin at 1:20 carrier to extract ratio, was selected for part 4 of the experiment.

The encapsulated extracts were utilized @ 0.01 to 0.1 per cent for development of fortified mango RTS beverages as per FSSAI standards and compared with commercial fortified beverage in the fourth part of study. Mango RTS beverage enriched with the freeze encapsulate of the extracts @ 0.05 per cent was found to be superior with respect to Total Soluble Solids, total phenolic content, antioxidant activity and total sugar content and these were on par with the beverage enriched with spray encapsulates @ 0.05 per cent and commercial fortified beverages. The highest TPC of 41.05 and 41.12 mg GAE 100 ml^{-1} were recorded in mango RTS beverage enriched with 0.05 per cent freeze encapsulate of varikka and koozha respectively which were found to be on par with the mango RTS beverage enriched with 0.05 per cent spray encapsulate. The highest scavenging activity (76.29 per cent inhibition) was noticed in RTS beverage enriched with 0.05 per cent freeze encapsulate, followed by the beverage mixed with 0.05 per cent spray encapsulate (73.21%). The lowest scavenging activity (55.19 per cent inhibition) was observed in control sample.

From the study, it was proved that the extracts prepared from combined inedible parts of both varikka and koozha jackfruit types are potential source for bioactive compounds. Extraction of freeze dried varikka and koozha types using 60 per cent ethanol at 1:50 solid to solvent ratio was standardized as the best extraction method for retention of phytochemicals, antioxidant activity, anti-hyperglycemic and anti-cancerous properties. Phytochemical profiling of the superior extracts revealed the presence of 15 sugars, 10 organic acids, 18 phenolic acids and 15 flavonoids. Extracts from varikka and koozha spray encapsulated using 20 DE maltodextrin at 1:20 carrier to extract ratio with 180 - 80°C inlet - outlet temperature and freeze encapsulated by using 20 DE maltodextrin at 1:20 carrier to extract ratio retained maximum phytochemicals and antioxidant properties. These spray and freeze encapsulates could be utilized for fortifying mango RTS beverage @ 50 mg 100 ml^{-1} without affecting the sensory parameters with an enhanced antioxidant activity of 13-16% compared to commercial fortified mango RTS beverage.

വെള്ളായണി, കാർഷികകോളേജിലെ പോസ്റ്റ്ഹാർവെസ്റ്റ് ടെക്നോളജി വിഭാഗത്തിൽ 2017-2020 കാലയളവിൽ ബയോആക്ടീവ് സംയുക്തങ്ങളുടെ ഉറവിടമായി ചക്ക (*ആർട്ടോകാർപസ്ഹെറ്ററോഫില്ലസ്*)എന്ന വിഷയത്തിൽ ഒരുഗവേഷണം നടത്തുകയുണ്ടായി.വരിക്ക, കൂഴ എന്നീ ചക്കപ്പഴങ്ങളുടെ ഭക്ഷ്യയോഗ്യമല്ലാത്ത ഭാഗങ്ങളിലെ ആന്റീ ഓക്സിഡന്റ്, കാൻസർ വിരുദ്ധ, ഹൈപ്പർഗ്ലൈസിമിക് വിരുദ്ധ ഗുണങ്ങൾ പരമാവധി വേർതിരിച്ചെടുക്കുവാനുള്ള മാർഗ്ഗങ്ങൾ കണ്ടുപിടിക്കുക. വിശദമായ ഫൈറ്റോകെമിക്കൽ പ്രൊഫൈലിങ്ങ്, വേർതിരിച്ച സത്തുക്കളുടെ പൊതിഞ്ഞെടുക്കൽ (encapsnlation), അവയുടെ വാണിജ്യവൽക്കരണം എന്നിങ്ങനെ നാല് ഭാഗങ്ങളായാണ് ഗവേഷണം നടത്തിയത്.

നിരോക്സീകാരക, ആന്റിഹൈപ്പർ ഗ്ലൈസിമിക്, കാൻസർ വിരുദ്ധ ഗുണങ്ങൾ പരമാവധി വേർതിരിച്ചെടുക്കുവാനുള്ള എക്സ്ട്രാക്ഷൻ രീതികൾ ഏതാണെന്ന് കണ്ടുപിടിക്കുവാനുള്ള പഠനം നടത്തി. ചുള, കുരു, പച്ചപുറംതൊലി എന്നിവ ഒഴികെയുള്ള ഭാഗങ്ങൾ കാബിനറ്റ് & ഫ്രീസ് ഡ്രയറുകളിൽ ഉണക്കിപ്പൊടിച്ച് 60 & 80% എത്തനോൾ, 60 80 & 90 % മെഥനേങ്ങറ്റ എന്നീ ലായകങ്ങൾ 1:30, 1:40, 1:50 എന്ന ഖര-ദ്രാവക അനുപാതത്തിൽ ഉപയോഗിച്ച് വിവിധ സത്തുക്കൾ തയ്യാറാക്കി. ഫ്രീസ്ഡ്രൈ ചെയ്ത വരിക്ക സാമ്പിളുകൾ 60% എത്തനോൾ, 1 : 50 അനുപാതത്തിൽ ഉപയോഗിച്ച് തയ്യാറാക്കിയ സത്തുക്കളിൽ ഏറ്റവുമധികം ഫ്ളേവനോയ്ഡുകൾ (TFC) (15.66mg QE $100g^{-1}$), ഫീനോളുകൾ (TPC) (156.10mg GAE $100g^{-1}$) & (DPPH 69.29%), ആക്ടിവിറ്റി എന്നിവരേഖപ്പെടുത്തി. ഇതേരീതിയിൽ കൂഴയിൽ നിന്നും തയ്യാറാക്കിയ സത്തുക്കളിലും പരമാവധി TFC (15.88 mg QE $100g^{-1}$) TPC (164.63mg GAE $100g^{-1}$), DPPH ആക്ടിവിറ്റി (68.64%)എന്നിവ അടങ്ങിയിട്ടുണ്ടായിരുന്നു.

ഫ്രീസ്ചെയ്തുണക്കിയവരിക്ക സാമ്പിളുകൾ 90% മെഥനോളുപയോഗിച്ച് 1:50 അനുപാതത്തിൽ ഉരുത്തിരിച്ചെടുത്ത സത്തുക്കളിൽ ($D_2S_1R_3$) ഏറ്റവും ഉയർന്ന (45.88 mg $100\ g^{-1}$) അസ്കോർബിക് ആസിഡ് അടങ്ങിയിരിന്നു. 1:40 അനുപാതത്തിലെടുത്ത കൂഴയുടെ ($D_2S_1R_2$) സത്തുക്കളിലാണ് ഏറ്റവും ഉയർന്ന (47.37 മില്ലിഗ്രാം 100 ഗ്രാം$^{-1}$) അസ്കോർബിക് ആസിഡ് ഉണ്ടായിരുന്നത്.

ഫ്രീസ് ചെയ്തുണക്കിയ സാമ്പിളുകൾ 60% എത്തനോൾ 1:40, 1:50 എന്നീ അനുപാതത്തിൽ ഉപയോഗിച്ചും കാബിനറ്റ് ഡ്രയറിൽ ഉണക്കിയ സാബിളുകൾ 60% എത്തനോൾ 1:40 അനുപാതത്തിൽ ഉപയോഗിച്ചും സത്തുക്കൾ വേർതിരിച്ചെടുക്കു

ന്നത്, കാര്യക്ഷമതയും സാമ്പത്തിക വശവും കണക്കിലെടുത്ത് മൂന്ന് മികച്ച എക്സ്ട്രാക്ഷൻ രീതികളായി തിരഞ്ഞെടുത്തു.

തിരിഞ്ഞെടുത്ത മൂന്ന് സത്തുക്കളുടെ കാൻസർ വിരുദ്ധ ഗുണങ്ങൾ വിലയിരുത്തിയ പഠനങ്ങളിൽ ഫ്രീസ് ചെയ്തുണക്കിയ വരിക്ക, കൂഴ സാമ്പിളുകൾ 60% എത്തനോൾ 1:50 അനുപാതത്തിൽ ഉപയോഗിച്ച് വേർതിരിച്ച സത്തുക്കൾക്ക് കൂടിയ കാൻസർ വിരുദ്ധ ഗുണങ്ങൾ (കുറഞ്ഞ IC50 വാല്യൂ129.30, 157.60 $\mu g\ mL^{-1}$) ഉണ്ടെന്ന് കണ്ടെത്തി.

ഈ സത്തുക്കളിലെ രാസ സംയുക്തങ്ങൾ വിശദമായ പഠനങ്ങൾക്ക് വിധേയമാക്കിയപ്പോൾ അവ, വേർതിരിച്ചെടുക്കുന്ന രീതികൾ, ചക്കയുടെ ഇനങ്ങൾ എന്നിവയ്ക്കനുസരിച്ച് വ്യത്യാസപ്പെടുന്നു എന്നു കണ്ടു. ഇവയിൽ നിന്നും 15 തരം പഞ്ചസാര (sugar), 10 തരം ഓർഗാനിക് ആസിഡുകൾ, 18 ഫീനോളിക് ആസിഡുകൾ, 15 ഇനം ഫ്ളേവനോയിഡുകൾ എന്നിവ വേർതിരിച്ചെടുക്കുകയും അവ തിരിച്ചറിയുകയും ചെയ്തു. ഫ്രീസ് ചെയ്തുണക്കിയ സാമ്പിളുകളിൽ നിന്നും 60% എത്തനോൾ 1:50 അനുപാതത്തിൽ ഉപയോഗിച്ച് വേർതിരിച്ചെടുത്ത സത്തുക്കളിൽ ഉയർന്ന അളവിൽ രാസസംയുക്തങ്ങൾ കാണപ്പെട്ടു. ഫ്രക്ടോസ്, ഗ്ലൂക്കോസ്, മാനോസ്, സൂക്രോസ്, സോർബിറ്റോൾ തുടങ്ങിയ പഞ്ചസാരകൾ, സിട്രികആസിഡ്, മാലിക്ആസിഡ്, ഷിക്കിമിക്ആസിഡ്, സക്സിനിക്ആസിഡ്, ഹൈഡ്രോക്സിസിട്രിക്ആസിഡ തുടങ്ങിയ ഓർഗാനിക് അമ്ലങ്ങൾ, ഫെറുലിക്ആസിഡ്, P-കൗമാരിക് ആസിഡ്, കഫീക്ആസിഡ്, ബെൻസോയിക് ആസിഡ്, ഒ-കൗമാരിക് ആസിഡ് തുടങ്ങിയ ഫീനോളിക്ആസിഡുകൾ, മിറിസ്റ്റിസിൻ, കറ്റെച്ചിൻ, നരെൻജനിൻ, ക്വെർസെറ്റിൻ, എപ്പികറ്റേച്ചിൻ തുടങ്ങിയ ഫ്ളാവനോയിഡുകൾ എന്നിവയായിരുന്ന പ്രധാന രാസഘടകങ്ങൾ.

പരീക്ഷണത്തിന്റെ മൂന്നാം ഘട്ടത്തചന്റ തിരഞ്ഞെടുത്ത മൂന്ന് സത്തുക്കളെയും, സെപ്രഡ്രയിങ്ങ്, ഫ്രീസ് ഡ്രയിങ്ങ് എന്നീ രണ്ടു മാർഗ്ഗങ്ങൾ വഴിവിവിധ രീതിയിൽ പൊതിഞ്ഞെടുത്തു (encapsnlation).($D_2S_4R_3$) സത്തുക്കൾസെക്സ്ട്രിൻ 1:20 അനുപാതത്തിൽ20DE മാൾട്ടോഡെക്സ്ട്രിൻ ഉപയോഗിച്ച്180 – 80^0C താപനിലയിൽസെപ്രഡ്രയിങ്ങ്വഴി പൊതിയുന്നതും ഇതേ രീതിയിൽ തയ്യാറാക്കിയ സത്തുക്കൾ ($D_2S_4R_3$) 1:20 അനുപാതത്തചന്റ മാൾട്ടോഡെക്സ്ട്രിൻ ഉപയോഗിച്ച് ഫ്രീസ്ഡ്രൈ ചെയ്ത് പൊതിയുന്നതും ഉയർന്ന രാസ ഭൗതികഗുണങ്ങൾ അടിസ്ഥാനമാക്കി, ഗുണമേന്മയുള്ള രീതികളായി തിരഞ്ഞെടുത്തു.

തിരഞ്ഞെടുത്ത പൊതിഞ്ഞ സത്തുക്കൾ 0.01-0.1% അളവിൽ ഉപയോഗിച്ച് ഗുണമേന്മയുള്ള മാമ്പഴ ശീതള പാനീയം ഉണ്ടാക്കുവാനായി നടത്തിയ പഠനങ്ങളിൽ, ഫ്രീസ്ചെയ്ത് പൊതിഞ്ഞ സത്തുക്കൾ 0.05% അളവിൽ ചേർക്കുന്നത്വഴി ശീതള

പാനീയങ്ങളുടെ ഗുണമേന്മ വർദ്ധിക്കുന്നതായികണ്ടു. വരിക്ക, കൂഴ ഇനങ്ങളുടെ ഫ്രീസ് & സ്പ്രേ പൊതിഞ്ഞ ചെയ്തു പൊതിഞ്ഞ സത്തുക്കൾ ചേർത്ത മാങ്ങാശീതളപാനീയത്തിൽ വാണിജ്യാടിസ്ഥാനത്തിലുള്ള പാനീയങ്ങളെക്കാൾ 13-16% കൂടുതൽ ആന്റിഓക്സിഡന്റുകൾ അടങ്ങിയിരുന്നു.