VALUE ADDITION OF PASSION FRUIT

(*Passiflora edulis* Sims.)

By

CHARAN S. M.

2014-12-128

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF PROCESSING TECHNOLOGY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 656

KERALA, INDIA

2016

DECLARATION

I hereby declare that the thesis entitled **"Value addition of passion fruit (*Passiflora edulis* Sims.)"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 15/10/2016

Charan S. M.

(2014-12-128)

CERTIFICATE

Certified that this thesis entitled **"Value addition of passion fruit (*Passiflora edulis* Sims.)"** is a bonafide record of research work done independently by **Charan S. M. (2014-12-128)** 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.

Dr. Saji Gomez

(Chairperson, Advisory Committee)
Assistant Professor (Horticulture)
Department of Processing Technology
College of Horticulture
Kerala Agricultural University
Thrissur, Kerala

Vellanikkara
Date: 15/10/2016

CERTIFICATE

We, the undersigned members of the advisory committee of **Charan S. M. (2014-12-128)** a candidate for the degree of **Master of Science in Horticulture**, with major field in **Processing Technolgy,** agree that the thesis entitled **"Value addition of passion fruit (*Passiflora edulis* Sims.)"** may be submitted by him in partial fulfillment of the requirement for the degree.

15/10/16

Dr. Saji Gomez
(Chairperson, Advisory Committee)
Assistant Professor (Horticulture)
Department of Processing Technology
College of Horticulture
Kerala Agricultural University
Thrissur, Kerala

15/10/16

Dr. K. B. Sheela
Professor and Head
Dept. of Processing Technology
College of Horticulture, Vellanikkara
Kerala Agricultural University
Thrissur, Kerala

15/10/16

Dr. Suman K.T
Assistant Professor
Krishi Vigyan Kendra (KVK), Mannuthy
Kerala Agricultural University
Thrissur, Kerala

15/10/16

Dr. P. B. Pushpalatha
Professor and Head
Banana Research Station (BRS), Kannara
Kerala Agricultural University
Thrissur, Kerala

15/10/2016.

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

And so comes the time to look back on the path travelled during the endeavour and to remember the faces and spirits behind the action with a sense of gratitude. Nothing of significance can be accomplished without the acts of assistance, words of encouragement and gestures of helpfulness from the others.

First, and foremost, I bow my head before the **God** *who enabled me to successfully complete the thesis work on time.*

It is with immense pleasure I avail this opportunity to express my deep sense of whole hearted gratitude and indebtedness to my major advisor **Dr. Saji Gomez,** *Assistant Professor (Horticulture), Department of Processing Technology, College of Horticulture, Vellanikkara for his expert advice, inspiring guidance, valuable suggestions, constructive criticisms, constant encouragement, affectionate advice and above all, the extreme patience, understanding and wholehearted co-operation rendered throughout the course of my study. I really consider it as my greatest fortune in having his guidance for my research work and my obligation to him lasts forever.*

I consider it as my privilege to express my deep-felt gratitude to **Dr. K. B. Sheela,** *Professor and Head, Department of Processing Technology for her constant support, valuable suggestions, cooperation throughout the research programme and critical scrutiny of the manuscript.*

I sincerely thank **Dr. K. T. Suman,** *Assistant Professor Krishi Vigyan Kendra (KVK), Mannuthy for her expert advice, constant inspiration, precious suggestions, generous support and constructive criticisms during my entire study which helped in successful completion of this work.*

I am deeply obliged to **Dr. P. B. Pushpalatha,** *Professor and Head Banana Research Station (BRS), Kannara, for her invaluable help, guidance and critical assessment throughout the period of work. I thank her for all the help and cooperation she has extended to me.*

I am extremely thankful to **Smt. P. Meagle Joseph** *Associate Professor, Department of Processing Technology, College of Horticulture for her unfailing support and enthusiasm, valuable suggestions and guidance for my research programme.*

I express my heartfelt thanks to ***Dr. S. Krishnan,*** *Professor and Head, Department of Agricultural Statistics, for his relentless support in resolving the statistical intricacies and valuable suggestions for my research programme.*

I don't have words to describe about ***Smt. C. V. Sruthi,*** *former Research Associate, Department of Processing Technology without her support the laboratory work would not have gone so smoothly. I express my heartfelt thanks for her inspiring guidance, valuable suggestions, friendly approach with constant encouragement and affectionate advice throughout my research work.*

I wish to express my sincere thanks to ***Dr. V. Sankar,*** *Senior Scientist (Horticulture), CENTRAL HORTICULTURAL EXPERIMENT STATION (CHES), sub station of Indian Institute of Horticultural Research (IIHR), Chettalli, Kodagu, Karnataka,* ***Head of the station,*** *Cashew Research Station, Madakkathara, Thrissur,* ***Dr. P. P. Joy,*** *Associate Professor and Head, Pineapple Research Station (PRS), Vazhakulam, Ernakulam, and other passion fruit growers for timely providing passion fruits during my course of research work.*

My heartfelt thanks to ***Dr. Deepa James*** *and* ***Smt. Anupama*** *for their whole hearted co-operation and immense help throughout my research programme. I would like to acknowledge the help extended by each of the non-teaching staff especially* ***Lathika chechi, Mini chechi, Athulya chichi, Jubi chechi, Jiyaana, Prasanna chechi, Shiji chichi,*** *and* ***Krishnettan*** *for their sincere help and whole hearted co-operation.*

I express my deep sense of gratitude and sincere thanks to ***Smt. H. B. Rashmi,*** *Assistant Professor (Post Harvest Technology), College of Horticulture, Mysuru for her untiring support and valuable guidance during my course of study.*

I express my special thanks to my dear friends ***Muhammad Aslam*** *and* ***Neeraja Puthiamadom*** *who were there with me for six long years in both UG and PG from Mysuru to Thrissur.*

I am genuinely indebted to my seniors ***Vikram, Basavaraj simpi, Rajanand, Ajithkumar, Vijayakumar, Veeresh, Naresh, Arun, Anand, Divya, Sumbula*** *and* ***Jeevan,*** *for valuable assistance and guidance during the entire period of my research.*

Let me express my sincere thanks to my batch mates and friends ***Ningappa, Sanjay, Supritha, Aishwarya, Greeshma, Zeenath, Sruthi, Andrew*** *and* ***Sameer*** *for their sincere help,*

support and encouragement. I thank my juniors ***Umesh, Nagendra, Vinay, Veeresh, Karishma*** *and* ***Rosemary*** *for their timely help and co-operation.*

I am thankful to ***Mr. Aravind K.S*** *of Students' Computer Club, College of Horticulture for rendering necessary help whenever needed.*

The award of KAU fellowship is thankfully acknowledged.

Above all, with gratitude and affection, I recall the moral support, boundless affection, constant encouragement, arm blessings and motivation of my ***parents*** *and* ***well-wishers*** *without which this endeavour would never have become a reality.*

I offer salutation at the feet of my mother ***T. Shashikala*** *at the heaven, whose blessings enabled me to undertake this venture successfully.*

Charan S. M.

CONTENTS

CHAPTER	TITLE	PAGE NO.
1.	INTRODUCTION	1
2.	REVIEW OF LITERATURE	3
3.	MATERIALS AND METHODS	34
4.	RESULTS	49
5.	DISCUSSION	87
6.	SUMMARY	113
7.	REFERENCES	i-xiv
	APPENDICES	
	ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
1	List of passion fruit accessions collected from various locations in Kerala and Karnataka	35
2	Physico-morphological attributes of passion fruit accessions	52
3	Nutritional and biochemical attributes of passion fruit accessions.	56
4	Cumulative physiological loss of weight (PLW) during storage of shrink wrap packaged passion fruit	58
5	Effect of shrink wrap packaging on total soluble solids (TSS), titratable acidity and vitamin C of passion fruit during storage	61
6	Effect of shrink wrap packaging on reducing, non-reducing and total sugar content of passion fruit during storage	63
7	Effect of shrink wrap packaging on total carotenoids, total phenols and total flavonoid content of passion fruit during storage.	66
8	Effect of shrink wrap packaging on organoleptic quality of passion fruit (1 WAS)	68
9	Effect of shrink wrap packaging on organoleptic quality of passion fruit (2 WAS)	69
10	Effect of shrink wrap packaging on organoleptic quality of passion fruit (3 WAS)	70
11	Organoleptic evaluation of passion fruit nectar	72
12	Effect of storage on total soluble solids (TSS), titratable acidity and vitamin C content of passion fruit nectar	75
13	Effect of storage on reducing, non-reducing and total sugar content of passion fruit nectar	77

14	Effect of storage on total phenols and total flavanoid content of passion fruit nectar	79
15	Effect of storage on total carotenoids and non-enzymatic browning of passion fruit nectar	81
16	Effect of storage on organoleptic quality of passion fruit nectar (1 MAS)	82
17	Effect of storage on organoleptic quality of passion fruit nectar (2 MAS)	83
18	Effect of storage on organoleptic quality of passion fruit nectar (3 MAS)	84
19	Effect of storage on microbial population of passion fruit nectar	86

LIST OF FIGURES

Figure No.	Title	After Page No.
1	Effect of shrink wrap packaging on shelf life of passion fruit	57
2	Antioxidant activity of passion fruit accessions	94
3	Effect of shrink wrap packaging on physiological loss of weight (PLW) of passion fruit	96
4	Effect of shrink wrap packaging on total soluble solids (TSS) of passion fruit during storage	99
5	Effect of shrink wrap packaging on titratable acidity of passion fruit during storage	99
6	Effect of shrink wrap packaging on vitamin C of passion fruit during storage	99
7	Effect of shrink wrap packaging on total sugar content of passion fruit during storage	100
8	Effect of shrink wrap packaging on total carotenoid content of passion fruit during storage	100
9	Effect of shrink wrap packaging on total phenols of passion fruit during storage	102
10	Effect of shrink wrap packaging on total flavanoid content of passion fruit during storage	102
11	Effect of storage on total soluble solids (TSS) of passion fruit nectar	105
12	Effect of storage on titratable acidity of passion fruit nectar	105
13	Effect of storage on vitamin C content of passion fruit nectar	105
14	Effect of storage on total sugar content of passion fruit nectar	108

15	Effect of storage on total phenols of passion fruit nectar	108
16	Effect of storage on total flavonoid content of passion fruit nectar	108
17	Effect of storage on total carotenoid content of passion fruit nectar	110
18	Effect of storage on non-enzymatic browning of passion fruit nectar	110

LIST OF PLATES

Plate No.	Title	After Page No.
1	Passion fruit accessions	35
2	Shrink wrapping machine	42
3	Flow chart for shrink wrap packaging of passion fruit	42
4	Shrink wrapped passion fruits	42
5	General view of storage room	42
6	Effect of shrink wrap packaging on shelf life of passion fruit	70
7	Passion fruit nectar	71
8	Effect of storage on quality of passion fruit nectar	84
9	Effect of storage on bacterial population of passion fruit nectar	86
10	Effect of storage on fungal population of passion fruit nectar	86
11	Effect of storage on yeast population of passion fruit nectar	86

LIST OF APPENDICES

Appendix No.	Title
I	Score card for organoleptic evaluation
II	Nutrient composition of media
III	Mean rank scores for shrink wrap packaged passion fruit during storage
IV	Mean rank scores for passion fruit nectar during storage

Introduction

1. INTRODUCTION

Horticulture produces play an important role in the Indian agriculture sector and economy. India is the second largest producer of fruits in the world. There is a wide gap between the gross production and net availability due to the improper post harvest operations. About 24-30% of loss occurs due to improper post-harvest handling in India. Many fruits grown in the homesteads of Kerala are considered minor and underutilized as they are not exploited to their full potential.

Passion fruit (*Passiflora edulis* Sims) which is considered as a minor fruit in India, bears a delicious fruit which occurs in purple (*Passiflora edulis f. edulis*) and yellow (*Passiflora edulis f. flavicarpa*) fruited forms (Joy, 2010). It is believed to have originated in the Amazon region of Brazil and belongs to the family Passifloraceae. The fruit is grown mostly in tropical and sub-tropical parts of the world from South America to Australia, Asia and Africa. It is introduced to India during twentieth century in the Nilgiris, Coorg and Malabar areas of South India (Rao *et al.*, 2014).

Passion fruit is a perennial, vigorous, climbing, woody vine which produces round or ovoid fruits having a tough, smooth, waxy dark purple/yellow coloured rind with faint, fine white specks. It contains orange coloured pulpy juice with large number of small, hard, dark brown to black pitted seeds. It is not used for table purpose because of its high acidity, low juice content and large number of seeds. The juice is delicious with good flavour, intense aroma and sweet-acid taste and is well known for its excellent blending quality. Yellow type fruits are generally larger than purple type with yellow mottled spots and turns golden yellow during ripening whereas purple type attains deep purple colour. The juice of yellow type is more acidic and its recovery is comparatively less (25-30%) than the purple type (35-38%) (Rao *et al.*, 2014).

As people are more concerned about their health, demand for passion fruit juice is increasing not only because of its exotic flavour but also for its high nutritional and medicinal properties. There is a lot of evidence that the passion

fruit could be a powerful medicinal source. Passion fruit is a prime source of bioactive compounds, which could extenuate oxidative stress. Some phenolic compounds identified in *Passiflora* species showed therapeutic effects like immunomodulation, anticarcinogenic and antioxidant activities (da Silva *et al.*, 2014).

The juice contains very good proportion of acids, sugars, Vitamin-A, fibre, phenolic compounds, ascorbic acid (Ramaiya *et al.*,2012) and minerals such as sodium, magnesium, sulphur, chlorides, etc. (Rao *et al.*, 2014).

Passion fruit cannot be stored at ambient temperature beyond a week in tropical conditions, as it is prone to losses due to shrinkage and decay. Therefore, efficient post harvest management techniques are inevitable to extend its shelf life through viable storage and packaging practices. Packaging in heat shrinkable film can protect the fruit from physical and chemical damage and will also provide a barrier against air, light and microbes. Wills *et al.* (1982) reported that passion fruit is a tropical, climacteric fruit and it requires storage temperatures above 12°C as it is sensitive to chilling injury.

Even though the high acidity of passion fruit limits its utilisation for table purpose, its intense flavour offers ample scope for processing into numerous value added products like fruit beverages, concentrate, etc. Fruit nectars are unfermented beverages that occupy a prominent place in the processed food sector. Passion fruit is an ideal choice for processing it into refreshing fruit nectar.

In India, limited study has been conducted on the post harvest technology of passion fruit. So, the intervention on this aspect has better scope in extending the shelf life of fruits and minimizing the loss by enhancing the storage life (Kishore *et al.*, 2010).

Review of literature

2. REVIEW OF LITERATURE

Passion fruit occurs in two fruited forms i.e., yellow, grown in tropical lowland areas and purple, grown in tropical highland areas (NARI, 2004). These species belong to the family Passifloraceae, native to Brazil, and are characterised by their exotic and distinctive aroma (Jimenez *et al.*, 2010).

The species of the genus Passifloraceae are distributed in the warm temperate and tropical regions of the New World; but they are much sparse in Asia, Australia and tropical Africa. The most widely grown species in tropics are *Passiflora edulis* Sims for their edible fruits (McGuire, 1999).

Under commercial cultivation, yellow type passion fruit (*Passiflora edulis* var. *flavicarpa*) is more popular and acceptable over purple type (*Passiflora edulis Sims f. edulis*) as it results in larger fruit size, greater yield, attractive fruit and juice colour and high acidity (Sandi *et al.*, 2004).

Felter and Lloyd (1983) reported the use of several species of *Passiflora* in the traditional therapeutic systems of medicine in many countries. The extract of *Passiflora alata* (fragrant granadilla) along with aloes is used against atrophy in various parts of the world.

The species *Passiflora edulis* is having excellent medicinal properties like sedative, diuretic, antihelmintic, anti-diarrheal, stimulant and tonic. Also, in South Africa this is being used against the treatment of hypertension, menopausal symptoms, colic of infants, etc. (Dhawan *et al.*, 2004).

Anesini and Perez (1993) reported that in West Indies, Mexico, Netherlands and South America, the roots are used as sedative and vermifuge. In Italy, the whole plant is used as an anti-spasmodic and sedative. In Mauritius, a combination of tincture and plant extract is used as a remedy for insomnia due to various nervous abnormalities, also roots are used as diuretic and a decoction of leaf as an emetic. The aerial parts of *Passiflora caerulea* are used as mild anti-

microbial agents in catarrh (inflammation of a mucous membrane in humans or animals) and pneumonia diseases in Argentina.

The fresh leaves of *Passiflora edulis* are boiled in small quantity of water and the extract is consumed for the treatment against dysentery and hypertension in Nagaland (Jamir *et al.*, 1999).

The literature available pertaining to the present study has been reviewed under the following heads:

2.1 Physico-morphological parameters

2.2 Nutritional and biochemical parameters

2.2.1 TSS

2.2.2 Titratable acidity

2.2.3 Sugars

2.2.4 Ascorbic acid

2.2.5 Total carotenoids

2.2.6 Total phenols

2.2.7 Total flavanoids

2.2.8 Antioxidant activity

2.3 Extension of shelf life through shrink wrap packaging

2.3.1 Quality of shrink wrap packaged passion fruit during storage

2.3.1.1 Shelf life

2.3.1.2 PLW

2.3.2.3 TSS

2.3.2.4 Titratable acidity

2.3.2.5 Sugars

2.3.2.6 Ascorbic acid

2.3.2.7 Total carotenoids

2.3.2.8 Total phenols

2.3.2.9 Total flavanoids

2.4 Processing of passion fruit

2.4.1 Preparation and preservation of nectar

2.4.2 Changes in quality of passion fruit nectar during storage

2.4.2.1 TSS

2.4.2.2 Titratable acidity

2.4.2.3 Sugars

2.4.2.4 Ascorbic acid

2.4.2.5 Total carotenoids

2.4.2.6 Total phenols

2.4.2.7 Total flavanoids

2.4.2.8 Non-enzymatic browning

2.4.3 Sensory quality/ organoleptic properties of nectar

2.4.4 Microbial quality of nectar

2.1 Physico-morphological parameters

Passion fruit is round-shaped with a diameter of 4 to 6 cm, peel colour changes from green to purple and yellow upon maturity; they contain numerous gelatinously surrounded seeds with yellow pulp responsible for an intense aroma and sweet-acid taste (Jimenez *et al.*, 2010).

Ramaiya *et al.* (2012) determined the fruit length (cm), fruit width (cm), fruit weight (g) and juice weight (g) of yellow and purple passion fruit types. According to them, purple type recorded highest fruit length (7.84 ± 0.90 g), fruit width (6.11 ± 0.44 g), and fruit weight (98.47 ± 10.68 g) whereas, juice weight was recorded highest in yellow type (37.01 ± 2.80 g).

The fruit shape of purple and yellow type passion fruit is round to ovoid with a dimension of 5-8 cm long and 4-8 cm diameter in purple and 8-10 cm long and 4-10 cm diameter in yellow type fruits. Both types contain yellow to orange coloured pulpy juice exhibiting excellent flavour (Joy, 2010).

A wide variability in morphological characters like fruit weight, rind weight, pulp weight, seed weight and juice weight was observed in Pineapple Research Station, Vazhakulam, Kerala, after evaluating over fifty passion fruit accessions collected from different parts of Kerala and South India (Joy, 2010).

The fruit length and equatorial diameter of yellow passion fruit harvested at different maturity stages based on peel colour were measured. The length of fruits with 1/3rd yellow peel, 2/3rd yellow peel and yellow fruits were 8.26 cm, 8.81 cm and 8.80 cm respectively whereas, the equatorial diameter was 7.83 cm, 7.81 cm and 7.91 cm, respectively (da Silva *et al.*, 2015).

The average pulp/juice yield of yellow passion fruit as reported by da Silva *et al.* (2015) was 44.43% whereas, Silva *et al.* (2008) reported 31.44 to 41.28% of pulp/juice yield in yellow passion fruits harvested at different seasons.

The average seed yield of ripened yellow passion fruit as reported by Oliveira *et al.* (2011) was 4.23%, Coelho *et al.*, (2011) reported 11.5% seed yield, also they found zero correlation between the seed yield and size and shape of yellow passion fruit whereas, da Silva *et al.* (2015) reported 17.51%, 15.78% and 15.75% of seed yield in 1/3rd yellow peel, 2/3rd yellow peel and yellow fruits, respectively.

da Silva *et al.* (2015) reported an average peel/rind thickness of yellow passion fruit as 0.58 cm, 0.58 cm and 0.56 cm in different levels of matured passion fruit based on peel colour such as, 1/3rd yellow peel, 2/3rd yellow peel and yellow fruits, respectively. Santos *et al.* (2009) reported 0.32 to 0.35 cm of peel/rind thickness whereas, Ferreira *et al.* (2010) and Cavalcante *et al.* (2007) reported a peel/rind thickness of 0.71 cm and 0.6 to 0.7 cm, respectively.

The physiological changes during fruit growth, development and maturity of six passion fruit genotypes viz. *Passiflora edulis* (Megha Purple and Nagaland Purple), *P. edulis* f. *flavicarpa* (Kerala Yellow, RCPS-1 and Panama Yellow) and *P. alata* were recorded. The fruit length and diameter were recorded maximum in *Passiflora alata* (10.17 cm, 7.05 cm) followed by RCPS-1 (7.33 cm, 6.75 cm), Panama Yellow (7.24 cm, 6.70 cm) and Kerala Yellow (6.5 cm, 6.38 cm) whereas, 4.9 and 4.2 cm, respectively in Nagaland Purple, 90 days after flowering (Patel *et al.*, 2014).

Patel *et al.* (2014) recorded the fruit weight of six passion fruit genotypes viz. *Passiflora edulis* (Megha Purple and Nagaland Purple), *P. edulis* f. *flavicarpa* (Kerala Yellow, RCPS-1 and Panama Yellow) and *P. alata* out of which, *Passiflora alata* recorded maximum weight (192.87 g) followed by RCPS-1 (133.75 g), whereas, the minimum weight 43.04 g and 41.02 g was recorded in Nagaland Purple and Megha Purple respectively, 90 days after flowering.

Patel *et al.* (2014) recorded the rind thickness of six passion fruit genotypes viz. *Passiflora edulis* (Megha Purple and Nagaland Purple), *P. edulis* f. *flavicarpa* (Kerala Yellow, RCPS-1 and Panama Yellow) and *P. alata,* in which,

Megha Purple recorded 0.28 to 1.34 cm and *P. alata* recorded 0.27 to 1.25 cm of rind thickness respectively, 90 days after flowering.

Patel *et al.* (2014) recorded juice percentage in six passion fruit genotypes viz. *Passiflora edulis* (Megha Purple and Nagaland Purple), *P. edulis* f. *flavicarpa* (Kerala Yellow, RCPS-1 and Panama Yellow) and *P. alata.* The maximum juice content (40.76%) was extracted from RCPS-1, followed by Panama Yellow (38.15%), Kerala Yellow (36.31%) and minimum in *P. alata* (22.35%), 90 days after flowering.

The rind colour of six passion fruit genotypes was observed during growth and development of fruits in which, deep purple colour was noticed in Megha Purple and Nagaland Purple, yellow colour was noticed in Kerala Yellow, RCPS-1 and Panama Yellow, whereas, deep yellow colour was noticed in *Passiflora alata,* 90 days after flowering (Patel *et al.*, 2014).

The juice colour in six passion fruit genotypes was observed during growth and development of fruits in which, yellowish orange colour was noticed in Megha Purple and Nagaland Purple, orange colour was noticed in Kerala Yellow, RCPS-1 and Panama Yellow, whereas, deep orange colour was noticed in *Passiflora alata,* 90 days after flowering (Patel *et al.*, 2014).

The fruit weight, rind weight and juice/pulp percentage of purple type passion fruit (*Passiflora edulis Sims f. edulis*) was 59.6 g, 27.6 g and 53.6 percentage respectively, whereas, yellow type passion fruit (*Passiflora edulis f. flavicarpa*) had 56.2 g, 31.1 g and 44.5 percentage of fruit weight, rind weight and juice/pulp percentage respectively (Arjona *et al.*, 1991a).

2.2 Nutritional and biochemical parameters

2.2.1 TSS

The total soluble solids (TSS) of different passion fruit (*Passiflora* spp.) cultivars, *P. edulis* cultivar Purple, Frederick, Yellow, Pink, *P. edulis* f. *flavicarpa*, *P. maliformis* and *P. quadrangularis* was 17.2°Brix, 15.2°Brix,

16.0°Brix, 15.6°Brix, 15.2°Brix, 11.7°Brix and 10.7°Brix, respectively (Ramaiya *et al.*, 2012).

Silva *et al.* (2005) reported an increasing amount of TSS during maturation of passion fruits ranging from 10.2°Brix to 16.8°Brix whereas, Uchoa *et al.* (2008) reported 20.56°Brix of TSS in the matured passion fruit pulp.

Arjona *et al.* (1991a) determined the total soluble solids (TSS) content in purple (*Passiflora edulis Sims f. edulis*) and yellow (*Passiflora edulis f. flavicarpa*) passion fruit types in which, purple type showed a TSS of 12.9°Brix whereas, yellow type had 15.2°Brix.

The total soluble solids (TSS) determined in six passion fruit genotypes at 90 days after flowering, ranged from 15°Brix to 19°Brix and the highest (19°Brix) was recorded in *Passiflora alata* followed by Panama Yellow (17.4°Brix), RCPS-1 (16.8°Brix), Kerala Yellow (16.4°Brix), Megha Purple (15.75°Brix) and lowest in Nagaland Purple (15°Brix) (Patel *et al.*, 2014).

2.2.2 Titratable acidity

Ramaiya *et al.* (2012) determined the titratable acidity in seven passion fruit (*Passiflora* spp.) cultivars: ***P. edulis*** cultivars Purple, Frederick, Yellow, Pink, *P. edulis* f. *flavicarpa*, *P. maliformis* and *P. quadrangularis*. The yellow type (*P. edulis* f. *flavicarpa*) recorded highest titratable acidity (3.03 ± 0.19%) whereas; the purple type (*P. edulis*) recorded second lowest titratable acidity (1.80 ± 0.10%) after *P. quadrangularis*.

The titratable acidity of yellow passion fruit harvested at different maturity stages based on peel colour was estimated. The titratable acidity of fruits with 1/3rd yellow peel, 2/3rd yellow peel and yellow fruits were 0.81%, 0.67% and 0.63% respectively (da Silva *et al.*, 2015). Also Silva *et. al.* (2005) reported 4.99% to 5.53% of titratable acidity in yellow passion fruit juice/pulp.

The titratable acidity in six passion fruit genotypes at 90 days after flowering was determined, in which, Kerala Yellow recorded the highest acidity (4.50%), followed by RCPS-1 (4.35%), Panama Yellow (3.5%), Nagaland Purple (3.25%), Megha Purple (2.82%) and lowest (1.41%) in *Passiflora alata* (Patel *et al.*, 2014).

2.2.3 Sugars

The amount of total sugars was determined from fruit juice of seven passion fruit (*Passiflora* spp.) cultivars: *P. edulis* cultivars Purple, Frederick, Yellow, Pink, *P. edulis* f. *flavicarpa*, *P. maliformis* and *P. quadrangularis*. Purple and yellow types of *Passiflora edulis* resulted in higher concentration of total sugar, 142.85 ± 0.17 g/kg and 139.69 ± 0.12 g/kg respectively, compared to other cultivars (Ramaiya *et al.*, 2012).

The amount of total, reducing and non reducing sugar content, in six passion fruit genotypes at 90 days after flowering was determined in which, total sugar was recorded highest in Nagaland Purple (18.1%), followed by Kerala Yellow (16.6%), RCPS-1 (15.38%), Megha Purple (14.58%), *Passiflora alata* (13.75%) and the lowest (13.34%) in Panama Yellow. The reducing sugar was maximum (6.67%) in *P. alata*, followed by RCPS-1 (5.40%), Kerala Yellow (5.26%), Megha Purple (5.15%), Panama Yellow (5.00%) and minimum in Nagaland Purple (3.92%). Also, the non reducing sugar recorded highest in Nagaland Purple (14.18%) followed by Kerala Yellow (11.34%), RCPS-1 (9.98%), Megha Purple (9.43%), Panama Yellow (8.34%) and the lowest (7.08%) was recorded in *Passiflora alata* (Patel *et al.*, 2014).

2.2.4 Ascorbic acid

Yellow passion fruit grown under different cultivation systems, an organic and a conventional system were harvested and estimated for ascorbic acid (L-ascorbic acid and L-dehydroascorbic acid) content. The concentration of ascorbic

acid present in organically cultivated fruits was higher than that of conventional system (Pertuzatti *et al.*, 2015).

Ramaiya *et al.* (2012) determined the ascorbic acid content in fresh juice of different passion fruit (*Passiflora* spp.) cultivars: *P. edulis* cultivars Purple, Frederick, Yellow, Pink, *P. edulis* f. *flavicarpa*, *P. maliformis* and *P. quadrangularis*. The juice of purple type (*P. edulis*) recorded highest mean ascorbic acid content (0.32 ± 0.72 g/kg) compared to other cultivars.

The ascorbic acid content in yellow passion fruit harvested at different maturity levels based on peel colour was estimated. The ascorbic acid content in 1/3rd yellow peel, 2/3rd yellow peel and yellow fruits were 25.98 mg/100g, 24.22 mg/100g and 26.55 mg/100g respectively (da Silva *et al.*, 2015). Uchao *et al.* (2008) also reported 11.76 mg/100g of ascorbic acid in yellow passion fruit.

The ascorbic acid content in six passion fruit genotypes at 90 days after flowering was determined in which, Megha Purple recorded the highest vitamin-C (48.75 mg/100ml) followed by Nagaland purple (41.34 mg/100ml), RCPS-1 (31.5 mg/100ml), *Passiflora alata* (30.8 mg/100ml), Kerala Yellow (22.8 mg/100ml) and lowest (22.5 mg/100ml) in Panama Yellow (Patel *et al.*, 2014).

2.2.5 Total carotenoids

Carotenoids are unstable compounds due to the presence of highly conjugated double-bond structure. They are mostly synthesized from the initial stage of fruit formation until veraison and then degrade towards the end of maturity (Mendes-Pinto, 2009). The biological functions and actions of carotenoids have increasingly being attributed to the antioxidant property of these natural pigments, through deactivation of free radicals and singlet oxygen quenching (Sharma *et al.*, 2012).

The carotenoids are natural plant pigments responsible for yellow, orange and red colour of fruits and acting as important vitamin-A precursors. Kathiravan

et al. (2013) reported a total carotenoid content of 1962.39 µg/100 ml in fresh yellow passion fruit juice (*Passiflora edulis*).

Yellow passion fruit grown under different cultivation systems, an organic and conventional system were harvested and estimated for total carotenoid content. The concentration of total carotenoids present in conventional system was twice that of fruits cultivated under organic system. The total carotenoid content in passion fruit ranges between 27,600 to 35,400 µg/100g. However the accumulation of carotenoids in passion fruit is variable according to the stage of maturity and systems of cultivation (Pertuzatti *et al.*, 2015).

2.2.6 Total phenols

Phenolic compounds are secondary metabolites occuring naturally in many fruits; they also exhibit good radical scavenging activity, maintain food quality, help in preventing human diseases such as cancer and cardiovascular disease (Kaur and Kapoor, 2001).

Existence of phenolic compounds is the main reason behind the antioxidant nature of any plant. They are an important group of secondary metabolites, synthesized due to plant adaptation in response to biotic and abiotic stresses. The antioxidant activity of these compounds depends mainly on molecular structure and availability of phenolic hydrogen's, which results in phenoxyl radical's formation due to hydrogen donation (Saptarini *et al.*, 2013).

The total phenolic content (TPC) of seven different passion fruit cultivars was determined by oxidation-reduction reaction using Folin-Ciocalteu reagent. The total phenolic content in all passion fruit cultivars ranged from 271.90 to 382.00 mg GAE/litre, also the highest TPC of 362.00 ± 4.68 and 361.73 ± 3.99 mg GAE/litre was observed in vine ripened purple and yellow passion fruit cultivars respectively (Ramaiya *et al.*, 2012).

The total phenolic content (TPC) of passion fruit albedo (PFA) and passion fruit seed and pulp fiber (PFSP) extracted from methanol, water and

dimethylsulfoxide (DMSO) ranged from 0.64 to 4.31 mg GAE/g. The highest TPC (4.31 mg GAE/g) was recorded in PFSP extracted from DMSO followed by PFSP extracted from methanol (2.98 mg GAE/g), PFA extracted from DMSO (1.86 mg GAE/g), PFSP extracted from water (0.98 mg GAE/g) and the lowest (0.64 mg GAE/g) in PFA extracted from methanol (Lopez-Vargas *et al.*, 2013).

The total phenolic content (TPC) of methanolic extract of fruit peel and fruit juice of banana passion fruit (*Passiflora tripartita*) was 56.03 ± 4.34 and 22.57 ± 1.43 mg gallic acid/100 g dry weight respectively (Simirgiotis *et al.*, 2013).

2.2.7 Total flavanoids

Flavanoids are a large group of different compounds with natural phenolic property. They are the most important yellow plant pigments having strong antioxidant and radical scavenging activity, antiallergic, anti-inflammatory and anticarcinogenic properties with important role in reducing the risk of high blood pressure, high cholesterol, chronic diseases, cardiovascular disorders and certain kinds of cancerous processes (Gattuso, 2007).

The concentration of flavanoids is more in passion fruit leaves as compared to fruit pulp, also the ethanol free liquid extract of *Pasiflora incarnata* contains higher amount of flavanoids compared to commercial preparations (Menghini *et al.*, 1993).

Simirgiotis *et al.* (2013) determined the total flavanoid content (TFC) from banana passion fruit (*Passiflora tripartita*) known as 'Tumbo'. The TFC of methanolic extract of fruit peel and fruit juice was 140.17 ± 4.23 and 77.16 ± 8.4 mg quercetin/100 g dry weight respectively.

The total flavanoid content (TFC) of passion fruit albedo (PFA) and passion fruit seed and pulp fiber (PFSP) extracted from methanol, water and dimethylsulfoxide (DMSO) ranged from 2.07 mg RE/g to 13.63 mg RE/g. The highest TFC (13.63 mg RE/g) was recorded in PFSP extracted from DMSO

followed by PFSP extracted from methanol (6.83 mg RE/g), PFA extracted from DMSO (5.12 mg RE/g), PFA extracted from methanol (3.18 mg RE/g) and the lowest (2.07 mg RE/g) in PFSP extracted from water (Lopez-Vargas *et al.*, 2013).

2.2.8 Antioxidant activity

The interest in growing passion fruit is becoming more popular because of its excellent antioxidant activity. The antioxidant activity of passion fruit is due to the presence of polyphenols which are involved in neutralizing the oxidants (da Silva *et al.*, 2012).

Antioxidant compounds such as phenolic acids, polyphenols, flavonoids, beta-carotene, lutein, lycopene, selenium, vitamin A, vitamin B, vitamin C, etc. are known to scavenge free radicals such as peroxide, hydroperoxide or lipid peroxyl thus inhibiting the oxidative mechanisms that lead to degenerative diseases in human beings (Murshid, 2013).

The total antioxidant activity (TAA) of seven different passion fruit cultivars was determined by using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) method. The TAA in all passion fruit cultivars ranged from 409.13 to 1964.90 µmol Trolox/litre and the strongest antioxidant activity of 547 ± 3.08 µmol Trolox/litre and 524 ± 1.96 µmol Trolox/litre was observed in vine ripened purple and yellow passion fruit cultivars respectively (Ramaiya *et al.*, 2012).

Passion fruit (*Passiflora edulis*) is a prime source of bioactive compounds, which could extenuate oxidative stress. Some phenolic compounds identified in *Passiflora* species showed therapeutic effects like immunomodulation, anticarcinogenic and antioxidant activities (da Silva *et al.*, 2014).

Saptarini *et al.* (2013) investigated the antioxidant activity in yellow passion fruit leaves by using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) method. The IC_{50} values in different extract and fractions such as, ethanolic extract, n-hexane fraction, ethyl acetate fraction, and water fraction of yellow passion fruit leaves was 66.7, 264.3, 49.3, and 52.7 µg/mL respectively.

Rudnicki *et al.* (2005) studied the antioxidant potential of hydro alcoholic leaf extracts of *Passiflora edulis* and *Passiflora alata,* in which, both extracts showed a significant correlation with the content polyphenols. However, leaf extract of *Passiflora alata* showed a higher amount of total antioxidant activity compared to *Passiflora edulis.*

Organically cultivated strawberries exhibited higher antioxidant enzymes activity and flavanoid content compared to conventional system, also, strawberries stored at higher (10°C) temperature had higher antioxidant activity than those stored at lower (5°C) temperatures (Jin *et al.,* 2010).

Afifa *et al.* (2014) investigated the free radical scavenging activity by using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) method in five mango (*Mangifera indica* L.) varieties such as Ashwina, Langra, Fazli, Himsagar and Amrapali, in which, the variety Langra showed the highest DPPH free radical scavenging activity followed by Fazli. They have also reported that, the antioxidant activity is directly proportional to the amount of total phenols and ascorbic acid present in the sample.

Lopez-Vargas *et al.* (2013) determined the antioxidant activity by using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging ability assay in yellow passion fruit co-products extracted from methanol, water and dimethylsulfoxide (DMSO). The higher ability to inhibit DPPH radical was observed in passion fruit seed pulp (PFSP) extracted from DMSO and methanol compared to passion fruit albedo (PFA) extracted from DMSO and methanol.

2.3 Extension of shelf life through shrink wrap packaging

Passion fruit is very much prone to shrivelling which results in deterioration of fruit quality and appearance, fruit starts dehydrating immediately after harvest. This is literally caused by an increase in respiration rate due to presence of ethylene biosynthesis during ripening which ultimately leads to the fruit becoming unmarketable or unfit for consumption (Shiomi *et al.*, 1995). The

fruit is very much prone to shrivelling, drying and microbial decay as they are wet and having high moisture content when picked. To avoid shrivelling and to increase shelf-life, proper packaging and storage condition is necessary. Adequate and proper packaging protects the fruit by maintaining physical firmness, reducing physiological loss of weight (PLW), microbial decay and deterioration (Zagory and Kader, 1988).

The post harvest life of yellow passion fruits can be effectively increased by polyolefin film packaging which helps to maintain the quality of fruits under good condition, reducing the percentage loss of fresh matter content and shrinkage of rind portion. Waxing was very much effective in retaining the sole characteristics of the fruits for a longer period (da Mota *et al.*, 2003).

Overwrapping freshly harvested fruits and vegetables by using highly permeable films like HDPE, LDPE, polyvinyl chloride (PVC), etc. helps to maintain the postharvest quality and extends the shelf life by minimising transpiration and respiration (Kader, 1986).

2.3.1 Effect of shrink wrap packaging on quality of passion fruit during storage

da Silva *et al.* (2015) reported that different maturity stages of passion fruit has no influence over physico-morphological characters like fruit length, diameter, volume, weight, peel, pulp, seed yield, rind thickness and biochemical characters such as pH, total soluble solids and vitamin-C. Pruthi (1963) observed no marked differences in the physico-chemical characteristics of partially and fully matured passion fruits except superior aroma in ripened fruits, but lower proportions of juice, sugars, ascorbic acid and flavour were recorded in immature fruits.

2.3.1.1 Shelf life (days)

The shelf life of purple passion fruit was up to 28 days with attractive colour, appearance and quality when packed in perforated HDPE films (0.03 mm) followed by storage at 5°C temperature, also the nutritional and biochemical parameters such as, total soluble solids (TSS), titratable acidity, sugars and ascorbic acid were at par with initial value even at the end of storage period (Singh *et al.*, 2007).

Packaging materials and storage conditions showed significant influence on the shelf life of passion fruits. All packaging materials increased the shelf life of passion fruits when compared with control, in which, highest shelf life (23.5 days) was observed in non perforated polythene packaging stored in Zero energy cool chamber (ZECC) while control had the shortest shelf life (5.5 days) (Lemtur *et al.*, 2013).

(Campbell and Knight, 1983) reported that the surface shrivelling of passion fruits can be controlled by storing them in sealed polyethylene bags at temperature of 6 to 10° C which also helped in extending the shelf life up to 3 to 4 weeks.

Cereda *et al.* (1976) reported that the temperature 7.2° C and relative humidity of 85 to 90% help to maintain the harvested passion fruits under marketable condition for up to 30 days without any shrivelling, drying and microbial decay.

2.3.1.2 PLW (%)

The physiological loss of weight of purple passion fruits stored in polyethylene film increased with the advancement of storage period in all treatments, also the minimum PLW (1.6-6.01%) was recorded in fruits packed in HDPE bags (0.03 mm), stored under 5°C temperature, whereas, maximum PLW

(32.5%) was observed in control fruits after 30 days of storage (Singh *et al.*, 2007).

Polystyrene trays containing yellow passion fruits were overwrapped with a plasticized PVC film and stored for 15 or 30 days at 10° C with 85% RH. Film-wrapped fruits showed better appearance, colour and less weight loss compared to non-wrapped fruits during the storage period. Around 50% surface of the non wrapped fruits shrivelled after 25 days of storage which then increased to 100% after 30 days (Matta *et al.*, 2006).

Maniwara *et al.* (2014) studied the physiological loss of weight in purple passion fruits by storing them in different packaging materials such as, perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system (MAP-1) and active packaging (MAP-2). Both MAP-1 and MAP-2 yielded less than 1.20% of total weight loss at the end of storage. However, MAP-2 was considered as the most effective packaging system in controlling the weight loss and shrinkage of fruits.

'Fairchild' mandarins shrink wrapped in polystyrene trays using two types of polyolefin films 19 μ and 20 μ were stored at room temperature 19-20°C and 70-75% relative humidity for 8 weeks. Both films were found very much effective in reducing weight loss, peel shrinkage and in maintaining freshness compared to unwrapped fruits (D'Aquino *et al.*, 1999).

2.3.2.3 TSS

The increase in TSS was observed during storage of purple passion fruits in polyethylene film irrespective of treatments up to 20 days and later a slight decrease was noticed in low temperature storage, whereas, in case of ambient condition, declining started from 10th day itself (Singh *et al.*, 2007).

Polystyrene trays containing yellow passion fruits overwrapped with a plasticized PVC film were stored for 15 or 30 days at 10° C with 85% RH. Loss in

soluble solids content (SSC) of juice was observed, but without any significant differences between the treatments (Matta *et al.*, 2006).

Jimenez *et al.* (2010) observed mild increase in pH and total soluble solids in the juice of different cultivars of passion fruit after harvesting them at different maturity levels according to peel colour as unripe, turning and full ripe.

Passion fruits harvested at five or ten days intervals of ages from 5 to 90 days after flowering (DAF) showed decrease in total soluble solids content during post harvest ripening with no significant decrease between 70 day fruits and older (Shiomi *et al.*, 1995).

2.3.2.4 Titratable acidity

Jimenez *et al.* (2010) observed mild decrease in titratable acidity in the juice of different cultivars of passion fruit after harvesting them at different maturity levels according to peel colour as unripe, turning and full ripe.

An increase in titratable acidity was observed during storage of purple passion fruits in polyethylene film irrespective of treatments up to 20 days and later a slight decrease was noticed in low temperature storage, whereas, in case of ambient condition, declining started from 10th day itself (Singh *et al.*, 2007).

Purple passion fruits stored in different packaging materials such as, perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system (MAP-1) and active packaging (MAP-2), showed mild decrease in titratable acidity with the advancement of storage time irrespective of treatments (Maniwara *et al.*, 2014).

A decreased amount of total acids was reported in Kinnow Mandarin juice starting from fully developed green fruit stage towards complete mature stage. This rate of decrease was consistent throughout the maturation period (Ram *et al.*, 2004).

2.3.2.5 Sugars

Increase in total sugars was observed during storage of purple passion fruits in polyethylene film irrespective of treatments up to 20 days and later a slight decrease was noticed in low temperature storage, whereas, in case of ambient condition, declining started from 10th day itself (Singh *et al.*, 2007).

Papaya fruits packaged by using perforated HDPE film, perforated LDPE film, dried banana leaves and newspaper, stored in evaporative cooler, showed increase in reducing and total sugar content with increased period of storage. Up to first six days, control fruits had higher amount of reducing and total sugar compared to packaged ones. However, packaged fruits stored in evaporative cooler maintained better sugar content towards the end of storage period (Azene *et al.*, 2011).

The increase in total sugars from 1.22 to 24.05% was observed in ethrel treated fruits of banana cv. Grand Naine during storage in CFB boxes at ambient temperature from day 1 to day 8. The maximum total sugar content (24.05%) was observed in fruits treated with 5000 ppm ethrel + NaOH pellets followed by fruits dipped in 1000 ppm ethrel (23.87%) while the minimum (14.84%) was noticed in control (untreated fruits) on eighth day of ripening (Subbaiah *et al.*, 2012).

Ram *et al.* (2004) observed significant increase in reducing, non-reducing and total sugar content progressively throughout the maturation period, right from fully developed green stage to mature stage in Kinnow Mandarin fruits with higher amount of non reducing sugar compared to reducing sugar content.

2.3.2.6 Ascorbic acid

The ascorbic acid content in purple passion fruits packed in polyethylene film decreased with increase in storage period in all treatments irrespective of storage condition. The decrease was minimum in refrigerated fruits as compared to fruits stored in ambient condition (Singh *et al.*, 2007).

Loss in ascorbic acid content was noticed in purple passion fruit juice when fruits are stored in different packaging materials such as, perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system (MAP-1) and active packaging (MAP-2). However, slight delay in vitamin-C loss was seen in (MAP-1) and (MAP-2) compared to LDPE (Maniwara *et al.*, 2014).

A significant increase in the amount of ascorbic acid was seen in Kinnow Mandarin juice right from fully developed green stage to colour break stage and it remained constant on subsequent stages (Ram *et al.*, 2004).

The ascorbic acid content in aonla fruits packed in different types of packaging materials, decreased rapidly during storage at ambient temperature, without any significant difference between the treatments. However, fruits stored in CFB with newspaper liner, retained maximum ascorbic acid content (450 mg/100g), followed by CFB with polythene liner, while minimum retention (350 mg/100g) was seen in control (fruits packed in gunny bags) on 13th day of storage (Singh *et al.*, 2009).

2.3.2.7 Total carotenoids

Purple passion fruits stored in different packaging materials such as, perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system (MAP-1) and active packaging (MAP-2), showed better retention of carotenoid content irrespective of treatments. However MAP-2 packaging was very much effective in delaying loss of bioactive compounds like, β-carotene, lycopene and phytoene with the advancement of storage time (Maniwara *et al.*, 2014).

Fresh and matured mango fruits after harvesting from the orchard were initially treated with thiophanate solution followed by packing in polyethylene film and stored at 8, 11, 14 and 25°C temperatures. A gradual increase in total carotenoid content was observed initially up to 25 days followed by decrease in

subsequent days, irrespective of storage temperatures and this decrease was rapid under ambient storage temperature (25°C) as compared to other storage conditions (Wen *et al.*, 2006).

The total carotenoid content in loquat fruits stored at room temperature(25°C), 4 and 8°C, increased gradually up to 12th day followed by decrease in subsequent days. At the end of storage period, the fruits stored at room temperature, showed higher concentrations of carotenoid compared to those fruits stored 4 and 8°C temperature (Chen *et al.*, 2015).

2.3.2.8 Total phenols

Purple passion fruits stored in different packaging materials such as, perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system (MAP-1) and active packaging (MAP-2), showed fluctuating trends in total phenolic content of passion fruit crude extract. However, packaging conditions did not show any obvious effects on total phenols (Maniwara *et al.*, 2014).

Ram *et al.* (2004) observed significant decrease in phenolic content of Kinnow Mandarin peel tissue with the advancement of fruit maturation, whereas, the phenolic content showed increasing trend in Kinnow Mandarin juice throughout the maturation period.

Carbone *et al.* (2011) reported a considerable decrease of total phenolic contents (50% in flesh and 20% in peel) in apple cultivar 'HillWell' stored at cold temperature (1°C) for three months, whereas, the total phenolic contents showed increasing trend in 'Wellant' cultivar when stored at ambient temperature (20°C) for two weeks.

Decrease in total phenolic content with increase in storage time was observed in rowanberry (*Sorbus aucuparia*) fruits during storage at 4 and 22°C temperature. The highest loss of phenolic content (50% of its initial) was seen in

22°C storage temperature and the minimum loss (30% of its initial) was observed in 4°C storage temperature at the end of 20 days of storage (Baltacioglu *et al.*, 2011).

2.3.2.9 Total flavanoids

A significant change in flavanoid compounds such as hesperidin and naringin was observed in Kinnow Mandarin juice during its maturation. The hesperidin content was higher in mature deep orange colour stage compared to fully developed green fruit stage, whereas, the naringin content was higher in 50% colour break stage compared to mature stage (Ram *et al.*, 2004).

The total flavanoid content in rowanberry (*Sorbus aucuparia*) fruits stored at 4 and 22°C temperature decreased significantly with increase in storage time. This decrease was more under 22°C compared to 4°C storage temperature (Baltacioglu *et al.*, 2011).

Decrease in flavanoid compounds such as, ellagic acid, quercetin 3-glucoside, quercetin derivative and kaempferol 3-glucuronide was observed with increase in ripening and storage period in raspberries (*Rubus ideaus* L.) (Wang *et al.*, 2008).

2.3.2.10 Sensory quality/ organoleptic properties of fruits

Sensory scores for flavour and sweetness in purple passion fruit stored at 25±1°C, increased up to fifth day followed by decrease during subsequent days, whereas, scores for sourness and overall quality, decreased throughout the storage (Kishore *et al.*, 2010).

Maniwara *et al.* (2014) conducted organoleptic evaluation after storing purple passion fruits in different packaging materials such as, perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system (MAP-1) and active packaging (MAP-2). After 28 days of storage, significant differences between LDPE, MAP-1 and MAP-2 packaging was noticed in terms of fruit peel colour, visual quality, sweetness, peel

shrivelling and overall satisfaction. MAP-1 and MAP-2 packaging retained better fruit quality during the storage period than LDPE, however, MAP-2 packaging resulted in longer shelf life of fruits compared to all other treatments.

The sensory scores of 'Kinnow' mandarins packed in high density polyethylene (HDPE) film in combination with edible oil and wax coating, decreased continuously during storage. Maximum score 8.0 was recorded in fruits packed in HDPE followed by 7.7 in neem oil + HDPE packed fruits, while, minimum score 4.0 was recorded in fruits treated with coconut oil (Randhawa *et al.*, 2009a).

Randhawa *et al.* (2009b) conducted sensory evaluation in ber fruits after packing them in CFB boxes followed by cold storage. An increasing trend in sensory scores was observed up to 10 days in all the treatments except control, but shows subsequent decrease in later stage of storage.

2.4 Processing of passion fruit

Nowadays, the interest in producing fruit and vegetable juices has increased significantly all over the world due to their benefit value, quality production, increased consumer awareness and preference for healthy food (Arsad *et al.*, 2015). Passion fruit is versatile in nature which can be used in several forms like raw fruits, pulp, juice, jams, yogurts, milk shakes, ice cream, etc. The presence of exotic flavour fetches high price in market (da Silva *et al.*, 2015). Passion fruit juice and its concentrate are more popular in world market; the juice could be processed into squash, ready to serve beverages, nectars, syrups, etc. by mixing with other tropical fruit juices/pulps as it is having excellent blending property. In India, Mizoram, Manipur and Nagaland leads in the production of passion fruit processed products (Kulkarni and Vijayanand, 2009).

2.4.1 Preparation and preservation of nectar

Passion fruits are highly preferred in international market as they exhibit excellent sensory, nutritional and/or nutraceutical properties and also they can be successfully processed into value added soft drinks and juices (Jimenez *et al.*, 2010). In Brazil, the juice processing sector is dominated by yellow passion fruit (*Passiflora edulis f. flavicarpa*) as its production was higher than guava and melon during 2012, which has made Brazil a top exporter of passion fruit juice in the world (Pertuzatti *et al.*, 2015).

Utilization of few highly nutritive fruits and vegetables is often limited because of high acidity, astringency, bitterness, etc. The core reason of blending different type of fruit juices is to enhaunce flavour, palatability, nutritive and medicinal value, to reduce astringency and polyphenols, etc. of the processed product (Sobhana *et al.*, 2014). Passion fruit, a nutritious fruit with excellent blending property is being underutilized due to many drawbacks, but can be very well exploited for the preparation of healthy refreshing drinks.

2.4.2 Changes in quality of passion fruit nectar during storage

2.4.2.1 TSS

The total soluble solids in RTS drink prepared by blending juices of passion fruit and cashew apple in different ratios such as 25:75, 50:50, 25:75 + ginger drops and 50:50 + ginger drops was 13.85°Brix, 14.50°Brix, 13.93°Brix and 14.92°Brix respectively (Sobhana *et al.*, 2014).

The total soluble solids (TSS) in both honey and sugar enriched mango nectars (20 % pulp, 15°B TSS and 0.30 % acidity) increased during storage in sterilized glass bottles for six months and this increase was more in nectar stored under ambient condition compared to those stored under refrigerated condition. However, at the end of six months of storage, honey enriched mango nectar

recorded maximum TSS compared to sugar based mango nectar (Lakhanpal and Vaidya, 2015).

A significant increase in total soluble solids (TSS) was observed in heat processed grape, orange and pear nectars during 28 days of storage at 4, 25 and 37°C temperature. This rate of increase advances with increase in storage time and temperature (Touati *et al.*, 2015).

Bal *et al.* (2014) prepared guava nectar by using four different pulp concentrations viz. 8, 12, 16 and 20 per cent along with three levels of total soluble solids (TSS) viz. 13, 15 and 17°Brix and stored at room temperature in sterilized glass bottles after pasteurization at 85°C for 30 minutes. The TSS decreased significantly throughout the storage period of 8 months irrespective of treatments.

2.4.2.2 Titratable acidity

The titratable acidity in RTS drink prepared by blending juices of passion fruit and cashew apple in different ratios such as 25:75, 50:50, 25:75 + ginger drops and 50:50 + ginger drops was 0.35%, 0.61%, 0.41% and 0.66% respectively (Sobhana *et al.*, 2014).

Nectar prepared by blending pulp of aonla and mango with 50 per cent sugar + 50 per cent stevia + 15 per cent TSS and 0.25 per cent acidity, did not show any changes in titratable acidity up to five months of storage in glass bottles at ambient temperature, but slight increase from 0.25 to 0.27 per cent was observed during 6^{th} and 7^{th} month and thereafter it decreased (Singh *et al.*, 2014).

Guava nectar prepared by using four different pulp concentrations viz. 8, 12, 16 and 20 per cent along with three levels of total soluble solids (TSS) viz. 13, 15 and 17°Brix, showed increasing trend in titratable acidity throughout the storage period of 8 months (Bal *et al.*, 2014).

The titratable acidity in both honey and sugar enriched mango nectars (20 % pulp, 15°B TSS and 0.30 % acidity) decreased during storage in sterilized glass bottles for six months at ambient and refrigerated condition. This decrease was more in nectar stored under ambient condition compared to those stored under refrigerated condition. However, at the end of six months of storage, honey enriched mango nectar showed maximum titratable acidity compared to sugar enriched mango nectar (Lakhanpal and Vaidya, 2015).

2.4.2.3 Sugars

Sandi *et al.* (2004) reported that the concentration of reducing sugar was increased in passion fruit juice pasteurized at both lower (75°C/60 sec) and higher (85°C/27 sec) temperatures irrespective of storage condition and this increase was maximum in juices pasteurized at lower temperatures and stored under refrigeration.

The amount of total sugars in RTS drink prepared by blending juices of passion fruit and cashew apple (50:50) along with the addition of ginger drops was 14.92% (Sobhana *et al.*, 2015).

Fang *et al.* (1986) reported that the concentration of organic acids are rich in passion fruit juice, which results in higher conversion of non-reducing sugars (sucrose) to reducing sugars when stored under ambient condition as compared to refrigeration, as long as the juice has been pasteurized correctly.

Guava nectar prepared by using four different pulp concentrations viz. 8, 12, 16 and 20 per cent along with three levels of total soluble solids (TSS) viz. 13, 15 and 17°Brix, showed increasing trend in reducing and total sugars while decreasing trend in non reducing sugar throughout the storage period of 8 months (Bal *et al.*, 2014).

Decrease in total sugars and increase in reducing sugar was observed in both honey and sugar enriched mango nectars (20 % pulp, 15°B TSS and 0.30 %

acidity) during storage in sterilized glass bottles for six months at ambient and refrigerated condition. These changes in sugar content were more in nectar stored under ambient condition compared to those stored under refrigerated condition (Lakhanpal and Vaidya, 2015).

2.4.2.4 Ascorbic acid

The retention of ascorbic acid in processed products during storage depends on preparation methods, processing time, temperature, salt and sugar concentration, pH, oxygen availability, activity of enzymes and metal catalysts. A percentage loss of 42%, 37% and 31% of ascorbic acid content in drumstick (*Moringa oleifera*) was observed after canning at 110°C for 32 min, 115°C for 27 min and 121°C for 20 min respectively (Wijayawardana and Bamunuarachchi, 2002).

The ascorbic acid content in RTS drink prepared by blending juices of passion fruit and cashew apple in different ratios such as 25:75, 50:50, 25:75 + ginger drops and 50:50 + ginger drops was 80.26 mg/100 g, 79.73 mg/100 g, 76.39 mg/100 g and 79.29 mg/100 g respectively (Sobhana *et al.*, 2015).

Nectar prepared by blending pulp of aonla and mango with 50 per cent sugar + 50 per cent stevia + 15 per cent TSS and 0.25 per cent acidity, showed decreasing trend in ascorbic acid content from 36.20 to 27.30 mg/100g during ten months of storage in glass bottles at ambient temperature (Singh *et al.*, 2014).

Decreasing trend in ascorbic acid content was observed in both honey and sugar enriched mango nectars (20 % pulp, 15°B TSS and 0.30 % acidity) during storage in sterilized glass bottles for six months at ambient and refrigerated condition. This decrease was more in bottles stored under ambient condition compared to those bottles stored under refrigerated condition (Lakhanpal and Vaidya, 2015).

2.4.2.5 Total carotenoids

Lakhanpal and Vaidya (2015) prepared two types of mango nectars (20 % pulp, 15°B TSS and 0.30 % acidity) by using honey and sugar as sweetening agents and stored in sterilized glass bottles for six months at different storage conditions. The carotenoid content in both honey and sugar enriched mango nectars decreased and this decrease was more in nectar stored under ambient condition compared to refrigerated condition. However, at the end of six months of storage, honey enriched mango nectar retained maximum carotenoid content than sugar based mango nectar.

The total carotenoid content in orange nectar stored at 4, 25 and 37°C temperature for 28 days decreased significantly from 26.19 mg βCE/100 mL to 24.50, 22.05 and 18.73 βCE/100 mL respectively with increase in storage period (Touati *et al.*, 2015).

The total carotenoid content in canned mango nectar (20% pulp,15°Brix and 0.3 % acidity) prepared from three popular mango cultivars viz. Sindura, Mallika and Totapuri was 1079.7, 854.5 and 319.4 µg/100 g (Vijayanand *et al.*, 2013).

The total carotenoid content remains stable without any significant differences between the homogenized and pasteurized juice of yellow mombin (*Spondias mombin* L.) (de Carvalho, 2013).

2.4.2.6 Total phenols

No significant differences were observed in the physicochemical parameters of homogenized and pasteurized yellow mombin (*Spondias mombin* L.) juice, but processing results in significant loss of total phenolic compounds (de Carvalho, 2013).

A significant decrease in total phenolic content was observed in heat processed grape, orange and pear nectars during 28 days of storage at 4, 25 and

37°C temperature. This rate of decrease advanced with increased storage time and temperature (Touati *et al.*, 2015).

Fluctuations in total phenolic content (TPC) were observed in six fruit juices viz. currant, cranberry, blueberry, pomegranate, strawberry and cherry out of which, TPC significantly increased in strawberry and cherry juices during the first 48 hours of processing followed by a decrease over the course of next 13 days (Piljac-Zegarac, 2008).

Two different brands of orange juice viz. orange juice 1 and orange juice 2 stored at 18, 28 and 38°C temperature for six months in cartons showed decreasing trend in total polyphenols up to four months followed by increase after six months. These changes in total polyphenols were rapid under 38°C compared to 18 and 28°C storage temperature (Klimczak *et al.*, 2006).

2.4.2.7 Total flavanoids

A decrease in flavanoid content was observed during storage of fruit juices under refrigerated condition and this decrease can be minimized by the addition of sodium benzoate (Sarkar *et al.*, 2014).

A significant increase in the amount of total flavanoids (hesperidin) was noticed in minimally processed citrus segments, whereas, citrus juice showed decreasing trend in flavanoid content (Caro *et al.*, 2003).

Micali *et al.* (2003) estimated total flavanoid content in the pulp obtained from refining citrus fruit juices by using HPLC. The concentration of flavanoids (hesperidin, narirutin, didymin and eriocitrin) was found more in the by-product of pulp from orange juice as compared to its juice and peel.

The total flavanoid compounds such as, narirutin, hesperidin, didymin, naringin and neohesperidin in two different brands of orange juice viz. orange juice 1 and orange juice 2 stored at 18, 28 and 38°C temperature for six months in

cartons decreased throughout the storage period. This decrease was rapid under 38°C compared to 18 and 28°C storage temperature (Klimczak *et al.*, 2006).

2.4.2.8 Non-enzymatic browning

Non-enzymatic browning in nectar prepared by blending pulp of aonla and mango with 50 per cent sugar + 50 per cent stevia + 15 per cent TSS and 0.25 per cent acidity, maintained steady phase up to six months during storage in glass bottles at ambient temperature followed by increase over the period of next four months (Singh *et al.*, 2014).

A significant increase in non-enzymatic browning was observed in heat processed grape, orange and pear nectars during 28 days of storage at 4, 25 and 37°C temperature. This rate of increase advances with increase in storage time and temperature (Touati *et al.*, 2015).

Non-enzymatic browning showed increasing trend in sweetened, filtered and pasteurized 'Nagpur' Mandarin orange juice throughout the storage period up to 180 days irrespective of storage conditions, however, the higher rate of increase was observed in ambient temperature compared to cold temperature (Ladaniya *et al.*, 2004).

A steady increase in non-enzymatic browning was observed in lime-aonla beverage during 6 months of storage, irrespective of storage conditions and glass containers. Less browning rate was recorded in beverages stored in amber coloured bottles under low temperature conditions as compared to white bottles at ambient temperature (Deka *et al.*, 2004).

2.4.3 Sensory quality/ organoleptic properties of beverages

Cashew apple juice when blended with equal quantity of passion fruit juice with and without the addition of ginger drops, showed better acceptability in terms of flavour, taste, sweetness, appearance and colour in both samples (Sobhana *et al.*, 2015).

The pasteurized, chemically preserved and control juice of purple passion fruit stored at -18°C, 4-8°C and 23°C were subjected to sensory evaluation using 7-point hedonic scale at monthly intervals for 3 months. The scores for off-flavour and after taste was recorded highest in pasteurized juice compared to chemical preservation and control indicating that pasteurization has adverse effects on flavour profile (Namutebi, 1998).

The organoleptic quality of nectar prepared by blending pulp of aonla and mango with 50 per cent sugar + 50 per cent stevia + 15 per cent TSS and 0.25 per cent acidity, did not show any changes up to three months of storage in glass bottles at ambient temperature and it was found to be acceptable up to nine months (Singh *et al.*, 2014).

Guava nectar prepared by using four different pulp concentrations viz. 8, 12, 16 and 20 per cent along with three levels of total soluble solids (TSS) viz. 13, 15 and 17°Brix, showed decreasing trend in organoleptic scores with respect to colour, flavour, taste and overall acceptability throughout the storage period of 8 months at ambient temperature (Bal *et al.*, 2014).

Mango nectars (20 % pulp, 15°B TSS and 0.30 % acidity) prepared by using honey and sugar as sweetening agents were subjected to organoleptic evaluation at three months intervals during storage at ambient and refrigerated condition. Honey enriched mango nectar stored under refrigerated condition recorded highest scores with respect to colour, taste and overall acceptability (Lakhanpal and Vaidya, 2015).

2.4.4 Microbial quality of nectar

Fang *et al.* (1986) reported that pasteurization of passion fruit juice at 75°C for 40 sec is sufficient to ensure the microbiological quality in both ambient and refrigerated storage conditions.

The yellow passion fruit juice after pasteurization at three different levels (85°C/27 sec, 80°C/41 sec, 75°C/60 sec) was initially subjected to microbial

analysis before storage. The treatment 75°C/60 sec itself showed complete inhibition of microbial population, also the juice stored under refrigeration remained microbiologically safe throughout the storage period (Sandi *et al.*, 2004).

Tchango-Tchango *et al.* (1997) reported that acidity in processed passion fruit juice inhibited the growth and multiplication of pathogenic microorganisms hence, the presence of pathogenic *Escherichia coli*, *Streptococcus* or *Staphylococcus* was nil, but might contain non-pathogenic fungi, yeasts or lactic acid bacteria.

Bacteria and yeast counts were negligible in sweetened 'Nagpur' Mandarin orange juice throughout the storage period irrespective of storage conditions. However, up to 45 days, no fungal population was detected in both refrigerated and ambient storage conditions, but detected after 180 days (Ladaniya *et al.*, 2004).

The aseptically processed ashgourd-mint leaves juice was investigated for microbial quality during 8 months of storage. The presence of coliform, spores, yeast and mold was nil throughout the storage period, also, total plate count (TPC) was nil up to 6 months of storage but TPC was 12 cfu/ml after 8 months of storage (Majumdar *et al.*, 2012).

Materials and methods

3. MATERIALS AND METHODS

MATERIALS

The present investigation "Value addition of passion fruit (*Passiflora edulis* Sims)" was carried out with accessions of passion fruit collected from different parts of Kerala. These accessions were compared with Kaveri, a popular purple fruited type, released by the Central Horticultural Experiment Station (CHES), Chettali, a substation of the Indian Institute of Horticulture Research (IIHR), Bengaluru. The investigation was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur during 2014-2016.

METHODS

The study was conducted under three experiments *viz.* (3.1) Characterization of passion fruit accessions. (3.2) Extension of shelf life of passion fruit through shrink wrap packaging. (3.3) Development of passion fruit nectar and its quality evaluation during storage. To support the aforesaid aspects of the investigation, various physico-chemical parameters were analysed. All the results were analysed statistically.

3.1 CHARACTERIZATION OF PASSION FRUIT ACCESSIONS

3.1.1 Collection of passion fruits

Passion fruit accessions (yellow and purple) were collected from various localities of Kerala. Kaveri, the only variety of passion fruit released in India which is a purple fruited type was used as standard/check variety (Table 1).

These accessions were characterized based on physico-morphological, nutritive and biochemical parameters, of which special emphasis was given to determine the antioxidant activity.

3.1.2 Lay out

The experiment was laid out in a Completely Randomized Design (CRD) with three replications each.

3.1.3 Observations

Observations on physico-morphological, nutritive and biochemical parameters were taken as detailed below.

Table 1. List of passion fruit accessions collected from various locations in Kerala and Karnataka

Passion fruit	Type	Location
Accession 1	Yellow	Ambalavayal, Wayanad
Accession 2	Purple	
Accession 3	Yellow	Vellanikara, Thrissur
Accession 4	Yellow	Mannuthy, Thrissur
Accession 5	Purple	Thiruvalla, Pathanamthitta
Accession 6	Yellow	
Accession 7	Yellow	Athirampuzha, Kottayam
Accession 8	Yellow	Pineapple Research Station (PRS), Vazhakulam, Ernakulam
Accession 9	Purple	
Accession 10 (KAVERI)	Purple	Central Horticultural Experiment Station (CHES), Chettalli, Karnataka

3.1.3.1 Physico-morphological parameters

3.1.3.1.1 Fruit length

Length of ten fruits was measured by using Vernier calliper and the average of these values was expressed in centimetre.

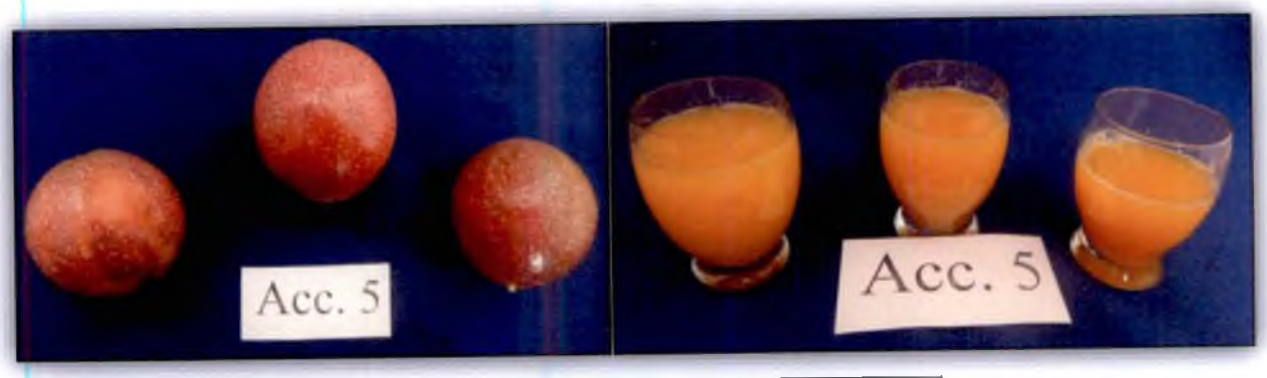
Yellow type- Ambalavayal, Wayanad

Purple type- Ambalavayal, Wayanad

Yellow type- Vellanikkara, Thrissur

Yellow type- Mannuthy, Thrissur

Plate 1a: Passion fruit accessions



Purple type- Thiruvalla, Pathanamthitta

Yellow type- Thiruvalla, Pathanamthitta

Yellow type- Athirampuzha, Kottayam

Yellow type- PRS, Vazhakulam, Ernakulam

Plate 1b: Passion fruit accessions

Purple type- PRS, Vazhakulam, Ernakulam

Purple type (Kaveri) - CHES, Chettalli, Coorg, Karnataka

Plate 1c: Passion fruit accessions

3.1.3.1.2 Fruit diameter

Diameter of ten fruits was measured by using Vernier calliper and the average of these values was expressed in centimetre.

3.1.3.1.3 Fruit girth

Girth of ten fruits was taken with the help of a thread and accordingly the girth was determined on a scale in centimetre.

3.1.3.1.4 Rind thickness

Rind thickness of ten fruits was measured by using Vernier calliper and the average of these values was expressed in centimetre.

3.1.3.1.5 Fruit size

Fruit size was expressed by the method "Description of passion fruit cultivars and their juices" suggested by Ramaiya *et al.* (2012).

3.1.3.1.6 Fruit weight

Weight of ten fruits was taken by using a weighing balance and the average values were expressed in gram.

3.1.3.1.7 Juice percentage

Juice extracted from each fruit of all accessions was weighed separately and the average juice percentage was calculated by the formula as given below.

$$\text{Juice (\%)} = \frac{\text{Weight of juice (g)}}{\text{Weight of fruit (g)}} \times 100$$

3.1.3.1.8 Fruit shape

Fruit shape was expressed as round or oval or round-oval based on the external appearance of the fruit.

3.1.3.1.9 Colour of rind

Rind colour was expressed as yellow or purple based on the external appearance of the fruit.

3.1.3.1.10 Colour of juice

Colour of the juice was visually identified with the help of Universal Colour Language (UCL). The Universal Colour Language was defined by the Inter-society Colour Council, National Bureau of Standards in 1946.

3.1.3.1.11 Physical composition

Weight of each physical component of fruits of all accessions was taken separately and its proportion to the total weight of the fruit was expressed as given below.

$$\text{Physical composition (\%)} = \frac{\text{Weight of physical component (g)}}{\text{Weight of fruit (g)}} \times 100$$

3.1.3.2 Nutritive and biochemical parameters

3.1.3.2.1 Total soluble solids (TSS)

TSS was measured/recorded directly using a digital refractometer (range 0-32°brix) and expressed in degree brix (^{0} Brix).

3.1.3.2.2 Titratable acidity

The titratable acidity was estimated by titrating a known weight/volume of the sample against 0.1N NaOH solution using phenolphthalein as an indicator for all the samples. The acidity was calculated and expressed as per cent citric acid (AOAC, 1998).

3.1.3.2.3 Reducing sugars

A known weight of filtered juice sample was first neutralised with 1N NAOH by using phenolphthalein as an indicator and transferred to a 250 ml volumetric flask. About 100ml of distilled water was added followed by 2ml pre standardised 45 per cent neutral lead acetate for clarification. Excess lead acetate was neutralized by addition of 2ml pre standardised 22 per cent potassium oxalate solution. The clarified solution was made up to the mark with distilled water. This was filtered through Whatman's No.1 filter paper. In the clarified filtrate, the reducing sugars were determined by titrating against standard Fehling's solution using methylene blue as an indicator (Ranganna, 1997). The reducing sugars were calculated by the formula as given below.

$$\text{Reducing sugars (\%)} = \frac{\text{Fehling's Factor x dilution x 100}}{\text{Titre value x weight of sample}}$$

3.1.3.2.4 Non reducing sugars

Non reducing sugars were estimated by deducting reducing sugars from total sugars (% total sugars - % reducing sugars).

3.1.3.2.5 Total sugars

50 ml of the filtrate used in the estimation of reducing sugars was taken into a 100ml volumetric flask and 5 ml of concentrated HCl was added for hydrolyzing the sample. Then the hydrolysed solution was neutralized with 20 per cent NaOH by using one or two drops of phenolphthalein. Diluted HCl was added till it became colourless. Finally, the volume was made upto 100ml and it was titrated against standard Fehlings solution using methylene blue as an indicator (Ranganna, 1997). The total sugars were calculated as given below.

$$\text{Total sugars (\%)} = \frac{\text{Fehling's factor x 250 x dilution}}{\text{Titre value x 50 x weight of sample}} \times 100$$

3.1.3.2.6 Ascorbic acid

Ascorbic acid was determined by titrating a known weight of sample with 2, 6-dichlorophenol indophenol dye, using metaphosphoric acid as stabilizing agent (AOAC, 1998).

A known weight of juice of each accession was taken in 100ml volumetric flask, followed by adding 3 per cent metaphosphoric acid to make up the volume. From this, 10 ml of aliquot was titrated against 2, 6-dichlorophenol indophenol dye. The dye factor was calculated by titrating standard ascorbic acid solution against dye and ascorbic acid content of sample was expressed as

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value x dye factor x volume made up x 100}}{\text{Weight of sample x aliquot of sample}}$$

3.1.3.2.7 Total carotenoids

A known weight of juice sample was taken in a separating funnel. Then 10-15ml of petroleum ether and water containing 5 per cent anhydrous sodium sulphate were added. Extraction of acetone phase was repeated with small volume of petroleum ether until no more colour was extracted. A small amount of anhydrous sodium sulphate was added to absorb the excess water and volume was made up with eluent (3% acetone in petroleum ether). The colour was measured at 452 nm using eluent as blank in spectrophotometer. Results were expressed as µg/100g of material (Ranganna, 1997).

$$\text{Total carotenoids (µg/100g)} = \frac{\text{3.857 x optical density x volume made up}}{\text{Weight of the sample}} \text{ x 100}$$

3.1.3.2.8 Total phenols

Estimation of total phenols was carried out with Folin - Ciocalteau reagent. Phenols react with phosphomolybdic acid in alkaline medium and produce a blue coloured complex (Molybdenum blue) (Asami *et al.*, 2003).

The juice sample (5ml) was added to 50ml of 80 per cent ethanol and the sample was extracted in hot water bath for 25-30 minutes. It was then cooled and filtered through Whatman's No.1 filter paper. The extracted sample was made up to a known volume of 50ml by using distilled water. The supernatant used for total phenol estimation was pipetted out into a series of test tubes. Sample extract (0.5ml) was pipetted out in other test tubes.

To each test tube including blank, 3ml distilled water was added. It was mixed with 0.5 ml Folin - Ciocalteau reagent. It was mixed well and allowed to stand for 3 minutes. To all test tubes, 20 per cent sodium carbonate (2ml) was added, mixed thoroughly and kept for 1 hour. All the tubes were kept in boiling water for exactly one minute and cooled. Optical density values were recorded in a spectrophotometer at 650nm. A standard graph was drawn and the amount of total phenols in the sample was calculated.

3.1.3.2.9 Total flavanoids

Aluminium chloride method was used for determination of flavanoids in the sample (Chang *et al.*, 2002). A known weight of sample (10g) was ground using ethanol in a pestle and mortar. Then it was centrifuged to obtain clear liquid. Centrifugation was done until it became colourless. Ethanol extract of the sample was mixed with 1.5 ml of methanol, 0.1 ml of 10 per cent aluminium chloride, 0.1 ml of 1M potassium acetate and 2.8 ml of distilled water. It was kept at room temperature for 30 minutes. The absorbance of the reaction mixture was measured at 415 nm with a UV-Vis spectrophotometer (Shimadzu UV-Vis spectrophotometer, 1800).

3.1.3.2.10 Antioxidant activity

The free radical scavenging activity of the extracts of passion fruit juice was determined based on the DPPH method (Braca *et al.,* 2001). The extract (33 µL) was added to 1.3 mL DPPH solution diluted in methanol (0.024 mg mL−1), shaken and incubated for 30 min in dark, and absorbance was measured at 517 nm. The percentage scavenging radical was calculated from formula given below

% Inhibition = (Control-sample)/ Control) x100.

The sample concentration providing 50% inhibition (Inhibitory concentration - IC_{50}) was calculated from the graph of RSA (radical scavenging activity) percentage against sample concentration. Gallic acid was used as standard.

3.2 EXTENSION OF SHELF LIFE OF PASSION FRUIT THROUGH SHRINK WRAP PACKAGING

Mature fruits of a yellow accession grown at the Cashew Research Station (CRS), Madakathara were used at the turning stage for evaluation of shelf life and quality through shrink wrap packaging. Fruits free of damage and bruises were washed in clean tap water followed by immersion in 100 ppm chlorine solution for 15 minutes. The chlorinated fruits were spread out on perforated trays to remove excess surface moisture. The surface dried fruits were subjected to two forms of shrink wrapping viz. shrink wrapping of individual fruits and also shrink wrapping of areca plates containing 6-7 fruits, depending on size of fruits. Polyolefin films of 15, 19 and 25 micron thickness were used for shrink wrapping. Observations on changes in quality of fruits were recorded at weekly intervals during storage at ambient temperature.

3.2.1 Treatments

T1- Individual shrink wrapping of passion fruit with polyolefin film of 15 µ

T2- Individual shrink wrapping of passion fruit with polyolefin film of 19 µ

T3- Individual shrink wrapping of passion fruit with polyolefin film of 25 μ

T4- Shrink wrapping of areca plates containing fruits with polyolefin film of 15 μ

T5- Shrink wrapping of areca plates containing fruits with polyolefin film of 19 μ

T6- Shrink wrapping of areca plates containing fruits with polyolefin film of 25 μ

T7- Control (unwrapped fruits)

3.2.2 Observations

Observations on both physical and biochemical changes during storage were taken as detailed below.

3.2.2.1 Physical parameters

3.2.2.1.1 Shelf life (days)

Shelf life was noted on the basis of physiological loss of weight (%), visual changes like wilting, shrivelling and also incidence of spoilage or rotting.

3.2.2.1.2 Physiological loss of weight (%)

Physiological loss of weight was calculated by the formula as given below.

$$PLW\ (\%) = \frac{\text{Initial weight (g) - Final weight (g)}}{\text{Initial weight (g)}} \times 100$$

3.2.2.2 Biochemical parameters

3.2.2.2.1 Total Soluble Solids (TSS)

TSS were estimated as in 3.1.3.2.1

Plate 2: Shrink wrapping machine

Freshly harvested fruits

Chlorination

Draining surface moisture

Enclosing in polyolefin film

Shrink wrapping

Plate 3: Flow chart for shrink wrap packaging of passion fruit

Plate 4: Shrink wrapped passion fruits

Plate 5: General view of storage room

3.2.2.2.2 Titratable acidity

Titratable acidity was estimated as in 3.1.3.2.2

3.2.2.2.3 Reducing sugars

Reducing sugars were estimated as in 3.1.3.2.3

3.2.2.2.4 Non-reducing sugars

Non-reducing sugars were estimated as in 3.1.3.2.4

3.2.2.2.5 Total sugars

Total sugars were estimated as in 3.1.3.2.5

3.2.2.2.6 Ascorbic acid

Ascorbic acid was estimated as in 3.1.3.2.6

3.2.2.2.7 Total carotenoids

Total carotenoids were estimated as in 3.1.3.2.7

3.2.2.2.8 Total phenols

Total phenols were estimated as in 3.1.3.2.8

3.2.2.2.9 Total flavanoids

Total flavanoids were estimated as in 3.1.3.2.9

3.2.2.3 Organoleptic evaluation

Quality of passion fruit was judged by a panel of judges of different age groups for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability, based on a 9 point hedonic scale rating (Amerine *et al.*, 1965). A score of 5.5 and above was considered acceptable.

3.3 DEVELOPMENT OF PASSION FRUIT NECTAR AND ITS QUALITY EVALUATION DURING STORAGE

3.3.1 Preparation of passion fruit nectar

Passion fruit nectar was prepared from yellow and purple types separately and also from blended juice of both yellow and purple, in the following specifications.

1. 15°brix, 20% juice(yellow)
2. 20°brix, 20% juice(yellow)
3. 15°brix, 20% juice (purple)
4. 20°brix, 20% juice (purple)
5. 15°brix, 20% juice (yellow and purple in 1:1 ratio)
6. 20°brix, 20% juice (yellow and purple in 1:1 ratio)

Based on organoleptic evaluation, nectar which obtained maximum score from each category (yellow and purple separately and also yellow blended with purple) was stored for three months under ambient and low temperature (5-7°C) conditions. The changes in quality of nectar were evaluated during storage at monthly intervals.

3.3.2 Treatments

T1- Nectar [20°brix, 20% juice (yellow)] at ambient temperature

T2- Nectar [20°brix, 20% juice (yellow)] at low temperature (5-7°C)

T3- Nectar [20°brix, 20% juice (purple)] at ambient temperature

T4- Nectar [20°brix, 20% juice (purple)] at low temperature (5-7°C)

T5- Nectar [20°brix, 20% juice (yellow + purple)] at ambient temperature

T6- Nectar [20°brix, 20% juice (yellow + purple)] at low temperature (5-7°C)

3.3.3 Observations

3.3.3.1 Biochemical parameters

3.3.3.1.1 Total Soluble Solids (TSS)

TSS were estimated as in 3.1.3.2.1

3.3.3.1.2 Titratable acidity

Titratable acidity was estimated as in 3.1.3.2.2

3.3.3.1.3 Reducing sugars

Reducing sugars were estimated as in 3.1.3.2.3

3.3.3.1.4 Non-reducing sugars

Non-reducing sugars were estimated as in 3.1.3.2.4

3.3.3.1.5 Total sugars

Total sugars were estimated as in 3.1.3.2.5

3.3.3.1.6 Ascorbic acid

Ascorbic acid was estimated as in 3.1.3.2.6

3.3.3.1.7 Total carotenoids

Total carotenoids were estimated as in 3.1.3.2.7

3.3.3.1.8 Total phenols

Total phenols were estimated as in 3.1.3.2.8

3.3.3.1.9 Total flavonoids

Total flavanoids were estimated as in 3.1.3.2.9

3.3.3.1.10 Non-enzymatic browning

To a known volume of sample (10g), 100ml of 60 per cent alcohol was added and mixed thoroughly. After keeping overnight, the contents were filtered through Whatman's No.1 filter paper. The colour was measured at 440nm in a spectrophotometer (model.EC) using 60 per cent alcohol as blank. The results were reported as absorbance (Optical density) value (Ranganna, 1997).

3.3.3.2 Organoleptic evaluation

Organoleptic evaluation of passion fruit nectars was conducted as in 3.2.2.3

3.3.3.3 Microbiological analysis

The estimation of microbial population present in the above samples was carried out by serial dilution plate count method as described by Agarwal and Hasija (1986). Ten gram sample was added to 90 ml distilled water and shaken well to form a suspension. From this suspension, 1 ml was transferred to a test tube containing 9 ml distilled water. This gave a dilution of 10^{-2}. Later 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} dilutions were prepared from these serial dilutions.

The passion fruit nectar was subjected to microbiological analysis initially and also at specific intervals during their storage. The samples were analysed for the population of bacteria, fungi and mould in standard plate count Nutrient Agar (NA), Martin Rose Bengal Agar (MRBA) and Sabouraud Dextrose Agar (SDA) media, respectively and the results were expressed in cfu/g of sample.

3.3.3.3.1 Estimation of bacterial population

Bacterial population was estimated using 10^{-5} dilution on nutrient agar medium. One ml of 10^{-5} dilution was pipetted into a sterile petridish using a micropipette. About 20 ml of the melted and cooled Nutrient Agar (NA) media

was poured into the petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three petridishes were kept as replicate for each sample. The petriplates were incubated at room temperature for 48 hours. The colonies developed were counted and expressed as cfu/g of sample.

3.3.3.3.2 Estimation of fungal population

Fungal population was estimated using 10^{-3} dilution on Martin Rose Bengal Agar medium. One ml of 10^{-3} dilution was pipetted into a sterile petridish using a micropipette. About 20 ml of the melted and cooled Martin Rose Bengal Agar (MRBA) media was poured into the petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three petridishes were kept as replicate for each sample. The petriplates were incubated at room temperature for 4 to 5 days. The colonies developed were counted and expressed as cfu/g of the sample.

3.3.3.3.3 Estimation of yeast population

Yeast population was estimated using 10^{-3} dilution on Sabouraud's Dextrose Agar media. One ml of 10^{-3} dilution was pipetted into a sterile petridish using a micropipette. About 20 ml of the melted and cooled Sabouraud's Dextrose Agar (SDA) was poured into the petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three petridishes were kept as replicate for each sample. The petriplates were incubated at room temperature for 4 to 5 days. The colonies developed were counted and expressed as cfu/g of the sample.

3.4 TABULATION AND STATISTICAL ANALYSIS

The data obtained were analysed statistically using analysis of variance (ANOVA) technique. The critical difference value at five per cent level was used for making comparison among different treatments. The scores of sensory evaluation were analysed by Kendall's coefficient of concordance.

Results

4. RESULTS

The results obtained in the present investigation entitled "Value addition of passion fruit (*Passiflora edulis* Sims.)" are presented below

4.1 CHARACTERIZATION OF PASSION FRUIT ACCESSIONS

Wide variation in physico-morphological, nutritional and biochemical attributes was found in the accessions of passion fruit collected from different parts of Kerala.

4.1.1 Physico-morphological parameters

4.1.1.1 Fruit size (appearance)

4.1.1.1.1 Fruit length (cm)

Fruit length of passion fruit accessions ranged from 5.33 to 6.96 cm (Table 2a). Acc. 9 (purple) had the highest fruit length (6.96 cm) and the lowest (5.33 cm) was recorded in Acc. 7 (yellow).

4.1.1.1.2 Fruit diameter (cm)

Fruit diameter of passion fruit accessions ranged from 5.63 to 7.10 cm (Table 2a). Acc. 9 (purple) had the highest fruit diameter (7.10 cm) and the lowest (5.63 cm) was recorded in Acc. 10 (purple).

4.1.1.2 Fruit girth (cm)

Fruit girth of passion fruit accessions ranged from 18.30 to 22.83 cm (Table 2a). Acc. 9 (purple) had the highest fruit girth (22.83 cm) and the lowest (18.30 cm) was recorded in Acc. 7 (yellow).

4.1.1.3 Rind thickness (cm)

Rind thickness of passion fruit accessions ranged from 0.46 to 0.96 cm (Table 2a). Acc. 2 (purple) had the highest rind thickness (0.96 cm) and the lowest (0.46 cm) was recorded in both Acc. 5 (purple) and Acc. 7 (yellow).

4.1.1.4 Fruit weight (g)

Fruit weight of passion fruit accessions ranged from 55.83 g in Acc. 10 (Kaveri, purple type) to 98.26 g in Acc. 5 which is also a purple type (Table 2).

4.1.1.5 Juice percentage (%)

Juice percentage of passion fruit accessions ranged from 15.27 to 46.46 % (Table 2a). Acc. 5 (purple) had the highest juice percentage (46.46 %) and the lowest (15.27 %) was obtained from Acc. 7 (yellow).

4.1.1.6 Physical composition (%)

Physical composition means percentage of each component (juice, rind and seed) to the total weight of the fruit. The data is presented in Table 2a. Rind percentage ranged from 37.78 to 78.12 %. Acc. 7 (yellow) showed maximum rind percentage (78.12 %) while the minimum (37.78 %) was observed in Acc. 5 (purple). Also, seed percentage ranged from 6.58 to 18.47 % in which the Acc. 10 (Kaveri, purple type) had the highest seed percentage whereas, the lowest was recorded in Acc. 7 (yellow).

4.1.1.7 Fruit shape

The data on fruit shape of passion fruit accessions is presented in Table 2b. Fruit shape was round in case of Acc. 1, Acc. 2, Acc. 3 and Acc. 4, oval in case of Acc. 4 and Acc. 8 whereas it was round-oval in case of Acc. 5, Acc. 6, Acc. 7 and Acc. 9.

4.1.1.8 Colour of rind

The data on colour of passion fruit accessions is presented in Table 2b. Rind colour was yellow in case of Acc. 1, Acc. 3, Acc. 4, Acc. 6, Acc. 7 and Acc. 8, whereas, it was purple in case of Acc. 2, Acc. 5, Acc. 9 and Acc. 10.

4.1.1.9 Colour of juice

The data on colour of juice of passion fruit accessions is presented in Table 2b. The juice colour was analysed using Universal Colour Language (UCL). Brilliant yellow was the commonly observed colour in majority of the accessions followed by vivid yellow and light orangish yellow.

Table 2a. Physico-morphological attributes of passion fruit accessions

Accessions	Fruit size		Fruit girth (cm)	Rind thickness (cm)	Fruit weight (g)	Physical composition (%)		
	Fruit length (cm)	Fruit diameter (cm)				Juice	Rind	Seed
Acc. 1 (Y)	6.63	6.36	20.00	0.70	97.96	40.04	45.37	14.74
Acc. 2 (P)	6.40	6.76	21.10	0.96	86.17	28.78	56.39	14.84
Acc. 3 (Y)	5.66	6.26	21.16	0.60	65.98	28.94	57.54	13.50
Acc. 4 (Y)	6.00	6.16	20.20	0.70	84.08	30.74	58.49	10.75
Acc. 5 (P)	6.86	6.43	21.06	0.46	98.26	46.46	37.78	15.73
Acc. 6 (Y)	5.66	5.86	18.66	0.66	79.64	31.26	53.20	15.52
Acc. 7 (Y)	5.33	5.70	18.30	0.46	62.73	15.27	78.12	6.58
Acc. 8 (Y)	6.23	6.10	19.30	0.50	87.15	36.60	51.91	11.47
Acc. 9 (P)	6.96	7.10	22.83	0.70	82.66	27.17	62.96	9.84
Acc. 10 (P)	5.70	5.63	19.20	0.63	55.83	23.93	57.58	18.47
SE	0.13	0.13	0.46	0.05	5.09	2.55	3.18	0.92
CD	0.38	0.39	1.38	0.16	15.14	7.57	9.45	2.74

Y: Yellow type; **P**: Purple type

Table 2b. Physico-morphological attributes (rind colour and juice colour) of passion fruit accessions

Accessions	Fruit shape	Colour of rind	Colour of juice
Acc. 1 (Y)	Round	Yellow with white specks	Light orangish yellow (22B)
Acc. 2 (P)	Round	Deep purple with white specks	Brilliant yellow (21C)
Acc. 3 (Y)	Round	Yellow with white specks	Light yellow (12C)
Acc. 4 (Y)	Oval	Yellow with white specks	Light orangish yellow (19A)
Acc. 5 (P)	Round-oval	Purple with white specks	Brilliant yellow (7A)
Acc. 6 (Y)	Round-oval	Yellow with white specks	Vivid yellow (9A)
Acc. 7 (Y)	Round-oval	Light yellow with white specks	Brilliant yellow (14C)
Acc. 8 (Y)	Oval	Yellow with white specks	Vivid yellow (17B)
Acc. 9 (P)	Round-oval	Light purple with white specks	Brilliant yellow (21C)
Acc. 10 (P)	Round	Deep purple with white specks	Brilliant yellow (8A)

Y: Yellow type; **P**: Purple type

4.1.2 Nutritional and biochemical characteristics

4.1.2.1 Total soluble solids (^{0}Brix)

The total soluble solids varied significantly among the different passion fruit accessions. TSS of passion fruit accessions ranged from 12.66 to 17.73 ^{0}Brix (Table 3). Acc. 5 (purple) had the highest TSS (17.73 ^{0}Brix) while the lowest (12.66 ^{0}Brix) was recorded in Acc. 4 (yellow).

4.1.2.2 Titratable acidity (%)

Titratable acidity of passion fruit accessions ranged from 2.87 to 4.86 % (Table 3). Acc. 6 (yellow) had the highest titratable acidity (4.86 %) and the lowest (2.87 %) was recorded in Acc. 9 (purple).

4.1.2.3 Sugars (%)

Wide variation in reducing, non-reducing and total sugar content was observed among the different passion fruit accessions. The reducing sugar content ranged from 2.34 to 10.14 % (Table 3). Acc. 2 (yellow) had the highest reducing sugar content (8.06 %) and the lowest (2.34 %) was recorded in Acc. 6 (yellow). Non reducing sugar content ranged from 1.44 to 5.27 % (Table 3) in which the highest non reducing sugar content (5.27 %) was recorded in Acc. 1 (yellow) and the lowest (1.44 %) was recorded in Acc. 5 (purple). The total sugar content ranged from 4.98 to 13.04 % (Table 3). Acc. 2 (yellow) had the highest total sugar content (13.04 %) and the lowest (4.98 %) was recorded in Acc. 6 which is also a yellow type.

4.1.2.4 Ascorbic acid (mg $100g^{-1}$)

Significant variation in ascorbic acid content was observed among passion fruit accessions. Ascorbic acid content of passion fruit accessions ranged from 16.98 to 30.50 mg $100g^{-1}$ (Table 3). Acc. 5 (purple) had the highest ascorbic acid

content (30.50 mg $100g^{-1}$) and the lowest (16.98 mg $100g^{-1}$) was recorded in Acc. 6 (yellow).

4.1.2.5 Total carotenoids (mg $100g^{-1}$)

Total carotenoid content of passion fruit accessions differed significantly. The total carotenoid content of passion fruit accessions ranged from 1.07 to 2.81 mg $100g^{-1}$ (Table 3). Acc. 8 (yellow) had the highest total carotenoid content (2.81 mg $100g^{-1}$) and the lowest (1.07 mg $100g^{-1}$) was recorded in Acc. 9 (purple).

4.1.2.6 Total phenols (mg $100g^{-1}$)

Considerable variation in total phenols was recorded in passion fruit accessions. Total phenols in passion fruit accessions ranged from 17.33 mg $100g^{-1}$ in Acc. 5 (purple) to 27.33 mg $100g^{-1}$ in Acc. 6 (yellow) (Table 3).

4.1.2.7 Total flavanoids (mg $100g^{-1}$)

Total flavanoid content varied significantly in passion fruit accessions. The total flavanoid content of passion fruit accessions ranged from 6.33 to 18.00 mg $100g^{-1}$ (Table 3). Acc. 3 (yellow) had the highest total flavanoid content (18.00 mg $100g^{-1}$) and the lowest (6.33 mg $100g^{-1}$) was recorded in Acc. 9 (purple).

4.1.2.8 Antioxidant activity (IC 50 mg ml^{-1})

The data on antioxidant activity of passion fruit accessions on the free radical compound DPPH (2,2-Diphenyl-1-picrylhydrazyl) IC 50 (Inhibitory concentration at 50 %) values are presented in Table 3 and Fig 1. Antioxidant activity varied significantly among passion fruit accessions. The antioxidant activity of passion fruit accessions ranged from 7.36 to 22.66 mg ml^{-1}. Acc no. 6 (yellow) had the maximum antioxidant activity (7.36 mg ml^{-1}) and the minimum (22.66 mg ml^{-1}) was reported in Acc no. 1 which is also a yellow type.

Table 3. Nutritional and biochemical attributes of passion fruit accessions

Accessions	TSS (°Brix)	Titratable acidity (%)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)	Vitamin C (mg $100g^{-1}$)	Total carotenoids (mg $100g^{-1}$)	Total phenols (mg $100g^{-1}$)	Total flavanoids (mg $100g^{-1}$)	Antioxidant activity (IC 50 mg ml^{-1})
Acc. 1 (Y)	16.00(4.12)	4.22(2.28)	3.45(2.10)	5.27(2.50)	8.71(3.11)	22.16(4.80)	1.61(1.61)	20.66(4.63)	11.33(3.48)	22.66(4.84)
Acc. 2 (P)	16.43(4.17)	3.17(2.04)	8.06(2.83)	4.98(2.23)	13.04(3.74)	18.62(4.42)	2.43(1.85)	22.66(4.86)	13.33(3.75)	14.66(3.95)
Acc. 3 (Y)	13.33(3.78)	3.92(2.21)	5.36(2.52)	4.48(2.34)	9.85(3.29)	21.09(4.69)	1.19(1.47)	19.33(4.50)	18.00(4.35)	8.16(3.02)
Acc. 4 (Y)	12.66(3.69)	3.64(2.15)	4.92(2.43)	4.27(2.29)	9.20(3.19)	23.05(4.90)	1.53(1.59)	18.66(4.43)	7.33(2.86)	14.76(3.97)
Acc. 5 (P)	17.73(4.32)	3.66(2.16)	4.86(2.42)	1.44(1.56)	6.31(2.70)	30.50(5.61)	1.51(1.58)	17.33(4.28)	12.00(3.59)	12.66(3.69)
Acc. 6 (Y)	13.33(3.78)	4.86(2.42)	2.34(1.82)	2.63(1.90)	4.98(2.44)	16.98(4.24)	1.47(1.56)	27.33(5.31)	17.33(4.25)	7.36(2.89)
Acc. 7 (Y)	14.60(3.94)	3.19(2.04)	6.41(2.72)	4.38(2.31)	10.80(3.42)	19.60(4.53)	2.46(1.84)	22.66(4.86)	14.66(3.90)	10.40(3.37)
Acc. 8 (Y)	14.93(3.99)	3.64(2.15)	6.03(2.64)	4.11(2.25)	10.14(3.33)	20.90(4.67)	2.81(1.95)	24.00(4.99)	7.33(2.85)	11.33(3.51)
Acc. 9 (P)	17.13(4.25)	2.87(1.96)	2.88(1.97)	3.91(2.21)	6.80(2.79)	20.90(4.67)	1.07(1.44)	24.00(4.98)	6.33(2.69)	12.43(3.66)
Acc. 10 (P)	15.20(4.02)	3.15(2.03)	6.68(2.76)	4.16 (2.26)	10.84(3.43)	21.08(4.69)	1.98(1.72)	24.66(5.06)	9.00(3.15)	15.66(4.08)
SE	0.48(0.06)	0.19(0.04)	0.32(0.06)	0.41(0.09)	0.56(0.08)	1.22(0.12)	0.25(0.07)	1.49(0.15)	1.96(0.27)	1.05(0.11)
CD	1.44(0.18)	0.57(0.13)	0.99(0.18)	1.21(0.27)	1.67(0.25)	3.64(0.38)	0.77(0.21)	4.42(0.45)	5.82(0.81)	3.13(0.32)

*Values in brackets are transformed values; **Y**: Yellow type; **P**: Purple type

4.2 EXTENSION OF SHELF LIFE OF PASSION FRUIT THROUGH SHRINK WRAP PACKAGING

4.2.1 Shelf life (days)

Shrink wrap packaging of passion fruit (wrapped individually and also in areca plates) stored at ambient temperature, prolonged the shelf life significantly. Individual shrink wrapping of passion fruit gave significantly longer shelf life as compared to fruits wrapped in areca plates, irrespective of the film thickness. Unwrapped fruits (control) gave only seven days (1 week) of shelf life while fruits wrapped in areca plates with polyolefin film of 15 and 25μ thickness, gave only 14 days of shelf life whereas, the shelf life extended to one more day in 19μ thickness polyolefin film. However, individual shrink wrapping of passion fruit in 25μ polyolefin film gave the maximum shelf life (26.66) whereas the minimum (7.00) was observed in the control samples (unwrapped fruits) (Fig. 2).

4.2.2 Physiological loss of weight (%)

Physiological loss of weight (PLW) increased in all the treatments during storage (Table. 4, Fig. 3). PLW of control fruits remained significantly higher throughout storage as compared to shrink wrapped fruits. After one week of storage, control samples had maximum PLW (6.34%) and the minimum (0.38%) was in areca plates containing fruits shrink wrapped with polyolefin film of 15μ thickness. However, with the advancement of storage period, individually shrink wrapped fruits exhibited minimum PLW values, which did not vary significantly with regard to film thickness. The PLW of individually shrink wrapped fruit with polyolefin film of 15μ, 19μ and 25μ thickness was 3.98, 4.42 and 3.26% respectively after 28 days of storage.

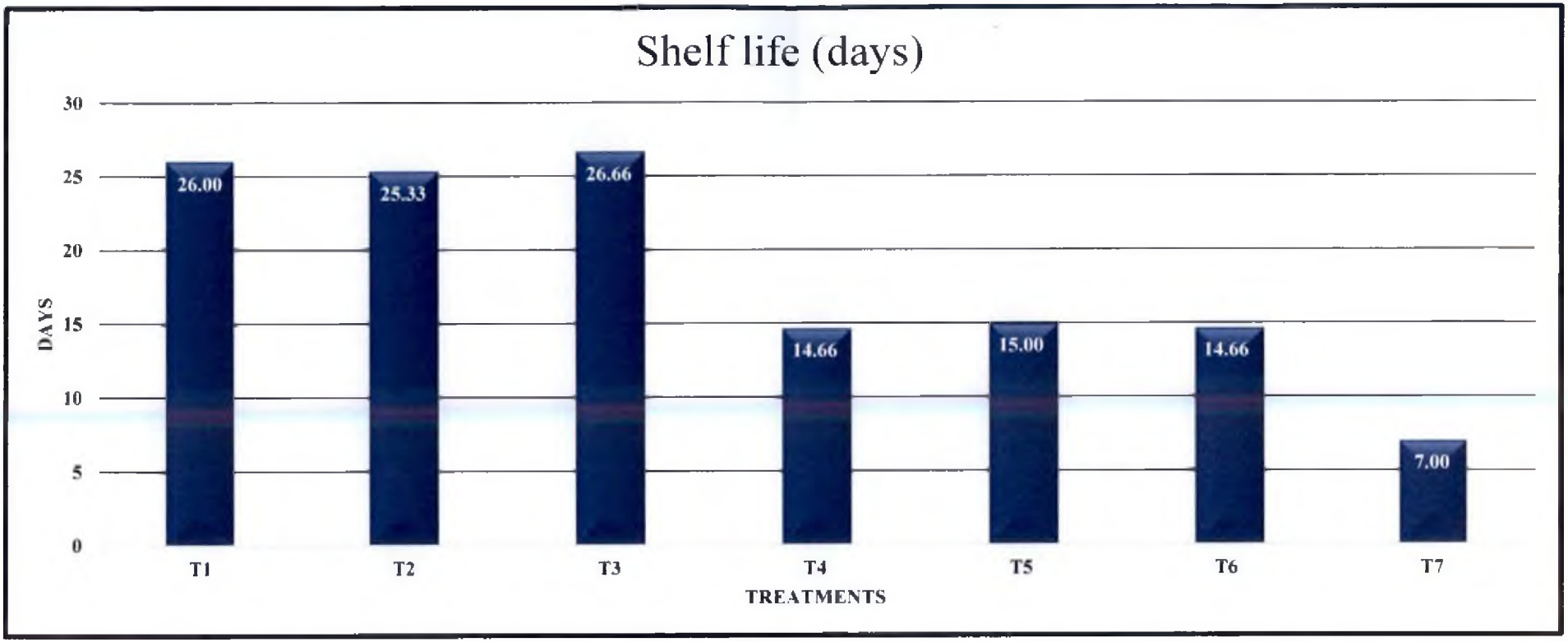


Figure 2: Effect of shrink wrap packaging on shelf life of passion fruit

T1- Individual shrink wrapping of passion fruit with polyolefin film of 15µ thickness
T2- Individual shrink wrapping of passion fruit with polyolefin film of 19µ thickness
T3- Individual shrink wrapping of passion fruit with polyolefin film of 25µ thickness
T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15µ thickness
T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19µ thickness
T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25µ thickness
T7- Control (unwrapped)

Table 4. Cumulative physiological loss of weight (PLW %) during storage of shrink wrap packaged passion fruit

DAYS	T 1	T 2	T 3	T 4	T 5	T 6	T 7
INITIAL	0	0	0	0	0	0	0
DAY 2	0	0	0	0	0	0	0
DAY 4	0.003	0.003	0	0	0	0	0.52
DAY 6	0.01	0.01	0.01	0.12	0.08	0.10	3.26
DAY 8	0.02	0.01	0.02	0.38	0.58	0.47	6.34*
DAY 10	0.05	0.04	0.05	0.94	0.90	0.88	-
DAY 12	0.10	0.09	0.09	1.17	1.18	1.13	-
DAY 14	0.17	0.18	0.15	2.16	2.37	2.27	-
DAY 16	0.43	0.37	0.35	3.08*	3.26*	3.18*	-
DAY 18	0.87	0.75	0.56	-	-	-	-
DAY 20	1.46	1.39	1.12	-	-	-	-
DAY 22	2.05	2.02	1.72	-	-	-	-
DAY 24	2.41	2.44	2.17	-	-	-	-
DAY 26	2.88	2.91	2.92	-	-	-	-
DAY 28	3.98*	4.42*	3.26*	-	-	-	-

* Unmarketable

T1- Individually shrink wrapped passion fruit with polyolefin film of 15μ

T2- Individually shrink wrapped passion fruit with polyolefin film of 19μ

T3- Individually shrink wrapped passion fruit with polyolefin film of 25μ

T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15μ

T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19μ

T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25μ

T7- Control

4.2.3 Effect of shrink wrap packaging on quality of passion fruit during storage

4.2.3.1 Total soluble solids (°Brix)

TSS content of fruits in all the treatments increased during storage (Table 5). However, TSS did not vary significantly among treatments. After one week of storage, control (T7) samples had the highest TSS (18.80 °Brix) as compared to shrink wrapped fruits. Thickness of polyolefin film did not influence the TSS content of fruits significantly. After 3 weeks of storage, individually shrink wrapped passion fruit with polyolefin film of 19μ thickness (T2) had the highest TSS (17.53 °Brix) and the lowest (17.00 °Brix) was observed in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness (T1).

4.2.3.2 Titratable acidity (%)

Titratable acidity of fruits in all the treatments decreased during storage (Table 5). After one week of storage, control (T7) samples had the lowest acidity (2.19%) as compared to all the shrink wrapped fruits. Titratable acidity of shrink wrapped fruits in areca plates was lower as compared to the individually shrink wrapped fruits. After 3 weeks of storage, individually shrink wrapped passion fruit with polyolefin film of 25μ thickness (T3) had the highest titratable acidity (2.38%), and the lowest (1.89%) was noticed in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness (T1).

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

The vitamin C content of the fruits in all the treatments decreased during storage (Table 5). After one week of storage, the unwrapped fruits (control) had the lowest vitamin C (22.58 mg $100g^{-1}$) as compared to the shrink wrapped fruits. However, the vitamin C content did not vary significantly among treatments. After 3weeks of storage, the highest vitamin C content (20.97 mg $100g^{-1}$) was observed in individually shrink wrapped passion fruit with polyolefin film of 19μ

thickness (T2) and the lowest (16.56 mg $100g^{-1}$) in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness (T1).

Table 5. Effect of shrink wrap packaging on total soluble solids (TSS), titratable acidity and vitamin C of passion fruit during storage

Treatments	Total soluble solids (°Brix)				Titratable acidity (%)				Vitamin C (mg $100g^{-1}$)			
	Initial	1WAS	2WAS	3WAS	Initial	1WAS	2WAS	3WAS	Initial	1WAS	2WAS	3WAS
T1	16.20	16.53	16.60	17.00*	3.68	3.19	3.00	1.89*	25.81	23.78	21.16	16.56*
T2		16.60	16.93	17.53*		3.13	2.40	2.23*		25.42	24.20	20.97*
T3		16.60	16.80	17.06*		3.13	3.09	2.38*		22.96	20.97	19.32*
T4		16.80	17.73*	-		2.74	1.64*	-		23.78	22.14*	-
T5		16.53	17.20*	-		2.87	1.89*	-		24.60	21.72*	-
T6		17.20	18.53*	-		3.19	2.27*	-		23.39	22.96*	-
T7		18.80*	-	-		2.19*	-	-		22.58*	-	-
SE	-	0.77	0.63	0.73	-	0.15	0.25	0.13	-	1.79	0.82	1.03
CD	-	NS	NS	NS	-	0.46	0.79	NS	-	NS	2.580	NS

* Unmarketable; **WAS**: Weeks after storage

T1- Individually shrink wrapped passion fruit with polyolefin film of 15µ
T2- Individually shrink wrapped passion fruit with polyolefin film of 19µ
T3- Individually shrink wrapped passion fruit with polyolefin film of 25µ
T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15µ
T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19µ
T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25µ
T7- Control

4.2.3.4 Sugars (%)

Reducing, non-reducing and total sugars in passion fruit increased during storage (Table 6). However, significant difference in the content of reducing, non-reducing and total sugars was not observed among the treatments throughout storage. After 3 weeks of storage, the highest reducing sugar content (10.00%) was observed in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness (T3) and the lowest (8.70%) was seen in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness (T1).

Similar to reducing sugar, non-reducing sugar content also showed increasing trend throughout the storage period without any significant difference between the treatments (Table 6). After 3 weeks of storage, the highest non-reducing sugar content (3.96%) was observed in individually shrink wrapped passion fruit with polyolefin film of 19μ thickness (T2) and the lowest (3.63%) was seen in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness (T1).

The amount of total sugar also showed an upward trend with the advancement of storage period (Table 6). After 3 weeks of storage, the highest total sugar content (13.63%) was observed in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness (T3) while the lowest (12.37%) was recorded in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness (T1).

Table 6. Effect of shrink wrap packaging on reducing, non-reducing and total sugar content of passion fruit during storage

Treatments	Reducing sugars (%)				Non-reducing sugars (%)				Total sugars (%)			
	Initial	1WAS	2WAS	3WAS	Initial	1WAS	2WAS	3WAS	Initial	1WAS	2WAS	3WAS
T1		8.39	8.46	8.70*		3.42	3.63	3.67*		11.81	12.09	12.37*
T2		8.05	8.39	8.78*		3.35	3.67	3.96*		11.40	12.06	12.74*
T3		8.46	9.88	10.00*		3.07	3.52	3.63*		11.53	13.40	13.63*
T4	8.00	8.78	9.25*	-	2.98	3.35	3.38*	-	10.98	12.13	12.63*	-
T5		9.01	9.80*	-		3.11	3.52*	-		12.12	13.32*	-
T6		8.05	9.27*	-		3.62	3.96*	-		11.67	13.23*	-
T7		8.78*	-	-		3.53*	-	-		12.31*	-	-
SE	-	0.38	0.68	0.54	-	0.81	1.00	0.71	-	0.77	0.78	1.13
CD	-	NS	NS	NS	-	NS	NS	NS	-	NS	NS	NS

* Unmarketable; **WAS**: Weeks after storage

T1- Individually shrink wrapped passion fruit with polyolefin film of 15μ
T2- Individually shrink wrapped passion fruit with polyolefin film of 19μ
T3- Individually shrink wrapped passion fruit with polyolefin film of 25μ
T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15μ
T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19μ
T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25μ
T7- Control

4.2.3.5 Total carotenoids (mg $100g^{-1}$)

A declining trend in carotenoid content of passion fruit was observed in all the treatments during storage (Table 7). Shrink wrap packaging resulted in significantly high retention of carotenoids as compared to unwrapped (control) samples. After one week of storage, control samples had the lowest total carotenoids (0.60 mg $100g^{-1}$) whereas, the carotenoid content of shrink wrapped samples was on par. After 3 weeks of storage, maximum retention of total carotenoids (0.57 mg $100g^{-1}$) was observed in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness (T3) and the minimum (0.51 mg $100g^{-1}$) in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness (T1).

4.2.3.6 Total phenols (mg $100g^{-1}$)

An increasing trend in total phenols was observed in the fruits during first week in all treatments, which decreased during the second and third week of storage (Table 7). Retention of total phenols was significantly high in shrink wrapped fruits as compared to the control (unwrapped) samples. After one week of storage, control samples had the lowest total phenols (24.66 mg $100g^{-1}$) whereas, its content was on par in all the shrink wrapped samples. However, after three weeks of storage, fruits shrink wrapped individually in polyolefin film of 15 and 19μ thickness had the highest total phenols (20.0 mg $100g^{-1}$) while the lowest (17.33 mg $100g^{-1}$) was seen in the samples wrapped with polyolefin film of 25μ thickness (T3).

4.2.3.7 Total flavanoids (mg $100g^{-1}$)

An increasing trend in total flavanoid content was observed during first week of storage in all the shrink wrapped fruits whereas it declined in the unwrapped (control) samples (Table 7). However, a declining trend was noticed in all the shrink wrapped fruits during the second and third week of storage. However, significant variation in total flavanoid content was not seen with respect

to film thickness in the individually shrink wrapped fruits. After three weeks of storage, maximum flavanoid content (8.33 mg $100g^{-1}$) was noticed in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness (T3) and the minimum (7.00 mg $100g^{-1}$) in individually shrink wrapped passion fruit with polyolefin film of 19μ thickness (T2).

Table 7. Effect of shrink wrap packaging on total carotenoids, total phenols and total flavanoids of passion fruit during storage

Treatments	Total carotenoids (mg $100g^{-1}$)				Total phenols (mg $100g^{-1}$)				Total flavanoids (mg $100g^{-1}$)			
	Initial	1WAS	2WAS	3WAS	Initial	1WAS	2WAS	3WAS	Initial	1WAS	2WAS	3WAS
T1	1.15	0.97	0.84	0.51*	19.33	32.00	20.00	20.00*	8.66	10.66	10.33	7.33*
T2		1.08	0.72	0.52*		32.00	24.00	20.00*		10.33	9.33	7.00*
T3		1.08	0.70	0.57*		34.00	24.66	17.33*		9.66	9.33	8.33*
T4		1.01	0.62*	-		32.00	21.33*	-		10.66	7.00*	-
T5		1.15	0.65*	-		32.00	20.00*	-		9.33	6.33*	-
T6		1.01	0.54*	-		34.66	22.66*	-		10.33	6.33*	-
T7		0.60*	-	-		24.66*	-	-		6.33*	-	-
SE	-	0.06	0.11	0.02	-	2.10	1.82	1.38	-	1.24	0.93	1.87
CD	-	0.20	NS	NS	-	1.98	NS	NS	-	NS	2.90	NS

* Unmarketable; **WAS**: Weeks after storage

T1- Individually shrink wrapped passion fruit with polyolefin film of 15µ
T2- Individually shrink wrapped passion fruit with polyolefin film of 19µ
T3- Individually shrink wrapped passion fruit with polyolefin film of 25µ
T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15µ
T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19µ
T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25µ
T7- Control

4.2.4 Organoleptic evaluation

Data on mean sensory scores of shrink wrapped passion fruit during first, second and third week of storage are presented in tables 8, 9 and 10 respectively. Shrink wrap packaging of passion fruit with polyolefin film was beneficial in retaining the marketability of fruits. Passion fruit samples subjected to shrink wrap packaging had higher mean scores for organoleptic properties as compared to the unwrapped (control) samples. However there was no significant difference in mean scores between the shrink wrapped and unwrapped fruits.

Table 8. Effect of shrink wrap packaging on organoleptic quality of passion fruit (1 WAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T1	7.2	7.2	6.8	6.8	6.5	6.9	7.1	7.0	55.5
T2	7.7	7.0	7.4	6.8	7.0	6.9	7.0	7.4	57.2
T3	7.4	7.2	6.3	6.9	6.8	6.8	7.0	7.0	55.4
T4	7.6	7.8	7.1	7.1	6.9	6.4	6.8	7.1	56.8
T5	8.0	7.8	7.6	7.1	6.7	6.8	7.1	6.9	58.0
T6	7.3	8.1	7.7	7.2	7.0	7.5	6.6	7.3	58.7
T7	7.3	7.6	7.3	6.7	7.0	6.5	6.6	7.0	56.0
Kendal's W test	0.131	0.314	0.237	0.113	0.108	0.081	0.098	0.087	

* **WAS-** Week after storage

T1- Individually shrink wrapped passion fruit with polyolefin film of 15µ
T2- Individually shrink wrapped passion fruit with polyolefin film of 19µ
T3- Individually shrink wrapped passion fruit with polyolefin film of 25µ
T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15µ
T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19µ
T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25µ
T7- Control

Table 9. Effect of shrink wrap packaging on organoleptic quality of passion fruit (2 WAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T1	7.0	7.2	7.1	7.1	7.2	7.4	6.8	7.1	56.9
T2	7.9	7.8	7.2	7.2	7.1	7.3	7.1	7.5	59.1
T3	7.3	7.1	7.0	6.5	7	7.1	7.2	7.4	56.6
T4	7.8	7.7	7.3	7.5	7.4	8.0	7.6	7.5	60.8
T5	7.3	7.3	7.9	7.4	7.8	7.7	7.7	7.6	60.7
T6	7.0	7.0	7.1	6.9	7.3	7.5	7.2	7.1	57.1
Kendal's W test	0.212	0.176	0.282	0.173	0.256	0.303	0.319	0.303	

* **WAS**- Week after storage

T1- Individually shrink wrapped passion fruit with polyolefin film of 15μ
T2- Individually shrink wrapped passion fruit with polyolefin film of 19μ
T3- Individually shrink wrapped passion fruit with polyolefin film of 25μ
T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15μ
T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19μ
T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25μ

Table 10. Effect of shrink wrap packaging on organoleptic quality of passion fruit (3 WAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T1	7.7	7.4	7.2	7.6	7.4	6.9	7.7	7.6	59.5
T2	7.9	7.7	7.8	8.0	7.4	7.4	7.6	7.6	61.4
T3	8.0	7.2	8.0	7.1	7.8	7.9	7.2	7.3	60.5
Kendal's W test	0.038	0.168	0.204	0.496	0.112	0.203	0.120	0.066	

* **WAS**- Week after storage

T1- Individually shrink wrapped passion fruit with polyolefin film of 15μ
T2- Individually shrink wrapped passion fruit with polyolefin film of 19μ
T3- Individually shrink wrapped passion fruit with polyolefin film of 25μ

Plate 6a: Effect of shrink wrap packaging on shelf life of passion fruit

Plate 6b: Effect of shrink wrap packaging on shelf life of passion fruit

4.3 DEVELOPMENT OF PASSION FRUIT NECTAR AND ITS QUALITY EVALUATION DURING STORAGE

4.3.1 Standardization of nectar

Passion fruit nectar was developed from yellow and purple passion fruit separately and also by blending both yellow and purple fruits, in different combinations of TSS and juice content as shown in 3.3.1. Organoleptic quality of different formulations of passion fruit nectar is given in Table 11.

Development of passion fruit nectar from juice of yellow and purple fruit separately and also from blended juice of yellow and purple fruit in different formulations of TSS and juice content revealed that passion fruit nectar containing 20% juice and 20°Brix was more acceptable in all the three categories (yellow and purple separately and yellow blended with purple). Therefore, the nectar developed with 20% juice and 20°Brix was used for storage studies and to evaluate the changes in quality under ambient and low temperature conditions.

Plate 7: Passion fruit nectar

A (T1): 15°brix, 20% juice (yellow)

B (T2): 20°brix, 20% juice (yellow)

C (T3): 15°brix, 20% juice (purple)

D (T4): 20°brix, 20% juice (purple)

E (T5): 15°brix, 20% juice (yellow and purple in 1:1 ratio)

F (T6): 20°brix, 20% juice (yellow and purple in 1:1 ratio)

Table 11. Mean sensory scores of passion fruit nectar

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T1	6.70	6.65	6.65	7.05	6.80	6.65	6.50	6.70	53.70
T2	6.75	6.80	7.60	7.40	7.35	7.75	7.50	**7.65**	**58.80**
T3	8.15	8.00	7.30	7.45	7.35	7.15	6.95	7.35	59.70
T4	8.00	7.90	7.70	7.45	7.90	7.75	7.45	**7.75**	**61.90**
T5	7.60	7.65	7.20	7.25	7.40	7.15	7.15	7.20	58.60
T6	7.50	7.70	7.55	7.30	7.45	7.70	7.85	**7.60**	**60.65**
Kendal's W test	0.364	0.321	0.187	0.031	0.166	0.227	0.230	0.199	

T1- 15°brix, 20% juice (yellow)

T2- 20°brix, 20% juice (yellow)

T3- 15°brix, 20% juice (purple)

T4- 20°brix, 20% juice (purple)

T5- 15°brix, 20% juice (yellow and purple in 1:1 ratio)

T6- 20°brix, 20% juice (yellow and purple in 1:1 ratio)]

4.3.2 Effect of storage on quality of passion fruit nectar

4.3.2.1 TSS (°Brix)

Total soluble solids (TSS) in all three types of passion fruit nectar increased throughout the storage period, irrespective of storage conditions (Table 12). Nectar stored under ambient temperature showed higher rate of increase compared to those stored under refrigerated condition. Significant increase in TSS content of passion fruit nectar was not observed after second and third month of storage. After three months of storage, nectar developed from juice of yellow passion fruit stored under ambient temperature (T1) showed highest TSS (21.90 °Brix) while the lowest (21.45 °Brix) was observed in nectar developed from juice of purple passion fruit and stored under low temperature (T4).

4.3.2.2 Titratable acidity (%)

Titratable acidity of passion fruit nectar showed decreasing trend throughout the storage period in all the treatments, irrespective of storage conditions and the rate of decrease was rapid in nectar stored under ambient condition (Table 12). After three months of storage, purple passion fruit nectar stored under refrigerated condition (T4) showed highest titratable acidity (0.86%) and the lowest (0.70%) was recorded in yellow passion fruit nectar stored under ambient condition (T1).

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

Ascorbic acid content in all three types of passion fruit nectar decreased significantly throughout the storage period, irrespective of storage conditions (Table 12). Nectar stored under refrigerated condition retained higher amount of ascorbic acid as compared to those stored under ambient condition. After three months of storage, purple passion fruit nectar stored under refrigerated condition (T4) showed highest retention of ascorbic acid content (10.51 mg $100g^{-1}$) and the

lowest retention (5.25 mg $100g^{-1}$) was observed in yellow passion fruit nectar stored under ambient condition (T1).

Table 12. Effect of storage on total soluble solids (TSS), titratable acidity and vitamin C content of passion fruit nectar

Treatments	Total soluble solids (°Brix)				Titratable acidity (%)				Vitamin C (mg $100g^{-1}$)			
	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS
T1	20.00	21.20	21.30	21.90	0.96	0.91	0.83	0.70	12.24	8.07	7.68	5.25
T2		21.00	21.10	21.70		0.96	0.86	0.73		11.15	7.68	6.57
T3		21.15	21.40	21.80	0.99	0.96	0.86	0.83	15.30	12.30	10.88	9.19
T4		21.00	21.15	21.45		0.97	0.96	0.86		14.61	12.30	10.51
T5		20.90	21.40	21.80	0.97	0.86	0.83	0.73	11.56	8.84	7.68	5.91
T6		20.35	21.15	21.70		0.96	0.86	0.80		11.53	9.60	7.22
SE	-	0.17	0.10	0.12	-	0.02	0.02	0.01	-	0.81	0.78	0.37
CD	-	0.52	NS	NS	-	NS	0.06	0.04	-	2.44	2.34	1.13

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

4.3.2.4 Sugars (%)

An increasing trend in reducing sugar content was observed in all three types of passion fruit nectar, irrespective of storage conditions (Table 13). This increase was rapid at ambient temperature, compared to low temperature throughout the storage period. After three months of storage, reducing sugar content of nectar varied significantly and the highest (12.34%) was seen in the nectar developed from purple type and stored under ambient condition (T3) and the lowest (9.00%) in the nectar from the same type stored under refrigerated condition (T4).

Non-reducing sugar also showed an increasing trend without any significant difference between the treatments except after three months of storage (Table 13). This increase was rapid in nectar stored at ambient temperature compared to low temperature, throughout the storage period. After three months of storage, nectar from purple fruit stored under ambient temperature (T3), showed maximum non-reducing sugar content (9.55%) while, the minimum (7.82%) was observed in both yellow and blended nectar (T2 & T6) stored under refrigerated condition.

Similar to reducing and non-reducing sugars, the total sugar content in passion fruit nectar also showed an increasing trend throughout the storage period, irrespective of storage conditions (Table 13). This increase was more under ambient conditions compared to refrigerated storage. During the first and second month of storage, total sugar did not vary significantly among the treatments. However, after three months of storage, significant difference in total sugar was observed and the highest (21.89%) and lowest (17.14%) total sugar content was observed in nectar from purple fruit stored under both ambient (T3) and refrigerated conditions (T4) respectively.

Table 13. Effect of storage on reducing, non-reducing and total sugar content of passion fruit nectar

Treatments	Reducing sugars (%)				Non-reducing sugars (%)				Total sugars (%)			
	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS
T1	8.52	9.06	9.65	10.51	6.62	7.82	9.18	9.40	15.14	16.88	18.83	19.91
T2		8.54	8.85	9.50		7.15	7.79	7.82		15.69	16.64	17.32
T3	8.85	9.25	9.50	12.34	7.52	7.87	7.98	9.55	16.37	17.12	17.48	21.89
T4		8.75	8.85	9.00		7.79	7.80	8.14		16.54	16.65	17.14
T5	8.75	9.00	9.65	12.21	6.83	7.54	7.79	8.37	15.58	16.54	17.44	20.58
T6		8.85	9.25	9.50		6.98	7.48	7.82		15.83	16.73	17.32
SE	-	0.36	0.24	0.54	-	0.62	0.72	0.30	-	0.40	0.70	0.49
CD	-	NS	NS	1.64	-	NS	NS	0.92	-	NS	NS	1.49

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

4.3.2.5 Total phenols (mg $100g^{-1}$)

The total phenols in passion fruit nectar decreased throughout the storage period without any significant difference between the treatments and storage conditions (Table 14). The rate of decrease was more in nectar stored under ambient conditions compared to those stored under refrigerated conditions. After three months of storage, nectar from yellow fruit stored under refrigerated condition (T2) had the highest total phenols content (8.50 mg $100g^{-1}$) while the lowest (6.00 mg $100g^{-1}$) was seen in both purple and blended nectar stored under ambient conditions (T3 & T5).

4.3.2.6 Total flavanoids (mg $100g^{-1}$)

The total flavanoid content of passion fruit nectar decreased throughout the storage period without any significant difference between the treatments and storage conditions (Table 14). The rate of decrease was faster in nectar stored under ambient conditions compared to those stored under refrigerated condition. After three months of storage, the maximum flavanoid content (3.50 mg $100g^{-1}$) was recorded in nectar from yellow fruit stored under refrigerated condition (T2) while the minimum (2.00 mg $100g^{-1}$) was noticed in both purple and blended nectar stored at ambient temperature (T3 & T5).

Table 14. Effect of storage on total phenols and total flavanoids of passion fruit nectar

Treatments	Total phenols (mg $100g^{-1}$)				Total flavanoids (mg $100g^{-1}$)			
	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS
T1	9.50	9.00	8.50	7.50	4.50	4.00	3.50	3.00
T2		9.50	9.00	8.50		4.25	4.00	3.50
T3	8.00	7.00	6.50	6.00	3.25	2.75	2.25	2.00
T4		7.50	7.00	7.00		3.00	2.75	2.75
T5	8.50	7.50	6.50	6.00	3.75	3.00	2.75	2.00
T6		8.00	7.50	6.50		3.50	3.00	3.00
SE	-	0.45	0.50	0.39	-	0.47	0.42	0.15
CD	-	1.36	1.49	1.17	-	NS	NS	0.46

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

4.3.2.7 Total carotenoids (mg $100g^{-1}$)

The total carotenoid content in passion fruit nectar decreased significantly throughout the storage period, irrespective of treatments and storage conditions (Table 15). The decrease was rapid in nectar stored under ambient conditions compared to those stored under refrigerated condition. After three months of storage, the maximum retention of total carotenoid (0.47 mg $100g^{-1}$) was noticed in nectar from purple fruit stored under refrigerated condition (T4) whereas, the minimum retention (0.11 mg $100g^{-1}$) was observed in nectar from yellow fruit stored at ambient temperature (T1).

4.3.2.8 Non-enzymatic browning (absorbance)

Non-enzymatic browning of passion fruit nectar increased significantly during the storage period (Table 15). All three types of nectar stored under ambient conditions showed significantly higher non enzymatic browning as compared to those stored under refrigerated condition. After three months of storage, nectar from purple fruit stored at ambient temperature (T3) recorded maximum non-enzymatic browning (0.06) and the minimum (0.02) was seen in nectar from yellow fruit stored under refrigerated condition (T2).

4.3.3 Organoleptic quality

Data on mean sensory scores of passion fruit nectar during first, second and third month of storage are presented in Tables 16, 17 and 18 respectively. Sensory quality of passion fruit nectar declined during storage in all the treatments. The rate of decrease was faster in nectar stored under ambient conditions compared to those stored under refrigerated condition. After three months of storage, nectar from purple fruits stored under refrigerated condition (T4) recorded maximum sensory score (60.20) while the minimum (47.3) was seen in nectar from yellow fruits stored under ambient condition (T1).

Table 15. Effect of storage on total carotenoids and non-enzymatic browning of passion fruit nectar

Treatments	Total carotenoids (mg $100g^{-1}$)				Non-enzymatic browning (absorbance)			
	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS
T1	0.40	0.33	0.28	0.11	0.01	0.01	0.02	0.03
T2		0.38	0.33	0.28		0.01	0.02	0.02
T3	0.91	0.59	0.43	0.38	0.02	0.04	0.06	0.06
T4		0.69	0.59	0.47		0.03	0.05	0.05
T5	0.69	0.47	0.30	0.28	0.02	0.02	0.03	0.04
T6		0.59	0.43	0.33		0.02	0.02	0.03
SE	-	0.06	0.009	0.05	-	0.002	0.06	0.003
CD	-	0.18	0.02	0.17	-	0.007	0.01	0.009

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

Table 16. Effect of storage on organoleptic quality of passion fruit nectar (1 MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T1	6.3	6.3	6.4	7.2	6.6	6.6	6.4	6.3	52.1
T2	6.9	6.5	7.4	7.1	7.3	8.0	7.4	7.5	58.1
T3	8.0	8.0	6.9	7.6	6.6	6.9	6.6	6.9	57.5
T4	8.2	8.2	7.4	7.9	7.6	8.1	7.9	8.1	63.4
T5	7.6	7.6	7.0	7.5	7.3	7.7	7.3	7.7	59.7
T6	7.6	6.7	7.6	7.9	7.7	7.7	6.4	7.6	59.2
Kendal's W test	0.453	0.673	0.229	0.230	0.207	0.167	0.279	0.262	

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

Table 17. Effect of storage on organoleptic quality of passion fruit nectar (2 MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T1	6.3	6.0	6.6	6.5	6.3	6.7	6.5	6.0	50.9
T2	6.8	6.3	7.4	7.2	7.3	7.8	7.4	7.3	57.5
T3	8.2	8.5	6.4	6.8	6.6	6.8	6.8	6.5	56.6
T4	8.0	8.2	7.2	7.2	7.1	7.5	7.6	7.5	60.3
T5	7.4	7.5	5.8	6.5	6.0	6.0	5.6	6.2	51.0
T6	7.7	7.6	6.9	7.3	7.3	7.5	7.3	7.4	59.0
Kendal's W test	0.272	0.419	0.181	0.360	0.248	0.227	0.198	0.201	

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

Table 18. Effect of storage on organoleptic quality of passion fruit nectar (3 MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T1	6.1	5.8	5.7	6.1	5.7	6.1	6.0	5.8	47.3
T2	6.4	6.0	6.4	6.5	6.2	6.8	6.5	6.7	51.5
T3	7.5	7.8	5.4	6.7	5.2	5.5	5.7	5.7	49.5
T4	8.0	7.8	7.4	7.4	7.1	7.7	7.5	7.3	60.2
T5	6.4	6.0	5.8	6.5	6.2	5.5	6.1	5.8	48.3
T6	7.1	6.7	7.1	7.1	6.8	7.5	6.8	7.0	56.1
Kendal's W test	0.659	0.777	0.457	0.199	0.293	0.364	0.242	0.454	

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

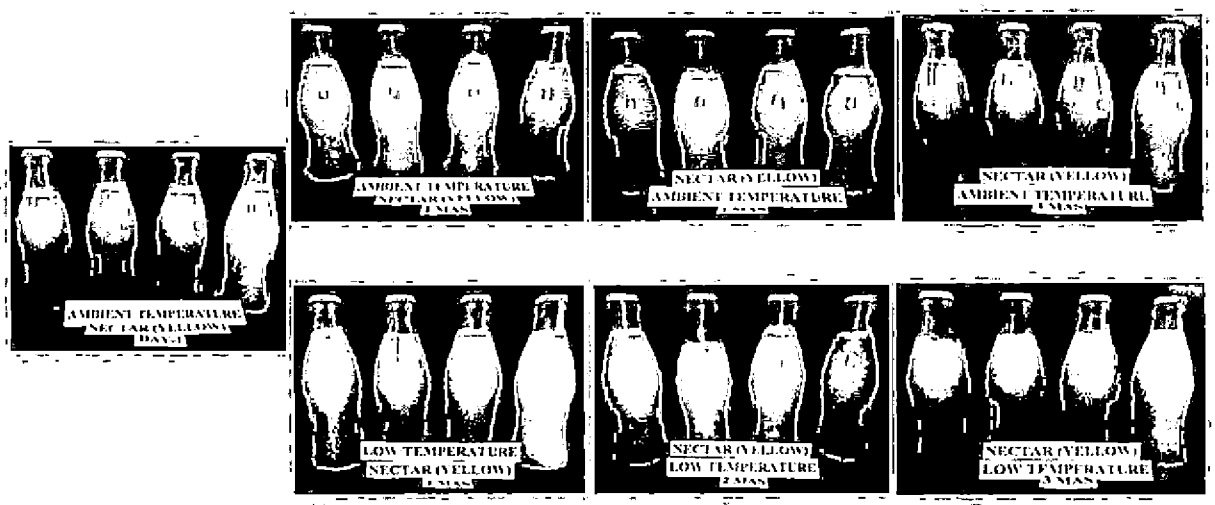


Plate 8a: Effect of storage on quality of passion fruit nectar (yellow type)

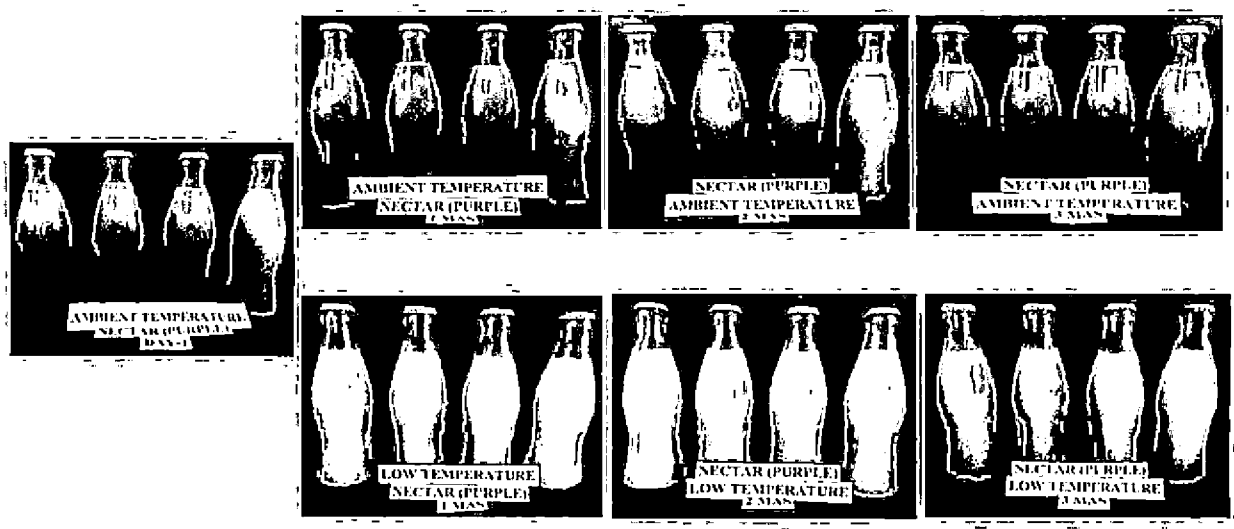


Plate 8b: Effect of storage on quality of passion fruit nectar (purple type)

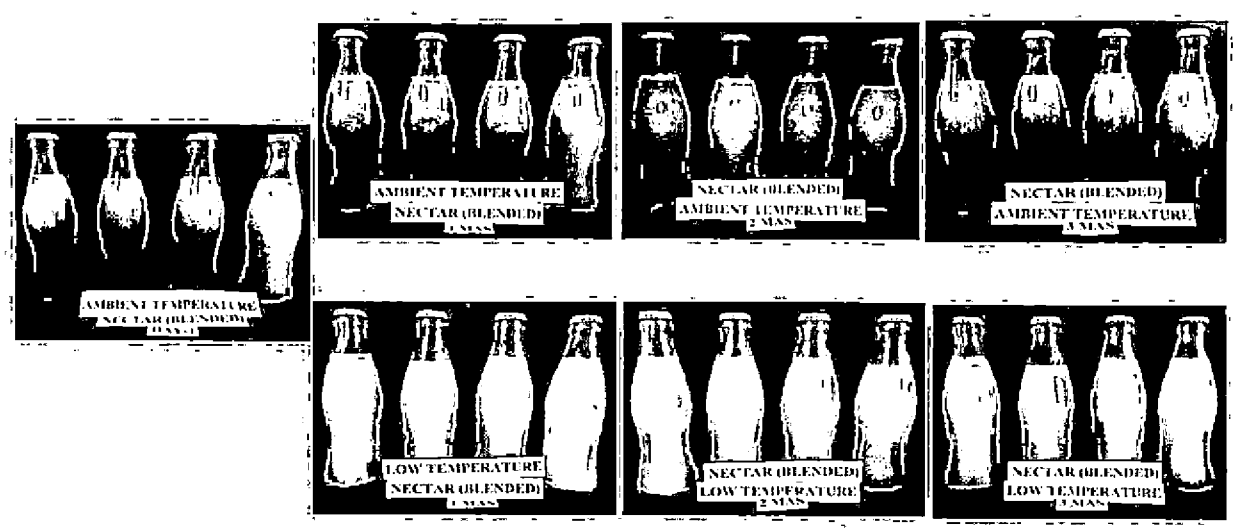


Plate 8c: Effect of storage on quality of passion fruit nectar (blend of yellow and purple types)

Plate 8a: Effect of storage on quality of passion fruit nectar (yellow type)

Plate 8b: Effect of storage on quality of passion fruit nectar (purple type)

Plate 8c: Effect of storage on quality of passion fruit nectar (blend of yellow and purple types)

4.3.4 Microbial load (cfu g^{-1})

Enumeration of microbial population (bacteria, fungi and yeast) in freshly prepared passion fruit nectar was done immediately after pasteurization. Bacteria were not detected up to two months of storage and yeast did not survive up to one month of storage, in any of the treatments. Even though, fungi were not detected initially, it was found one month after storage. However, the microbial load in all the samples was within the acceptable limits. Microbial load was higher in all the treatments under ambient conditions compared to those at low temperature (Table 19).

After three months of storage, nectar from yellow and purple fruits stored under ambient conditions had a bacterial load (0.50×10^5 cfu $g^{-1}$and 0.25×10^5 cfu g^{-1}respectively) while in other treatments, bacteria were not detected. Fungi were detected during first month of storage itself and it showed an increasing trend throughout the storage period. After three months of storage, blended nectar stored under ambient condition showed the highest (1.75×10^3 cfu g^{-1}) fungal load while the lowest (0.50×10^3 cfu g^{-1}) was seen in the same sample stored under refrigerated condition. Yeast load was maximum (1.50×10^3 cfu g^{-1}) in both yellow and blended nectar stored under ambient conditions whereas, the minimum load (0.50×10^3 cfu $g^{-1}$was observed in nectar from purple fruits stored under refrigerated condition.

Table 19. Effect of storage on microbial population of passion fruit nectar

Treatments	Bacterial load (10^5 cfu g^{-1})				Fungal load (10^3 cfu g^{-1})				Yeast load (10^3 cfu g^{-1})			
	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS	Initial	1 MAS	2 MAS	3 MAS
T1	ND	ND	ND	0.50	ND	0.25	0.50	1.00	ND	ND	0.50	1.50
T2		ND	ND	ND		ND	0.50	0.75		ND	ND	1.00
T3	ND	ND	ND	0.25	ND	0.50	1.25	1.50	ND	ND	0.50	1.25
T4		ND	ND	ND		ND	0.75	1.25		ND	0.25	0.50
T5	ND	ND	ND	ND	ND	ND	0.25	1.75	ND	ND	ND	1.50
T6		ND	ND	ND		ND	ND	0.50		ND	ND	1.00
SE	-	-	-	0.22	-	0.15	0.33	0.33	-	-	0.19	0.45
CD	-	-	-	NS	-	NS	NS	NS	-	-	NS	NS

MAS: Months after storage

T1- Nectar (yellow fruit) at ambient temperature

T2- Nectar (yellow fruit) at low temperature (5-7°C)

T3- Nectar (purple fruit) at ambient temperature

T4- Nectar (purple fruit) at low temperature (5-7°C)

T5- Nectar (blend of yellow and purple) at ambient temperature

T6- Nectar (blend of yellow and purple) at low temperature (5-7°C)]

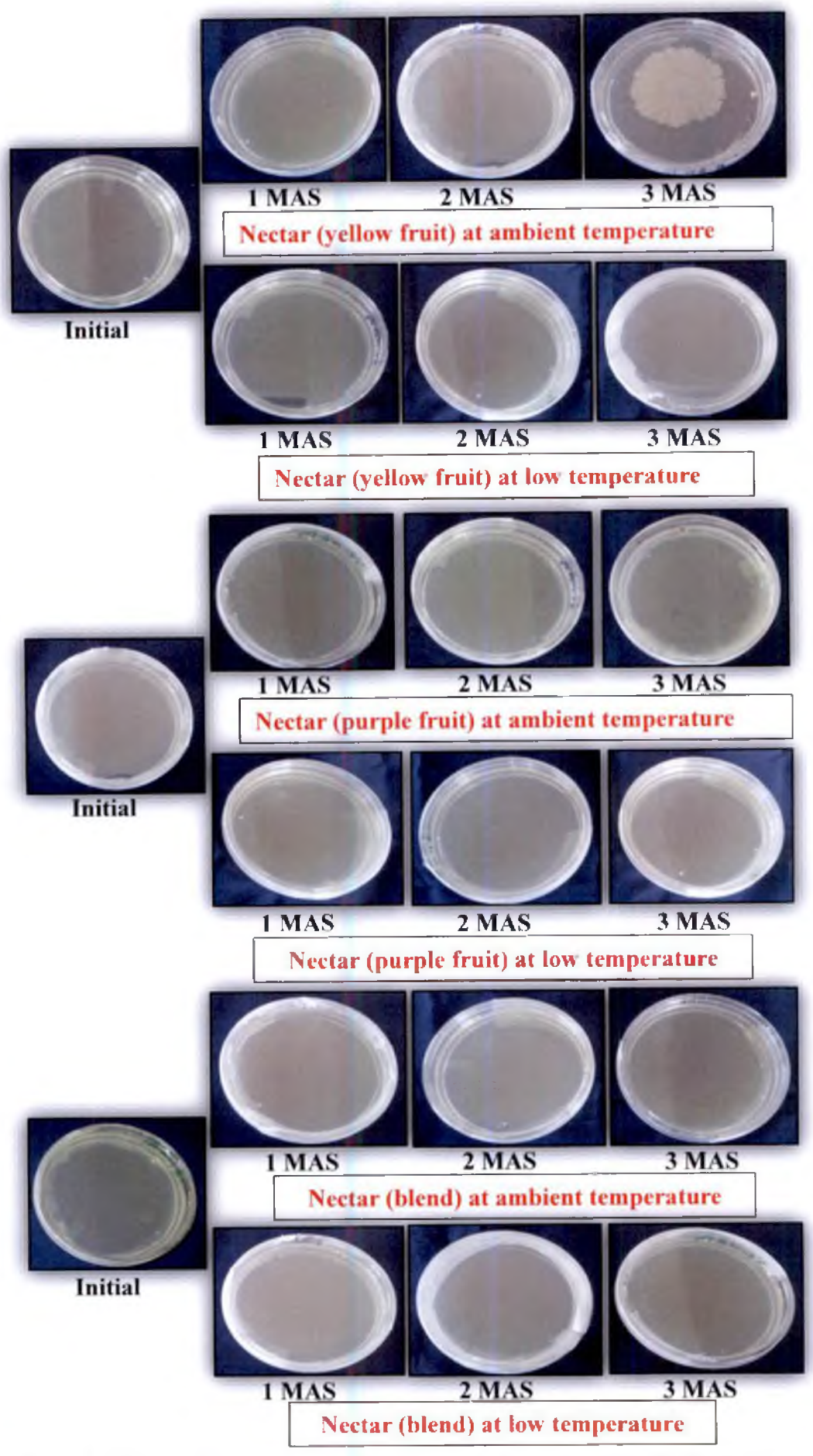


Plate 9: Effect of storage on bacterial population of passion fruit nectar

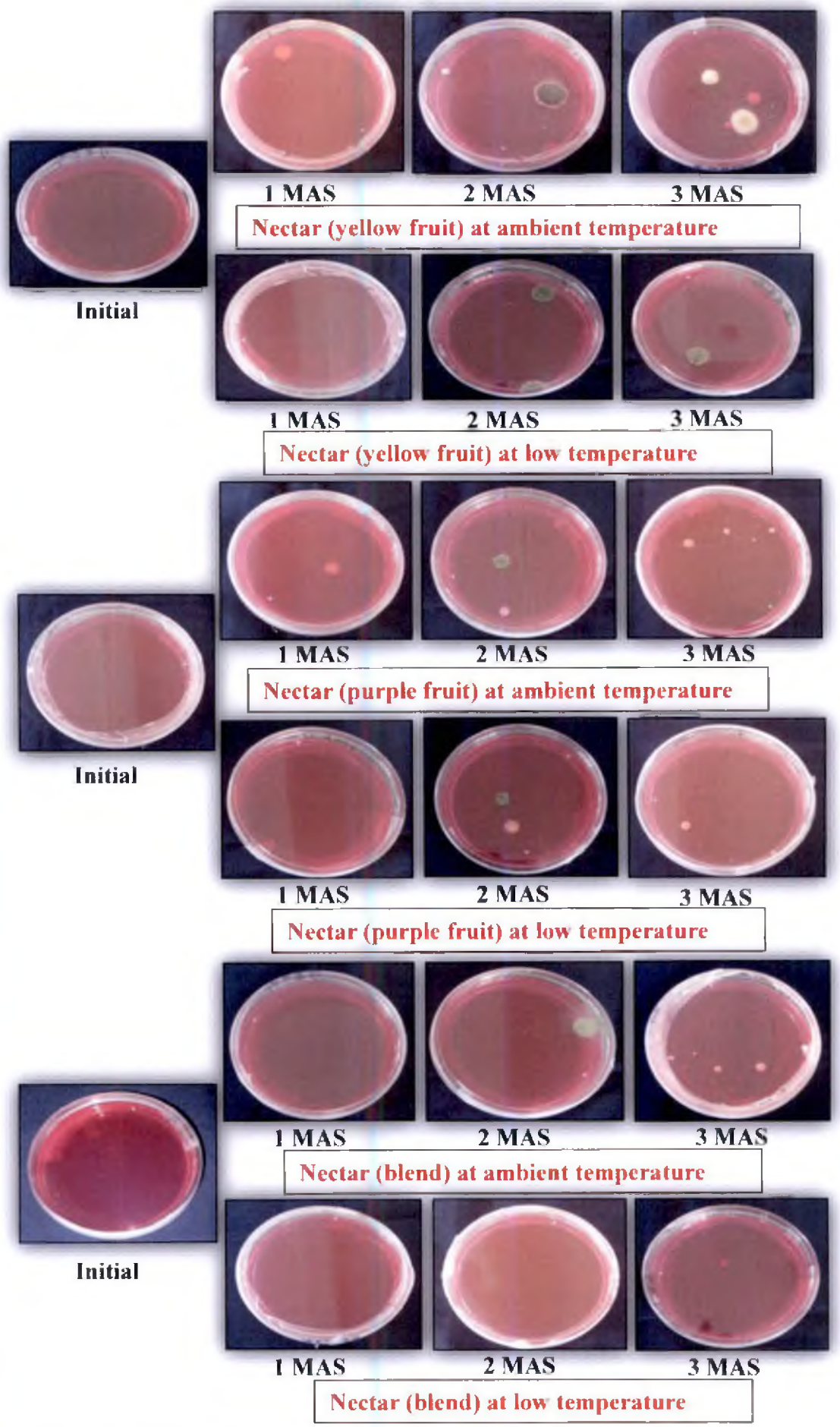


Plate 10: Effect of storage on fungal population of passion fruit nectar

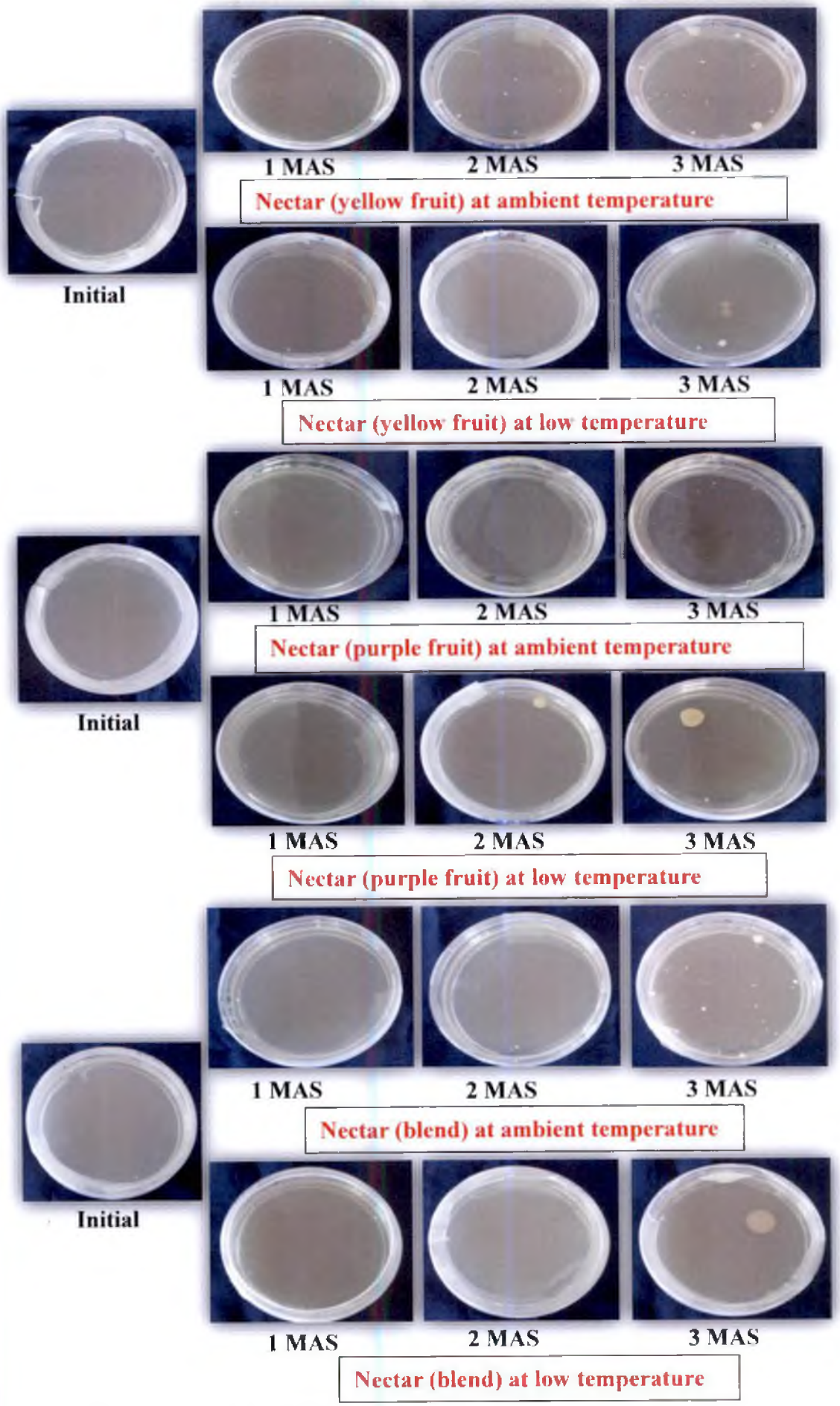


Plate 11: Effect of storage on yeast population of passion fruit nectar

Discussion

5. DISCUSSION

Passion fruit (*Passiflora edulis* Sims) is the fruit of exotic passion flower which although native to Brazil, is now cultivated in many tropical and subtropical regions of the world. It was first introduced to India near Western Ghats, Nilgiris and Wayanad (Kerala) regions of south India during twentieth century. Purple and yellow are the two main types of passion fruit grown commercially all around the world. Both types have almost same morphological features but with respect to juice recovery and taste, purple type is better than yellow type. In western countries the fruit is valued for its powerful medicinal activity and high antioxidant capacity. Juice exhibits pronounced flavour and aroma which helps not only in producing high quality beverages but also in flavouring several other products. It is quite delicious, nutritious and liked for its excellent blending property. Even though passion fruit is having these many advantages, its utilization is limited in processing sector mainly due to the fruit's short storage life, minimum juice recovery and intense acidity of juice. These limitations can be overcome by adopting proper post harvest technology and processing the juice in to number of value added products. Hence, the study on "Value addition of passion fruit (*Passiflora edulis* Sims)" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 2014-16.

The discussion pertaining to the study is presented under the following heads.

5.1 Characterization of passion fruit accessions

5.2 Extension of shelf life of passion fruit through shrink wrap packaging

5.3 Development of passion fruit nectar and its quality evaluation during storage

5.1 CHARACTERIZATION OF PASSION FRUIT ACCESSIONS

Passion fruit accessions (yellow and purple) collected from various localities of Kerala, were characterized based on physico-morphological, nutritive and biochemical parameters, of which special emphasis was given to determine the antioxidant activity.

5.1.1 Physico-morphological parameters

5.1.1.1. Fruit size

5.1.1.1.1 Fruit length (cm)

Among different passion fruit accessions collected from various localities of Kerala, Acc. 5 (purple) had the highest fruit length (6.96 cm) and the lowest (5.33 cm) was recorded in Acc. 7 (yellow). Ramaiya *et al.* (2012) reported a fruit length of 6.24 and 7.84 cm in yellow and purple type passion fruits respectively. Joy (2010) reported a fruit length ranging from 5-8 cm in purple and 8-10 cm in yellow type passion fruit. da Silva *et al.*, (2015) also reported a fruit length in yellow type as 8.26, 8.81 and 8.80 cm in 1/3rd yellow peel, 2/3rd yellow peel and yellow fruits respectively.

5.1.1.1.2 Fruit diameter (cm)

Considerable variation in fruit diameter was observed among passion fruit accessions. Acc. 9 (purple) had the maximum fruit diameter (7.10 cm) and the minimum (5.70 cm) was recorded in Acc. 7 (yellow). Ramaiya *et al.* (2012) reported a fruit diameter of 5.63 cm in yellow and 6.11 cm in purple type passion fruit. Joy (2010) reported a fruit diameter ranging from 4-8 cm in purple and 4-10 cm in yellow type passion fruit. Patel *et al.* (2014) reported a fruit diameter of 7.05 cm in *'Passiflora alata'*, 6.75 cm in 'RCPS-1', 6.70 cm in 'Panama Yellow', 6.38 cm in 'Kerala Yellow' and 4.20 cm in 'Nagaland Purple' passion fruit types.

5.1.1.2 Fruit girth (cm)

Among different passion fruit accessions collected from various localities of Kerala, Acc. 9 (purple) had the maximum fruit girth (22.83 cm) and the minimum (18.30 cm) was recorded in Acc. 7 (yellow). John (2008) reported a fruit girth ranged from 4.25 to 4.50 cm in banana cv. Robusta. Desai *et al.*, (2012) reported a fruit girth ranged from 3.80 to 6.47 cm in tomato cv. Gujarat Tomato-3 (GT-3).

5.1.1.3 Rind thickness (cm)

Among different passion fruit accessions collected from various localities of Kerala, Acc. 2 (purple) had the maximum rind thickness (0.96 cm) and the minimum (0.46 cm) was recorded in both Acc. 5 (purple) and Acc. 7 (yellow). da Silva *et al.* (2015) reported an average rind thickness of yellow passion fruit as 0.58 cm, 0.58 cm and 0.56 cm in 1/3rd yellow peel, 2/3rd yellow peel and yellow fruits, respectively. Also, Santos *et al.* (2009) reported a rind thickness ranging from 0.32 to 0.35 cm in yellow passion fruits.

5.1.1.4 Fruit weight (g)

Significant variation in fruit weight was observed among the different accessions of passion fruit collected from various localities of Kerala. Acc. 5 (purple) recorded highest fruit weight (98.26 g) and the lowest (55.83 g) was recorded in Acc. 10 (Kaveri) a purple type. Ramaiya *et al.* (2012) reported a fruit weight of 88.41 g and 98.47 g in yellow and purple passion fruit types respectively. Arjona *et al.* (1991a) also reported a fruit weight of 59.6 and 56.2 g in purple and yellow passion fruit types respectively.

5.1.1.5 Physical composition (%)

Wide variation was observed in physical composition of passion fruit accessions. Juice content of passion fruit accessions collected from various localities of Kerala, differed significantly. Acc. 5 (purple) had the highest juice

percentage (46.46 %) and the lowest (15.27 %) was obtained from Acc. 7 (yellow). da Silva *et al.* (2015) reported an average juice yield of 44.43 % in yellow passion fruit, whereas, Silva *et al.* (2008) reported a juice content ranging from 31.44 to 41.28 % in yellow type passion fruit. Arjona *et al.* (1991a) also reported 53.6 % and 44.5 % of juice in purple and yellow type passion fruit harvested at different seasons.

Rind percentage was maximum (78.12 %) in Acc. 7 (yellow) while the minimum (37.78 %) was observed in Acc. 5 (purple). Also, seed percentage was highest (18.47 %) in Acc. 10 (Kaveri) a purple type, whereas, the lowest (6.58 %) was recorded in Acc. 6 (yellow). Arjona *et al.* (1991a) reported a rind composition of 46.30 and 53.33 % in purple and yellow passion fruit types respectively. da Silva *et al.* (2015) reported a rind and seed yield of 43.25% and 17.51% in 1/3rd yellow peel, 45.62% and 15.78% in 2/3rd yellow peel, 42.63% and 15.75% in yellow fruits. Oliveira *et al.* (2011) reported 4.23% of seed yield in ripened yellow passion fruit, whereas, Coelho *et al.* (2011) reported 11.5% of seed yield in yellow type fruit.

5.1.1.6 Colour of rind

Among different passion fruit accessions collected from various localities of Kerala, the rind colour in accessions 1, 3, 4, 6, 7 and 8 were yellow whereas, accessions 2, 5, 9 and 10 were purple. Patel *et al.* (2014) observed deep purple colour in Megha Purple and Nagaland Purple, yellow colour in Kerala Yellow, RCPS-1 and Panama Yellow, deep yellow colour in *Passiflora alata* types of passion fruit.

5.1.1.7 Colour of juice

Juice colour of passion fruit accessions collected from various localities of Kerala was determined by using Universal Colour Language (UCL). Juice colour of yellow passion fruit varied from vivid yellow (9A) to light orangish yellow (22B) and that of purple from brilliant yellow (7A) to brilliant yellow (21C). Patel

et al. (2014) observed the colour of juice in passion fruit cultivars as yellowish orange in Megha Purple and Nagaland Purple, orange in Kerala Yellow, RCPS-1 and Panama Yellow, deep orange in *Passiflora alata* types of passion fruit.

5.1.2 Nutritional and biochemical characteristics

5.1.2.1 TSS (^{0} Brix)

Considerable variation in TSS content was observed among passion fruit accessions. Purple types had comparatively higher TSS than yellow ones. Acc. 5 (purple type) had the maximum TSS (17.73 ^{0}Brix) while the minimum (12.66 ^{0}Brix) was recorded in Acc. 4 (yellow type). Ramaiya *et al.* (2012) reported 17.2, 15.2, 16.0, 15.6, 15.2, 11.7 and 10.7 ^{0}Brix of TSS in *Passiflora edulis* cultivar Purple, Frederick, Yellow, Pink, *P. edulis* f. *flavicarpa*; *P. maliformis* and *P. quadrangularis* respectively. Arjona *et al.* (1991a) reported 12.9 ^{0}Brix TSS in purple and 15.2 ^{0}Brix TSS in yellow passion fruit types. Patel *et al.* (2014) reported 19 ^{0}Brix TSS in *Passiflora alata,* 17.4 ^{0}Brix in PanamaYellow, 16.8 ^{0}Brix in RCPS-1, 16.4 ^{0}Brix in Kerala Yellow, 15.75 ^{0}Brix in Megha Purple and 15 ^{0}Brix in Nagaland Purple types of passion fruit.

5.1.2.2 Titratable acidity (%)

Significant variation in titratable acidity was recorded in passion fruit accessions obtained from different locations of Kerala. Yellow types had comparatively higher titratable acidity than purple ones. Acc. 6 (yellow type) had the maximum titratable acidity (4.86 %) while the minimum (2.87 %) was recorded in Acc. 9 (purple type). Ramaiya *et al.* (2012) reported a titratable acidity of 3.03% in yellow and 1.80% in purple passion fruit types. Patel *et al.* (2014) reported 4.50% acidity in Kerala Yellow, 4.35% in RCPS-1, 3.50% in Panama Yellow, 3.25% in Nagaland Purple and 2.82% in Megha Purple cultivars of passion fruit. According to Silva *et. al.* (2005) the titratable acidity of yellow passion fruit juice/pulp ranged from 4.99 to 5.53%.

5.1.2.3 Sugars (%)

Sugar content of passion fruit accessions varied significantly. Purple types had comparatively higher reducing and total sugar contents whereas, non-reducing sugars were higher in yellow types. The maximum reducing and total sugar content (8.06% and 13.04%) was recorded in Acc. 2 (purple type) while the lowest (2.34% and 4.98%) was recorded in Acc. 6 (yellow type). Non reducing sugar content was recorded maximum (5.27%) in Acc. 1 (yellow type) and minimum (1.44%) in Acc. 5 (purple type). Patel *et al.* (2014) reported a reducing, non reducing and total sugar content of 6.67, 7.08 and 13.75% in *Passiflora alata*, 5.40, 9.98 and 15.38% in RCPS-1, 5.26, 11.34 and 16.6% in Kerala Yellow, 5.15, 9.43 and 14.58% in Megha Purple, 5.00, 8.34 and 13.34% in Panama Yellow and 3.92, 14.18 and 18.1% in Nagaland Purple cultivars of passion fruit respectively. Ramaiya *et al.* (2012) reported a total sugar of 142.85 and 139.69 g/kg in purple and yellow types of passion fruit respectively.

5.1.2.4 Ascorbic acid (mg $100g^{-1}$)

Ascorbic acid content differed significantly among passion fruit accessions collected from various localities of Kerala. Purple types had comparatively higher ascorbic acid than yellow ones. Acc. 5 (purple type) had the maximum ascorbic acid content (30.50 mg $100g^{-1}$) and the minimum (16.98 mg $100g^{-1}$) was recorded in Acc. 6 (yellow type). Joy (2010) reported an ascorbic acid content of 22-32 mg $100g^{-1}$ in purple and 16-20.4 mg $100g^{-1}$ in yellow type passion fruits. According to Patel *et al.* (2014), Megha Purple recorded highest vitamin-C content (48.75 mg $100g^{-1}$) followed by Nagaland purple (41.34 mg $100g^{-1}$), RCPS-1 (31.5 mg $100g^{-1}$), *Passiflora alata* (30.8 mg $100g^{-1}$), Kerala Yellow (22.8 mg $100g^{-1}$) and lowest (22.5 mg $100g^{-1}$) in Panama Yellow cultivars of passion fruit.

5.1.2.5 Total carotenoids (mg $100g^{-1}$)

Significant differences in total carotenoids were observed in passion fruit accessions collected from various localities of Kerala. Yellow types had

comparatively higher carotenoids than purple ones. Acc. 8 (yellow type) had the maximum total carotenoid content (2.81 mg $100g^{-1}$) while the minimum (1.07 mg $100g^{-1}$) was recorded in Acc. 9 (purple type). Pertuzatti *et al.* (2015) reported that the accumulation of carotenoids in passion fruit is variable according to stage of maturity and systems of cultivation. They also reported a total carotenoid content of 1.39 and 2.51 mg $100g^{-1}$ in yellow type passion fruit grown under organic and conventional systems of cultivation respectively. Kathiravan *et al.* (2013) reported a total carotenoid content of 1962.39 µg $100g^{-1}$ in fresh yellow passion fruit juice.

5.1.2.6 Total phenols (mg $100g^{-1}$)

Total phenols varied significantly in passion fruit accessions. Yellow types had comparatively higher total phenols than purple ones. Acc. 6 (yellow type) had the maximum total phenols (27.33 mg $100g^{-1}$) while the minimum (17.33 mg $100g^{-1}$) was observed in Acc. 5 (purple type). Ramaiya *et al.* (2012) reported that the total phenol in fresh passion fruit juice is dependent mainly on species/cultivars and level of ripeness. They also reported a total phenol content of 310.93 and 362.00 mg GAE^{-1} litre in yellow and purple passion fruit types respectively. According to Lopez-Vargas *et al.* (2013), the total phenolic content (TPC) of passion fruit albedo (PFA), passion fruit seed and pulp fiber (PFSP) extracted from methanol, water and dimethylsulfoxide (DMSO) ranged from 0.64 to 4.31 mg $GAEg^{-1}$.

5.1.2.7 Total flavanoids (mg $100g^{-1}$)

Significant variation in total flavanoids was observed among passion fruit accessions collected from different localities of Kerala. Yellow types had comparatively higher total flavanoids than purple ones. Acc. 3 (yellow type) had the maximum total flavanoid content (18.00 mg $100g^{-1}$) while the minimum (6.33 mg $100g^{-1}$) was recorded in Acc. 9 (purple type). Menghini *et al.* (1993) reported that the concentration of flavanoids is more in passion fruit leaves as compared to fruit pulp. Simirgiotis *et al.* (2013) reported 140.17 and 77.16 mg quercetin $100g^{-1}$ of

flavanoid content in fruit peel and fruit juice of banana passion fruit (*Passiflora tripartita*).

5.1.2.8 Antioxidant activity (IC 50 mg ml^{-1})

Wide variation in antioxidant activity was observed in passion fruit accessions in which the inhibitory concentration ranged from 7.36 to 22.66 mg ml^{-1}. Acc no. 6 (yellow type) had the maximum antioxidant activity (7.36 mg ml^{-1}) and the minimum (22.66 mg ml^{-1}) was reported in Acc no. 1 which is also a yellow type. Maximum antioxidant activity in Acc no. 6 may be due to high total phenols in this accession, which had the highest total phenols among all the accessions. Moreover, it ranks second in total flavanoid content among the accessions. Role of phenolic compounds in contributing to antioxidant activity of fruits was proved by Kaur and Kapoor (2005). According to Kaur and Kapoor (2005), aonla had maximum antioxidant activity (58.8 ± 5.0 mM FRAP) among commonly available fruits in India and they attributed this property of aonla to its very high content of phenolic compounds. da Silva *et al.*, (2012) reported that the antioxidant activity of passion fruit is due to the presence of polyphenols which are involved in neutralizing the oxidants. Ramaiya *et al.* (2012) reported that the total antioxidant activity ranged from 409.13 to 1964.90 µmol Trolox $litre^{-1}$ in seven different passion fruit cultivars and the strongest antioxidant activity of 547 ± 3.08 µmol Trolox $litre^{-1}$ and 524 ± 1.96 µmol Trolox $litre^{-1}$ was observed in vine ripened purple and yellow passion fruit cultivars respectively.

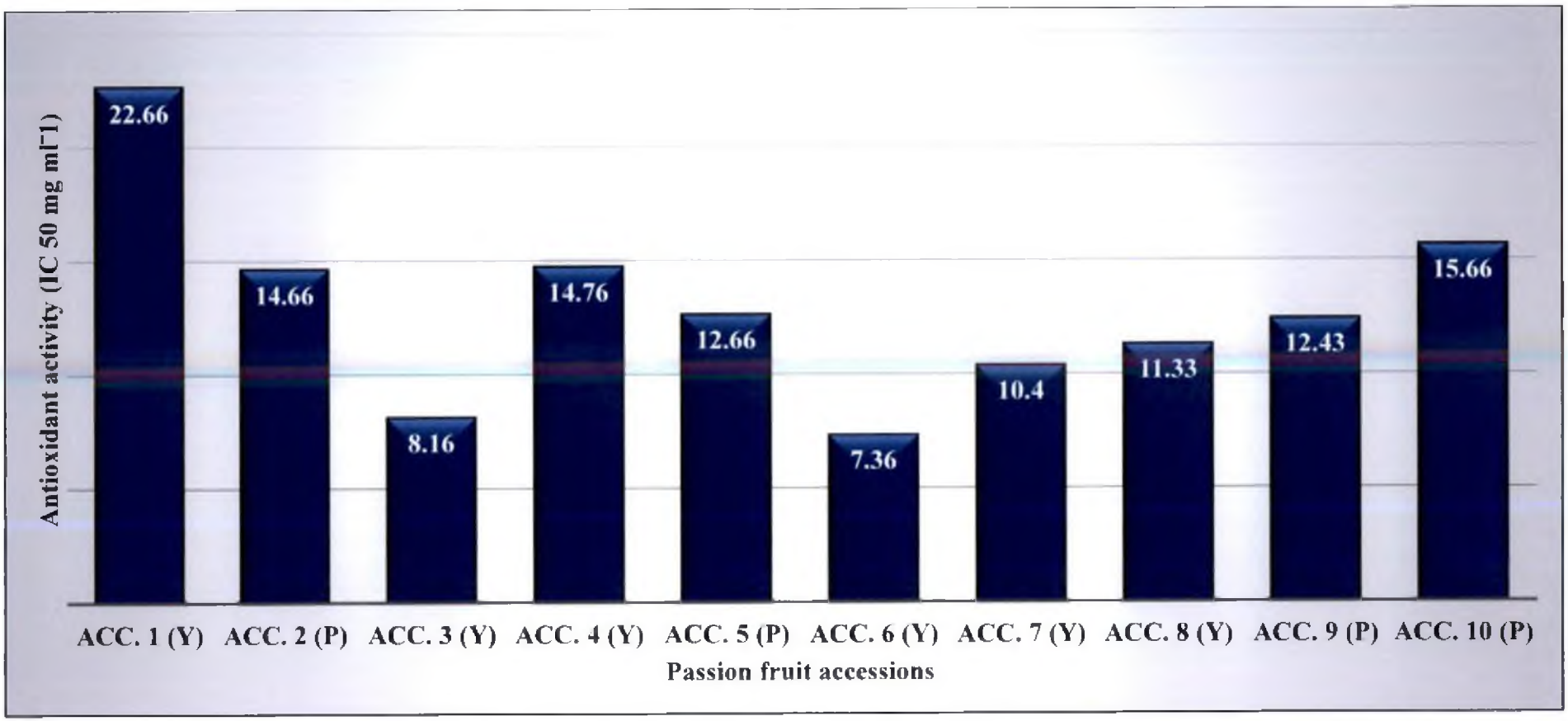


Figure 1: Antioxidant activity of passion fruit accessions

Y: Yellow type; P: Purple type

5.2 EXTENSION OF SHELF LIFE OF PASSION FRUIT THROUGH SHRINK WRAP PACKAGING

Mature passion fruits at the turning stage were collected from Cashew Research Station (CRS), Madakathara during October to evaluate shelf life and quality through shrink wrap packaging. Fruits free of damage and bruises were washed in clean tap water and immersed in 100 ppm chlorine solution for 15 minutes. The chlorinated fruits were spread out on perforated trays to remove excess surface moisture. The surface dried fruits were subjected to two forms of shrink wrapping viz. shrink wrapping of individual fruits and also shrink wrapping of areca plates containing 6-7 fruits by using polyolefin films of 15, 19 and 25μ. Observations on changes in quality of fruits were recorded at weekly intervals during storage at ambient temperature.

5.2.1 Shelf life (days)

Individually shrink wrapped passion fruit gave significantly higher shelf life as compared to fruits wrapped in areca plates and control, irrespective of the film thickness. However, individual shrink wrapping of passion fruit in 25μ polyolefin film gave the maximum shelf life (26.66 days) whereas the minimum (7.00 days) was observed in the control samples (unwrapped fruits).

Longer shelf life in shrink wrapped fruits may be due to modified atmosphere surrounding the fruits in which an elevated level of carbon dioxide and reduced level of oxygen may have retarded the respiratory activity of the fruits. Lower shelf life for fruits shrink wrapped in areca plate may be due to the absorption of condensed moisture by areca plate which led to spoilage of the fruits.

Lemtur *et al.* (2013) reported a positive correlation between packaging materials and shelf life of passion fruit in which 23.5 days of shelf life was observed in non perforated polythene packaging stored in Zero energy cool chamber (ZECC) while control had only 5.5 days of shelf life. Singh *et al.* (2007)

reported 28 days of shelf life in purple passion fruit when stored at 5°C temperature by packing in perforated HDPE film. Campbell and Knight (1983) reported a shelf life of 3 to 4 weeks in passion fruit stored in sealed polyethylene bags at 6 to 10° C temperature. Kumar (2002) reported up to 18-20 days of shelf life in mango stored in 80 gauge LDPE film with a total loss of about 20 per cent as compared to the control. The shelf life of Kinnow Mandarins could be effectively extended up to 45 days by packing them in high density polyethylene (HDPE) film and storing under ambient condition (Randhawa *et al.*, 2009a).

5.2.2 Physiological loss of weight (%)

Physiological loss of weight (PLW) increased in all the treatments during storage. PLW (%) of control fruits remained significantly higher throughout storage as compared to shrink wrapped fruits. However, with the advancement of storage period, individually shrink wrapped fruits exhibited minimum PLW values, which did not vary significantly with regard to film thickness. The PLW of individually shrink wrapped fruit with polyolefin film of 15μ, 19μ and 25μ thickness was 2.88, 2.91 and 2.92% respectively, after 28 days of storage. Reduced PLW in shrink wrapped fruits may be due to the lower respiratory activity of the fruits.

Singh *et al.* (2007) observed an increasing trend in PLW of purple passion fruit during storage in polyethylene film in which, maximum PLW (32.5%) was noticed in control and minimum (1.6-6.01%) in HDPE bags, after 30 days of storage. Matta *et al.* (2006) noticed minimum changes in appearance, colour and PLW in yellow passion fruit, film wrapped in polystyrene trays as compared to non wrapped fruits, during 30 days of storage. Minimum PLW (<1.20%) was observed by Maniwara *et al.* (2014) in purple passion fruit packed in polypropylene-polyethylene lamination along with oxygen transmission system and active packaging as compared to control. 'Fairchild' mandarins shrink wrapped in polystyrene trays using two types of polyolefin films such as 19 and 20μ thickness was found very much effective in reducing weight loss, peel

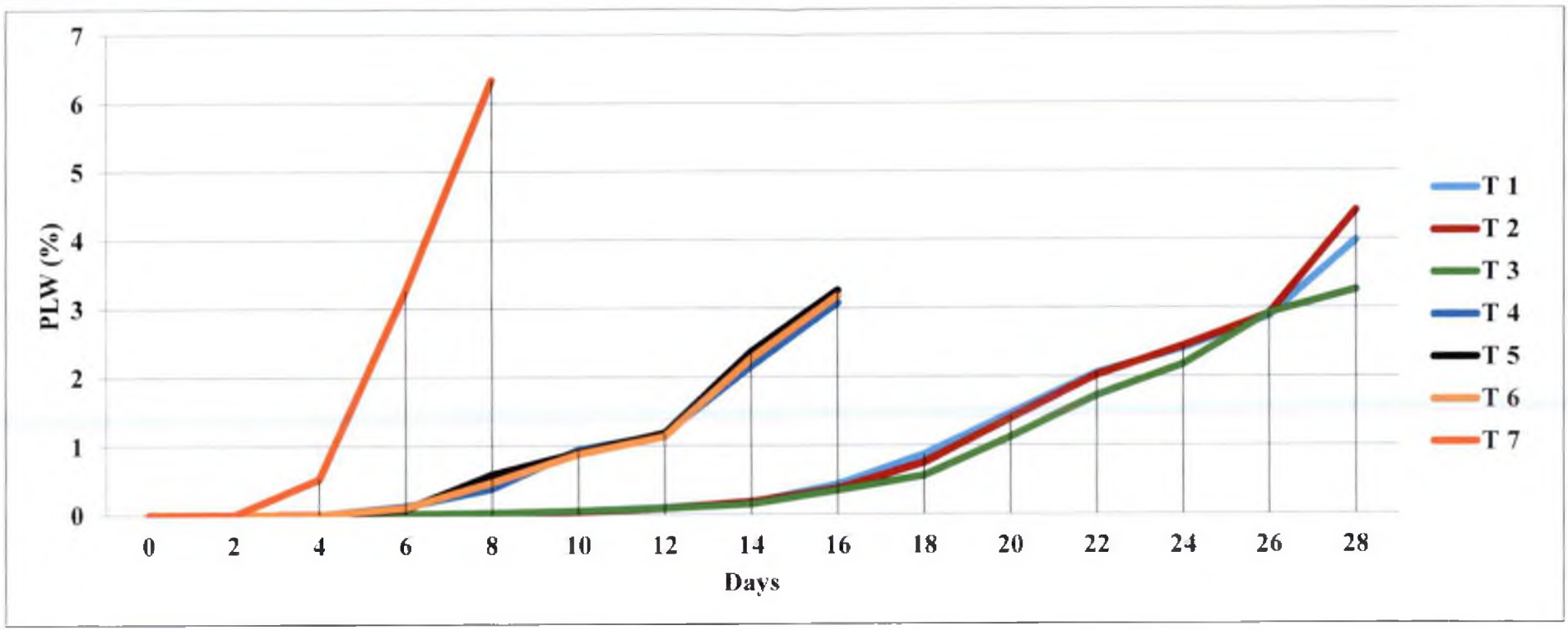


Figure 3: Effect of shrink wrap packaging on physiological loss of weight (PLW) of passion fruit

T1- Individual shrink wrapping of passion fruit with polyolefin film of 15µ thickness
T2- Individual shrink wrapping of passion fruit with polyolefin film of 19µ thickness
T3- Individual shrink wrapping of passion fruit with polyolefin film of 25µ thickness
T4- Passion fruit shrink wrapped in areca plate with polyolefin film of 15µ thickness
T5- Passion fruit shrink wrapped in areca plate with polyolefin film of 19µ thickness
T6- Passion fruit shrink wrapped in areca plate with polyolefin film of 25µ thickness
T7- Control (unwrapped)

shrinkage and in maintaining freshness compared to unwrapped fruits (D'Aquino *et al.*, 1999).

5.2.3 TSS (°Brix)

TSS content in shrink wrapped passion fruit increased in all the treatments during storage, which did not vary significantly among the treatments. After one week of storage, control samples (T7) had the highest TSS (18.80°Brix) as compared to shrink wrapped fruits (16.53, 16.60, 16.60, 16.80, 16.53 and 17.20°Brix in T1, T2, T3, T4, T5 and T6 respectively). Thickness of polyolefin film did not influence the TSS content of fruits significantly. After three weeks of storage, individually shrink wrapped passion fruit with polyolefin film of 19μ thickness had the highest TSS (17.53°Brix) and the lowest (17.00°Brix) was observed in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness.

Higher TSS in unwrapped (control) samples may be due to increased physiological and biochemical activities in these fruits as compared to the shrink wrapped samples. Increase in TSS was reported by Singh *et al.* (2007) during storage of purple passion fruit in polyethylene film, irrespective of treatments and this increase in TSS could be due to excess conversion of reserved starch and other polysaccharides to soluble form of sugar.

Jimenez *et al.* (2010) also observed mild increase in TSS in different cultivars of passion fruit after harvesting them at different maturity levels according to peel colour. A significant increase in total soluble solids (TSS) was observed in Kinnow Mandarin throughout the maturation period and this increase further gets accelerated at the later stages of fruit maturation (Ram *et al.*, 2004). An increasing trend in TSS content was observed during storage of aonla fruits in different packaging materials without any significant difference between the treatments (Singh *et al.*, 2007). Papaya fruit packed in perforated HDPE film, perforated LDPE film, dried banana leaves and newspaper when stored in

evaporative cooler, showed increasing trend in TSS with increased period of storage (Azene *et al.*, 2011).

5.2.4 Titratable acidity (%)

Titratable acidity of shrink wrapped passion fruits in all the treatments decreased during storage in which, control samples had the lowest acidity (2.19%) compared to shrink wrapped fruits, after one week of storage. After 3 weeks of storage, individually shrink wrapped passion fruit with polyolefin film of 25μ thickness had the highest titratable acidity (2.38%), and the lowest (1.89%) was noticed in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness.

Lower titratable acidity in unwrapped fruits may be due to the higher rates of conversion of complex sugars into simple ones and also due to the increased organic acid metabolism in these fruits as compared to the shrink wrapped fruits.

Reduction in acidity could be due to loss of organic acids in passion fruits during acid metabolism and degradation (Arjona and Matta, 1991b). Jimenez *et al.* (2010) observed mild decrease in titratable acidity in different passion fruit cultivars after harvesting them at different maturity levels based on peel colour. Maniwara *et al.* (2014) observed mild decrease in titratable acidity during storage of purple passion fruits in perforated low density polyethylene (LDPE). According to Singh *et al.* (2007) purple passion fruits packed in polyethylene film showed increase in titratable acidity up to 10 days and then decreased. Decreasing trend in titratable acidity was observed during storage of aonla fruits in different packaging materials irrespective of treatments (Singh et al., 2009).

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

Vitamin C content of shrink wrapped passion fruit decreased in all the treatments during storage which did not vary significantly among the treatments. After one week of storage, control fruits had the lowest vitamin C (22.58 mg

$100g^{-1}$) as compared to shrink wrapped fruits. After 3 weeks of storage, the highest vitamin C content (20.97 mg $100g^{-1}$) was observed in individually shrink wrapped passion fruit with polyolefin film of 19μ thickness and the lowest (16.56 mg $100g^{-1}$) in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness. Better retention of vitamin C in shrink wrapped fruits may be due to reduced rates of oxidation and slower biochemical reactions, as compared to unwrapped samples.

Decrease in ascorbic acid content might be due to oxidation of L-ascorbic acid to dehydro ascorbic acid (Mapson, 1970). According to Singh *et al.* (2007) the ascorbic acid content in purple passion fruits packed in polyethylene film decreased with increase in storage period. Maniwara *et al.* (2014) also observed mild decrease in vitamin C content during storage of purple passion fruits in perforated low density polyethylene (LDPE). The ascorbic acid content in aonla fruits packed in different types of packaging materials, decreased rapidly during storage at ambient temperature, without any significant difference between the treatments (Singh *et al.*, 2009).

5.2.6 Sugars (%)

Reducing, non-reducing and total sugars in passion fruit increased during storage without showing any significant difference between the treatments. After 3 weeks of storage, the highest reducing and total sugar content (10.00 and 13.63%) was observed in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness and the lowest (8.70 and 12.37%) was seen in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness respectively, whereas, highest non-reducing sugar content (3.96%) was observed in individually shrink wrapped passion fruit with polyolefin film of 19μ thickness and the lowest (3.63%) in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness. Higher levels of total sugar in control (unwrapped) fruits may be due to increased conversion of complex sugars into simple ones in these fruits as compared to the shrink wrapped fruits.

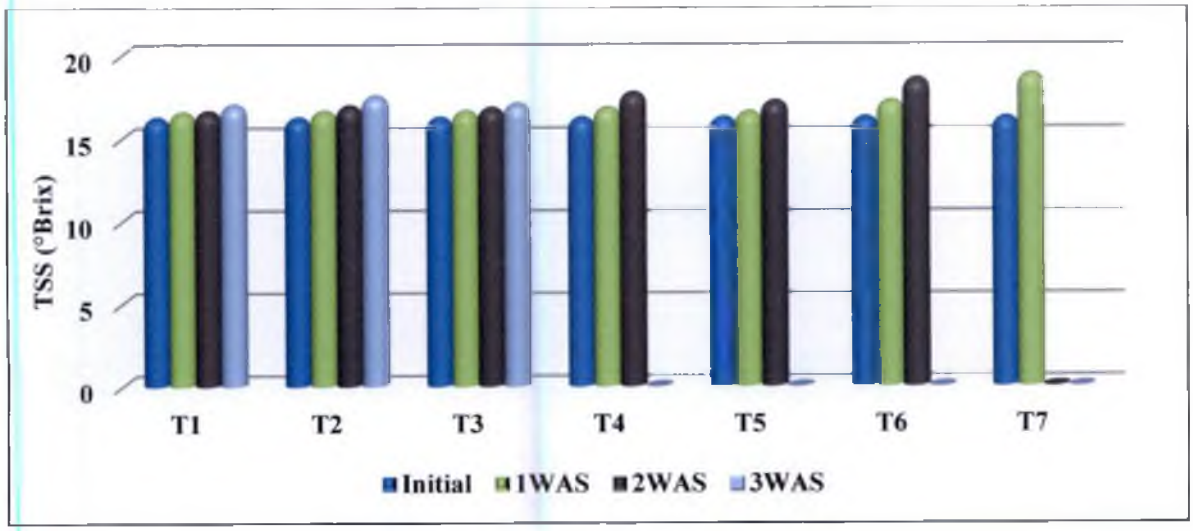


Figure 4: Effect of shrink wrap packaging on total soluble solids (TSS) of passion fruit during storage

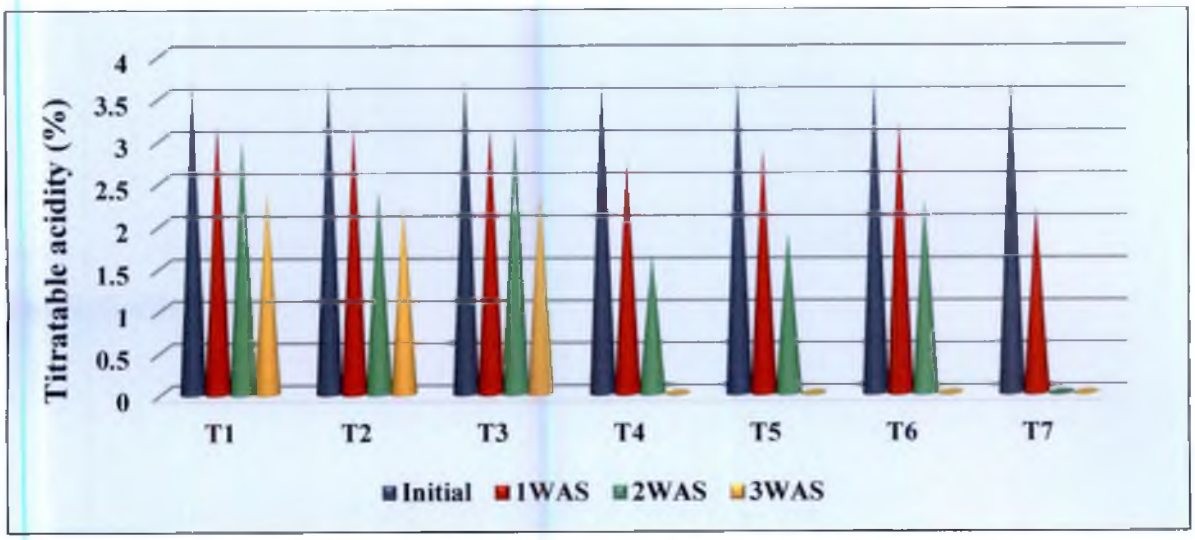


Figure 5: Effect of shrink wrap packaging on titratable acidity of passion fruit during storage

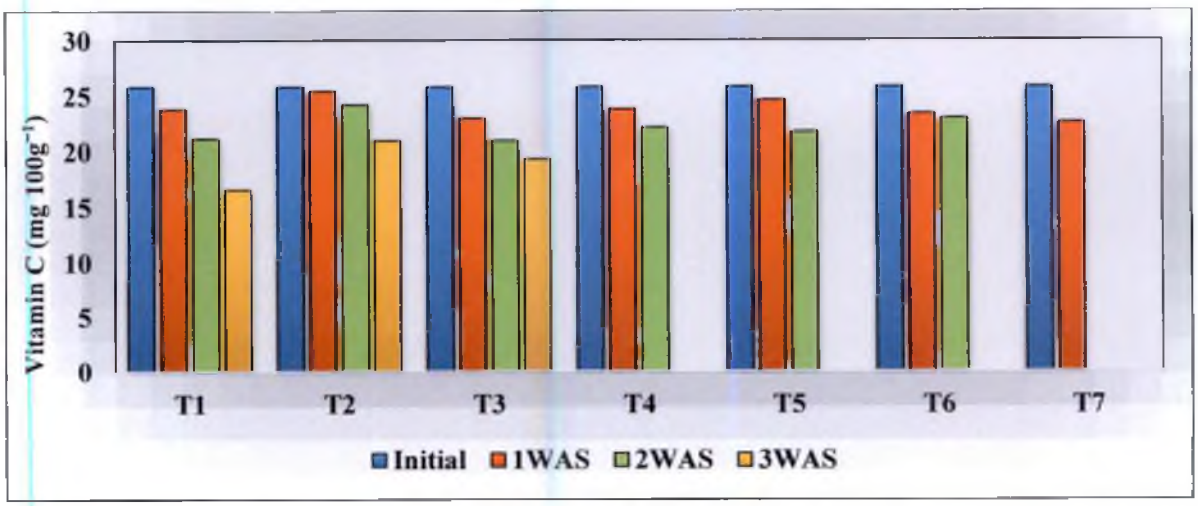


Figure 6: Effect of shrink wrap packaging on vitamin C content of passion fruit during storage

According to Singh *et al.* (2007), the total sugar content in purple passion fruits packed in polyethylene film increased with increase in storage period. According to Singh *et al.* (2009) the amount of total and reducing sugars in aonla fruits packed in different types of packaging materials, increased during storage at ambient temperature. Ram *et al.* (2004) observed significant increase in reducing, non-reducing and total sugar content during maturation period of Kinnow Mandarin. An increase in total sugars from 1.22 to 24.05% was observed in ethrel treated fruits of banana cv. Grand Naine during storage in CFB boxes at ambient temperature (Subbaiah *et al.*, 2012). Papaya fruits packed in perforated HDPE film, perforated LDPE film, dried banana leaves and newspaper and stored in evaporative cooler, showed increasing trend in reducing and total sugar content with increased period of storage (Azene *et al.*, 2011).

5.2.7 Total carotenoids (mg $100g^{-1}$)

Total carotenoid content of passion fruit decreased in all the treatments during storage. After one week of storage, control samples had the lowest total carotenoid content compared to shrink wrapped samples. After 3 weeks of storage, maximum retention of carotenoid (0.57 mg $100g^{-1}$) was observed in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness and the minimum (0.51 mg $100g^{-1}$) in individually shrink wrapped passion fruit with polyolefin film of 15μ thickness. Higher retention of carotenoids in shrink wrapped fruits may be due to lower rates of oxidation in these samples as compared to the exposed fruits in the unwrapped form.

According to Maniwara *et al.* (2014), purple passion fruit packed in perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system and active packaging showed better retention of carotenoid content during storage. According to Wen *et al.* (2006) the total carotenoid content in freshly harvested mango fruits increased gradually up to 25 days followed by decrease in subsequent days during storage. According to Chen *et al.* (2015) the total carotenoid content in loquat fruits stored at room

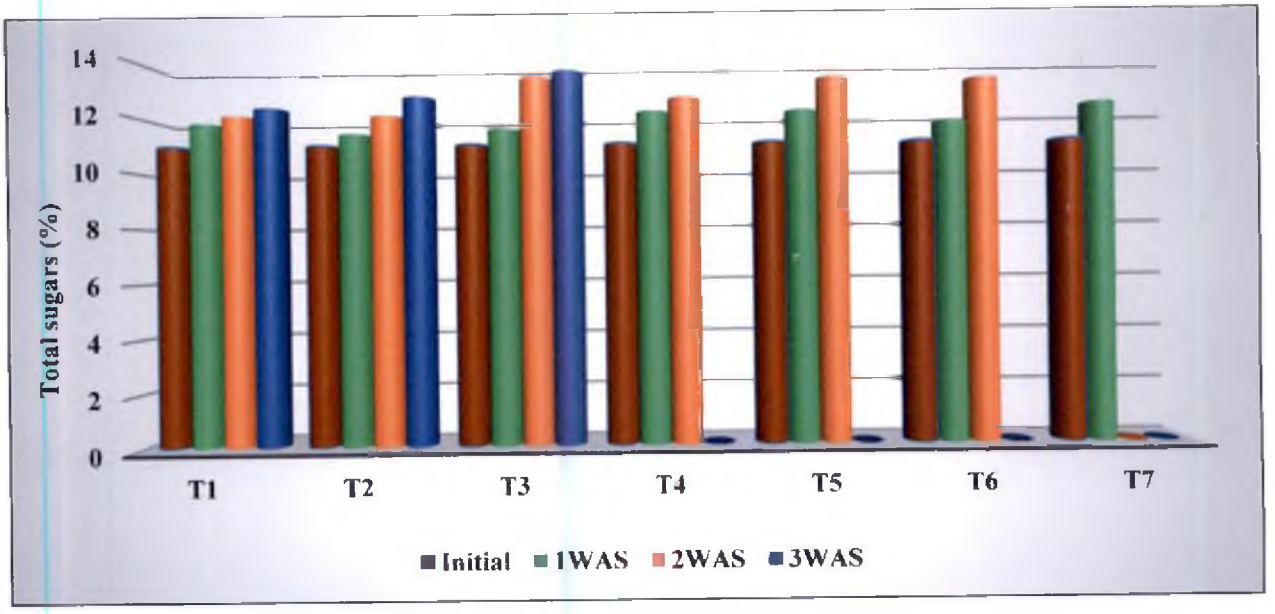


Figure 7: Effect of shrink wrap packaging on total sugar content of passion fruit during storage

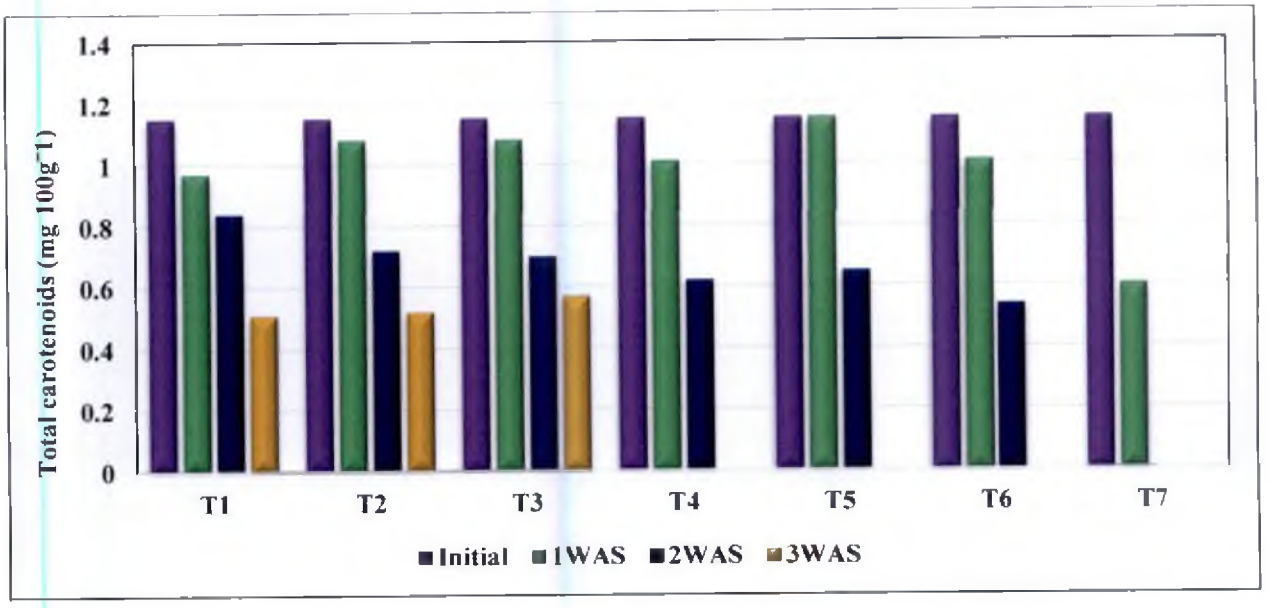


Figure 8: Effect of shrink wrap packaging on total carotenoid content of passion fruit during storage

temperature, increased gradually up to 12th day followed by decrease in subsequent days.

5.2.8 Total phenols (mg $100g^{-1}$)

The total phenols in shrink wrapped passion fruits in all treatments, increased during the first week followed by a decrease during the second and third weeks of storage. Retention of total phenols was significantly high in shrink wrapped fruits as compared to the control samples. After one week of storage, control samples had the lowest total phenols compared to shrink wrapped samples. After three weeks of storage, fruits shrink wrapped individually in polyolefin film of 15 and 19μ thickness had the highest total phenols (20.0 mg $100g^{-1}$) while the lowest (17.33 mg $100g^{-1}$) was seen in the samples wrapped with polyolefin of 25μ thickness.

Increase in total phenols during first week could be due to excess production of secondary metabolites which might be triggered by stress condition immediately after harvesting and also exposing passion fruit to very high temperature during shrink wrap packaging. Decrease in total phenols during second and third week of storage might be due to increase in the activity of polyphenol oxidase enzyme (Mowlah and Itoo, 1982).

Maniwara *et al.* (2014) reported fluctuating trends in total phenols of purple passion fruits packed in perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system (MAP-1) and active packaging. Ram *et al.* (2004) observed significant decrease in total phenols in peel tissue of Kinnow Mandarin whereas, it showed increasing trend in juice throughout the maturation period. According to Matthes and Eiberger (2009), apple cultivars stored under cold storage and controlled atmosphere storage maintained good amounts of total phenols throughout the storage period compared to ambient storage condition. Decrease in total phenols was observed with increased period of storage in rowanberry (*Sorbus aucuparia*) fruits during storage at 4 and 22°C temperature (Baltacioglu *et al.*, 2011). Carbone *et al.* (2011)

reported a considerable decrease of total phenols in apple cultivar 'HillWell' stored at refrigerated condition, whereas, it showed increasing trend in 'Wellant' cultivar when stored at ambient temperature (20°C) for two weeks.

5.2.9 Total flavanoids (mg $100g^{-1}$)

The total flavanoids in shrink wrapped passion fruits in all treatments, increased during first week whereas it declined in the unwrapped samples. However, a declining trend was noticed in all the shrink wrapped fruits during the second and third week of storage without any significant variation with respect to film thickness. After three weeks of storage, the maximum flavanoid content (8.33 mg $100g^{-1}$) was noticed in individually shrink wrapped passion fruit with polyolefin film of 25μ thickness and the minimum (7.00 mg $100g^{-1}$) in individually shrink wrapped passion fruit with polyolefin film of 19μ thickness. Decrease in total flavanoid content may be associated with enzymatic activities because of naturally synthesized enzymes such as, polyphenoloxidase (PPO) and peroxidase (POD) (Tomas-Barberan and Espin, 2001).

According to Baltacioglu *et al.* (2011) the total flavanoid content in rowanberry (*Sorbus aucuparia*) fruits stored at 4 and 22°C temperature decreased significantly with increase in storage time. According to Wang *et al.* (2008) the flavanoid compounds in raspberry (*Rubus ideaus* L.) decreased with increase in ripening and storage time. Ram *et al.* (2004) observed a significant change in flavanoid compounds such as hesperidin and naringin in Kinnow Mandarin juice during maturation. The hesperidin content was higher in mature deep orange colour stage compared to fully developed green fruit stage, whereas, the naringin content was higher in 50% colour break stage compared to mature stage.

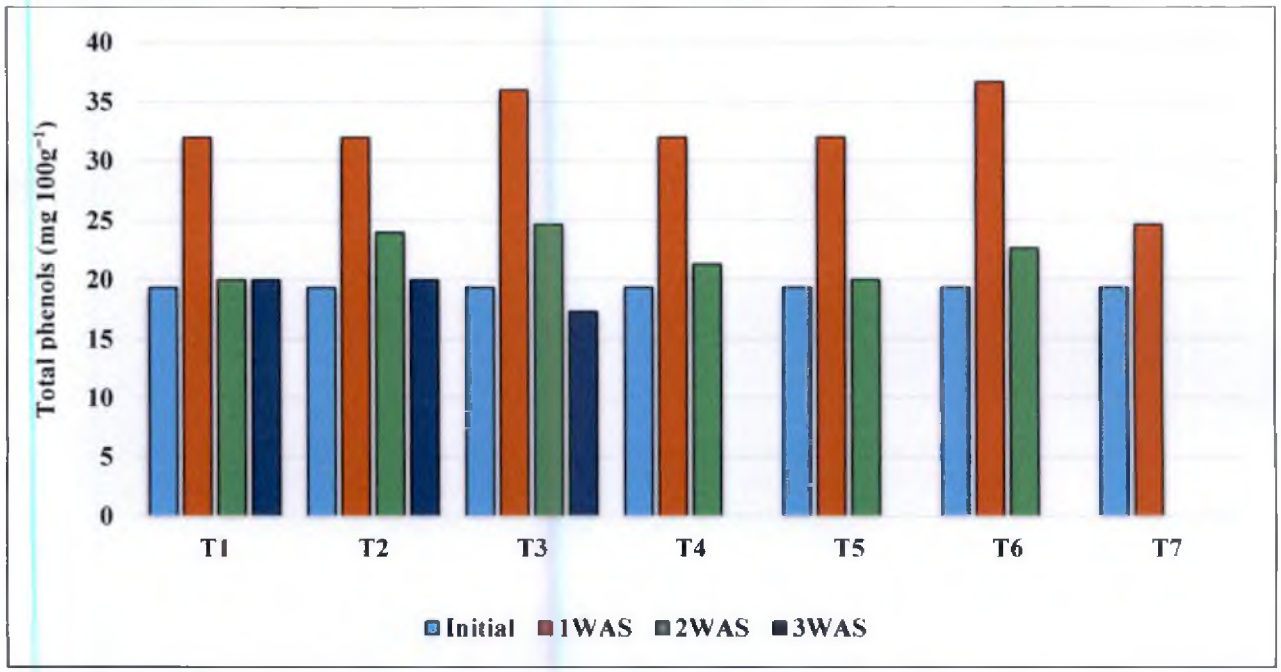


Figure 9: Effect of shrink wrap packaging on total phenols of passion fruit during storage

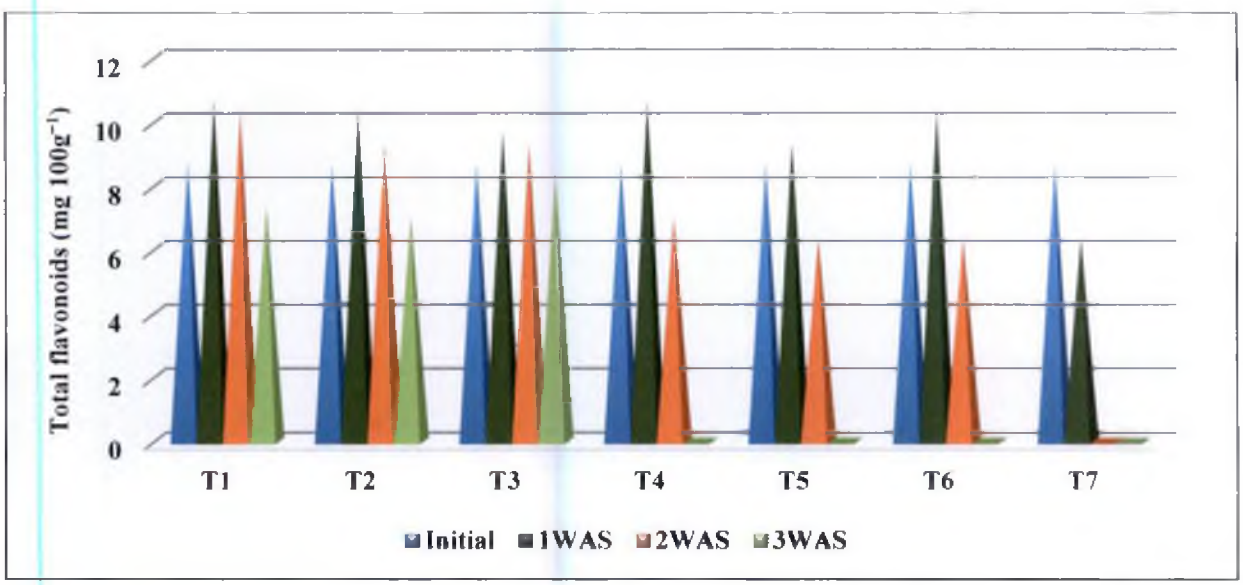


Figure 10: Effect of shrink wrap packaging on total flavanoid content of passion fruit during storage

5.2.10 Organoleptic evaluation

Shrink wrap packaging of passion fruit with polyolefin film was beneficial in retaining the marketability of fruits. Passion fruit samples subjected to shrink wrap packaging had higher mean scores for organoleptic properties as compared to the unwrapped (control) samples. However there was no significant difference in mean scores between the shrink wrapped and unwrapped fruits.

Sensory scores for flavour and sweetness in purple passion fruit stored at 25±1°C, increased up to fifth day followed by decrease during subsequent days, whereas, scores for sourness and overall quality, decreased throughout the storage (Kishore *et al.,* 2010). According to Maniwara *et al.* (2014) purple passion fruits packed in perforated low density polyethylene (LDPE), polypropylene-polyethylene lamination with oxygen transmission system and active packaging, retained better fruit quality and longer shelf life throughout the storage compared to control. Randhawa *et al.* (2009a) reported that the sensory scores of 'Kinnow' mandarins packed in high density polyethylene (HDPE) film in combination with edible oil and wax coating, decreased continuously during storage. According to Rathore *et al.* (2007) the sensory score for skin colour of mango variety 'Dasehari' packed in cardboard boxes increased initially up to 6th day followed by decrease, whereas, scores for flesh colour, texture, taste and flavour decreased significantly during storage at ambient temperature.

5.3 DEVELOPMENT OF PASSION FRUIT NECTAR AND ITS QUALITY EVALUATION DURING STORAGE

5.3.1 Standardization of nectar

Passion fruit nectar developed from yellow and purple passion fruit separately and also by blending both yellow and purple fruits, in different combinations of TSS and juice was initially subjected to organoleptic evaluation for standardization, before storage. Organoleptic evaluation revealed that passion fruit nectar containing 20% juice and 20°brix was more acceptable in all the three

categories (yellow and purple separately and yellow blended with purple). Therefore, the nectar developed with 20% juice and 20°brix was used for storage studies, to evaluate the changes in quality under ambient and low temperature conditions.

5.3.2 Changes in quality of passion fruit nectar during storage

5.3.2.1 TSS (°Brix)

Total soluble solids (TSS) in all three types of passion fruit nectar increased throughout the storage period, irrespective of storage conditions. Nectar stored under ambient temperature showed higher rate of increase compared to the samples at low temperature. After three months of storage, nectar developed from juice of yellow passion fruit stored under ambient temperature showed highest TSS (21.90°Brix) while the lowest (21.45°Brix) was observed in nectar developed from juice of purple passion fruit stored under low temperature.

Increase in TSS could be due to solubilisation of passion fruit pulp constituents during storage and degradation of complex starch into simple sugars due to hydrolysis of polysaccharides (Jawanda *et al.*, 1978).

Touati *et al.* (2015) observed significant increase in total soluble solids (TSS) in heat processed grape, orange and pear nectars during 28 days of storage at 4, 25 and 37°C temperature. According to Lakhanpal and Vaidya (2015) the total soluble solids (TSS) in both honey and sugar enriched mango nectar increased during storage and this increase was more in nectar stored under ambient condition compared to refrigerated condition. According to Deka *et al.* (2004) TSS in lime-aonla spiced beverage increased during 6 months of storage and also this increase was more in white bottles stored at ambient temperature compared to low temperature. According to Singh *et al.* (2014) no changes in total soluble solids (TSS) were observed in blended aonla and mango nectar up to five months during storage and thereafter it showed an increasing trend.

5.3.2.2 Titratable acidity (%)

Titratable acidity in all three types of passion fruit nectar decreased throughout the storage period irrespective of storage conditions. Nectar stored under ambient temperature showed higher rate of decrease compared to low temperature. After three months of storage, nectar developed from juice of purple passion fruit stored under refrigerated condition showed highest titratable acidity (0.86%) and the lowest (0.70%) was recorded in the nectar from juice of yellow passion fruit stored under ambient condition.

Decrease in titratable acidity of nectar during storage could be due to increase in simple sugars as a result of hydrolysis of complex constituents and also due to the biochemical reactions between sugars and organic acids which get accelerated at higher temperatures.

According to Lakhanpal and Vaidya (2015) the titratable acidity in both honey and sugar enriched mango nectar decreased during storage and this decrease was more in nectar stored under ambient condition compared to refrigerated condition. Deka *et al.* (2004) also reported decreasing trend in titratable acidity in lime-aonla spiced beverage during 6 months of storage and this decrease was less in amber coloured bottles stored at low temperature as compared to the samples stored in cool chamber and ambient temperature. According to Ladaniya *et al.* (2004) Nagpur Mandarin orange juice stored in crown corked glass bottles at ambient and refrigerated conditions, showed decrease in titratable acidity up to 45 days and then recovered to initial value after 90 and 180 days, irrespective of storage conditions.

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

Ascorbic acid in all three types of passion fruit nectar decreased throughout the storage period, irrespective of storage conditions. Nectar stored under ambient temperature showed higher rate of decrease compared to low temperature. After three months of storage, nectar developed from juice of purple passion fruit, stored

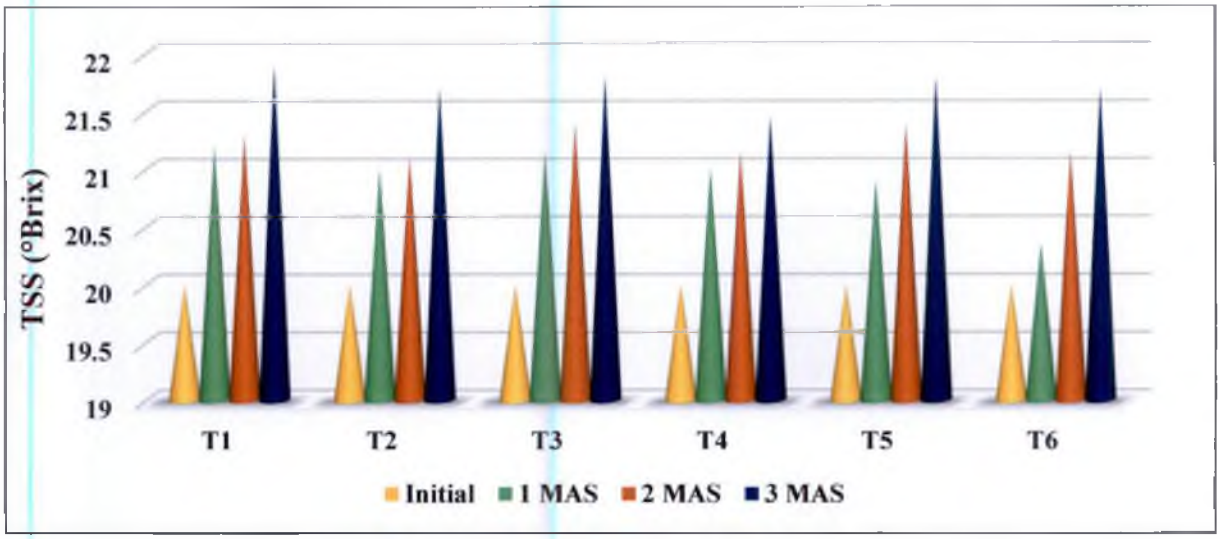


Figure 11: Effect of storage on total soluble solids (TSS) of passion fruit nectar

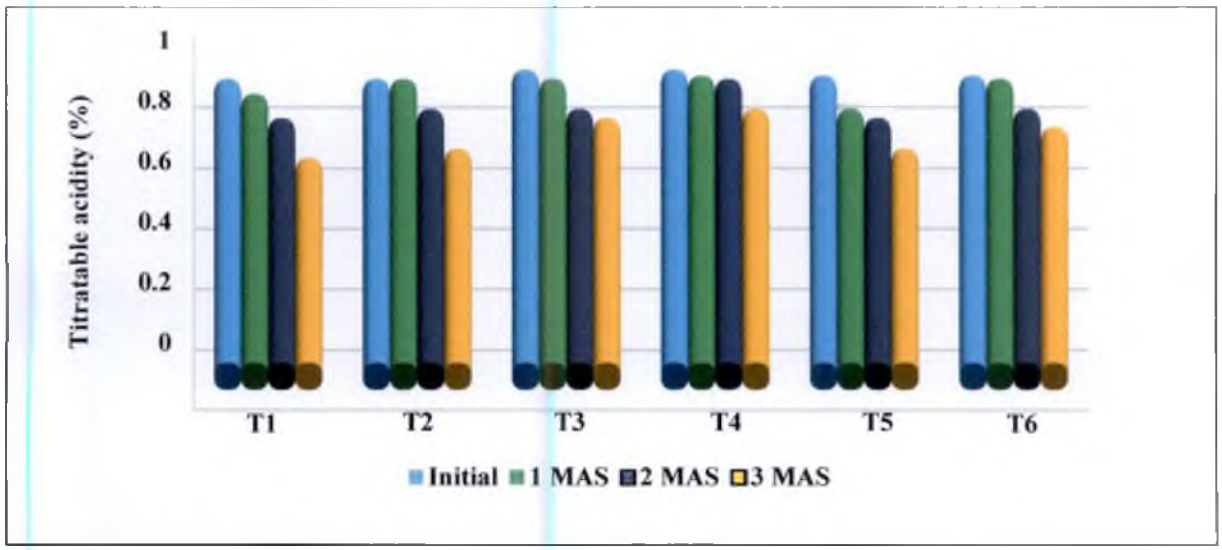


Figure 12: Effect of storage on titratable acidity of passion fruit nectar

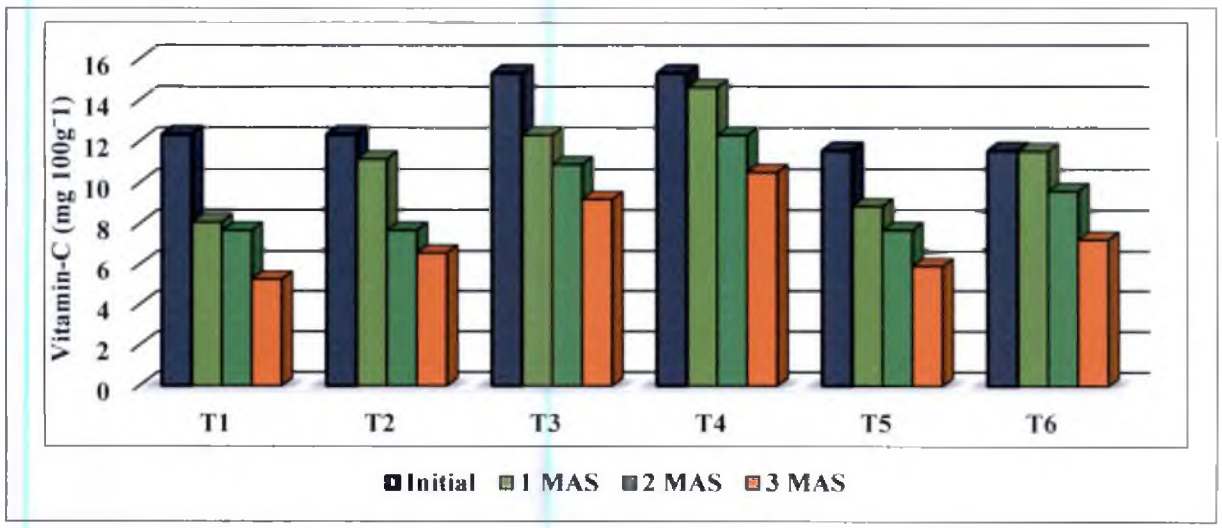


Figure 13: Effect of storage on vitamin C content of passion fruit nectar

under refrigerated condition showed highest retention of ascorbic acid content (10.51 mg $100g^{-1}$) while the lowest (5.25 mg $100g^{-1}$) was observed in nectar developed from juice of yellow passion fruit stored under ambient condition. The reason behind decrease in ascorbic acid could be due to oxidation of vitamin-C to furfural and hydroxymethylfurfural (Aruna *et al.*, 1997).

According to Wijayawardana and Bamunuarachchi (2002) the retention of ascorbic acid in processed products during storage depends on preparation methods, processing time, temperature, salt and sugar concentration, pH, oxygen availability, activity of enzymes and metal catalysts. Singh *et al.* (2014) reported a decreasing trend in ascorbic acid content in blended aonla and mango nectar during ten months of storage in glass bottles at ambient temperature. According to Lakhanpal and Vaidya (2015) the ascorbic acid content in both honey and sugar enriched mango nectar decreased during storage and this decrease was more in nectar stored under ambient condition compared to the samples in refrigerated condition.

5.3.2.5 Sugars (%)

Reducing, non-reducing and total sugars in all three types of passion fruit nectar increased during storage irrespective of storage conditions. However significant difference between the treatments was observed after three months of storage. After three months of storage, the highest reducing and total sugar content (12.34 and 21.89%) was observed in nectar developed from juice of purple passion fruit stored under ambient condition and the lowest (9.00 and 17.14%) was in the nectar from the same type stored under refrigerated condition respectively. The highest non-reducing sugar content (9.55%) was observed in nectar developed from juice of purple passion fruit stored under ambient temperature and the lowest (7.82%) in samples developed from juice of both yellow and blended passion fruit stored under refrigerated condition.

Increase in reducing sugar could be due to partial hydrolysis of starch and disaccharide into invert sugar, also increase in total sugar could be due to

solubilization of pulp constituents and hydrolysis of polysaccharides (Murari and Verma, 1989; Choudhary *et al.*, 2008; Chakraborthy *et al.*, 1991). Selvaraj *et al.* (1989) also reported that increase in sugar content may be due to breakdown of complex starch into simple glucose and sucrose.

According to Bal *et al.* (2014) reducing sugar is the most important component for a processed product as for as quality, shelf life, taste and discoloration is concerned during storage and they also reported an increasing trend in reducing and total sugars in guava nectar stored at ambient temperature for a period of eight months. According to Lakhanpal and Vaidya (2015) the reducing sugar content in both honey and sugar enriched mango nectar increased during storage and this increase was more in nectar stored under ambient condition compared to the samples in refrigerated condition. Saikia and Saikia (2002) also reported an increasing trend in total and reducing sugars in ripe ou-tenga (*Dillenia indica*) fruits during 60 days of storage in glass bottles.

5.3.2.6 Total phenols (mg $100g^{-1}$)

Total phenols in all three types of passion fruit nectar decreased throughout the storage period irrespective of storage conditions. Nectar stored under ambient temperature showed higher rate of decrease compared to the samples at low temperature. After three months of storage, nectar developed from juice of yellow fruit stored under refrigerated condition had the highest total phenols (8.50 mg $100g^{-1}$) while the lowest (6.00 mg $100g^{-1}$) was seen in the samples developed from juice of both purple and blended fruit, stored under ambient conditions.

Decrease in total phenols might be due to impact of thermal processing on passion fruit nectar and also, non-enzymatic reaction of organic acid with sugar and/or oxidation of phenols, which results in formation of brown pigments (Simenthy, 2015). Secondary metabolites like phenols, flavanoids, carotenoids, anthocyanin present in fruits are important as they are involved in browning reactions during and after processing, they also have an influence on sensory qualities of fruit juice such as flavour, taste, aroma, colour and astringency

(Filgueiras *et al.*, 2000). According to Zulueta *et al.* (2013), phenolic compounds are relatively resistant during refrigerated storage compared to ambient conditions.

de Carvalho (2013) reported that processing of yellow mobin (*Spondias mombin* L.) juice results in significant loss of total phenolic compounds. Klimczak *et al.* (2006) also reported decreasing trend in total phenols in orange juice stored at 18, 28 and 38°C temperature up to four months, followed by increase after six months and these changes were rapid under 38°C compared to 18 and 28°C. According to Touati *et al.* (2015), the total phenols in heat processed grape, orange and pear nectar decreased during 28 days of storage at 4, 25 and 37°C temperature. Jaworska *et al.* (2014), also reported a significant decrease in total phenols from 0-13% up to six months in Blackcurrant nectar followed by increase from 12-26% over the period of next six months.

5.3.2.7 Total flavanoids (mg $100g^{-1}$)

Total flavanoids in all three types of passion fruit nectar decreased throughout the storage period irrespective of storage conditions. Nectar stored under ambient temperature showed higher rate of decrease compared to low temperature. After three months of storage, maximum flavanoid content (3.50 mg $100g^{-1}$) was recorded in nectar developed from juice of yellow fruit stored under refrigerated condition, while the minimum (2.00 mg $100g^{-1}$) was noticed in the samples from juice of both purple and blended nectar stored at ambient temperature. Higher retention of flavanoids under refrigerated condition may be due to slower rate of bio chemical reactions at low temperature compard to ambient condition.

According to Sarkar *et al.* (2014), the flavanoid content in fruit juices stored under refrigerated condition decreased and this decrease can be minimized by the addition of sodium benzoate. A significant decrease in total flavanoid content was observed in citrus juice during storage, whereas, it showed increasing trend in minimally processed citrus segments (Caro *et al.*, 2003). According to Klimczak *et al.* (2006), the total flavanoid compounds such as, narirutin,

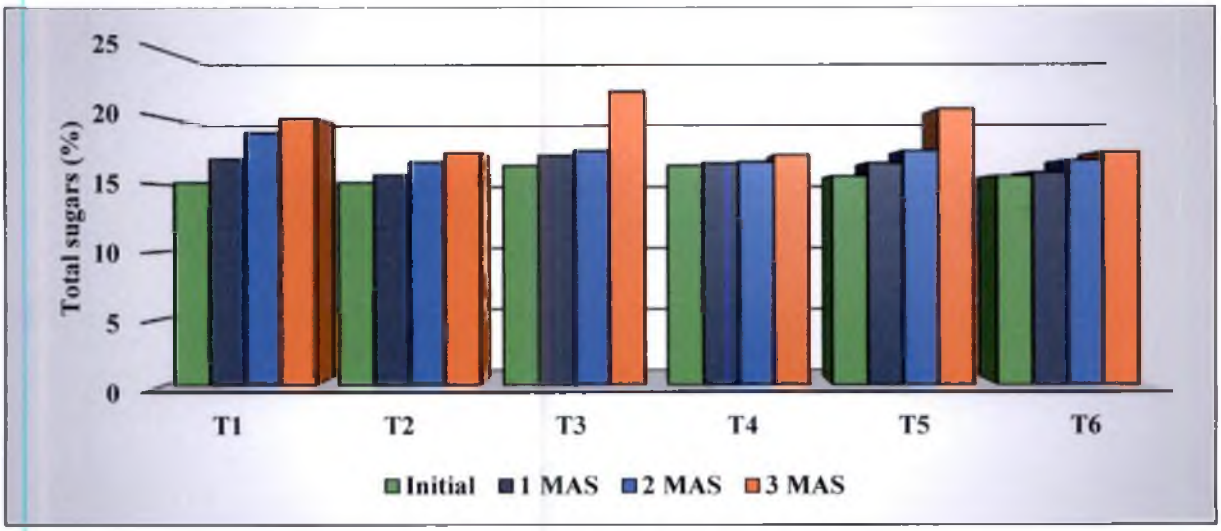


Figure 14: Effect of storage on total sugar content of passion fruit nectar

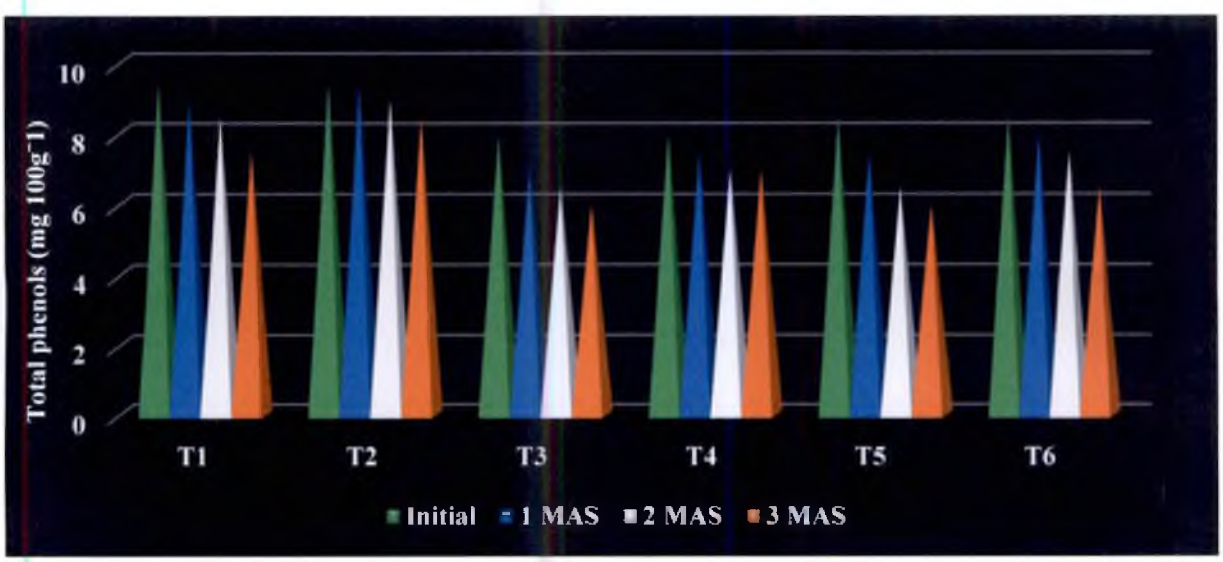


Figure 15: Effect of storage on total phenols of passion fruit nectar

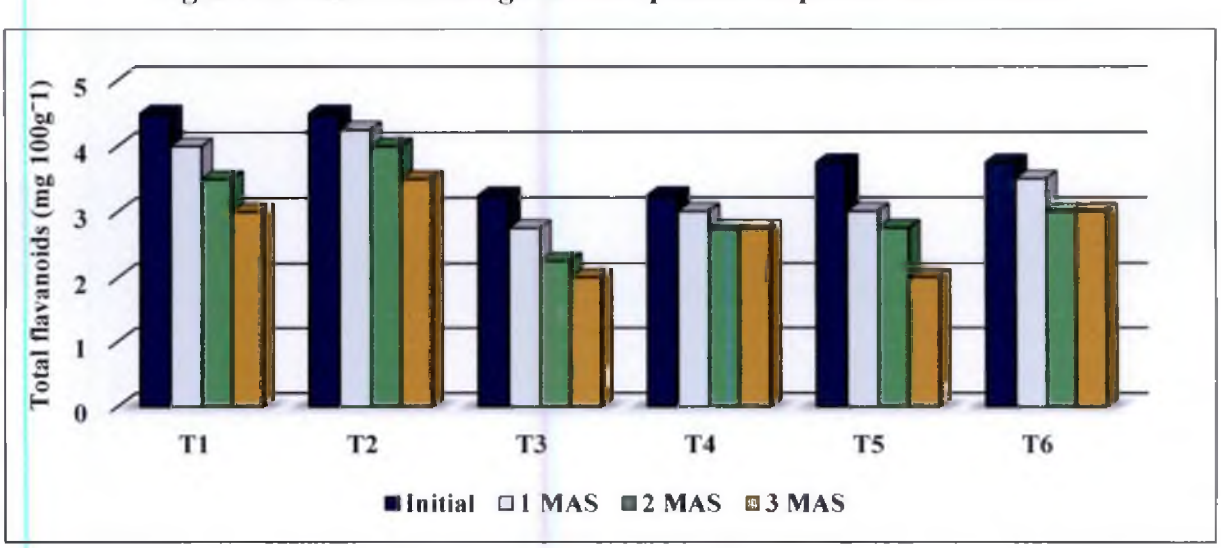


Figure 16: Effect of storage on total flavonoid content of passion fruit nectar

hesperidin, didymin, naringin and neohesperidin in orange juice decreased during storage and this decrease was rapid under 38°C compared to 18 and 28°C storage temperature.

5.3.2.8 Total carotenoids (mg $100g^{-1}$)

Total carotenoids in all three types of passion fruit nectar decreased throughout the storage period irrespective of storage conditions. Nectar stored under ambient temperature showed higher rate of decrease compared to the samples at low temperature. After three months of storage, maximum retention of total carotenoid (0.47 mg $100g^{-1}$) was noticed in nectar developed from juice of purple passion fruit stored under refrigerated condition whereas, the minimum retention (0.11 mg $100g^{-1}$) was observed in nectar developed from juice of yellow passion fruit stored at ambient temperature.

Decrease in total carotenoid content might be due to the oxidative reactions during storage. Maximum retention of carotenoids under refrigerated condition might be attributed to minimum degradation and lesser oxidation of these pigments under lower temperature (Deka *et al.*, 2005).

According to Lakhanpal and Vaidya (2015), the total carotenoid content in both honey and sugar enriched mango nectar decreased during storage and this decrease was more in nectar stored under ambient condition compared to the samples in refrigerated condition. According to Touati *et al.* (2015), the total carotenoid content in orange nectar stored at 4, 25 and 37°C temperature for 28 days decreased significantly from 26.19 mg βCE $100ml^{-1}$ to 24.50, 22.05 and 18.73 mg βCE $100ml^{-1}$ ml respectively. Doreyappa Gowda and Ramanjaneya (1995) also reported significant decrease in total carotenoid content in canned mango juice during 12 months of storage.

5.3.2.9 Non-enzymatic browning (absorbance)

Non-enzymatic browning in all three types of passion fruit nectar increased throughout the storage period irrespective of storage conditions. Nectar stored at ambient temperature showed higher rate of increase as compared to the samples at low temperature. After three months of storage, nectar developed from juice of purple fruit stored at ambient temperature, showed maximum non-enzymatic browning (0.06) and the minimum (0.02) was observed in the samples from juice of yellow fruit stored under refrigerated condition.

Increase in non-enzymatic browning during storage might be due to non-enzymatic reaction between organic acids and sugars and/or oxidation of phenols which inturn helped in the formation of brown pigments (Deka *et al.*, 2004). Higher non-enzymatic browning under ambient condition may be due to faster rates of bio chemical reactions at higher temperature compared to low temperature.

According to Singh *et al.* (2014), non-enzymatic browning in blended aonla and mango nectar maintained steady phase up to six months during storage at ambient temperature followed by an increase over the period of next four months. According to Touati *et al.* (2015), non-enzymatic browning in heat processed grape, orange and pear nectar increased during 28 days of storage and this increase was more at 37°C compared to 4 and 25°C temperature. According to Ladaniya *et al.* (2004), non-enzymatic browning in sweetened, filtered and pasteurized 'Nagpur' Mandarin orange juice increased throughout the storage period, irrespective of storage conditions with higher rate of increase under ambient condition compared to refrigerated temperature. Deka *et al.* (2004), also observed a steady increase in non-enzymatic browning in lime-aonla beverage during 6 months of storage, irrespective of storage conditions, with higher rate of increase under ambient condition compared to refrigerated condition.

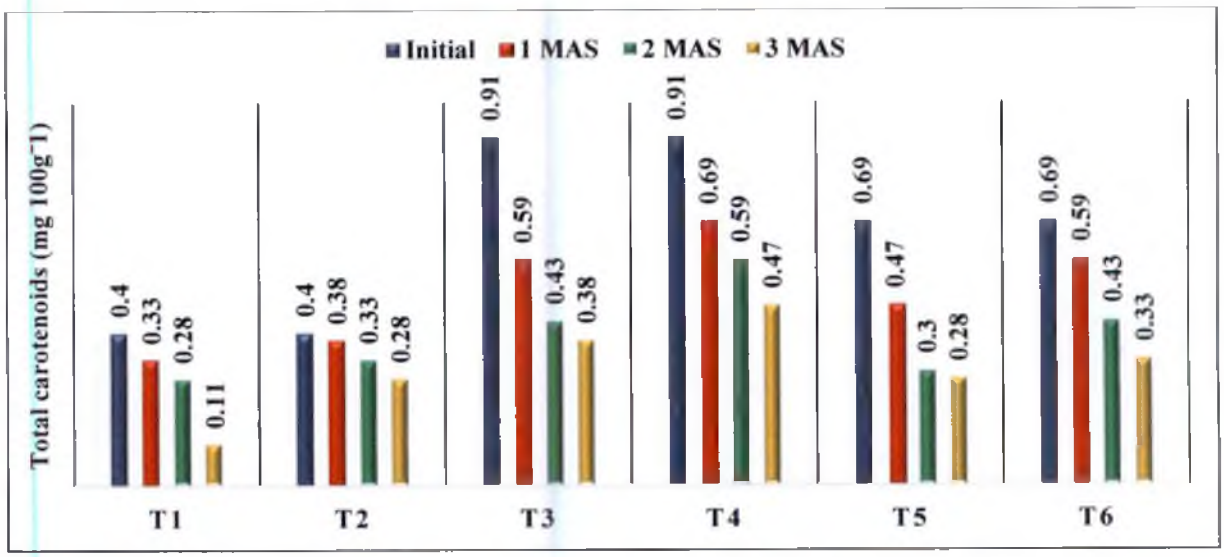


Figure 17: Effect of storage on total carotenoid content of passion fruit nectar

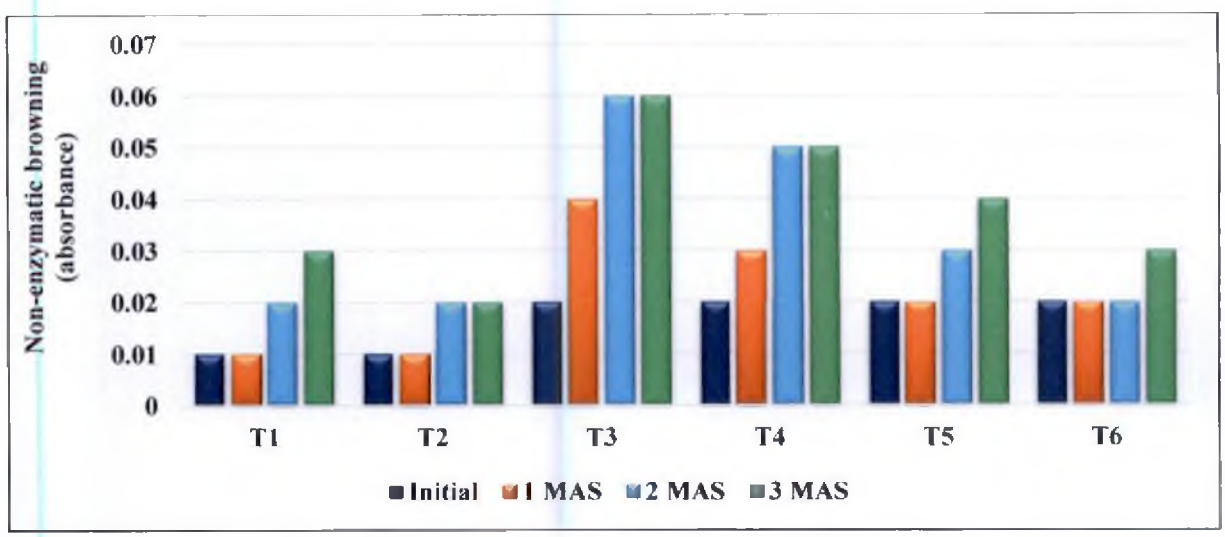


Figure 18: Effect of storage on non-enzymatic browning of passion fruit nectar

5.3.2.10 Organoleptic evaluation

Sensory scores of passion fruit nectar declined during storage in all the treatments. The rate of decrease was faster in nectar stored under ambient condition compared to the samples under refrigerated condition. After three months of storage, nectar developed from the juice of purple fruit stored under refrigerated condition recorded maximum sensory score (60.20) while the minimum (47.3) was seen in the samples from the juice of yellow fruit stored under ambient condition.

Blending equal quantity of cashew apple and passion fruit juice with and without the addition of ginger drops, showed better acceptability in terms of flavour, taste, sweetness, appearance and colour in both samples (Sobhana *et al.*, 2014). The pasteurized juice of purple passion fruit stored at -18, 8 and 23°C recorded higher sensory scores in terms of after taste and off-flavour compared to chemically preserved and control samples (Namutebi, 1998). The organoleptic scores for body, taste, colour and aroma of sweetened 'Nagpur' Mandarin orange juice decreased with increase in storage period irrespective of storage conditions, whereas, score for bitterness increased. However, scores for overall acceptability topped in refrigerated condition compared to ambient temperature (Ladaniya *et al.*, 2004). According to Deka *et al.* (2004) the sensory scores of lime-aonla spiced beverage showed decreasing trend during six months of storage, irrespective of storage conditions and storage containers. Bal *et al.* (2014) reported a decreasing trend in organoleptic scores of guava nectar with respect to colour, flavour, taste and overall acceptability throughout the storage period at ambient temperature. According to Lakhanpal and Vaidya (2015), the sensory scores with respect to colour, taste and overall acceptability in both honey and sugar enriched mango nectar decreased during storage and this decrease was more in nectar stored under ambient condition compared to the samples in refrigerated condition.

5.3.2.11 Microbial load (cfu g^{-1})

Nectar stored at ambient temperature had higher microbial load than those stored at low temperature. Bacteria were not detected up to two months of storage and yeast did not survive up to one month of storage, in any of the treatments. Even though, fungi were not detected initially, it was found one month after storage. However, the microbial load in all the samples was within the acceptable limits.

Tchango-Tchango *et al.* (1994) reported that acidity in processed passion fruit juice inhibited the growth and multiplication of pathogenic microorganisms like *Escherichia coli*, *Streptococcus* or *Staphylococcus*, but might contain non-pathogenic fungi, yeasts or lactic acid bacteria. The yellow passion fruit juice pasteurized at 75°C/60 sec showed complete inhibition of microbial population, also the juice stored under refrigeration remained microbiologically safe throughout the storage period (Sandi *et al.,* 2004). According to Fang *et al.* (1986), pasteurization of passion fruit juice at 75°C for 40 sec was sufficient to ensure microbiological quality under both ambient and refrigerated storage conditions. According to Ladaniya *et al.* (2004), bacteria and yeast counts were negligible in sweetened 'Nagpur' Mandarin orange juice throughout the storage period irrespective of storage conditions. However, up to 45 days, no fungal population was detected in both refrigerated and ambient storage conditions, but detected after 180 days. According to Majumdar *et al.* (2012), presence of coliform, spores, yeast and mold was nil in aseptically processed ashgourd-mint leaves juice throughout the storage period, also, total plate count (TPC) was nil up to 6 months of storage but TPC was 12 cfu ml^{-1} after 8 months of storage.

Summary

6. SUMMARY

The main objectives of the study were to characterize passion fruit accessions for physico-morphological, biochemical and nutritional attributes including antioxidant activity, to extend shelf life through packaging and to impart value through processing.

Passion fruit accessions (yellow and purple) were collected from various localities of Kerala *viz.*,Wayanad (yellow and purple), Vellanikkara (yellow), Mannuthy (yellow), Thiruvalla (yellow and purple), Athirampuzha (yellow), Pineapple Research Station (PRS), Vazhakulam (yellow and purple) and Kaveri, a purple type and the only variety of passion fruit released in India by the Central Horticultural Experiment Station (CHES), Chettalli, a sub station of the Indian Institute of Horticulture Research (IIHR), Bengaluru was used as check variety. These accessions were characterized based on physico-morphological, nutritive and biochemical parameters, of which special emphasis was given to determine the antioxidant activity.

Considerable variation in physico-morphological attributes was observed among the passion fruit accessions. Maximum fruit length (6.96 cm), fruit diameter (7.10 cm), fruit girth (22.83 cm), rind thickness (0.96 cm), fruit weight (98.26 cm), juice recovery (46.46%) and seed yield (18.47%) was recorded in purple type fruits whereas, rind percentage was highest (78.12%) in yellow type fruit. Brilliant yellow was the commonly observed juice colour in majority of the accessions, followed by vivid yellow and light orangish yellow. However, juice colour of yellow type fruit varied from vivid yellow (9A) to light orangish yellow (22B) and that of purple type from brilliant yellow (7A) to brilliant yellow (21C).

Nutritional and biochemical characteristics also varied significantly among passion fruit accessions. Maximum TSS (17.73^0 Brix), reducing sugar (8.06%), total sugar (13.04%) and vitamin C (30.50 mg $100g^{-1}$) was observed in purple type fruits whereas, maximum titratable acidity (4.86%), non reducing sugar (5.27%), total carotenoids (2.81 mg $100g^{-1}$), total phenols (27.33 mg $100g^{-1}$) and

total flavanoids (18.00 mg $100g^{-1}$) was observed in yellow type fruits. Antioxidant activity ranged from 7.36 to 22.66 mg ml^{-1}. Acc. 6 (yellow type) exhibited the maximum antioxidant activity (7.36 mg ml^{-1}) and the minimum (22.66 mg ml^{-1}) was reported in Acc. 1 which is also a yellow type.

Mature fruits of a yellow accession grown at the Cashew Research Station (CRS), Madakathara were used at the turning stage for the evaluation of shelf life and assessment of changes in quality through shrink wrap packaging. Fruits free of damage and bruises, were washed in clean tap water followed by immersion in 100 ppm chlorine solution for 15 minutes. The chlorinated fruits were spread out on perforated trays to remove excess surface moisture. The surface dried fruits were subjected to two forms of shrink wrapping *viz.,* shrink wrapping of individual fruits and also shrink wrapping of areca plates containing fruits. Polyolefin films of 15, 19 and 25μ thickness were used for shrink wrapping. Observations on changes in quality of fruits were recorded at weekly intervals during storage at ambient temperature.

Shrink wrap packaging of passion fruit (wrapped individually and also in areca plates) prolonged the shelf life significantly compared to control, but it did not show any significant difference with respect to film thickness. Individually shrink wrapped passion fruit with 25μ thickness polyolefin film gave highest shelf life (26.66 days) whereas the lowest shelf life (7.00 days) was observed in control samples (unwrapped fruits). Fruits wrapped in areca plates became unmarketable after two weeks of storage, irrespective of the film thickness. Physiological loss of weight (PLW), total soluble solids, reducing, non reducing and total sugars increased, while, titratable acidity, vitamin C and total carotenoids decreased in all the treatments during storage. Total phenols and total flavanoids increased during first week and decreased afterwards during second and third week of storage. Sensory quality of passion fruit increased throughout the storage period in all the treatments.

Passion fruit nectar was developed from yellow and purple passion fruit separately and also by blending both yellow and purple fruits, in different combinations of TSS and juice. It was initially subjected to organoleptic evaluation to determine the best combination of TSS and juice content in nectar. Organoleptic evaluation revealed that passion fruit nectar containing 20% juice and 20°Brix was more acceptable in all the three categories (yellow and purple separately, and yellow blended with purple). Therefore, the nectar developed with 20% juice and 20°Brix was used for storage studies, to evaluate the changes in quality under ambient and low temperature conditions.

Total soluble solids, non-enzymatic browning, reducing, non reducing and total sugars increased while, titratable acidity, vitamin C, total carotenoids, total phenols and total flavanoids decreased during storage of nectar, irrespective of treatments and storage conditions. Qualitative changes in passion fruit nectar were more conspicuous under ambient conditions than under low temperature storage. After three months of storage, nectar developed from juice of yellow passion fruit stored at ambient temperature showed highest TSS (21.90°Brix), whereas, nectar developed from juice of purple passion fruit stored at refrigerated temperature showed highest titratable acidity (0.86%) and vitamin C (10.51 mg $100g^{-1}$). Maximum non-enzymatic browning (0.06), reducing sugar (12.34%), non reducing sugar (9.55%) and total sugar (21.89%) was observed in nectar developed from juice of purple passion fruit stored under ambient condition while, nectar developed from juice of yellow passion fruit stored under refrigerated condition showed highest total phenols (8.50 mg $100g^{-1}$) and total flavanoids (3.50 mg $100g^{-1}$).

Organoleptic quality of passion fruit nectar declined during storage in all the treatments. The rate of decline was faster in nectar stored under ambient conditions compared to those stored under refrigerated condition. After three months of storage, nectar from purple fruits stored under refrigerated condition recorded maximum sensory score (60.20) while the minimum (47.3) was seen in nectar from yellow fruits stored under ambient condition.

Microbial load in all the samples was within the acceptable limits even after three months of storage and it was higher in nectar stored under ambient conditions compared to those stored under refrigerated condition.

References

7. REFERENCES

Afifa, K., Kamruzzaman, M., Mahfuza, I., Afzal, H., Arzina, H., and Roksana, H. 2014. A comparison with antioxidant and functional properties among five mango (*Mangifera indica* L.) varieties in Bangladesh. *Int. Food Res. J.* **21**(4): 1501-1506.

Agarwal, G. P. and Hasija, S. K. 1986. Microorganisms in the Laboratory. Print House India Ltd. Lucknow, 155p.

Amerine, M. A., Pangborn, R. N., and Rossler, E. B. 1965. Principles of sensory evaluation of food. Acad. Press, London.

Anesini, C. and Perez, C., 1993. Screening of plants used in argentine folk medicine for antimicrobial activity. *J. Ethnopharmacology* **39:** 119–128.

AOAC [Association of Official Agricultural Chemists] 1998. *Official method of analysis of AOAC International* (16th Ed.). Association of Official Agricultural Chemists, Wasington, D. C. p. 899.

Arjona, H. E., Matta, F. B., and Garner, J. O. 1991a. Growth and composition of passion fruit (*Passiflora edulis*) and maypop (*P. incarnata*). *Hortic. Sci.* **26**(7): 921-923.

Arjona, H. E. and Matta, F. B. 1991b. Postharvest quality of passion fruit as influenced by harvest time and ethylene treatment. *Hort. Sci.* **26**: 1297-1298.

Arsad, P., Sukor, R., Ibadullah, W. W. Z., Mustapha, N. A., and Hussin, M. A. S. 2015. Effect of enzymatic treatment on physicochemical properties of sugar palm fruit juice. *Int. J. Adv. Sci. Eng. Inf. Tecnol.* **5**(2015): 2088-5334.

Aruna, K., Vimala, V., Giridhar, N., and Raio, D. G. 1997. Studies on preparation and storage of nectar prepared from papaya. *Beverage Food World* **24**(1): 29-32.

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**:1237-1241.

Azene, M., Workneh, T. S., and Woldetsadik, K. 2011. Effect of packaging materials and storage environment on postharvest quality of papaya fruit. *J. Food Sci. Technol.* **51**(6): 1041-1055.

Bal, L. M., Ahmad, T., Senapati, A. K., and Pandit, P. S. 2014. Evaluation of quality attributes during storage of guava nectar Cv. Lalit from different pulp and TSS ratio. *J. Food Processing Technol.* **5**(329): 2157-7110.

Baltacioglu, C., Velioglu, S., and Karacabey, E. 2011. Changes in total phenolic and flavonoid contents of rowanberry fruit during postharvest storage. *J. Food Qual.* **34**(2011): 278-283.

Braca, A., De Tommasi, N., Di Bari, L., Pizza, C., Politi, M., and Morelli, I. 2001. Antioxidant principles from *Bauhinia tarapotensis*. *J. Nat Products* 64(7): 892-895.

Campbell, C. W. and Knight, R. J. 1983. Production of granadilla. Communication XIII Congress NORCOFEL. Ministry of Agriculture, Pesca Alimentacion, Canary Islands, Spain. p. 223-231.

Carbone, K., Giannini, B., Picchi, V., Scalzo, R. L., and Cecchini, F. 2011. Phenolic composition and free radical scavenging activity of different apple varieties in relation on the cultivar, tissue type and storage. *Food Chem.* **127**: 493-500.

Caro, A. D., Piga, A., Vacca, V., and Agabbio, M. 2003. Changes of flavanoids, vitamin C and antioxidant capacity in minimally processed citrus segments and juices during storage. *Food Chemist.* **84**(1): 99-105.

Cavalcante, L. F., Santos, G. D., Oliveira, F. A., Cvalcante, I. H. L., Gondim, S. C., and Cavalcante, M. Z. B. 2007. Growth and production of yellow passion fruit in a soil of low fertility treated with liquid biofertilizers. *Rev. Bras. Ceinc. Agr.* **2**(1): 15-19.

Cereda, E., Cereda, M. P., and Brasil, M. A. M. 1976. Concervacao do maracuja amarelo para utilizacao *in natura*. *Acta Hort.* **57**:145-151.

Chakraborthy, S., Bisht, H. C., Agarwal, M. D., Verma, L. N., and Shukla, I. C. 1991. Studies on varietal screening of mangoes of Uttar Pradesh for their suitability for production of canned nectar, juice and pulp. *Indian Food Packer.* **55**: 49-57.

Chang, C., Yang, M., Wen, H., and Chern, J. 2002. Estimation of total flavonoid content in propolis by two complementary colorimetric methods. *J. Food Drug Anal.* **10**(3): 178-182.

Chen, Y., Lin, S., Xu, L., and Wu, J. 2015. Effects of postharvest storage temperatures on carotenoid content of loquat fruits. *Acta Hortic.* **1092**: 159-165.

Choudhary, M. L., Dikdshit, S., Shukla, N. N., and Saxena, R. R. 2008. Evolution of guava varities and standardization for nectar preparation. *J. Hort. Sci.* **3**: 161-163.

Coelho, A. A., Cenci, S. A., and Resende, E. D. 2011. Yields and wastes of yellow passion fruit juice as a result of fruit size and different storage harvesting spots. *Rev. Bras. Prod. Agroind.* **13**(1): 55-63.

D'Aquino, S., Piga, A., and Agabbio, M. 1999. Condition of film wrapped "fairchild" fruits held in shelf -life conditions. Paper presented during 11th international association of packaging research institutes, The Westin Stamford and Westin Plaza Hotel, Singapore.

da Mota, W. F., Salomao, L. C. C., Cecon, P. R., and Finger, F. L. 2003. Waxes and plastic film in relation to the shelf life of yellow passion fruit. *Scientia Agricola* **60**(1): 51-57.

da Silva, J. K., Cazarin, C. B. B., Colomeu, T. C., Batista, A. G., Meletti, L. M. M., Paschoal, J .A. R., Junior, S. B., Furlan, M. F., Reyes, F. G. R., Augusto, F., Junior, M. R. M., and Zollner, R. L. 2012. Antioxidant activity of aqueous extract of passion fruit (*Passiflora edulis*) leaves: In vitro and in vivo study. *Food Res. Int.* **53**(2013): 882–890.

da Silva, J. K., Cazarin, C. B. B., Batista, A. G., and Marostica, M. 2014. Effects of passion fruit (*Passiflora edulis*) byproduct intake in antioxidant status of Wistar rats tissues. *Food Sci. Technol.* **59**(2014): 1213-1219.

da Silva, M. A. P., Placido, G. R., Caliari, M., Carvalho, B. S., da Silva, R. M., Cagnin, C., de Lima, M. S., do Carmo, R. M., and da Silva, R. C. F. 2015. Physical and chemical characteristics and instrumental colour parameters of passion fruit (*Passiflora edulis* Sims). *African J. Agric. Res.* **10**(10): 1119-1126.

de Carvalho, J. M., Maia, G. A., da Fonseca, A. V. V., de Sousa, P. H. M., and Rodrigues, S. 2013. Effect of processing on physicochemical composition, bioactive compounds and enzymatic activity of yellow mombin (*Spondias mombin* L.) tropical juice. *J. Food Sci. Technol.* **52**(2): 1182-1187.

Deka, B. C., Sethi, V., Suneja, P., and Srivastava, V. K. 2004. Physico-chemical changes of lime-aonla beverage during storage. *J. Food Sci. Technol.* **41**(3): 329-332.

Deka, B. C., Sethi, V., and Saikia, A. 2005. Changes in quality of mango-pineapple spiced beverage during storage. *Indian J. Hortic.* **62**(1): 71-75.

Desai, S. S., Chovatia, R. S., and Singh, V. 2012. Effect of different plant growth regulators and micronutrients on fruit characters and yield of tomato cv. Gujarat Tomato-3 (GT-3). *Asian J. Hortic.* **7**(2): 546-549.

Dhawan, K., Dhawan, S., and Sharma, A. 2004. *Passiflora*: a review update. *J. Ethnopharmacology* **94**(2004): 1–23.

Doreyappa Gowda. I. N. and Ramanjaneya, K. H. 1995. Evaluation of some mango varieties for their suitability for canned mango juice. *J. Food Sci. Technol.* **32**(4): 323-325.

Fang, T, Chen, H. E. and Chiou, L. M. J. 1986. Effects of heat treatment and subsequent storage on the quality of passion fruit (*Passiflora edulis*) juice. Paper presented during 19th symposium of international federation of fruit juice producers, Den Haag, Netherlands.

Felter, H. W. and Lloyd, J. U. 1983. King's American Dispensatory 1898. Reprint by Eclectic Medical Publications, Portland.

Ferreira, F. M., Neves, L. G., Bruckner, C. H., Viana, A. P., Cruz, C. D., and Barelli, M. A. A. 2010. Development of super-traits for selection of families of yellow passion fruit. *Acta. Sci.* **2**(32): 247-254.

Filgueiras, H. A. C., Alves, R. E., Moura, C. F. H. 2000. Caja (*Spondias mombim* L.). In: Alves, R. E., Filgueiras, H. A. C., Moura, C. F. H. (eds), Characterisation of fruits native to Latin America. pp 19-22.

Gattuso, G., Barreca, D., Gargiulli, C., Leuzzi, U., and Caristi, C. 2007. Flavonoid Composition of *Citrus* Juices. **12**: 1641-1673.

Jamir, T. T., Sharma, H. K., and Dolui, A. K., 1999. Folklore medicinal plants of Nagaland, India. Fitoterapia **70:** 395–401.

Jawanda, J. S., Singh, R., and Kumar, K. 1978. Studies on extending post harvest life of Kinnow Mandarin. *Punjab Hort. J.* **18**:149-153.

Jaworska, G., Pogon, K., Klimek, M., and Gwozdz, E. 2014. Quality changes of Blackcurrant nectar under different storage conditions. *J. Life Sci. Res.* **1**(1): 16-20.

Jimenez, A. M., Sierra, C. A., Rodriguez-Pulido, F. J., Gonzalez-Miret, M. L., Heredia, F. J. and Osorio, C. 2010. Physicochemical characterisation of gulupa (*Passiflora edulis* Sims. fo edulis) fruit from Colombia during the ripening. *Food Res. Int.* **44**(2011): 1912-1918.

Jin, P., Wang, S. Y., Wang, C. Y., and Zheng, Y. 2010. Effect of cultural system and storage temperature on antioxidant capacity and phenolic compounds in strawberries. *Food Chem.* **124**(2011): 262-270.

John, P. J. 2008. A handbook on post harvest management of fruits and vegetables. Daya publishing house, Delhi, 147p.

Joy, P. P. 2010. Passion fruit *(Passiflora edulis Sims)*: Passifloraceae. Pineapple Research Station [Kerala Agricultural University], Vazhakulam- 686670, Muvattupuzha, Ernakulam District, Kerala, India.

Kader, A. A. 1986. Biochemcial and physiological basic for effects of controlled and modified atmosphere on fruit and vegetables. *Food Technol.* **40**(5): 99-104.

Kathiravan, T., Nadanasabapathi, S., and Kumar, R. 2013. Optimization of pulsed electric field processing conditions for passion fruit juice (*Passiflora edulis)* using Response Surface Methodology. *Int. J. Adv. Res.* **1**(8): 399-411.

Kaur, C. and Kapoor, H. C. 2001. Antioxidants in fruits and vegetables: the millennium's health. *Int. J. Food Sci. Technol.* **36**:703–725.

Kaur, C. and Kapoor, H.C. 2005. Antioxidant Activity of Some Fruits in Indian Diet. In. J.S. Chauhan (ed.), Proceedings of VIIth on TZFTS. *Acta Hort.* 696, ISHS, pp.563-565.

Kishore, K., Pathak, K. A., Shukla, R., and Bharali, R. 2010. Effect of storage temperature on physico-chemical and sensory attributes of purple passion fruit (*Passiflora edulis* Sims). *J. Food Sci. Technol.* **48**(4): 484–488.

Klimczak, I., Malecka, M., Szlachta, M., and Gliszczynska-Swiglo, A. 2006. Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices. *J. Food Composition Anal.* **20**(3-4): 313-322.

Kulkarni, S. G. and Vijayanand, P. 2009. Effect of extraction conditions on the quality characteristics of pectin from passion fruit peel (*Passiflora edulis f. flavicarpa* L.). *Food Sci. Technol.* **43**(2010): 1026–1031.

Kumar, S. 2002. Modified atmosphere packaging of mangoes (*Mangifera indica* L.) in polymeric films. Phd.(Ag.) Thesis, Punjab agricultural university, Ludhiana. 220p.

Ladaniya, M. S., Das, A. K., Khan, N. A., Mahalle, B., and Kumar, A. 2004. Changes in quality of sweetened 'Nagpur' Mandarin orange juice in crown corked glass bottles at ambient and refrigerated conditions. *J. Food Sci. Technol.* **41**(3): 344-348.

Lakhanpal, P. and Vaidya, D. 2015. Development and evaluation of honey based mango nectar *J. Food Sci. Technol.* **52**(3): 1730–1735.

Lemtur, K., Biswas, P. K., and Sema, A. 2013. Juice percentage and shelf-life of passion fruit, *Passiflora edulis* as affected by postharvest treatments and storage conditions. *Int. J. Farm Sci.* **3(1)**: 18-21.

Lopez-Vargas, J. H., Fernandez-Lopez, J., Perez-Alvarez, J. A., Viuda-Martos, M. 2013. Chemical, physico-chemical, technological, antibacterial and

antioxidant properties of dietary fiber powder obtained from yellow passion fruit (*Passiflora edulis* var. *flavicarpa*) co-products. Food Res. Int. **51**(2013): 756-763.

Majumdar, T. K., Wadikar, D. D. and Bawa, A. S. 2012. Development and storage stability of aseptically processed ashgourd-mint leaves juice. *Int. Food Res. J.* **19**(3): 823-828.

Maniwara, P., Boonyakiat, D., Poonlarp, P. B., Natwichai, J., and Nakano, K. 2014. Changes of postharvest quality in passion fruit (*Passiflora edulis* Sims) under modified atmosphere packaging conditions. *Int. Food Res. J.* **22**(4): 1596-1606.

Mapson, L. W. 1970. Vitamins in fruits. Stability of L-ascorbic acid. In: Biochemistry of fruits and their products. Hulme AC (ed), Academic Press, London, p. 376-377.

Matta, F. B., Arjona, H. E., Garner, J. O., and Silva, J. L. 2006. Studies on postharvest quality of passion fruit. Technical bulletin 1153, Mississippi agricultural and forestry experiment station, 9p.

Matthes, A. and Eiberger, M, S. 2009. Polyphenol content and antioxidant capacity of apple fruit: effect of cultivar and storage conditions. *J. Appl. Bot. Food Qual.* **82**: 152-157.

McGuire, C. M. 1999. *Passiflora incarnata* (Passifloraceae): a new fruit crop. *Econ. Bot.* **53:** 161–176.

Mendes-Pinto, M. M. 2009. Carotenoid breakdown products the—norisoprenoids-in wine aroma. *Arch. Biochem. Biophys.* **483**(2009): 236-245.

Menghini, A., Capuccella, M., Mercati, V., Mancini, L., and Burata, M., 1993. Flavonoids contents in *Passiflora* spp. *Pharmacol. Res. Commun.* **27**: 13–14.

Micali, G., Coppolino, R., Coco, F. L., and Lanuzza, F. 2003. Flavonoids in the pulp obtained from refining citrus fruit juices. *Forum Ware Int.* **2**: 54-61.

Mowlah, G. and Itoo, S. 1982. Guava (Psidium guajava) sugar components and related enzymes at stages of fruit development and ripening. *J. Jpn. Soc. Food Sci. Technol.* **29**: 472-476.

Murari, K. and Verma, R. A. 1989. Studies on the effect of varieties and pulp extraction methods on the quality of guava nectar. *Indian Food Packer.* **43**: 11-15.

Murshid, F. S. B. A. 2013. Determination of antioxidant activities, total phenolic content, total flavonoid content and ascorbic acid in pomegranate (*Punica granatum*) and passion (*Passiflora edulis*) peel, seed and juice. B.Sc. (Hons.) project report, University Technology MARA, Shah Alam, Selangor, 24p.

[NARI] National Agricultural Research Institute. 2004. Passion fruit post harvest care and market preparation. Technical Bulletin No. 14, National Agricultural Research Institute, Mon Repos, East Coast Demerara, Guyana.

Namutebi, A. 1998. Effects of preservation method and storage conditions on the flavour and colour of passion fruit juice. *Afr. Crop Sci. J.* **6**(4): 397-405. 1998.

Oliveira, E. M. S. D. E., Regis, S. A., and Resende, E. D. D. E. 2011. Characterization of yellow passion fruit pulp wastes. *Cienc. Rural.* **41**(4): 725-730.

Patel, R. K., Singh, A., Prakash, J., Nath, A., and Deka, B. C. 2014. Physico-biochemical changes during fruit growth, development and maturity in passion fruit genotypes. *Indian J. Hort.* 71(4): 486-493.

Pertuzatti, P. B., Sganzerla, M., Jacques, A. C., Barcia, M. T., and Zambiazi, R. C. 2015. Carotenoids, tocopherols and ascorbic acid content in yellow passion fruit (*Passiflora edulis*) grown under different cultivation systems. *Food Sci. Technol.* **64**(2015): 259-263.

Piljac-Zegarac, J., Valek, L., Martinez, S., and Belscak, A. 2008. Fluctuations in the phenolic content and antioxidant capacity of dark fruit juices in refrigerated storage. *Food Chem.* **113**(2009): 394-400.

Pruthi, J. S., 1963. Physiology, chemistry and technology of passion fruit. *Adv. Food Res.* **12**: 203-282.

Ram, L., Godara, R. K., Sharma, R. K., and SIddique, S. 2004. Primary and secondary metabolite changes of Kinnow Mandarin fruits during different stages of maturity. *J. Food Sci. Technol.* **41**(3): 337-340.

Ramaiya, S. D., Bujang, J. S., Zakaria, M. H., Kinga, W. S., and Sahrira, M. A. S. 2012. Sugars, ascorbic acid, total phenolic content and total antioxidant activity in passion fruit (*Passiflora*) cultivars. *J. Sci. Food Agric.* **93**: 1198–1205.

Randhawa, J. S., Jawandha, S. K., and Gill, P. P. S. 2009a. Effect of high density polyethylene packaging with edible oil and wax coating on storage quality of 'Kinnow' mandarin. *J. Food Sci. Technol.* **46**(2): 169-171.

Randhawa, J. S., Jawandha, S. K., Mahajan, B. V. C., and Gill, P. P. S. 2009b. Effect of different pre-harvest treatments on quality of ber fruit during cold storage. *J. Food Sci. Technol.* **46**(2): 174-176.

Ranganna, S. 1997. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products* (2nd Ed). Tata McGraw Hill Publishing Company Limited, New Delhi. 1112p.

Rao, T. M., Tripathi, P. C., Karunakaran, G., Sakthivel, T., Sankar, V., and Kumar, R. S. 2014. Passion fruit cultivation in India. Technical bulletin No. 3, Central Horticultural Experiment Station (CHES), ICAR – Indian Institute of Horticulture Research (IIHR), Chettalli- 571248, Kodagu, Karnataka, India,17p.

Rathore, H. A., Masud., T., Sammi, S., and Soomro, A. H. 2007. Effect of storage on physic-chemical composition and sensory properties of mango (*Mangifera indica* L.) variety Dasehari. *Pakist. J. Nutr.* **6**(2): 143-148.

Rudnicki, M., de Oliveira, M. R., Pereira, T. V., Reginatto, F. H., Dal-Pizzol, F., and Moreira, J. C. F. 2005. Antioxidant and antiglycation properties of *Passiflora alata* and *Passiflora edulis* extracts. *Food Chem.* **100**(2007): 719-724.

Saikia, L. and Saikia, J. 2002. Processing of Ou-tenga (*Dillenia indica*) fruit for preparation of squash and its quality changes during storage. *J. Food Sci. Technol.* **39**(2): 149-151.

Sandi, D., Chaves, J. B. P., de Sousa, A. C. G., Parreiras, J. F. M., da Silva, M. T. C., and Constant, P. B. L. 2004. Hunter colour dimensions, sugar content and volatile compounds in pasteurized yellow passion fruit juice (*Passiflora edulis* var. *flavicarpa*) during storage. *Brazilian Arch. Biol. Technol.* **47**(2): 233-245.

Santos, C. E. M. D. O. S., Bruckner, C. H., Cruz, C. D., Siquerira, D. L. D. E., and Pimentel, L. D. 2009. Passion fruit physical traits in function of the genotypes and fruit weight. *Rev. Bras. Frutic.* **31**(4): 1102-1119.

Saptarini, N. M., Wardati, Y., and Juliawati, R. 2013. Antioxidant activity of extract and fraction of yellow passion fruit (*Passiflora flavicarpa*) leaves. *Int. J. Pharmacy Pharma. Sci.* **5**(2): 194-196.

Sarkar, S., Saha, S., Rai, C., and Bhattacharya, S. 2014. Effect of storage and preservatives on antioxidant status of some refrigerated fruit juices. *Int. J. Current Micro. Applied Sci.* **3**(7): 1007-1013.

Selvaraj, Y., Kumar, R. and Pal, D. K. 1989. Changes in sugars, organic acids, amino acids, lipid constituents and aroma characteristics of ripening mango (*Mangifera indica* L.) fruit. *J. Food. Sci. Tech.* **26**: 308-13.

Sharma, K. D., Karki, S., Thakur, N. S., and Attri, S. 2012. Chemical composition, functional properties and processing of carrot-a review. *J. Food Sci. Technol.* **49**(1): 22-32.

Shiomi, S., Wamocho, L. S., and Agong, S. G. 1995. Ripening characteristics of purple passion fruit on and off the vine. *Postharvest Biol.Technol.* **7**(1996): 161-170.

Silva, T. V., Resende, E. D., Viana, A. P., Pereira, S. M. F., Carlos, C. A., and Vitorazi, L. 2008. Determination of peel colour scale and juice yield of yellow passion fruits in different harvest seasons. *Rev. Bras. Frutic.* **30**(4): 880-884.

Silva, T. V., Resende, E. D., Viana, A. P., Rosa, R. C. C., Pereira, S. M., Carlos, L. A., and Vitorazi, L. 2005. Influence of the ripening stages on quality of the yellow passion fruit juice. *Rev. Bras. Frutic.* **27**(3): 472-475.

Simenthy, T. 2015. Proximate analysis and product development in nutmeg rind (*Myristica fragrans* Houtt.). Msc thesis. Kerala Agricultural University, Thrissur, Kerala.

Simirgiotis, M. J., Schmeda-Hirschmann, G., Borquez, J., and Kennelly, E. J. 2013. The *Passiflora tripartita* (banana passion) fruit: a source of bioactive flavonoid *c*-glycosides isolated by HSCCC and characterized by HPLC–DAD–ESI/MS/MS. *Molecules*. **18**(2013): 1672-1692.

Singh, A., Yadav, D. S., Patel, R. K., and Bhuyan, M. 2007. Effect on shelf-life and quality of passion fruit with polyethylene packaging under specific temperature. *Food Sci. Technol.* **44**(2): 201-204.

Singh, O., Pathak, S., Singh., R and Singh, P. 2014. Changes in chemical constituents and overall acceptability of aonla-mango low calorie blended beverages during storage. *Plant Arch.* **14**(1): 343-346.

Singh, S., Singh, A. K., Joshi, H. K., Bagle, B. G., and Dhandar, D. G. 2009. Evaluation of packages for transportation and storability of aonla (*Emblica officinalis*) under semi-arid environment of western India. *J. Food Sci. Technol.* **46**(2): 127-131.

Sobhana, A., Appukutan, A. A., and Raghavan, C. M. 2014. Blending of cashew apple juice with fruit juices and spices for improving nutritional quality and palatability. *Indian J. Hort.* **71(3)**: 397-401.

Subbaiah, K. V., Jagadeesh, S. L., Thammaiah, N., and Chavan, M. L. 2012. Changes in physico-chemical and sensory characteristics of banana fruit cv. Grand Naine during ripening. *Karnataka J. Agric. Sci.* **26**(1): 111-114.

Tchango-Tchango, J., Tailiez, R., Eb, P., Njine, T., and Hornez, J. P. 1997. Heat resistance of the spoilage yeasts *Candida pelliculosa* and *Kloeckera apis* and pasteurization values for some tropical fruit juices and nectars. *Food Microbiol.* **14**: 93-99.

Tomas-Barberan, F. A. and Espin, J. C. 2001. Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. *J. Sci. Food Agric.* **81**: 853-876.

Touati, N., Barba, F. J., Louaileche, H., Frigola, A., and Esteve, M. J. 2015. Effect of storage time and temperature on the quality of fruit nectars: Determination of nutritional loss indicators. *J. Food Qual.* **39**(2016): 209–217.

Uchoa, A. M. A., Costa, J. M. C., Maia, G. A., Silva, E. M. C. S., Carvalho, A. F. F. U., and Meira, T. R. 2008. Physicochemical parameters and crude and dietary fiber content of edible powders from tropical fruit residues. *Seguran. Aliment. Nutric.* **15**(2): 58-65.

Vijayanand, P., Deepu, E., and Kulkarni, S. G. 2013. Physico chemical characterization and the effect of processing on the quality characteristics of Sindura, Mallika and Totapuri mango cultivars. *J. Food Sci. Technol.* **52**(2): 1047-1053.

Wang, S. Y., Chen, C., and Wang, C. Y. 2008. The influence of light and maturity on fruit quality and flavonoid content of red raspberries. *Food Chem.* **112**(2009): 676-684.

Wen, Q., Ma, R., Dong, Q., and Xin, Y. 2006. Studies on postharvest physiology and the storage technology of mango (*Mangifera indica* L.) *J. Food Processing Preservation.* **30**(2006): 670-683.

Wijayawardana, R. and Bamunuarachchi, A. 2002. Effect of different thermal treatments on vitamin-C and microbial sterility of canned drumstick (*Moringa oleifera*). *J. Food Sci. Technol.* **39**(2): 161-163.

Wills, R. B. H., Lee, T. H., Graham, D., McGlasson, W. B., and Hall, E. G. 1982. Postharvest: An introduction to the physiology and handling of fruit and vegetables. New South Wales Univ. Press, Kensington, New South Wales, Australia.

Zagory, D. and Kader, A. A. 1988. Modified packaging of fresh produce. *Food Technol.* **42**(9): 70-77.

Zulueta, A., Barba, F. J., Esteve, M. J. and Frigola, A. 2013. Changes in quality and nutritional parameters during refrigerated storage of an orange juice-milk beverage treated by equivalent thermal and non-thermal processes for mild pasteurization. *Food Biol. Proc. Tech.* **6**: 2018-203.

Appendices

APPENDIX - I

Score card for organoleptic evaluation of shrink wrap packaged passion fruit and passion fruit nectar

Name of the judge:
Date:

Characteristics	Score						
	T1	T2	T3	T4	T5	T6	T7
Appearance							
Colour							
Flavour							
Texture							
Odour							
Taste							
After taste							
Overall acceptability							

9 point Hedonic scale

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

Signature:

APPENDIX II

MEDIA COMPOSITION

1. NUTRIENT AGAR MEDIA (FOR BACTERIA)

Beef extract	: 3 g
Peptone	: 5 g
Sodium chloride	: 5 g
Agar	: 18 g
Distilled water	: 1000 ml
pH	: 6.8-7.2

2. MARTIN ROSE BENGAL AGAR (FOR FUNGUS)

Glucose	: 10 g
Peptone	: 5 g
KH_2PO_4	: 1 g
$MgSO_4\ 7H_2O$	: 0.5 g
Rose Bengal	: 0.035 g
Agar	: 18 g
Distilled water	: 1000 ml

3. SABOURAUD DEXTROSE AGAR MEDIA (FOR YEAST)

Dextrose	: 40 g
Mycological, peptone	: 10 g
Agar	: 15 g
Final pH	: 5.6 ± 0.2
Distilled water	: 1000 m

APPENDIX III

A. Mean rank scores for shrink wrap packaged passion fruit (1 WAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	3.45	3.15	3.25	3.85	3.60	4.65	4.35	3.65
T2	4.00	2.75	4.35	3.75	4.35	4.30	4.30	4.90
T3	3.35	2.85	2.45	3.05	3.15	4.05	3.50	3.25
T4	3.55	4.25	4.30	3.70	5.10	3.80	3.55	4.30
T5	5.25	4.55	4.80	4.30	3.65	3.95	7.95	3.65
T6	3.80	5.50	5.15	4.50	4.10	4.30	3.20	4.40
T7	4.60	4.95	3.70	4.85	4.05	2.95	4.15	3.85
Kendal's W test	0.131	0.314	0.237	0.113	0.108	0.081	0.098	0.087

B. Mean rank scores for shrink wrap packaged passion fruit (2 WAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	2.95	3.20	3.40	3.25	3.30	3.35	2.65	3.05
T2	4.50	4.35	3.55	3.60	3.05	3.00	3.35	3.90
T3	2.40	2.65	1.95	2.80	2.45	2.30	2.25	2.15
T4	4.15	4.10	3.90	4.20	3.70	4.85	4.55	4.55
T5	3.65	3.70	4.70	4.30	4.80	4.00	4.55	4.30
T6	3.35	3.00	3.50	2.85	3.70	3.50	3.65	3.05
Kendal's W test	0.212	0.176	0.282	0.173	0.256	0.303	0.319	0.303

C. Mean rank scores for shrink wrap packaged passion fruit (3 WAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	1.85	1.85	1.65	2.10	1.80	1.55	2.30	2.15
T2	2.00	2.35	2.00	2.50	1.85	2.15	2.00	2.10
T3	2.15	1.80	2.35	1.40	2.35	2.30	1.70	1.75
Kendal's W test	0.038	0.168	0.204	0.496	0.112	0.203	0.120	0.066

APPENDIX IV

A. Mean rank scores for passion fruit nectar

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	2.35	2.20	2.22	3.08	2.38	2.18	2.32	2.18
T2	2.30	2.35	3.95	3.78	3.42	4.30	4.08	4.02
T3	4.62	4.20	3.32	3.58	3.50	3.20	3.00	3.65
T4	4.42	4.28	4.15	3.75	4.52	4.25	4.00	4.15
T5	3.72	3.98	3.38	3.38	3.50	3.10	3.20	3.05
T6	3.58	4.00	3.98	3.45	3.68	3.98	4.40	3.95
Kendal's W test	0.364	0.321	0.187	0.031	0.166	0.227	0.230	0.199

B. Mean rank scores for passion fruit nectar (1 MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	2.00	2.05	2.91	3.45	2.77	2.64	2.64	2.14
T2	2.23	1.73	4.45	3.14	3.64	3.86	3.59	3.14
T3	4.68	5.18	2.64	2.55	2.45	2.82	2.77	3.18
T4	4.68	4.86	4.41	4.82	4.41	4.50	5.00	4.55
T5	3.64	3.68	3.18	3.86	3.77	3.82	3.55	4.00
T6	3.77	3.50	3.41	3.18	3.95	3.36	3.45	4.00
Kendal's W test	0.453	0.673	0.229	0.230	0.207	0.167	0.279	0.262

C. Mean rank scores for passion fruit nectar (2 MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	2.32	1.82	3.18	2.50	2.86	3.32	3.09	3.00
T2	2.45	2.41	3.91	3.14	3.95	4.27	3.68	3.73
T3	4.18	4.18	3.14	4.32	2.95	2.68	3.14	3.14
T4	4.41	4.59	3.91	3.73	3.86	3.73	4.41	4.23
T5	3.59	3.73	2.41	2.55	2.59	2.55	2.45	2.45
T6	4.05	4.27	4.45	4.77	4.77	4.45	4.23	4.45
Kendal's W test	0.272	0.419	0.181	0.360	0.248	0.227	0.198	0.201

D. Mean rank scores for passion fruit nectar (3 MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	1.93	2.00	2.71	2.86	2.64	3.07	3.21	2.64
T2	2.50	2.36	3.64	3.00	3.57	3.71	3.57	3.71
T3	4.71	5.29	2.29	3.36	2.36	2.50	2.64	2.50
T4	5.50	5.29	4.86	4.57	4.71	4.93	4.93	5.43
T5	2.50	2.29	2.57	3.07	3.43	2.14	2.71	2.43
T6	3.86	3.79	4.93	4.14	4.29	4.64	3.93	4.29
Kendal's W test	0.659	0.777	0.457	0.199	0.293	0.364	0.242	0.454

Abstract

VALUE ADDITION OF PASSION FRUIT

(*Passiflora edulis* Sims.)

By

CHARAN S. M.

2014-12-128

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF PROCESSING TECHNOLOGY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 656

KERALA, INDIA

2016

ABSTRACT

Passion fruit (*Passiflora edulis* Sims.) is the fruit of exotic passion flower. Purple and yellow are the two main types of passion fruit grown commercially all around the world. The fruit is valued for its powerful medicinal property and high antioxidant activity. The juice exhibits pronounced flavour and aroma which help in producing high quality beverages and also in flavouring several other products. It is quite delicious, nutritious and liked for its excellent blending property. Even though passion fruit is having many such advantages, its utilization is limited in processing sector mainly due to the short shelf life, minimum juice recovery and intense acidity.

Hence, to overcome these limitations, a study on "Value addition of passion fruit (*Passiflora edulis* Sims.)" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara, with three main objectives *viz.*, to characterize passion fruit accessions for nutritional and biochemical attributes, to extend shelf life through packaging and to impart value through processing.

Passion fruit accessions (yellow and purple) from various localities of Kerala and Kaveri, the only variety of passion fruit released in India by the Central Horticultural Experiment Station (CHES), Chettalli, a sub station of the Indian Institute of Horticulture Research (IIHR), Bengaluru, were collected and characterized based on physico-morphological, nutritive and biochemical parameters. Considerable variation in physical composition, fruit length, fruit diameter, fruit girth, rind thickness and fruit weight was observed among the accessions. Juice recovery was higher in purple types as compared to the yellow ones. Brilliant yellow was the commonly observed colour of the juice in majority of the accessions, followed by vivid yellow and light orangish yellow, based on the descriptor of the Royal Horticulture Society (Universal Colour Language).

Nutritional and biochemical characteristics also varied significantly among passion fruit accessions. Purple types had comparatively higher TSS, reducing

sugars, total sugars and vitamin C whereas, titratable acidity, non-reducing sugars, total carotenoids, total phenols, total flavanoids and antioxidant activity were higher in yellow types.

Mature fruits of a yellow accession grown at the Cashew Research Station (CRS), Madakathara were used at the turning stage for the evaluation of shelf life and assessment of changes in quality through shrink wrap packaging, using polyolefin films of 15, 19 and 25μ thickness, in two methods *viz.*, shrink wrapping of individual fruits and shrink wrapping of areca plates containing fruits. Observations on changes in quality of fruits were recorded at weekly intervals during storage at ambient temperature.

Individually shrink wrapped passion fruit with 25μ polyolefin film gave highest shelf life (26.66 days) whereas the lowest shelf life (7.00 days) was observed in control in which fruits were kept unwrapped. Fruits wrapped in areca plates became unmarketable after two weeks of storage, irrespective of the film thickness. Physiological loss of weight (PLW), total soluble solids, reducing, non reducing and total sugars increased, while, titratable acidity, vitamin-C and total carotenoids decreased in all the treatments during storage. Total phenols and total flavanoids increased during the first week and decreased during second and third week of storage. Sensory quality of passion fruit increased throughout the storage period in all the treatments.

Nectar developed from yellow and purple fruits separately and also by blending juice of yellow and purple fruits in 1:1 ratio with 20% juice and 20^0 Brix was used for storage studies to evaluate the changes in quality under ambient and low temperature conditions for three months.

Total soluble solids, non-enzymatic browning, reducing, non reducing and total sugars increased while, titratable acidity, vitamin-C, total carotenoids, total phenols and total flavanoids decreased during storage of nectar, irrespective of treatments and storage conditions. Qualitative changes in passion fruit nectar were more conspicuous under ambient conditions than under low temperature storage.

Microbial load in all the samples were within the acceptable limits even after three months of storage.

It may be concluded that there exists considerable variation in passion fruit accessions collected from various parts of Kerala. Shelf life of passion fruit can be prolonged through shrink wrap packaging and fruit nectar having 20% juice and 20^0 Brix is organoleptically acceptable. Storage of nectar at low temperature helps to retain quality.