POST HARVEST CHARACTERISATION AND VALUE ADDITION OF SWEET LOVI-LOVI (*Flacourtia* spp.)

by

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(2015-12-014)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled "**POST HARVEST CHARACTERISATION AND VALUE ADDITION OF SWEET LOVI-LOVI (*Flacourtia* spp.)**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"POST HARVEST CHARACTERISATION AND VALUE ADDITION OF SWEET LOVI-LOVI (*Flacourtia* spp.)"** is a record of research work done independently by Ms. Karishma Sebastian under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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We, the undersigned members of the advisory committee of Ms. Karishma Sebastian (2015-12-014), a candidate for the degree of **Master of Science in Horticulture** with major field in Processing Technology, agree that the thesis entitled "**POST HARVEST CHARACTERISATION AND VALUE ADDITION OF SWEET LOVI-LOVI (*Flacourtia* spp.)**" may be submitted by Ms. Karishma Sebastian, in partial fulfilment of the requirement for the degree.

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EXTERNAL EXAMINER

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"Commit your works to the Lord
And your plans will be established"
Holy Bible (Proverbs 16:3)

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Karishma Sebastian

Dedicated to

Major Advisor &

My Beloved Family

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Introduction

1. INTRODUCTION

India holds a significant position on the pomological map of the world. The diverse agro- climatic conditions of this country provide a suitable environment for growing a variety of fruits. Major fruits like mango, banana, pineapple and citrus are available in plenty throughout the year in one season or the other. This has resulted in limited scope for expansion of other minor fruits, though they are nutritious, and the main source of livelihood for poor. Underutilized fruit crops are lesser known plant species, which are well adapted to marginal and stress conditions and contribute to food security, nutrition, dietary and culinary diversification, health and income generation (Thakur, 2014). Most of the underutilized fruits of the tropics are often available only in the local markets and are practically unknown in other parts of the world. But the marketing and research on this untapped resource is in a very low profile. Hence the focus is on exploiting the less utilized plant species for multifarious use.

Lovi-lovi, a member of *Flacourtiaceae* family has its origin in Indian peninsular region is not being utilized for its full potential. *Flacourtia cataphracta* and *Flacourtia inermis* are the two common species found in Kerala homesteads, of which *F. inermis* is sour. *F. cataphracta* is sweet in taste and other species seen are *F. jangomas* and *F. montana* which are also sweet. Sweet lovi-lovi trees are characterized by sharp spines on the trunk, which limits its cultivation. Trees are medium sized, spreading with dark green leaves, and the fruits are red to dark purple in colour with medium sweetness. The fruit is rich in vitamins like ascorbic acid, β carotene, and minerals like calcium, magnesium and iron. The fruits also contain high amount of anthocyanin, which is valued as a bioactive compound. Unfortunately, utilization of this valuable natural resource is less due to lack of knowledge on their nutrient value resulted from limited research work on this fruit.

Poor shelf life and browning of the fruits during storage make them popular only in the area of production. After full maturity, the fruit detach itself from the short pedicel and fall down. At this stage, the fruit possesses maximum organoleptic qualities. Since the pedicel is absent at this stage, the fruit starts browning from the opening at the proximal end of the fruit and favours rapid phenolic oxidation. The extent of browning is more in sweet lovi-lovi fruits when compared to sour lovi-lovi as they are harvested along with their short pedicels. In addition, high temperature and humidity, prevalent in tropical region cause deterioration of the fruits soon after harvest. The short shelf life of the fruit can be overcome with suitable packaging materials and storage condition.

Value addition of minor crops also plays a significant role in marketing, at domestic and distant markets (Srivastava and Sanjeev, 2002). In the present scenario of changing food habits, health awareness and increased demand for novel processed products, standardization of technology for processing and value addition of sweet lovi-lovi will be of immense use. Product with excellent nutritive quality will be having good acceptance. Evaluation of available sweet lovi-lovi accessions for value addition and product standardization will help to increase the status of this under exploited fruit. In this view, present study entitled "Post harvest characterisation and value addition of sweet lovi-lovi (*Flacourtia* spp.)" is proposed with the following objectives:

1. To characterise sweet lovi-lovi fruits based on physico-chemical and morphological parameters
2. To standardise suitable packaging and storage requirements
3. To evaluate the varieties for value addition.

Review of literature

2. REVIEW OF LITERATURE

Lovi-lovi, a minor fruit, belonging to the family *Flacourtiaceae*, has its origin in Indian peninsular region. The tree is common in Kerala homesteads and two species found are *Flacourtia inermis* (sour type) and *Flacourtia cataphracta* (sweet type). Sweet lovi-lovi is a small spreading tree with sharp spines on the trunk and clustered fruits borne on leaf axils are spheroid in shape with dark purple peel and yellowish brown flesh. The fruit is rich in vitamins like ascorbic acid, β carotene and minerals like calcium and phosphorus. The fruits also contain high amount of anthocyanin, which is valued as a bioactive compound. Knowledge on these properties of fruit is meagre and scientific studies are required to assess the nutritive quality of the fruit.

The poor shelf life of sweet lovi-lovi, also limits its consumption. Storage loss of fresh produce in ambient condition is very high in Kerala, due to high temperature and humidity. Hence standardisation of packaging containers and storage condition can help in extending post-harvest life of lovi-lovi fruits. Value addition will also help to prevent the post harvest loss of this valuable natural resource.

2.1 EVALUATION OF GENOTYPES

The quality of any fruit is the result of interaction between the genetic makeup and environment. There exists wide variability in the fruit quality due to genotypic characters. During value addition the fruit quality plays an important role. The physical and biochemical characters of the fruit are vital in determining the superiority of genotypes.

2.1.1 Physical characters

The various aspects of fruit development, including physiological and biochemical aspects were reviewed by Nitsch (1953). During the process of development, fruits become sweet, soft, juicy and coloured.

The morphological characters like fruit length, diameter, weight and volume help to assess the suitability of the fruit in standardizing the procedures for product development and assessing the product recovery. The research on developing processes for product development has been done in many fruit crops with preliminary studies on physical characters.

2.1.1.1 *Fruit length*

Physical characters of wood apple and bael were studied by Pandey *et al.* (2013) and found that fruit length ranged from 6.50 to 8.40 cm in wood apple whereas in bael, fruit length ranged from 7.70 to 17.5 cm.

28 genotypes of aonla having economically important horticultural traits were screened for variability studies by Pandey *et al.* (2014) and the study revealed that the fruit length of aonla ranged from 2.51 to 4.04 cm.

2.1.1.2 *Fruit diameter*

Changes in physical and chemical characteristics of the carambola fruit at different stages of maturity was studied by Narain *et al.* (2001). There is wide variation in fruit composition. The diameter of the ripe carambola fruits was higher (5.24 cm) than that of the green mature (4.69 cm) fruits. Patil *et al.* (2010) also reported similar results in carambola.

The fruit diameter of aonla genotypes varied from 2.87 to 4.81 cm (Pandey *et al.*, 2014).

Corneanu *et al.* (2016) investigated chemical and physical characteristics of seven sweet cherry cultivars and reported that cultivar Alexus ranked highest score (26.40 mm) followed by Andreias (24.80 mm) and Bucium (24.40 mm) whereas, Mihailis bagged lowest for diameter (20.60 mm)

2.1.1.3 *Fruit weight*

Physico-chemical analysis of wood apple fruits revealed that the average fruit weight ranged from 140.08 to 256.65 g (Pandey *et al.*, 2013).

The fruit weight of aonla varied from 13.40 to 54.33 g in different genotypes (Pandey *et al.*, 2014).

On reviewing sweet cherry cultivars, Corneanu *et al.* (2016) stated that highest fruit weight was for Alexus (10.1 g) followed by Andreias (9.1 g) and lowest for Mihailis (6.2 g).

2.1.1.4 *Fruit volume*

Physico-chemical characters of 24 genotypes of ber was studied by Singh and Misra (2011). The study revealed that genotype Umran topped other genotypes in fruit volume (26.23 ml) whereas Chhuhara scored least (11.56 ml).

The volume of wood apple fruits varied from 81.66 to 248.50 ml (Pandey *et al.*, 2013).

Ingale *et al.* (2016) studied the fruit characteristics of aonla (*Phyllanthus emblica* L*)* for designing the equipments for handling, storage and processing of the aonla fruits. The study revealed that the volume was higher for the variety Francis with 42.809 cm^3 followed by Kanchan, Krishna and Chakaiya with 37.565, 31.565 and 27.513 cm^3 respectively.

The fruit characteristics and nutritional composition of mangaba (*Hancornia speciosa* Gomes) fruit was studied by Placido *et al.* (2016). The study revealed that ripe mangaba fruits have a volume of 41.74 cm^3.

2.1.1.5 *Specific gravity*

Reni (2005) evaluated banana varieties for post harvest attributes, and reported that specific gravity was found to be highest in Grand Naine (1.08) and lowest in Matti (0.69).

Pandey *et al.* (2013) reported that specific gravity of wood apple fruits ranged from 1.04 to 1.74.

On comparing the specific gravity values of aonla fruits Singh *et al.* (2015) observed that the values ranged between 1.06 to 1.43 being the highest in Banarasi (1.43) followed by Anand-1 (1.35) while it was least in Francis (1.06) followed by NA-7 (1.13).

2.1.1.6 *Colour of rind*

Morphological and nutritional qualities of six under exploited citrus species *Citrus medica, C. jambheri, C. aurantium, C. limon, C. sinensis* and *C. grandis* were studied by Nalini and Chimmad (2003). The colour of the fruits at harvest stage were lemon yellow to deep yellow in all citrus species, except in *C. aurantium* and *C. jambheri* which were green.

Bhowmick (2011) reported that tender fruits of *Flacourtia jangomas* are green in colour and turns reddish brown or brown at maturity.

A study was conducted in passion fruit by Pongener *et al.* (2013) to determine the correct stage of harvesting and post harvest ripening behaviour. For optimum post harvest storage, proper ripening, and development of characteristic flavour and fruit

quality attributes, passion fruit should be harvested only when half of the fruit surface has developed colour.

Silva *et al.* (2014) conducted a study to evaluate the skin colour and physico-chemical quality of passion fruit at different stages of maturity. Harvesting of passion fruit, when two third of skin turned yellow gave high value for total soluble solids.

Simenthy (2015) described the colour of nutmeg rind using Universal Colour Language and reported as pale greenish yellow during harvest and it changed to moderate orangish yellow when kept under room temperature.

Gjamovski *et al.* (2016) opined that skin colour of sweet cherry cultivars ranged from yellow to blackish.

2.1.1.7 *Colour of flesh*

Colour of pulp is pink in some pummelos and grapefruits and straw coloured in lemons (Ghosh, 2001).

Mitra *et al.* (2010) evaluated 1200 bael trees and observed wide variation in fruit pulp colour. The colours of bael fruit identified are deep yellow, golden yellow, orange and light orange.

The flesh colour of sweet cherry cultivars varied from cream to dark red (Gjamovski *et al.*, 2016).

2.1.1.8 *Colour of juice*

Ali and Rab (2000) opined that wild almonds have attractive deep red juice which can be used as an excellent colourant in other food products such as dairy, custards, bakery and juices.

Colour variations ranging from pale yellow, cream, pale pink, pink and reddish were recorded for juice of different accessions of pummelo (Anupama, 2006).

2.1.1.9 *Seed number*

Anupama (2006) did variability studies in pummelo and noted that the number of seeds per fruit ranged from 3.0 to 38.60

The variation in morphological and physico-chemical traits of bael fruits was studied by Pandey *et al.* (2013). The number of seeds per fruit was found to be 33 to 200.

2.1.1.10 *Physical composition*

Physico-chemical characteristics of pomegranate was evaluated by Zarei *et al.* (2010). The result revealed that highest percentage of aril (57.86 %) and juice (48.01 %) and lowest percentage of peel (42.13 %) and seed (10.49 %) were observed in 140 day old fruits.

2.1.2 Biochemical characters

2.1.2.1 *Total Soluble Solids (TSS)*

Soluble sugars are a universal component of most living organisms and a fundamental building block in biosynthetic process. The TSS is primarily represented by sugars, acids and minerals.

Prasad (1998) reported that ripe fruits of sweet lovi-lovi has high quantities of TSS (20°Brix) which is highly useful for product development.

The TSS of sweet and sour lovi-lovi fruits were recorded as 17 to 19°Brix and 11 to 13°Brix respectively by George (1999).

The percentage of total soluble solids (TSS) increased gradually with the advancement of the ripening process of sunberry fruit (*Physalis minima* L.) and the ripe fruit was found to contain the highest quantity of TSS (6.0 %), while the lowest TSS (2.5 %) occurred in the young fruit (Patel *et al.*, 2009).

It was reported by Mundaragi and Thangadurai (2015) that *Flacourtia montana* fruits has a TSS content of 21.2°Brix.

2.1.2.2 *Acidity*

The titrable acidity is an important physico-chemical parameter which affects the product quality and protects against the development of microorganism to a large extent.

Biochemical analysis of sour lovi-lovi fruits were conducted at different developmental stages by George (1999). Acidity was found to be gradually increasing towards ripening of fruits and maximum acidity (0.80 %) was noted during red ripe stage after 130 to 135 days from fruit set.

Al-Maiman and Ahamad (2002) conducted physico-chemical studies of pomegranate fruits (*Punica granatum*) variety Taifi. The acidity decreased significantly with advance in maturity, being 25.1 mg $100g^{-1}$ for green unripe, 21.2 mg $100g^{-1}$ for half ripe and 19.5 mg $100g^{-1}$ for full ripe fruit.

According to Joy (2003) the acidity of *Flacourtia cataphracta* fruit is 1.86 per cent.

Mundaragi and Thangadurai (2015) opined that fruits of *Flacourtia montana* has an acidity of 0.25 per cent.

2.1.2.3 *Total sugar, non reducing and reducing sugar*

Total, non reducing and reducing sugar contribute to the sweetness of fruits in general. The monosaccharides and disaccharides present in food constitutes sugar.

The reducing sugar content of sweet lovi-lovi at different maturity stages was determined, in which, ripe stage recorded the highest reducing sugars (11.56 %),

followed by three-fourth (7.62 %) and half maturity stages (4.60 %) and lowest (1.10 %) in one-fourth maturity stage (George, 1999).

The reports of Imran *et al.* (2010) on *Morus alba*, *M. nigra* and *M. laevigata* showed that the total sugar, non reducing and reducing sugar ranges from 6.64 to 10.89 g $100g^{-1}$, 1.56 to 1.78 g $100g^{-1}$ and 4.94 to 8.11 g $100g^{-1}$ respectively.

Nikdel *et al.* (2016) conducted a study to compare the physico-chemical properties of five pomegranate culltivars and reported that reducing sugar content ranged between 1.72 to 5.81 mg $100g^{-1}$.

2.1.2.4 *Ascorbic acid*

Ascorbic acid, the water soluble vitamin which is found in many biological systems and foodstuffs like fresh vegetables and fruits, is the most abundant antioxidant in plants.

Musinguzi *et al.* (2007) opined that *Physalis minima* contain 29 mg of vitamin C $100g^{-1}$.

Devi *et al.* (2010) evaluated 15 different kinds of plant species used by the Kani tribals for their food, distributed in eight different families and the study revealed that maximum ascorbic acid content was for *Citrus maxima* (36.62 mg g^{-1}) followed by *Averrhoa bilimbi* and *Citrus medica* with 26.98 and 26.93 mg g^{-1} of fresh juice.

In *Flacourtia jangomas*, the ascorbic acid content was reported as 89.39 mg $100g^{-1}$ (Mohamed, 2012).

The ascorbic acid content in yellow passion fruit harvested at different maturity levels based on peel colour was estimated. The ascorbic acid content in one-

third yellow peel, two-third yellow peel and yellow fruits were 25.98 mg $100g^{-1}$, 24.22 mg $100g^{-1}$ and 26.55 mg $100g^{-1}$ respectively (da Silva *et al.*, 2015).

The proximate analysis done by Mundaragi and Thangadurai (2015) showed that fruits of *F. montana* is a good source of ascorbic acid (23.30 mg $100g^{-1}$).

2.1.2.5 *Anthocyanin*

Anthocyanin is one of the major flavonoids widespread among the groups of phytochemicals. They are phenolic substances, seen distributed in vegetables, giving rise to the blue, purple, red and orange colour of flowers and fruits.

Pigment analysis of ripe sweet lovi-lovi fruits by spectrophotometric method was done by George (1999). Maximum absorbance was obtained at a wavelength of 530 nm and the pigment was identified as anthocyanin.

In pomegranate, a rapid increase in the anthocyanin pigment was observed in the arils between 20 and 80 days of development (Kulkarni and Aradhya, 2005). The highest concentration of anthocyanins (138 mg $100g^{-1}$) was recorded for 100 day old fruit.

Method for extracting anthocyanin in Malay apple flowers was standardized by Markose (2008). Maximum anthocyanin (0.4 mg g^{-1}) was obtained from Malay apple flowers which was incubated in citric acid (4 per cent) for twelve hours.

Alakolanga *et al.* (2015) studied the biological activity of sour lovi-lovi fruits and reported that it contain anthocyanin content of 108 mg cyanidin-3-glucoside equivalents per 100 g of fresh fruits.

Maran *et al.* (2015) extracted anthocyanin pigment and colours from pulp of jamun fruit under different extraction conditions such as extraction temperature (40-

60°C), time (20-100 min) and solid-liquid ratio (1:10 – 1:15 g ml^{-1}) by aqueous extraction method. The total anthocyanin content was found to be 10.58 mg $100g^{-1}$.

Naresh (2016) standardized method for extracting anthocyanin pigments from jamun. The highest content of anthocyanin (61.07 mg $100g^{-1}$) was obtained in acidified solvent extraction method with 20 per cent ethanol and 0.5 per cent citric acid.

2.1.2.6 *Tannin*

Tannin is a polyphenolic biomolecule that binds and precipitates protein and other organic compounds including amino acids and alkaloids.

Radha and Mathew (2007) reported Jackal berry (*Diospyros mespiliformis*) fruits as a source of tannin.

Adepoju and Adeniji (2012) has reported that African star apple (*Chrysophyllum albidum*) contains 1.345 to 1.560 mg tannin $100g^{-1}$.

The tannin content of bael fruits varied from 2.01 to 4.53 per cent among the 48 genotypes analyzed (Pandey *et al.*, 2013).

The tannin content in aonla fruit ranged from 2.80 to 7.08 per cent (Pandey *et al.*, 2014).

2.1.2.7 *Antioxidant activity*

Antioxidant molecule inhibits the oxidation reaction which will produce free radicals, that may damage cells. Antioxidants like ascorbic acid is used as food additives to help guard against food deterioration.

Recent research on antioxidant determination showed that plant foods with rich colours had high scores of oxygen radical absorbance capacity (ORAC) whereas those that were white had low ORAC (Wu *et al.*, 2004).

Amudha and Shanthi (2011) determined the total antioxidant capacity of different plant extracts and expressed as μg of ascorbic acid g^{-1} of plant extract. The highest value found in *Flacourtia cataphracta* (1.27 ± 0.08 μg g^{-1}) followed by *Caesalpinia coriaria* (1.20 ± 0.09 μg g^{-1}).

The antioxidant activities and phytochemical composition of extracts of the unripe fruit of *Flacourtia jangomas* was investigated by Dubey *et al.* (2013). The total antioxidant activity increased with increasing concentration of the extracts with the activity value for unripe fruits ranging from 0.043 to 0.144.

The highest IC_{50} value of any extract exhibited the lowest scavenging activity. Yan *et al.* (2013) indicated that IC_{50} of bilimbi (6.93 ± 0.25 mg ml^{-1}) was significantly higher than carambola (1.88 ± 0.62 mg ml^{-1}) and reported that carambola was a better radical scavenger as compared to bilimbi which was attributed to its high total phenolic content.

Pulp, peel and whole fruit extracts of breadfruit was extracted by Jalal *et al.* (2015) with methanol as solvent and concluded that IC_{50} was 55 ± 5.89 μg ml^{-1}, 123 ± 10.57 μg ml^{-1} and 123 ± 10.86 μg ml^{-1} respectively for the pulp, peel and whole peel part of methanol extract.

The antioxidant activity of nutmeg rind was compared to that of gallic acid and was found that the IC_{50} value of sample was 120 μg ml^{-1} while that of standard was 1.25 μg ml^{-1} showing moderate antioxidant activity (Simenthy, 2015).

A study was conducted by Bao *et al.* (2016) to compare the potent antioxidant activity of common mulberry cultivars. They concluded that black mulberry fruits are abundant in bioactive compounds and rich in antioxidant activity.

2.1.2.8 *Carotenoids*

Carotenoids are tetraterpenoids which give characteristic colour to carrot, corn, banana, rutabaga etc. The most common carotenoids include lycopene and β carotene.

Total carotenoid content which is found to be the most desirable trait in bael, ranged from 1.38 to 2.72 mg $100g^{-1}$ pulp (Pandey *et al.*, 2013).

Pertuzatti *et al.* (2015) studied the variation in carotenoid content of yellow passion fruit grown under organic and conventional systems and they observed that conventional passion fruit (25.10 mg $100g^{-1}$) contained double the content of the carotenoids present in the organic fruits (13.99 mg $100g^{-1}$).

Zaghdoudi *et al.* (2015) suggested accelerated solvent extraction as an efficient extraction process for carotenoid from persimmon (*Diospyros kaki*), peach (*Prunus persica* L.) and apricot (*Prunus armeniaca* L.) and reported that carotenoid content is 67.84 μg g^{-1}, 39.83 μg g^{-1} and 66.22 μg g^{-1} of fruit powder respectively.

2.1.2.9 *Minerals*

Minerals are elements that originate in the soil and cannot be synthesized by living things. Hence it should be supplemented through food and balance of different minerals is necessary for maintaining health. Fruits are major source of necessary minerals.

Concentration of minerals in sweet lovi-lovi fruits at different stages of development was studied by George (1999) and reported that after 80 days from fruit

set, it contains 218, 98, 6.4, 3.0 and 32.0 mg $100g^{-1}$ Ca, Mg, Zn, Mn and Fe respectively on dry weight basis.

George (1999) determined the concentration of Mg in bilimbi fruits during different stages of development. Mg concentration declines from 348.8 mg $100g^{-1}$ dry weight to 96.3 mg$100g^{-1}$ dry weight from seven days after fruit set to 50 days after fruit set.

Musinguzi *et al.* (2007) did chemical analysis on *Physalis minima* and observed that it compares very well with its exotic counterpart, *Physalis peruviana,* in calcium, magnesium and iron.

Adepoju (2009) studied the proximate composition of *Spondias mombin*, *Dialium guineense* and *Mordii whytii* and concluded that *M. whytii* was rich in calcium (300 mg $100g^{-1}$) and phosphorus (170 mg $100g^{-1}$) and the iron content of the three fruits ranged between 2.0 and 4.1 mg $10g^{-1}$.

Valvi and Rathod (2011) estimated the mineral compositions of the eight wild edible fruits where in *Ficus racemosa* contained a highest calcium content (928.4 mg $100g^{-1}$) followed by *Cordia dichotoma* (615.4 mg $100g^{-1}$), *Glycosmis pentaphylla* (505.1 mg $100g^{-1}$) and *Flacourtia indica* (434.8 mg $100g^{-1}$). They also revealed that fruits of *Flacourtia indica* contain 130 mg $100g^{-1}$ Mg, 0.13 mg $100g^{-1}$ P and 15.23 mg $100g^{-1}$ Fe.

Adepoju and Adeniji (2012) conducted a study on African star apple and observed that it contain 365.50 to 425.00 mg $100g^{-1}$ calcium, 211 to 228 mg $100g^{-1}$ phosphorus and low amount of iron (2.23 to 2.29 mg $100g^{-1}$).

Mohamed (2012) reported calcium as the major mineral in *Flacourtia jangomas* fruit (174.75 mg $100g^{-1}$).

Mundaragi and Thangadurai (2015) observed that *Flacourtia montana* fruits contain 0.3 per cent calcium, 0.6 per cent magnesium, 57.1 mg $100g^{-1}$ phosphorus and 0.004 mg $100g^{-1}$ iron.

Simenthy (2015) have reported that potassium (0.810 %), calcium (0.413 %), magnesium (0.130 %) and iron (6.078 mg $100g^{-1}$) as the important minerals present in nutmeg pericarp.

2.1.2.10 *Fibre*

Indigestible cellulose, pentosans, lignin, and other components in food constitutes crude fibre.

Considerable variation in the crude fibre composition was noticed among different species of citrus fruits, with maximum in *Citrus grandis* (0.21 mg $100g^{-1}$) and minimum in *C. sinensis* (0.05 mg $100g^{-1}$) (Nalini and Chimmad, 2003).

Crude fibre content in bael as reported by Pandey *et al.* (2013) is 0.79 to 2.03 g $100g^{-1}$ pulp.

Adepoju and Adeniji (2012) has reported that African star apple (*Chrysophyllum albidum*) contains 4.5 g $100g^{-1}$ crude fibre. Proximate and nutritive analysis of *Flacourtia montana* were carried out by Mundaragi and Thangadurai (2015). The crude fibre content of *F. montana* fruits was found to be 15.12 per cent.

2.1.2.11 *Starch*

Starch is a polymeric carbohydrate produced in green plants as an energy store and is a major constituent of staple foods such as potatoes, rice, wheat, cassava, and corn.

Reni (2005) estimated starch content of banana varieties where in Batheesa contained highest starch content (25.39 %) followed by Kanchikela (23.31 %) and

Monthan (22.46 %). Among the table varieties Zanzibar ranked first (2.29 %) and minimum in Amritsagar (1.05 %).

Patel *et al.* (2009) studied the physico-chemical changes in sunberry (*Physalis minima* L.) fruit during growth and ripening and opined that fruit is a rich source of starch at young stage (170.24 mg g^{-1}), which declined and reached a minimum at ripe stage (78.57 mg g^{-1}).

Starch content of nutmeg rind was 0.95 g $100g^{-1}$ (Simenthy, 2015), while it was higher for peeled sample when compared to that of unpeeled rind.

The maximum value for starch was registered during the middle phase of fruit development (170 mg g^{-1}) at 115 and 107 days after full blooming in pear fruits and later in the season it was almost fully degraded with a simultaneous increase in soluble carbohydrates (Mesa *et al.*, 2016).

2.1.2.12 *Protein*

Protein built from building blocks called amino acids, has a number of important functions. Protein also serves prominent functional roles in food preparation, processing, storage and consumption which contribute to the quality and sensory attributes of food products.

The reports of Kulkarni and Aradhya (2005) on pomegranate arils showed that highest total protein (209 mg $100g^{-1}$) was observed for 20 day old fruit followed by a rapid decrease (66.9 %) in total protein up to 80 days of fruit development and showed a significant increase between 80 and 120 days, finally showing significant decrease after 120 days.

Bhowmick (2011) has reported that *Flacourtia jangomas* fruit contains 3.9 per cent protein.

2.2 PACKAGING AND STORAGE STUDIES

2.2.1 Physiological Loss in Weight (PLW)

A study was conducted by D'Aquino *et al.* (2010) on the influence of film wrapping on quality of pomegranate fruit. Weight loss in wrapped fruits was only 0.6 per cent, while in unwrapped fruits it was 5.1 per cent after 6 weeks at 8°C. A further increase in weight loss of 12.7 per cent was detected in unwrapped fruits against 3.1 per cent of wrapped fruit after 13 weeks of cold storage.

Mphahlele *et al.* (2016) reported that pomegranate fruits packed in shrink wrap has significantly minimum loss in weight, with no significant difference observed after three months of storage. The weight loss remained below 3 per cent of the fruit stored in shrink wrap throughout the storage duration, whereas in the control fruit weight loss was about 16.29 per cent by the third month when the trial was terminated due to excessive shriveling.

Aiswarya (2016) studied the effect of shrink wrap packaging on shelf life and quality of pineapple. After 12 days of storage, unwrapped fruits had significantly higher PLW (16.52 %) compared to shrink wrapped fruits and individually shrink wrapped pineapple in 19μ polyolefin film had the lowest PLW (2.35 %).

Raut *et al.* (2016) reported significantly minimum loss in weight (23.48 %) of sapota (variety Kalipatti) fruits during storage after precooling and packing in polyethylene bags. The control (non precooled) fruits showed maximum shrinkage on 8^{th} day of storage in all treatments of packaging.

2.2.2 Shriveling / browning

The chemical reaction taking place within the food causes browning. Browning affects the colour, flavour, and nutritional value of foods thus reducing its overall acceptability and sensory qualities.

Yellow passion fruit held at 6 to 10°C for three to four weeks had less shrivel (Campbell and Knight, 1983).

Storing of litchi fruits for more than four days cause pericarp browning, which reduces its flavour, affects its commercial value (Zhang and Quantick, 1997).

The pineapple fruits harvested at 50-100 per cent eyes turned yellow stage, recorded signs of external browning on sixth day of storage (Reshma, 2014).

2.2.3 Shelf life

Shelf life is the maximum time the commodity remains fresh and fit for human consumption.

Melo *et al.* (2000) reported that refrigeration (8°C ± 1 and R.H 90-95 %) preserved the innate external appearance of half mature and mature fruits upto 10 days of storage and 20 days in case of green surinam cherries.

Purple passion fruit stored at 10 and 20°C in perforated plastic bags survived for up to 34 days (Schotsmans *et al.*, 2008).

Reshma (2014) carried out post harvest management studies in pineapple and reported that fruits stored at 8 ± 2°C have highest post harvest shelf life (33 days) while those stored at ambient condition had shortest shelf life. Biochemical and sensory qualities were also found to be better in fruits stored at 8 ± 2°C.

Roopa *et al.* (2015) reported that minimally processed and polyethylene packed breadfruit sticks can be stored for up to 45 days at 6°C without incidence of pathogens and coliforms.

Aiswarya (2016) conducted a study on shrink wrap packaging of selected tropical fruits. Individually shrink wrapped mangoes in 25 μ polyolefin film had the longest shelf life (18 days) and the shrink wrapped fruits in areca plates with 19 μ polyolefin film had the shortest shelf life (8 days).

2.2.4 Biochemical characters

2.2.4.1 *Total Soluble Solids (TSS)*

Nanda *et al.* (2001) reported a decline in TSS on individual shrink film wrapping of soft-seeded 'Ganesh' pomegranates with two polyolefin films and skin coating with Semperfresh. D'Aquino *et al.* (2010) also reported similar results for film wrapping of pomegranate.

The controlled atmosphere storage of yellow passion fruits at lower O_2 and higher CO_2 levels were effective to minimize the quality losses and to extend their post harvest life (Cerqueira *et al.*, 2011). The reduction in O_2 levels to less than 5 per cent increased the total soluble sugars during the 30 days of storage.

Unwrapped banana fruits retained the highest TSS (16.87°Brix) after four days of storage, whereas in shrink wrapped fruits, TSS ranged from 14.2 to 16°Brix (Aiswarya, 2016). The study also revealed that after seven days of storage, the unwrapped fruits scored highest TSS of 18.67°Brix.

Mphahlele *et al.* (2016) studied the effect of packaging and storage duration on TSS of fruits. During the first month of storage, no significant change was observed in shrink wrapped fruits. A significant decline in TSS of fruits was observed after the second month of storage in shrink wrapped film, followed by increase in

TSS after the third month of storage. At the end of storage, TSS content declined by approximately 5.89 per cent in individual shrink wrap.

2.2.4.2 *Acidity*

The effect of different modified atmosphere packaging on antioxidant compounds and storage quality of 'Hicrannar' sweet pomegranates was investigated by Selcuk and Erkan (2014). The titratable acidity content was 0.71 per cent at harvest, which decreased after 120 days of storage to 0.44 per cent in modified atmospheric storage while the decrease was to the tune of 0.39 per cent in control.

The reduction in O_2 levels in controlled atmosphere storage of yellow passion fruits to less than 5 per cent dropped the titratable acidity content during the 30 days of storage (Cerqueira *et al.*, 2011).

Mphahlele *et al.* (2016) also reported similar results for shrink wrapped pomegranate in which the titratable acidity of 16.70 g initially got reduced to 12.38 g in shrink wrapped fruits.

In mango, as reported by Aiswarya (2016) there was a decline in acidity of unwrapped mango fruits and was significantly higher as compared to shrink wrapped samples after one week of storage.

2.2.4.3 *Sugars*

Individually shrink wrapped pomegranate recorded a slight decrease in total sugar content during storage at different temperatures (Nanda *et al.*, 2001).

Biochemical properties of banana in the storage condition was studied by Hakim *et al.* (2012). The total sugar content of banana cultivars Amritsagar and Sabri increased with the progress of storage time. The total sugar content gradually increased and reached the peak point after 12 days of storage in both varieties. It was

also noticed that both reducing and non reducing sugar content gradually increased in both the varieties during storage.

2.2.4.4 *Ascorbic acid*

The reduction in O_2 levels in controlled atmosphere storage of yellow passion fruit to less than 5 per cent preserved the vitamin C content, during the 30 days of storage (Cerqueira *et al.*, 2011).

Higher vitamin C content retention was noticed in shrink wrapped banana (16.32 to 18.65 mg $100g^{-1}$) after four days of storage as compared to unwrapped fruits (16.20 mg $100g^{-1}$) (Aiswarya, 2016).

2.3 STUDIES ON VALUE ADDITION OF SWEET LOVI-LOVI

2.3.1 Sensory evaluation

According to Herrington (1991) sensory evaluation technology is a method using skilled management and trained panelists to provide confirmation on the acceptability of the product in terms of product profile, consumer acceptability and consistency. Sensory evaluation of wine, preserve and Ready To Serve beverage comprises the acceptability of these products.

2.3.1.1 *Wine*

Joshi *et al.* (2012) studied effect of dilution on sensory qualities of jamun wine. The TSS and ethanol content of different dilutions ranged from 8.6 to 10°Brix and 9.9 to 11.8 per cent (v/v) respectively, whereas the wine made with 1:1 dilution was found to be best with good sensory qualities.

Herbal wines from wild berry fruits with 8 to 10°Brix had 10 to 15 per cent alcohol and 3.5 to 3.8 pH. It was rated acceptable with good sensory scores for colour, taste, sweetness and astringency (Rana and Singh, 2013).

The fermentation condition of mulberry wine was standardized by Wang *et al.* (2013). He reported that, a pH of 3.2, fermentation temperature of 31.4°C and six days fermentation time were optimal for mulberry fermentation.

Method of preparing bael fruit wine was developed by Panda *et al.* (2014) and he opined that the novel beverage rich in antioxidants have an alcohol content of 7.87 per cent.

Simenthy (2015) standardized a method for making wine from nutmeg rind. Wine prepared using nutmeg rind, sugar and water in the ratio 1:1:1 was found to be best after biochemical estimation and organoleptic evaluation.

The jamun wine was reported to have 6.6 to 9.0°Brix and 6.6 to 7.5 per cent alcohol by Gaikwad *et al.* (2016).

Valim *et al.* (2016) reported that initial conditions of 23 to 25°Brix, 4.8 to 5.0 pH and 1.6 to 2.5 g L^{-1} of yeast concentration was possible to obtain wine from star fruit, with an alcohol content of 11.15°GL, pH from 4.13 to 4.22, a final yeast concentration of 89 g L^{-1}, and fermented yield from 82 to 94 per cent.

2.3.1.1.1 ***Total Soluble Solids (TSS)***

The effect of maturation on physico-chemical and sensory quality characteristics of custard apple wine was studied by Kumar *et al.* (2016). The study revealed that the TSS content was reduced to 9.87°Brix and 9.63°Brix three and six months after storage respectively from 10.13°Brix.

The TSS of strawberry wines from the cultivars Camarosa (9.8 to 9.6°Brix) and Doughlas (9.1 to 8.6°Brix) decreased during storage of three months (Sharma and Joshi, 2003).

2.3.1.1.2 *Phenol*

The phenolic compounds are the most abundant secondary metabolites in plant parts which are essential for the quality of plant derived food products due to oxidative stability and organoleptic characteristics (Lorrain *et al.*, 2013).

Simenthy (2015) reported that nutmeg wine prepared with rind, sugar and water in the ratio 1:1:1 have total phenol content of 0.99 mg g^{-1} initially and 1.17 mg g^{-1} after three months of storage.

Kumar *et al.* (2016) reported a significant decrease in phenol content of custard apple wine during storage. The total phenol content was 226 mg L^{-1} initially which was reduced to 175 mg L^{-1} after six months of maturation period.

Budak (2017) studied the bioactive components of *Prunus avium* L. Black gold (red cherry) and *Prunus avium* L. Stark gold (white cherry) wines and found that the former is having a phenol content of 450 mg gallic acid equivalent L^{-1} and latter with 350 mg gallic acid equivalent L^{-1}.

2.3.1.1.3 *Alcohol content*

The acceptability of wine is mostly influenced by its alcohol content. Amino acid biosynthesis from carbohydrates or deamination or decarboxylation of existing aminoacids bring about alcohol in wines (Sharma *et al.*, 2009).

2.3.1.2 *Preserve*

A preserve is a mature fruit or vegetable piece impregnated with heavy sugar syrup till it become tender and transparent.

Amban (1987) observed that jack fruit preserve is an acceptable and appealing product.

Joy (2003) conducted studies on utilization of underexploited fruits for product development. The study revealed that characters like appearance and colour decreased during storage whereas flavour, texture, taste and overall acceptability gradually increased in lovi-lovi preserve.

Geetha *et al.* (2006) reported that aonla preserve with 70°Brix have maximum acceptability, because of maximum leaching of acids and moisture with maximum sugar which lead to increased concentration of TSS and sugars.

Carrisa macrocarpa fruits with juicy red pulp, *Pouteria viridis* fruits with orange red pulp and attractive flavour, *Psidium guineense* (Brazilian guava) fruits and *Randia formosa* Jacq. (Blackberry jam fruit) are suitable for making preserves (Radha and Mathew, 2007).

2.3.1.3 *RTS beverage*

Verma and Gehlot (2006) reported that overall acceptability of Ready To Serve (RTS) beverage of bael prepared with 10 per cent bael pulp, 14 per cent total soluble solids and 0.28 per cent acidity decreased during storage period, whereas organoleptic score remained above acceptable level even after 60 days of storage.

Methodology for preparation of RTS beverage using osmoextracted pulp and juice of pink watery rose apple, white watery rose apple and malay apple was developed by Markose (2008). Among the three types of fruits, RTS beverage prepared with pink watery rose apple gained more acceptance in sensory evaluation.

Rayaguru *et al.* (2008) undertook a study on RTS beverage from raw stone apple (*Aegle marmelos* Correa). The RTS beverage with 13 per cent pulp, 14°Brix and 0.3 per cent acidity was considered standard based on organoleptic evaluation.

The quality of RTS beverage from jamun was found to be acceptable upto five months of storage (Das, 2009).

Prakash *et al.* (2014) conducted studies on preparation and preservation of RTS beverage from phalsa fruit and concluded that RTS beverage of 10 per cent juice, 13 per cent TSS and 0.2 per cent acidity were ideal with highest score in organoleptic test.

2.3.2 Microbial study

Joy (2003) reported that no visible presence of microflora was observed in sweet lovi-lovi preserve throughout the storage of six months.

Irrespective of the storage conditions, bacteria and yeast counts were found negligible in sweetened 'Nagpur' Mandarin orange juice throughout the storage period. 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).

Rayaguru *et al.* (2008) reported that raw stone apple (*Aegle marmelos* Correa) RTS beverage could be stored safely upto eight months. Though there was a gradual increase in total mould count and total bacterial count, the level was well within the safe limits till the end of eight months.

The suitability of *Cydonia oblonga* (Quince) fruit for value addition was studied by Kumari *et al.* (2013). The quince RTS beverage was free from any microbial load at fresh and three months of storage but thereafter microbial growth were observed and the mean values of total bacterial count for RTS beverage were 1.38 and 1.52 (CFU ml^{-1}) for six and nine months of storage interval, respectively.

Priya and Khatkar (2013) studied the effect of processing methods on keeping quality of aonla (*Emblica officinalis* Gaertn.) preserve. Preserves prepared by 'no-cooking method' with sugar syrup of 70°Brix were most effective in retaining the nutrients, with low bacterial and mould count as compared to the traditional methods.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on 'Post harvest characterisation and value addition of sweet lovi-lovi (*Flacourtia* spp.)' was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur during 2015-2017.

The whole programme was divided into three major experiments

3.1 Evaluation of genotypes

3.2 Packaging and storage studies

3.3 Studies on value addition of sweet lovi-lovi

3.1 EVALUATION OF GENOTYPES

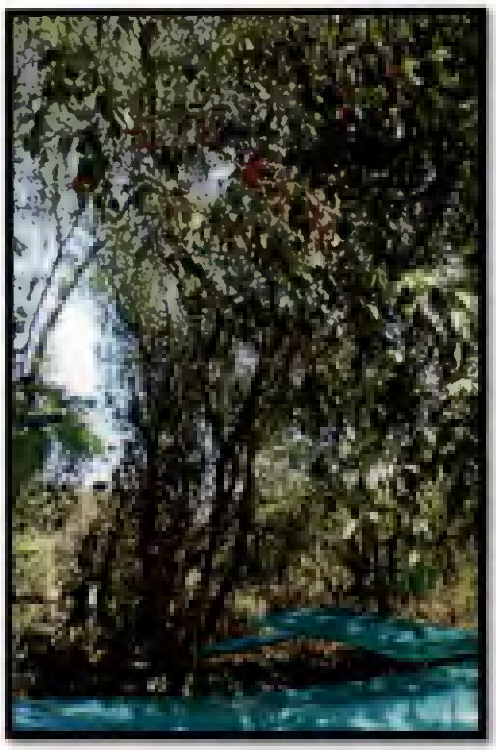
The sweet lovi-lovi accessions were collected from three centers (Plate 1) located at Vellanikkara namely, college orchard of Department of Fruit Science, Central nursery and Regional station of National Bureau of Plant Genetic Resources.

Table 1. Details of *Flacourtia* spp. used for study

Accessions	Species	Location
Accession 1	*Flacourtia cataphracta*	College orchard, Dept. of Fruit Science
Accession 2	*Flacourtia cataphracta*	College orchard, Dept. of Fruit Science
Accession 3	*Flacourtia cataphracta*	College orchard, Dept. of Fruit Science
Accession 4	*Flacourtia cataphracta*	Central Nursery
Accession 5	*Flacourtia montana*	NBPGR

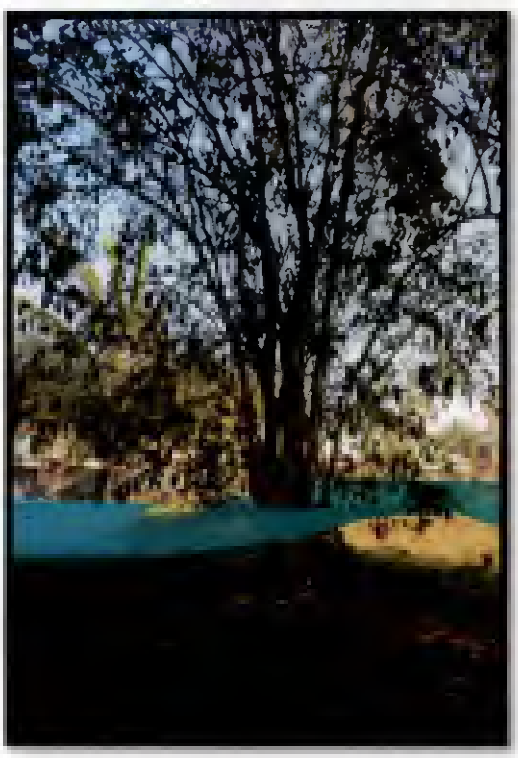
Sweet lovi-lovi fruits (Plate 2) were collected from the trees when they were fully ripe during the main harvesting season (Feb. – Apr.). The sorting of fruits were done to remove the damaged and undesirable ones and selected fruits were carefully

Accession 1



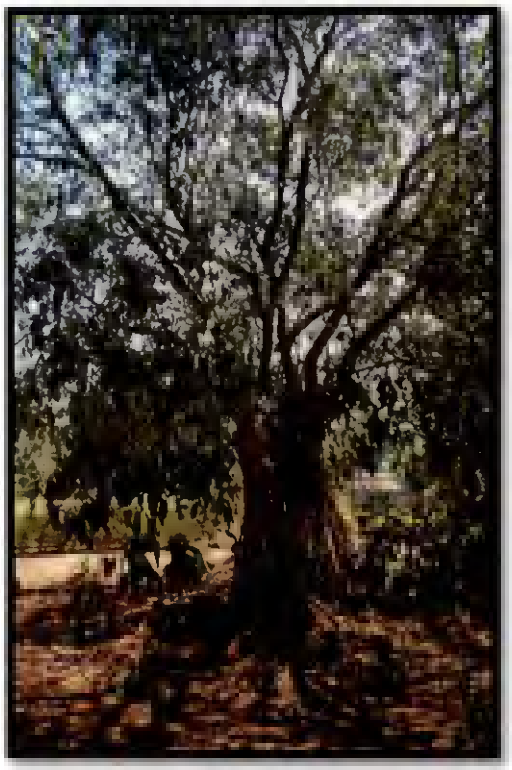
Accession 2

Accession 3



Accession 4

Plate 1. Sweet lovi-lovi (*Flacourtia cataphracta*) trees from different locations



Accession 5

Plate 1a. Sweet lovi-lovi (*Flacourtia montana*) tree

Accession 1

Accession 2

Accession 3

Accession 4

Accession 5

Plate 2. Sweet lovi-lovi fruits of five accessions

transported to the laboratory of the Department of Processing Technology in polythene bags. They were then washed in clean water in order to minimize the field heat. The physico-chemical properties of sweet lovi-lovi fruits were studied without any delay and the mean value of the biochemical constituents were found out.

3.1.1 Physical parameters

Physical characters were studied in sweet lovi-lovi fruits.

3.1.1.1 *Fruit length*

The length of fruit was measured using digital vernier caliper as an average of ten randomly selected fruits and expressed in centimeter (cm).

3.1.1.2 *Fruit diameter*

The diameter of the fruit was measured at the widest point of the fruit using digital vernier caliper and expressed in centimeter (cm) as the average of ten fruits.

3.1.1.3 *Fruit weight*

Individual fruit weight was recorded and expressed in gram as the average of ten fruits.

3.1.1.4 *Fruit volume*

The volume of the fruit was estimated by water displacement method and expressed in millilitres as the average of ten fruits.

3.1.1.5 *Specific gravity*

Specific gravity was computed by dividing weight by volume of the ripe fruit.

3.1.1.6 ***Colour of rind***

Rind colour of sample was visually observed and identified with the help of Universal Colour Language (UCL). The Universal Colour Language is a colour menu defined by the Inter-society Colour Council, National Bureau of Standards in 1946 and approved by Royal Horticultural Society (Anonymous, 1999). A valid UCL colour name contains a value, plus hue and a hue modifier which are denoted by alphabets and numbers.

3.1.1.7 ***Colour of flesh***

Universal Colour Language (UCL) was used for observing and identifying colour of flesh.

3.1.1.8 ***Colour of juice***

Identification of juice colour was done by visual observation with the help of Universal Colour Language (UCL).

3.1.1.9 ***Seed number***

The number of seeds in ten sweet lovi-lovi fruits was counted and mean worked out.

3.1.1.10 ***Physical composition***

Weight of fruit was recorded and then separated into different components by cutting and peeling. Weight of skin, pulp and seed were recorded separately and relative proportion of each of the component to total weight was worked out.

3.1.2 Biochemical parameters

3.1.2.1 *Total soluble solids (TSS)*

TSS of the juice extracted from the fruit was measured using a hand refractometer (Erma) (range 0-32°Brix) expressed in degree brix (A.O.A.C, 1980).

3.1.2.2 *Acidity*

The titrable acidity was estimated by titrating with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator and expressed as per cent of citric acid. A known weight of sample was ground using distilled water and made upto 100 ml in a standard flask. An aliquot of 10 ml from this was titrated against 0.1 N NaOH (Ranganna, 1997).

$$\text{Acidity} = \frac{\text{Normality} \times \text{titre value} \times \text{equivalent weight} \times \text{volume made up} \times 100}{\text{Weight of sample} \times \text{aliquot of sample} \times 1000}$$

3.1.2.3 *Total sugar, reducing and non reducing sugars*

Total sugars and reducing sugars were determined according to the procedure described by Ranganna (1997) using Fehling's solution and expressed as gram of glucose per 100 grams of pulp. The estimation of non reducing sugars was done by subtracting the reducing sugars from the total sugars and expressed as grams of glucose per 100 grams of pulp.

3.1.2.4 *Ascorbic acid*

Five grams of the sample was taken and extracted with four per cent oxalic acid. Ascorbic acid was estimated by using standard indicator dye 2, 6-dichlorophenol indophenol and expressed as mg $100g^{-1}$ of fruit (Sadasivam and Manickam, 1996).

3.1.2.5 *Anthocyanin*

Hot water extraction of the sample was done by placing fifty grammes of the homogenate in the beaker containing water equal to thrice the quantity of homogenate and then it was boiled for about five to six hours at 60-70°C for complete extraction of the pigment. After extraction, the pigment was filtered with Whatman filter paper and stored in glass bottles at refrigerated condition by covering with aluminium foil for protection from light (Harbone, 1978).

Flow chart for extraction of anthocyanin pigment

Harvest ripe sweet lovi-lovi fruits

↓

Wash thoroughly

↓

Extract pulp and remove seeds

↓

Homogenize the pulp

↓

Extract with hot water

↓

Filter the extract using Whatman filter paper

↓

Store in glass bottles covered with aluminium foil in refrigerator

Anthocyanin content estimation was done based on the method given by Iland *et al.* (1996). Malvidin-3-glucoside was used as the standard. 0.2 ml of the extract was transferred to a test tube. 3.8 ml of 1.0 M HCl was added to it and incubated for 22 hours at room temperature by covering with parafilm. This step is critical in allowing full expression of the colour. The absorbance of the acidified diluted extract was measured at 520 nm using a 1.0 M HCl blank in a UV spectrophotometer.

Anthocyanin content

$$= \frac{\text{Absorbance at 520 x D.F x Final volume (ml) x Berry weight (g) x 1000}}{\text{D X 100 X Homogenate weight (g)}}$$

Where,

D.F = Dilution factor

D = absorbance of one per cent w/v solution of malvidin-3-glucoside

3.1.2.6 *Tannin*

Tannin content of sweet lovi-lovi fruit was determined by the Folin- Denis method (Schanderl, 1970).

0.5 g sample was weighed and transferred to a 250 ml conical flask. Water (75 ml) was added and the flask was heated gently for 30 minutes. Aliquots were centrifuged at 2000 rpm for 20 minutes. The supernatant was collected in 100 ml volumetric flask and volume made up. 1 ml aliquot was transferred into 100 ml volumetric flask containing 75 ml water, 5 ml of Folin-Denis reagent and 10 ml sodium carbonate were added and made up to 100 ml. Optical density was recorded at 700 nm in a spectrophotometer after 30 minutes. Blank was prepared with water.

A standard graph was drawn using serial dilution of tannic acid solution and from the graph tannin content of fruit was estimated. Tannin was expressed as mg g^{-1}.

3.1.2.7 *Antioxidant activity*

The antioxidant activity of the sweet lovi-lovi was estimated by the method suggested by Blois (1958) using DPPH (1,1-diphenyl-1-picryl hydrazine). To various concentrations of the sample, methanolic solution containing DPPH radicals (0.1 mM) was added and shaken vigorously. The reaction mixture was then left to stand

for thirty minutes in dark. After the incubation period the absorbance was measured at 517 nm against the corresponding test blanks. The percentage inhibition of DPPH free radical was calculated using the formula,

$$\text{Per cent inhibition} = \frac{\text{Control} - \text{Sample} \times 100}{\text{Control}}$$

The sample concentration providing 50 per cent 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.

3.1.2.8 ***Carotenoids***

A known weight of sample was ground in a pestle and mortar with acetone. The extract was poured into a conical flask. Extraction was continued till the residue became colourless. The extract was transferred to a separating funnel and then 10 - 15 ml of petroleum ether, little amount of distilled water and a little amount of anhydrous sodium sulphate was added. Then it was shaken well. The upper layer was collected and the lower layer was re-extracted. Extraction of acetone phase was repeated with small volume of petroleum ether till it became colourless. The extract was collected into a volumetric flask by passing through cotton containing small amount of anhydrous sodium sulphate and then the volume was made up with petroleum ether. The colour was measured at 452 nm using petroleum ether as blank in spectrophotometer. Results were expressed as μg $100g^{-1}$ of material (Ranganna, 1997).

$$\text{Total carotenoids } (\mu g\ 100g^{-1}) = \frac{3.857 \times \text{optical density} \times \text{volume made up} \times 100}{\text{Weight of the sample}}$$

3.1.2.9 *Minerals*

3.1.2.9.1 *Calcium*

The calcium content of sample was estimated by precipitating calcium as calcium oxalate and dissolving precipitate in hot dilute H_2SO_4 and titrating with standard potassium permanganate (Ranganna, 1997).

Saturated ammonium oxalate solution (10 ml) and two drops of methyl red indicator are added to 20 ml of aliquot of ash solution obtained by dry ashing. The solution is made alkaline by the addition of dilute ammonia and then acidic with few drops of acetic acid until the colour is faint pink. The solution is then heated to the boiling point and allowed to stand at room temperature for four hours followed by filtering and washing with water till the filtrate is oxalate free. The point of filter paper was broken with glass rod and the precipitate was washed using hot dilute H_2SO_4 and titrated with 0.01 N $KMnO_4$ to the first permanent pink colour. Then filter paper is added to the solution and titration is completed.

$$\text{Calcium} = \frac{\text{Titre value} \times 0.2 \times \text{Total volume of ash solution} \times 100 \text{ (mg } 100g^{-1})}{\text{Volume taken for estimation} \times \text{Weight of sample taken for ashing}}$$

3.1.2.9.2 *Magnesium*

Magnesium present in sweet lovi-lovi fruits were estimated using method suggested by Perkin – Elmer (1982). 1 gram of sweet lovi-lovi fruit was predigested using 10 ml of 9:4 ratio of nitric and perchloric acid. The prepared diacid of the fruit sample was used for estimation of magnesium in Atomic Absorption Spectrophotometer.

3.1.2.9.3 ***Iron***

The iron content of sample was determined by converting iron to ferric form using potassium persulphate and titrating thereafter with potassium thiocyanate to form the red ferric thiocyanate measured colorimetrically at 480 nm (Ranganna, 1997).

$$\text{Iron} = \frac{\text{OD of sample} \times 0.1 \times \text{Total volume of ash solution} \times 100 \text{ (mg } 100g^{-1})}{\text{OD of standard} \times 5 \times \text{Weight of sample taken for ashing}}$$

3.1.2.10 ***Crude fibre***

Crude fibre content of the sample was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978).

A known weight of the sample was first treated with acid and subsequently with alkali. The residue obtained after final titration was weighed, incinerated, cooled and weighed again. The crude fibre was given by the difference in weight and expressed as percentage.

3.1.2.11 ***Starch***

The starch content was analysed colorimetrically using anthrone reagent as suggested by Sadasivam and Manickam (1996). Starch content was estimated by hydrolyzing starch into simple sugars. The sample (0.5 g) was treated with 80 per cent ethanol to remove sugars and then starch was extracted with perchloric acid. Sample extract (0.2 ml) was pipetted and tubes with one ml water served as blank. To each test tube including blank, anthrone reagent (4 ml) was added. The tubes were kept in boiling water bath for 8 minutes and cooled rapidly. The compound formed a green coloured product and its absorbance was measured at 630 nm which was expressed as percentage.

3.1.2.12 *Protein*

The protein content of sweet lovi-lovi was determined by Lowry's method (Lowry *et al.*, 1951).

The sample (0.5 g) was ground well in a mortar and pestle with 5 to 10 ml of phosphate buffer. It was centrifuged and supernatant needed for protein estimation was pipetted out into a series of test tubes. Sample extract (0.2 ml) was pipetted out in other test tubes. Tubes with one ml water served as blank.

To each test tube including blank, alkaline copper solution (5ml) was added. It was mixed well and allowed to stand for 10 minutes. To all test tubes Folin-ciocalteau reagent (0.5 ml) was added, mixed well and incubated at room temperature in the dark for 30 minutes till blue colour was developed. Optical density values were recorded in a spectrophotometer at 660 nm. A standard graph was drawn and the amount of protein in the sample was calculated.

3.2 PACKAGING AND STORAGE STUDIES

Ripe fruits of sweet lovi-lovi from Accession 2 belonging to *Flacourtia cataphracta* grown at college orchard, Department of Fruit Science were used for packaging and storage studies. Fruits free of damage and bruises were washed in clean tap water followed by immersion in 100 ppm sodium hypochlorite solution. The treated fruits were spread out to remove excess surface moisture. The surface dried fruits were packaged in six different materials. Observations on changes in quality of fruits were recorded daily during storage at ambient temperature, refrigerated condition (5 ± 2°C) and in cold storage (12 ± 2°C) condition.

The treatments are,

T_1- Control (Fruits kept unwrapped)

T_2- Polythene cover (200 gauge) with ventilation

T_3- Polythene cover (200 gauge) without ventilation

T_4- Polypropylene punnets

T_5- Polystyrene box wrapped with cling film

T_6- Shrink wrapping in areca plate

3.2.1 Physiological loss in weight (PLW)

PLW was calculated on the initial weight basis as suggested by Srivastava and Tandon (1968) at daily interval and expressed as percentage.

$$PLW = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

3.2.2 Shriveling / Browning

Browning of the fruits was observed visually as black/ brown discolouration and lesions appearing on fruit surface.

3.2.3 Shelf life

The shelf life was calculated as number of days from harvest till the fruits remained marketable. The fruits were rated not marketable when more than 25 per cent of the fruits in a lot showed incidence of spoilage, browning and microbial growth.

3.2.4 Biochemical analysis

3.2.4.1 *TSS*

Same as mentioned in 3.1.2.1

3.2.4.2 *Acidity*

Same as mentioned in 3.1.2.2

3.2.4.3 *Sugars*

Same as mentioned in 3.1.2.3

3.2.4.4 *Ascorbic Acid*

Same as mentioned in 3.1.2.4

3.3 STUDIES ON VALUE ADDITION OF SWEET LOVI-LOVI

3.3.1 Product diversification

3.3.1.1 *Wine*

Ripe fresh and good quality sweet lovi-lovi fruits were selected for wine preparation. The fruits were crushed and must obtained was transferred to porcelain jar. Sugar was added to raise the TSS and lukewarm water was added. Crushed fruit, sugar and water was added in 1:0.75:1 ratio. Starter solution with yeast was prepared and kept for 10 to 15 minutes until frothing was observed and it was added. After adding all the ingredients, the jar was sealed. The contents were stirred without opening the jars on alternate days for a period of 21 days. The wine was kept for clarification and the clear wine decanted after 10 days, transferred to sterilized glass bottles and sealed.

Sensory attributes of wine prepared from all accessions were evaluated on a nine point hedonic scale by a panel of 15 semi trained judges. The best wine was stored for a period of three months. The TSS, phenol content and alcohol content of wine from best accession was also analysed during initial and final months of storage. The yeast counts were observed during the initial and final months.

3.3.1.2 *Preserve*

The preserve was prepared (Appendix I) from all the accessions and sensory attributes of preserve were evaluated on a nine point hedonic scale initially with a panel of 15 semi trained judges. The best preserve was stored for three months under ambient conditions. The microbial counts were observed during the initial and final months.

3.3.1.3 *RTS beverage*

The RTS beverage was prepared by standard procedure according to FSSAI specification (TSS 15°Brix and 15 per cent juice, 0.3 per cent acidity) (Appendix Ia) and sensory attributes were evaluated on a nine point hedonic scale initially with a panel of 15 semi trained judges and the best RTS beverage were stored for three months under refrigerated conditions. The microbial counts were observed during the initial and final months.

3.3.2 Sensory evaluation

The prepared products were evaluated using a nine point hedonic scale to assess the colour, appearance, flavour, taste, texture, after taste and overall acceptability of the products by a panel of 15 semi trained judges (Appendix II). For organoleptic test, Kendalls co-efficient of concordance was performed and the mean rank scores were taken to differentiate the best product. The best products were stored for three months and sensory evaluation was done at monthly intervals.

3.3.2.1 *TSS*

Same as mentioned in 3.1.2.1

3.3.2.2 *Phenols*

Phenol content of sweet lovi-lovi wine was determined using Folin-Ciocalteau reagent in which phenols react with phosphomolybdic acid in Folin-Ciocalteau reagent in alkaline medium and produce blue coloured complex (molybdenum blue), which indicates the phenol content (Malick and Singh, 1980).

1 g of sweet lovi-lovi wine was weighed and ground with 10 times volume of 80 per cent ethanol. The homogenate obtained were centrifuged for 20 minutes. Supernatant was collected. The residue was re extracted with five times the volume of 80 per cent ethanol and centrifuged and supernatants was pooled, which was evaporated to dryness. Residue was dissolved with 5 ml distilled water. To 0.5 ml aliquot 3 ml water, 0.5 ml Folin- Ciocalteau reagent and 2 ml of 20 per cent sodium carbonate was added. The test tube was placed in boiling water for one minute and absorbance was read at 650 nm against a reagent blank after cooling. A standard curve was prepared using different concentration of catechol.

The concentration of phenol in test sample was find out using standard curve and expressed as mg $100g^{-1}$.

3.3.2.3 *Alcohol content*

100 ml of sample and 50 ml of distilled water was taken in round bottom flask and kept for distillation. Distillation is done until a 90 ml of alcohol is collected and it is made upto 100 ml with distilled water. The alcohol is weighed in a specific gravity bottle and the specific gravity value is then compared with standard alcohol percentage chart.

3.3.3 Microbial load – initial and three months after storage

Enumeration of total microorganisms

The microbial population of the above products was assessed initially as well after a period of three months. The quantitative assay of the micro flora was carried out by serial dilution pour plate technique (Johnson and Curl, 1972). Nutrient agar medium, Rose Bengal agar medium and Sabourd Dextrose agar medium were used for the enumeration of bacterial, fungal and yeast population of the products respectively (Appendix III).

One gram of sample was suspended in100 ml of sterile distilled water taken in a conical flask and shaken thoroughly for 20 minutes in an orbit shaker. From this 1 ml of the supernatant was accurately pipetted out using a micropipette into a test tube containing 9 ml of sterile distilled water to get 10^{-2} dilution. This procedure was again repeated to get 10^{-5} dilution. One ml each of 10^{-5} and 10^{-3} dilution was used for enumeration of total bacterial, fungal and yeast count of the sample respectively. The bacterial count was recorded after two days whereas fungal and yeast count was recorded four days after inoculation. The number of microorganisms per gram of sample was calculated by the formula

$$\text{No. of colony forming units (CFU) per gram of the sample} = \frac{\text{Mean number of CFU} \times 100}{\text{Quantity of the sample weight}}$$

Results

4. RESULTS

The results of the present study entitled "Post harvest characterisation and value addition of sweet lovi-lovi (*Flacourtia* spp.)" is presented in this chapter under the following sections.

4.1 Evaluation of genotypes

4.2 Packaging and storage studies

4.3 Studies on value addition of sweet lovi-lovi

4.1 EVALUATION OF GENOTYPES

Sweet lovi-lovi trees being hardy in nature can easily grow under adverse soil and climatic conditions. These neglected and underutilized species play a crucial role in maintaining good health and prevention of various diseases. Hence the objective of this study was set out to find the nutritional benefits of this crop. The sweet lovi-lovi fruits harvested during the Feb. – Apr. season was used for analysis. Ripe red fruits, which attained full maturity, were used for taking observations. Observations on the physical and biochemical attributes of sweet lovi-lovi were recorded and presented below.

4.1.1 Physical parameters

Ten fruits were randomly collected from each accessions to record the physical attributes like fruit length, fruit diameter, fruit weight, fruit volume, specific gravity, seed number and physical composition using standard procedures.

4.1.1.1 *Fruit length (cm)*

Fruit length of sweet lovi-lovi accessions showed significant variation. Fruit length ranged from 1.30 to 1.59 cm (Table 2). Acc. 1 had the highest fruit length (1.59 cm) and the lowest (1.30 cm) was recorded in Acc. 5.

4.1.1.2 *Fruit diameter (cm)*

Fruit diameter of sweet lovi-lovi accessions showed significant variation among accessions ranging from 1.44 to 1.87 cm (Table 2). Acc. 2 had the highest fruit diameter (1.87 cm) and the lowest (1.44 cm) was recorded in Acc. 5.

4.1.1.3 *Fruit weight (g)*

The weight of sweet lovi-lovi fruits from different accessions varied significantly. The highest fruit weight (3.92 g) was for Acc. 2 and the lowest (2.29 g) was recorded in Acc. 5 (Table 2). High fruit weight is considered to be a good processing quality.

4.1.1.4 *Fruit volume (ml)*

Fruit volume is considered as a quality contributing to the value of processed products like preserve, jam etc. The fruit volume which showed significant difference among the different accessions ranged from 1.95 to 3.6 ml (Table 2). Acc. 4 had the highest fruit volume (3.6 ml) and the lowest (1.95 ml) was recorded in Acc. 5.

4.1.1.5 *Specific gravity*

Specific gravity did not show any significant difference among sweet lovi-lovi accessions (Table 2).

4.1.1.6 *Colour of rind*

The data on colour of sweet lovi-lovi accessions is presented in Table 2. The skin colour was described using Universal Colour Language (UCL) and it was deep pink (51 B) in Acc. 1 and Acc. 3, deep pink (50 B) in Acc. 2, whereas it was deep yellowish pink (47 C) in case of Acc. 4 and strong pink (50 C) in Acc. 5.

4.1.1.7 *Colour of flesh*

Universal Colour Language (UCL) was used to describe the flesh colour. Pale yellow was the commonly observed colour in all accessions and it was pale yellow (18 C) in Acc. 1 and Acc. 4, pale yellow (19 D) in Acc. 2, pale yellow (18 D) in Acc. 3 and pale yellow (20 C) in Acc. 5 (Table 2).

4.1.1.8 *Colour of juice*

The juice colour of sweet lovi-lovi was described as Vivid purplish red in all accessions as per Universal Colour Language (UCL). Vivid purplish red (61 C) in Acc. 1 and Acc. 3, Vivid purplish red (61 B) in Acc. 2, Vivid purplish red (63 A) in Acc. 4 and Vivid purplish red (63 B) in Acc. 5 was observed (Table 2).

4.1.1.9 *Seed number*

The presence of seeds was observed in sweet lovi-lovi fruits. Number of seeds showed significant variation among accessions, ranging from 10.30 to 11.90 (Table 2). Acc. 3 had the lowest number of seeds (11.90) and highest was recorded in Acc. 5 (10.30).

4.1.1.10 *Physical composition (%)*

The percentage of each component of the fruit namely skin, flesh and seed is the physical composition of fruit (Table 2). Significant difference was observed in the physical composition among the accessions. The pulp percentage ranged from 70.12 to 78.78 per cent. Acc. 2 showed maximum pulp percentage (78.78 %) while the minimum (70.12 %) was observed in Acc.5. The pulp percentage of the fruit contributes to the processing quality. The skin percentage ranged from 8.18 to 11.09 per cent. Acc. 1 showed maximum skin percentage (11.09 %) while the minimum (8.18 %) was observed in Acc.5. Also, seed percentage ranged from 12.38 to 21.69

Table 2. Physical characters of sweet lovi-lovi accessions

Accessions	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit volume (ml)	Specific gravity	Seed number	Physical composition (%)		
							Skin	Pulp	Seed
Acc. 1	1.59	1.69	3.68	3.35	1.14	11.6	11.09	71.28	17.61
Acc. 2	1.41	1.87	3.92	3.55	1.13	11.8	8.82	78.77	12.38
Acc. 3	1.34	1.68	2.72	2.75	1.05	10.3	10.71	73.07	16.20
Acc. 4	1.48	1.82	3.75	3.60	1.17	11.2	9.80	76.69	13.50
Acc. 5	1.30	1.44	2.29	1.95	1.30	11.9	8.17	70.12	21.69
SE	0.04	0.05	0.24	0.26	0.14	0.38	0.53	1.63	1.43
CD (0.05)	0.11	0.15	0.69	0.74	NS	1.10	1.51	4.65	4.06

Table 2. continued

Accessions	Colour of skin	Colour of flesh	Colour of juice
Acc. 1	Deep Pink – 51 B	Pale Yellow – 18 C	Vivid Purplish Red – 61 C
Acc. 2	Deep Pink – 50 B	Pale Yellow – 19 D	Vivid Purplish Red – 61 B
Acc. 3	Deep Pink – 51 B	Pale Yellow – 18 D	Vivid Purplish Red – 61 C
Acc. 4	Deep Yellowish Pink – 47 C	Pale Yellow – 18 C	Vivid Purplish Red – 63 A
Acc. 5	Strong Pink – 50 C	Pale Yellow – 20 C	Vivid Purplish Red – 63 B

per cent in which Acc. 2 had the lowest seed percentage, whereas, the highest was recorded in Acc. 5.

4.1.2 Biochemical parameters

4.1.2.1 *Total soluble solids (TSS) (°Brix)*

The total soluble solids varied significantly among the different sweet lovi-lovi accessions. TSS of sweet lovi-lovi accessions ranged from 17 to 21.33°Brix (Table 3). Acc. 5 had the highest TSS (21.33°Brix) while the lowest (17°Brix) was recorded in Acc. 4.

4.1.2.2 *Acidity (%)*

Significant variation in titrable acidity was observed among sweet lovi-lovi accessions. Titrable acidity of sweet lovi-lovi accessions ranged from 0.92 to 1.42 per cent (Table 3). Lowest acidity (0.92 %) was recorded in Acc. 3 and highest acidity (1.42 %) was observed in both Acc. 1 and 5.

4.1.2.3 *Total sugar, reducing and non reducing sugars (%)*

Reducing, non reducing and total sugar showed significant variation among different sweet lovi-lovi accessions. The reducing sugar content ranged from 6.68 to 12.13 per cent (Table 3). Acc. 1 had the highest reducing sugar content (12.13 %) and the lowest (6.68 %) was recorded in Acc. 5. Non reducing sugar content ranged from 0.67 to 1.33 per cent (Table 3) in which the highest non reducing sugar content (1.33 %) was recorded in Acc. 2 and lowest (0.67 %) was recorded in Acc. 5. The total sugar content ranged from 7.36 to 12.81 per cent (Table 3). Acc. 1 and 2 had the highest total sugar content (12.81 %) and the lowest (7.36 %) was recorded in Acc. 5.

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

Sweet lovi-lovi accessions did not register any significant difference in ascorbic acid content. Ascorbic acid content of sweet lovi-lovi accessions ranged from 16.83 to 20.63 mg 100g^{-1} (Table 3). Acc. 5 had the highest ascorbic acid content (20.63 mg 100g^{-1}) and the lowest (16.83 mg 100g^{-1}) was recorded in Acc. 3.

4.1.2.5 *Anthocyanin (mg 100g^{-1})*

Anthocyanin content of sweet lovi-lovi accessions differed significantly. The anthocyanin content of sweet lovi-lovi accessions ranged from 0.03 to 0.04 mg 100g^{-1} (Table 3). Acc. 2 had the highest anthocyanin content (0.04 mg 100g^{-1}) and the lowest (0.03 mg 100g^{-1}) was recorded in other accessions.

4.1.2.6 *Tannin (mg 100g^{-1})*

Considerable variation in tannin content was recorded in sweet lovi-lovi accessions. Tannin content in sweet lovi-lovi accessions ranged from 0.21 to 0.27 mg 100g^{-1} (Table 3). Acc. 2 had the lowest tannin content (0.21 mg 100g^{-1}) and the highest (0.27 mg 100g^{-1}) was recorded in Acc. 3.

4.1.2.7 *Antioxidant activity (µg ml^{-1})*

The antioxidant content in sweet lovi-lovi accessions ranged from 0.16 to 0.23 µg ml^{-1} (Table 3) which varied significantly. The highest antioxidant value was noticed for Acc. 3 (0.23 µg ml^{-1}) and the lowest (0.16 µg ml^{-1}) was noticed in Acc. 4.

4.1.2.8 *Carotenoids (mg 100g^{-1})*

The carotenoid content recorded varied significantly in sweet lovi-lovi fruits. It ranged from 347.02 to 582.55 mg 100g^{-1} (Table 3). Acc. 2 had the highest carotenoid content (582.55 mg 100g^{-1}) and the lowest (347.02 mg 100g^{-1}) was recorded in Acc. 4.

4.1.2.9 *Minerals*

The minerals play a prime role in determining the nutritional value of fruits. The calcium, magnesium and iron content of sweet lovi-lovi fruits were assessed and are given below.

4.1.2.9.1 *Calcium (mg 100g^{-1})*

Calcium content in sweet lovi-lovi accessions ranged from 193.33 to 213.33 mg 100g^{-1} (Table 3) with significant variation. Acc. 4 had the highest calcium content (213.33 mg 100g^{-1}) and the lowest (193.33 mg 100g^{-1}) was recorded in Acc.1.

4.1.2.9.2 *Magnesium (mg 100g^{-1})*

The magnesium content varied significantly among different sweet lovi-lovi accessions. The magnesium content of sweet lovi-lovi accessions ranged from 10.35 to 13.55 mg 100g^{-1} (Table 3). Acc. 3 had the highest magnesium content (13.55 mg 100g^{-1}) and the lowest (10.35 mg 100g^{-1}) was recorded in Acc. 5.

4.1.2.9.3 *Iron (mg 100g^{-1})*

The iron content of sweet lovi-lovi accessions ranged from 25.08 to 33.23 mg 100g^{-1} (Table 3) which varied significantly. Acc. 2 had the highest iron content (33.23 mg 100g^{-1}) and the lowest (25.08 mg 100g^{-1}) was recorded in Acc. 1.

4.1.2.10 *Crude fibre (g 100 g^{-1})*

Significant variation in crude fibre content was observed among sweet lovi-lovi accessions. Crude fibre content of sweet lovi-lovi accessions ranged from 1.2 to 2.92 g 100g^{-1} (Table 3). Acc. 2 had the highest crude fibre content (2.92 g 100g^{-1}) and the lowest (1.2 g 100g^{-1}) was recorded in Acc. 5.

Table 3. Biochemical characters of sweet lovi-lovi accessions

Accessions	TSS (^{0}Brix)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg $100g^{-1}$)	Anthocyanin (mg $100g^{-1}$)	Tannin (mg $100g^{-1}$)
Acc. 1	18.67	1.42	12.81	12.13	0.68	18.21	0.03	0.23
Acc. 2	18.33	1.28	12.81	11.49	1.33	20.04	0.04	0.21
Acc. 3	17.67	0.92	9.74	8.91	0.83	16.83	0.03	0.27
Acc. 4	17.00	1.07	8.92	7.95	0.97	19.09	0.03	0.23
Acc. 5	21.33	1.42	7.36	6.68	0.67	20.63	0.03	0.24
SE	0.70	0.05	0.16	0.16	0.12	1.79	0	0
CD (0.05)	2.20	0.17	0.50	0.50	0.37	NS	0.003	0.01

Table 3. continued

Accessions	Antioxidant ($\mu g\ ml^{-1}$)	Carotenoids (mg $100g^{-1}$)	Minerals			Crude fibre (g $100\ g^{-1}$)	Starch (g $100\ g^{-1}$)	Protein (g $100\ g^{-1}$)
			Ca (mg $100g^{-1}$)	Mg (mg $100g^{-1}$)	Fe (mg $100g^{-1}$)			
Acc. 1	0.18	441.03	193.33	13.53	25.08	2.18	3.93	1.74
Acc. 2	0.19	582.55	210.00	10.38	33.23	2.92	2.73	1.05
Acc. 3	0.23	488.14	202.00	13.55	32.19	2.35	3.6	0.80
Acc. 4	0.16	347.02	213.33	13.39	29.57	2.58	3.4	1.18
Acc. 5	0.20	476.82	202.67	10.35	27.55	1.2	4.6	2.33
SE	0	4.00	3.83	0.20	0.65	0.19	0.20	0.08
CD (0.05)	0.02	12.60	12.07	0.62	2.05	0.59	0.64	0.25

4.1.2.11 *Starch (g 100 g^{-1})*

The starch content of different sweet lovi-lovi accessions also exhibited significant variation. Starch content of sweet lovi-lovi accessions ranged from 2.73 g 100g^{-1} in Acc. 2 to 4.6 g 100g^{-1} in Acc. 5 (Table 3).

4.1.2.12 *Protein (g 100 g^{-1})*

Significant variation in protein content was observed among sweet lovi-lovi accessions. Protein content of sweet lovi-lovi accessions ranged from 0.80 to 2.33 g 100g^{-1} (Table 3). Acc. 5 had the highest protein content (2.33 g 100g^{-1}) and the lowest (0.80 g 100g^{-1}) was recorded in Acc. 3.

The data regarding physical attributes of sweet lovi-lovi fruits showed significant difference in all parameters except specific gravity. Highest fruit weight, pulp percentage and lesser seed percentage were for Accession 2. With regard to biochemical parameters, highest total sugar (12.81 %), highest non reducing sugar content (1.33 %), highest anthocyanin content (0.04 mg 100g^{-1}), highest carotenoid content (582.55 mg 100g^{-1}), highest iron content (33.23 mg 100g^{-1}), highest crude fibre content (2.92 g 100g^{-1}) and lowest tannin (0.21 mg 100g^{-1}) was observed in Accession 2 and it was concluded that Accession 2 (*Flacourtia cataphracta*) is the best and hence selected for further storage studies.

4.2 PACKAGING AND STORAGE STUDIES

The benefits of production are lost unless wastage is effectively reduced during storage and distribution of fruits. The controlled temperature in refrigerated and cold storage retards the respiration and ripening of fruits, also reduces the decomposition and disintegration of the fruit tissues which are brought about by enzymes. Thus shelf life can be increased. Hence packaging and storage of sweet lovi-lovi fruits in different packages were resorted in this study. Also post harvest

care is needed to safeguard against the injurious effects of the physiological and biochemical changes, also microbial activity taking place after the detachment of the fruit from the mother plant. The sweet lovi-lovi fruits harvested from the best type (Accession 2) were sanitized with sodium hypochlorite (100ppm) and packed in different materials.

4.2.1 Physiological loss in weight (PLW) (%)

The weight of fruit reduced after harvest due to the water loss and the loss in weight of fruits affects the quality of produce. Physiological loss in weight (PLW) of sweet lovi-lovi fruits increased in all the treatments during storage under ambient, refrigerated and cold storage condition (Table 4). PLW of fruits kept without packing kept as control remained significantly higher during storage under three different storage conditions. On comparing the three storage conditions, fruits packed in polythene cover (200 gauge) without ventilation in cold storage at 10°C to 14°C had least PLW (0.02 %), followed by shrink wrapped fruits in areca plate (0.04 %) stored under refrigerated condition (3°C to 7°C). The maximum PLW was recorded for ambient stored fruits without any package (10.64 %).

The minimum PLW (0.25 %) was observed when fruits were packaged in areca plates wrapped with polyolefin film of 15μ thickness and the control sample had maximum PLW (10.64 %) after one day of storage under ambient condition. The same trend was observed in refrigerated condition in which the minimum PLW (0.04 %) was recorded in areca plates containing fruits wrapped with polyolefin film of 15μ thickness and maximum PLW (4.54 %) was for unwrapped fruits kept without packing. Under cold storage condition the minimum PLW (0.02 %) was noticed in fruits stored in polyethylene cover (200 gauge) without ventilation and maximum PLW (1.78 %) was recorded for unwrapped fruit sample.

Table 4. Effect of packaging and storage condition on physiological loss in weight (%) of sweet lovi-lovi fruits

Physiological loss in weight (%)						
Treatments	Ambient	Refrigerated storage		Cold Storage		
	1 DAS	1 DAS	2 DAS	1 DAS	2 DAS	3 DAS
T_1	10.64 (3.26)	4.54 (2.13)	-	1.78 (1.33)	-	-
T_2	4.82 (2.19)	0.41 (0.61)	0.83	0.73 (0.85)	-	-
T_3	1.70 (1.30)	0.45 (0.67)	0.72	0.02 (0.15)	0.16	0.29
T_4	0.84 (0.92)	0.54 (0.73)	-	0.13 (0.36)	0.17	-
T_5	2.66 (1.63)	0.85 (0.92)	-	0.18 (0.42)	0.48	-
T_6	0.25 (0.50)	0.04 (0.18)	0.23	0.04 (0.19)	0.07	0.26
SE	0.21 (0.04)	0.09 (0.06)	-	0.03 (0.02)	-	-
CD (0.05)	0.64 (0.12)	0.29 (0.18)	-	0.09 (0.05)	-	-
CD for interaction	0.13					

Values in bracket are square root transformed values

T_1 – Control (Fruits kept unwrapped)

T_2 - Polythene cover (200 gauge) with ventilation

T_3 - Polythene cover (200 gauge) without ventilation

T_4 - Polypropylene punnets

T_5 - Polystyrene tray overwrapped with cling film

T_6 - Shrink wrapping in areca tray

4.2.2 Shriveling / Browning (%)

Loss of colour of fruits during storage affects its quality. Browning of sweet lovi-lovi fruits stored in different packages was assessed visually and found that it varied significantly among treatments in all storage conditions. The finding is depicted in Table 5. On considering the three storage conditions, fruits packed in polythene cover (200 gauge) without ventilation stored under refrigerated condition (3°C to 7°C) developed least browning (15.68 %), followed by fruits stored in polypropylene punnets in cold storage condition (10°C to 14°C). The fruits packed in polythene cover (200 gauge) with ventilation stored in cold storage developed maximum browning (83.33 %).

Under ambient storage, the browning of sweet lovi-lovi fruits in different packages ranged from 39.21 to 73.81 per cent. The lowest percentage of browning (39.21 %) was observed in polythene cover (200 gauge) without ventilation which is significantly on par with unwrapped fruits (control) and fruits stored in polythene cover (200 gauge) with ventilation, whereas the highest percentage of browning (73.81 %) was noticed in fruits packed in polystyrene box covered with cling film which is on par with fruits shrink wrapped in areca plate and fruits stored in polypropylene punnets under ambient condition. The browning of sweet lovi-lovi fruits in different packages under refrigerated storage ranged from 15.68 to 75 per cent. The lowest browning percentage under refrigerated storage was noticed in polythene cover (200 gauge) without ventilation (15.68 %), and the highest browning percentage (75 %) was recorded for unwrapped fruits (control). Fruits packed in polypropylene punnets had lowest browning percentage (22.67 %) and fruits packed in polythene cover (200 gauge) with ventilation recorded highest browning percentage (83.33 %) under cold storage condition.

4.2.3 Shelf life (days)

The shelf life was calculated as number of days from harvest till the fruits remained marketable. Unmarketability was attributed when more than 25 per cent of the fruits in a lot showed incidence of spoilage, browning and microbial growth.

Shelf life of sweet lovi-lovi fruits stored under ambient, refrigerated (3°C to 7°C) and cold storage (10°C to 14°C) condition is given in Table 6. Shelf life of sweet lovi-lovi fruits was longer when stored in different packages under cold storage condition than fruits stored in ambient and refrigerated condition in different packages, except in case of control. On comparing the three storage conditions, areca plates containing fruits wrapped with polyolefin film of 15μ thickness and fruits packed in polythene cover (200 gauge) without ventilation stored under cold storage was found to have longest shelf life. This was followed by cold storage of fruits in

Table 5. Effect of packaging and storage condition on browning (%) of sweet lovi-lovi fruits

Treatments	Browning (%)					
	Ambient	Refrigerated storage		Cold Storage		
	1 DAS	1 DAS	2 DAS	1 DAS	2 DAS	3 DAS
T_1	45.83 (42.61)	75.00 (60.12)	-	33.33 (35.13)	-	-
T_2	46.29 (42.86)	24.08 (29.24)	53.7	83.33 (66.82)	-	-
T_3	39.21 (38.73)	15.68 (23.04)	45.1	35.29 (36.40)	39.21	49.02
T_4	66.67 (54.79)	46.67 (43.09)	-	22.67 (28.29)	29.33	-
T_5	73.81 (59.27)	68.89 (56.13)	-	26.19 (30.73)	38.09	-
T_6	68.62 (55.95)	53.33 (46.92)	71.11	39.22 (38.7)	49.02	68.63
SE	3.31 (1.96)	3.26 (2.19)	-	4.18 (2.97)	-	-
CD (0.05)	10.19 (6.05)	10.04 (6.74)	-	0.31 (9.16)	-	-
CD for interaction	5.97					

Values in bracket are angular transformed values

Table 6. Effect of packaging and storage condition on shelf life (days) of sweet lovi-lovi fruits

Treatments	Shelf life (days)		
	Ambient	Refrigerated	Cold storage
T_1	1	1.00	1.33
T_2	1	2.00	1.33
T_3	1	2.33	3.00
T_4	1	1.33	2.00
T_5	1	1.33	2.33
T_6	1	2.00	3.00
SE	0	0.23	0.23
CD (0.05)	NS	0.73	0.73
CD for interaction	0.46		

T_1 – Control (Fruits kept unwrapped)

T_2 - Polythene cover (200 gauge) with ventilation

T_3 - Polythene cover (200 gauge) without ventilation

T_4 - Polypropylene punnets

T_5 - Polystyrene tray overwrapped with cling film

T_6 - Shrink wrapping in areca tray

polystyrene box covered with cling film and refrigerated storage of fruits in polythene cover (200 gauge) without ventilation. All the packages stored under ambient condition and fruits stored in refrigerated condition without any package were found to have shortest shelf life (1 day) (Plate 3, 3a).

All the treatments had a shelf life of one day under ambient storage and the percentage of spoilage was higher compared to other storage systems. Fruits stored in polythene cover (200 gauge) without ventilation had the longest shelf life (2 days) and unwrapped fruits had shortest shelf life (1 day) under refrigerated condition. Storage of fruits under cold storage condition increased the shelf life significantly, in which fruits stored in polythene cover (200 gauge) without ventilation and shrink wrapping on areca tray gave significantly highest shelf life (3 days) as compared to unwrapped fruits and polythene cover (200 gauge) with ventilation (1 day).

4.2.4 Biochemical analysis

4.2.4.1 *Total Soluble Solids (°Brix)*

TSS content of fruits in all the treatments decreased during storage and varied significantly under three different storage conditions (Table 7). On comparing the three storage conditions, areca plates containing fruits wrapped with polyolefin film of 15μ thickness stored under cold storage (10°C to 14°C) was found to be best for preserving TSS (17.27°Brix) which is on par with fruits packed in polythene cover (200 gauge) without ventilation followed by fruits stored in refrigerated condition (3°C to 7°C) in areca plates wrapped with polyolefin film of 15μ thickness. The least retention of TSS was found in fruits stored in ambient condition without any package (16.03°Brix).

Under ambient storage condition, fruits packed in polypropylene punnets (T_4) had the highest TSS (16.73°Brix) and lowest (16.03°Brix) was observed in unpacked samples after one day of storage. Whereas under refrigerated and cold storage

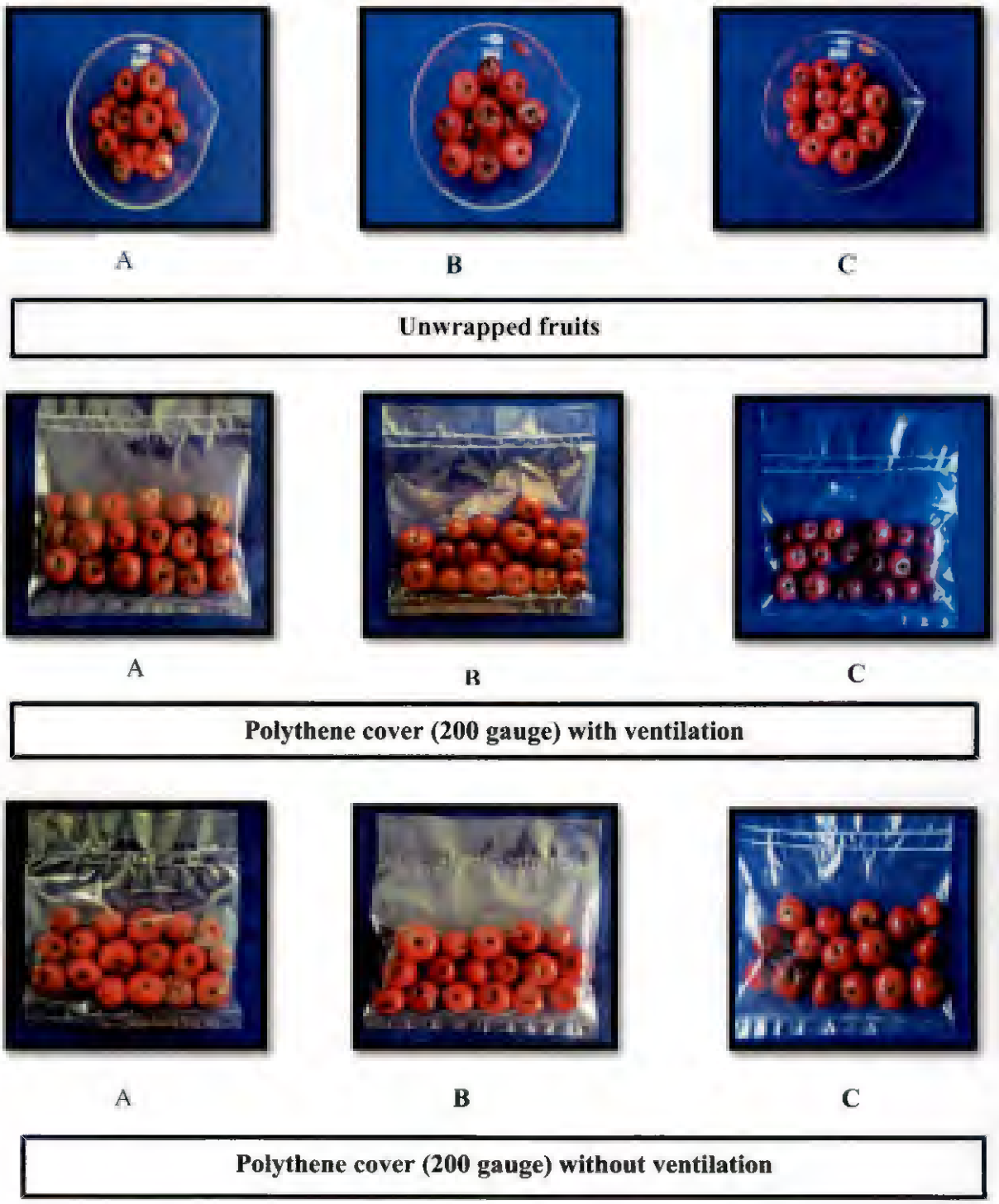


Plate 3. Spoilage of fruits in different packaging materials one day after storage

A – Ambient condition B – Refrigerated storage C – Cold storage

A B C

Polypropylene punnets

A B C

Polystyrene box wrapped with cling film

A B C

Shrink wrapped areca plate

Plate 3a. Spoilage of fruits in different packaging materials one day after storage

A – Ambient condition B – Refrigerated storage C – Cold storage

conditions, highest TSS (16.93°Brix and 17.27°Brix) was observed for shrink wrapped fruits on areca trays and lowest (16.23°Brix and 16.33°Brix) was noticed in unwrapped fruit samples after one day of storage.

4.2.4.2 *Acidity (%)*

Acidity of fruits in all the treatments increased during storage under three different storage conditions (Table 8). On comparing the three storage conditions, the fruits packed in polystyrene box covered with cling film stored under cold storage have lowest acidity (1.35 %) after one day of storage followed by fruits wrapped in areca plates with polyolefin film of 15μ thickness and fruits packed in polypropylene punnets, both stored under cold storage. The highest acidity which is an undesirable attribute was recorded in fruits stored in ambient condition without any package (1.77 %).

Only under ambient condition, acidity varied significantly with the treatments and no significant variation was observed under refrigerated and cold storage conditions. After one day of storage, lower acidity (1.49 %) was noticed in polythene cover (200 gauge) without ventilation and in polystyrene box covered with cling film which is on par with other treatments under ambient storage and the unwrapped fruits retained significantly higher acidity (1.77 %).

4.2.4.3 *Sugars (%)*

The total sugars, reducing and non reducing sugar in sweet lovi-lovi fruits decreased during storage under three different storage conditions (Table 9, 10, 11). However, significant difference in the content of total sugars, reducing and non reducing sugar was not observed among the treatments in refrigerated storage conditions.

The amount of total sugar showed a downward trend with the advancement of storage period. On comparing the three storage conditions, shrink wrapped fruits in

Table 7. Effect of packaging and storage condition on TSS (°Brix) content of sweet lovi-lovi fruits

TSS (°Brix)						
Treatments	Ambient	Refrigerated storage		Cold Storage		
	1 DAS	1 DAS	2 DAS	1 DAS	2 DAS	3 DAS
T_1	16.03	16.23	-	16.33	-	-
T_2	16.27	16.53	13.43	16.60	-	-
T_3	16.67	16.87	13.37	17.20	13.60	10.17
T_4	16.73	16.77	-	16.63	13.13	-
T_5	16.43	16.77	-	16.67	13.37	-
T_6	16.63	16.93	13.87	17.27	13.57	10.87
SE	0.08	0.06	-	0.10	-	-
CD (0.05)	0.24	0.18	-	0.31	-	-
CD for interaction	0.23					

Table 8. Effect of packaging and storage condition on acidity (%) of sweet lovi-lovi fruits

Acidity (%)						
Treatments	Ambient	Refrigerated storage		Cold Storage		
	1 DAS	1 DAS	2 DAS	1 DAS	2 DAS	3 DAS
T_1	1.77	1.56	-	1.56	-	-
T_2	1.56	1.56	1.77	1.56	-	-
T_3	1.49	1.49	1.78	1.49	1.63	1.77
T_4	1.56	1.56	-	1.42	1.77	-
T_5	1.49	1.56	-	1.35	1.85	-
T_6	1.56	1.49	1.63	1.42	1.70	1.85
SE	0.06	0.06	-	0.06	-	-
CD (0.05)	0.17	NS	-	NS	-	-
CD for interaction	0.13					

T_1 – Control (Fruits kept unwrapped)

T_2 - Polythene cover (200 gauge) with ventilation

T_3 - Polythene cover (200 gauge) without ventilation

T_4 - Polypropylene punnets

T_5 - Polystyrene tray overwrapped with cling film

T_6 - Shrink wrapping in areca tray

areca plates in cold storage found to be best in retention of sugar (12.74 %), which is on par with polythene cover (200 gauge) without ventilation in cold storage, polystyrene box covered with cling film in cold storage, unwrapped fruits in refrigerated storage, polypropylene punnets in cold storage, polythene cover (200 gauge) without ventilation in refrigerated storage and polythene cover (200 gauge) with ventilation in cold storage. The lowest total sugar was observed in fruits stored in ambient condition without any package (12.22 %).

After one day of storage in ambient condition, the highest total sugar content of 12.51 per cent was noticed in polythene cover (200 gauge) without ventilation and lowest of 12.22 per cent was seen in unwrapped fruit sample. Under refrigerated storage, no significant difference was observed among treatments in total sugar content. Whereas, under cold storage condition shrink wrapped fruits in areca plates had significantly higher total sugar content (12.74 %) and lowest (12.58 %) was recorded in unwrapped fruit sample after one day of storage.

Of the three storage conditions, the highest retention of reducing sugar after one day was seen in shrink wrap packaging of fruits in areca plates in cold storage (11.46 %) and least content of reducing sugar (11.12 %) was seen in fruits stored in polypropylene punnets under ambient condition.

After one day of storage in ambient condition, the highest reducing sugar content (11.31 %) was noticed in polythene cover (200 gauge) without ventilation and lowest (11.12 %) was observed in polypropylene punnets. No significant difference in reducing sugar content was observed among treatments under refrigerated storage. Whereas, under cold storage condition, shrink wrapped fruits in areca plates had significantly higher reducing sugar content (11.46 %) and lowest (11.37 %) was recorded in unwrapped fruit sample after one day of storage.

Similar to reducing sugar, non reducing sugar content also showed a decreasing trend throughout the storage period with significant variation in ambient

Table 9. Effect of packaging and storage condition on total sugar (%) content of sweet lovi-lovi fruits

Total sugars (%)						
Treatments	Ambient	Refrigerated storage		Cold Storage		
	1 DAS	1 DAS	2 DAS	1 DAS	2 DAS	3 DAS
T_1	12.22	12.65	-	12.58	-	-
T_2	12.39	12.54	10.98	12.61	-	-
T_3	12.51	12.61	11.37	12.69	11.32	10.91
T_4	12.25	12.42	-	12.63	11.12	-
T_5	12.24	12.56	-	12.67	11.26	-
T_6	12.49	12.47	10.84	12.74	11.66	10.65
SE	0.05	0.06	-	0.02	-	-
CD (0.05)	0.17	NS	-	0.06	-	-
CD for interaction	0.14					

Table 10. Effect of packaging and storage condition on reducing sugar (%) content of sweet lovi-lovi fruits

Reducing sugar (%)						
Treatments	Ambient	Refrigerated storage		Cold Storage		
	1 DAS	1 DAS	2 DAS	1 DAS	2 DAS	3 DAS
T_1	11.15	11.41	-	11.37	-	-
T_2	11.23	11.32	10.07	11.39	-	-
T_3	11.31	11.40	10.40	11.43	10.34	10.01
T_4	11.12	11.24	-	11.39	10.20	-
T_5	11.16	11.35	-	11.42	10.30	-
T_6	11.29	11.30	9.96	11.46	10.66	9.8
SE	0.04	0.04	-	0.04	-	-
CD (0.05)	0.13	NS	-	0.03	-	-
CD for interaction	0.08					

T_1 – Control (Fruits kept unwrapped)

T_2 - Polythene cover (200 gauge) with ventilation

T_3 - Polythene cover (200 gauge) without ventilation

T_4 - Polypropylene punnets

T_5 - Polystyrene tray overwrapped with cling film

T_6 - Shrink wrapping in areca tray

and cold storage condition. However, no significant difference in non reducing sugar content was observed among treatments in refrigerated storage. On comparing the three storage conditions, the shrink wrapped fruits in areca plates in cold storage performed best in retaining non reducing sugar (1.27 %), followed by fruits stored in polythene cover (200 gauge) without ventilation in cold storage and the lowest non reducing sugar was observed in fruits stored in ambient condition without any package (1.07 %).

Highest non reducing sugar content (1.2 %) was noticed in polythene cover (200 gauge) without ventilation and lowest of 1.07 per cent was observed in control treatment after one day of storage in ambient condition. Under cold storage condition, after one day of storage highest non reducing sugar content (1.27 %) was noticed in shrink wrap packaging in areca plates and lowest (1.21 %) was observed in unwrapped fruit sample.

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

A declining trend in ascorbic acid content of sweet lovi-lovi fruits was observed in all treatments under three different storage conditions. The results are shown in the Table 12. Significant variation in ascorbic acid content among treatments was noticed in ambient and refrigerated condition and no significant difference was observed among treatments under cold storage condition. On comparing the three storage conditions, the fruits packed with cling film in polystyrene box in refrigerated storage (18.11 mg $100g^{-1}$) retained the ascorbic acid best, followed by shrink wrap packaging in areca plates (17.87 $100g^{-1}$) in refrigerated storage and lowest retention of ascorbic acid (9.67 mg $100g^{-1}$) was recorded in fruits stored under ambient storage without packaging.

Significantly higher ascorbic acid content (11.00 mg $100g^{-1}$) was observed in fruits stored in polystyrene box covered with cling film and lowest ascorbic acid

Table 11. Effect of packaging and storage condition on non reducing sugar (%) content of sweet lovi-lovi fruits

Non reducing sugar (%)						
Treatments	**Ambient**	**Refrigerated storage**		**Cold Storage**		
	1 DAS	**1 DAS**	**2 DAS**	**1 DAS**	**2 DAS**	**3 DAS**
T_1	1.07	1.25	-	1.21	-	-
T_2	1.16	1.22	0.90	1.21	-	-
T_3	1.20	1.20	0.97	1.27	0.98	0.89
T_4	1.13	1.17	-	1.24	0.92	-
T_5	1.09	1.20	-	1.25	0.96	-
T_6	1.20	1.17	0.89	1.27	1.01	0.85
SE	0.02	0.02	-	0.02	-	-
CD (0.05)	0.06	NS	-	0.04	-	-
CD for interaction	0.05					

Table 12. Effect of packaging and storage condition on ascorbic acid (mg $100g^{-1}$) content of sweet lovi-lovi fruits

Ascorbic acid (mg $100g^{-1}$)						
Treatments	**Ambient**	**Refrigerated storage**		**Cold Storage**		
	1 DAS	**1 DAS**	**2 DAS**	**1 DAS**	**2 DAS**	**3 DAS**
T_1	9.67	15.76	-	16.20	-	-
T_2	10.08	14.95	11.55	16.83	-	-
T_3	10.66	16.69	11.21	17.55	13.03	9.01
T_4	10.33	17.78	-	16.77	11.93	-
T_5	11.00	18.11	-	16.19	10.64	-
T_6	10.84	17.87	10.71	17.55	13.23	8.06
SE	0.26	0.46	-	0.39	-	-
CD (0.05)	0.81	1.43	-	NS	-	-
CD for interaction	1.06					

T_1 – Control (Fruits kept unwrapped)

T_2 - Polythene cover (200 gauge) with ventilation

T_3 - Polythene cover (200 gauge) without ventilation

T_4 - Polypropylene punnets

T_5 - Polystyrene tray overwrapped with cling film

T_6 - Shrink wrapping in areca tray

content (9.67 mg $100g^{-1}$) was noticed in unwrapped fruit sample after one day of storage under ambient condition. Fruits stored in polystyrene box covered with cling film had highest ascorbic acid content (18.11 mg $100g^{-1}$) under refrigerated storage and lowest (14.95 mg $100g^{-1}$) was observed in polythene cover (200 gauge) with ventilation after one day of storage.

Areca plates containing fruits wrapped with polyolefin film of 15µ thickness (T_6) and fruits packed in polythene cover (200 gauge) without ventilation (T_3) in cold storage were found to have longest shelf life (3 days) with good retention of biochemical parameters on storage.

4.3 STUDIES ON VALUE ADDITION OF SWEET LOVI-LOVI

Processing of fruits helps reduce post harvest losses, preserve the nutritive value and quality of raw material and make the seasonal produce available throughout the year. An attempt was made in this study to evaluate the organoleptic qualities of wine, preserve and RTS beverage (Plate 4) from sweet lovi-lovi fruits.

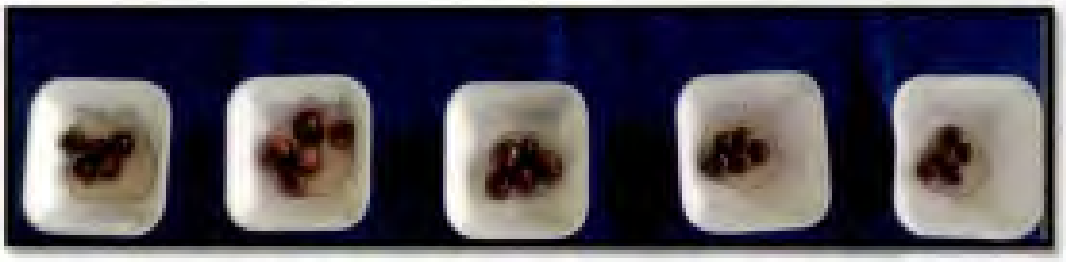
4.3.1 Sensory evaluation

4.3.1.1 *Wine*

The mean rank scores of appearance, colour, flavour, texture, taste, after taste and overall acceptability of wine prepared from five accessions of sweet lovi-lovi fruits are given in Table 13. The mean rank scores for flavour (7.43), texture (7.13), odour (7.37), taste (7.33) and after taste (7.30) were highest for Accession 5. Accession 3 and Accession 4 bagged highest score (7.57 and 7.47) for appearance and colour respectively. The overall acceptability was also maximum for Accession 5 (7.50) with a total score of 58.09. Thus sweet lovi-lovi wine prepared from Accession 5 (*Flacourtia montana*) was selected for storage studies. It was evident from the Table 14 that, on storage, all the attributes show an increasing trend and the total score raised from 58.09 to 61.77 after three months.

Acc. 1 Acc. 2 Acc. 3 Acc. 4 Acc. 5

Sweet lovi-lovi wine



Acc. 1 Acc. 2 Acc. 3 Acc. 4 Acc. 5

Sweet lovi-lovi preserve

Acc. 1 Acc. 2 Acc. 3 Acc. 4 Acc. 5

Sweet lovi-lovi Ready To Serve Beverage

Plate 4. Value added products from sweet lovi-lovi

Table 13. Mean sensory score of sweet lovi-lovi wine

Accessions	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
Acc. 1	7.27 (2.93)	7.27 (3.03)	7.13 (3.10)	7.00 (3.30)	7.20 (3.47)	6.87 (2.90)	6.67 (2.77)	7.20 (2.93)	56.61
Acc. 2	7.30 (3.13)	6.80 (2.67)	6.80 (3.07)	7.07 (3.03)	6.67 (2.63)	6.87 (3.13)	6.87 (3.23)	7.33 (3.20)	55.71
Acc. 3	7.57 (3.50)	7.37 (2.93)	6.50 (2.50)	6.63 (2.67)	7.00 (3.23)	6.63 (2.73)	6.40 (2.43)	6.60 (2.30)	54.70
Acc. 4	7.13 (2.83)	7.47 (3.37)	6.83 (2.87)	6.80 (2.83)	6.57 (2.30)	6.57 (2.60)	6.53 (2.77)	7.17 (2.97)	55.07
Acc. 5	7.00 (2.60)	7.03 (3.00)	7.43 (3.47)	7.13 (3.17)	7.37 (3.37)	7.33 (3.63)	7.30 (3.80)	7.50 (3.60)	58.09
Kendal's W	0.06	0.03	0.07	0.04	0.12	0.08	0.14	0.11	

Table 14. Effect of storage on organoleptic qualities of sweet lovi-lovi wine

	Initial								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 5	7.00	7.03	7.43	7.13	7.37	7.33	7.30	7.50	58.09
Kendal's W test	0.06	0.03	0.07	0.04	0.12	0.08	0.14	0.11	
	1 MAS								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 5	7.6	7.6	7.07	7.37	7.23	7.56	6.9	7.53	58.86
Kendal's W test	0.07	0.06	0.10	0.07	0.07	0.09	0.16	0.10	
	2 MAS								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 5	7.1	7.37	7.57	7.5	7.03	7.23	7.03	7.57	58.4
Kendal's W test	0.10	0.07	0.10	0.04	0.19	0.23	0.15	0.10	
	3 MAS								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 5	8.10	7.53	7.47	7.70	7.73	7.67	7.57	8.00	61.77
Kendal's W test	0.05	0.10	0.10	0.10	0.10	0.15	0.15	0.15	

MAS : Months after storage

4.3.1.1.1 *TSS (°Brix)*

The TSS of wine prepared from Accession 5 was accessed initially and finally after three months of storage (Table 19). The TSS was 24° Brix in the beginning which was reduced to 23° Brix after three months of storage.

4.3.1.1.2 *Phenol content (mg $100g^{-1}$)*

Phenol content of sweet lovi-lovi wine was assessed initially and at the end of storage (Table 19), and it was found to increase during storage which witnessed 0.22 mg $100g^{-1}$ initially and 0.33 mg $100g^{-1}$ three months after storage.

4.3.1.1.3 *Alcohol content (%)*

The alcohol content of sweet lovi-lovi wine increased slightly with advancement of the maturation period (three months) (Table 19). Alcohol content of 8.06 per cent was noticed initially and it was elevated to 8.71 per cent three months after storage.

4.3.1.2 *Preserve*

Preserve prepared from five accessions of sweet lovi-lovi fruits were organoleptically evaluated by a panel of 15 semi trained judges and the mean sensory scores are recorded in Table 15. Initially highest mean scores for flavour (7.54), texture (7.27), odour (7.27), taste (8.00), after taste (7.54) and overall acceptability (7.86) were recorded for Accession 2 and for appearance and colour highest mean score were noticed in Accession 3. Highest score (58.02) for preserve was recorded in Accession 2, followed by Accession 3 (57.07), Accession 4 (49.90), Accession 5 (49.45) and least score (49.09) was noticed in Accession 1. Hence preserve prepared from Accession 2 (*Flacourtia cataphracta*) was selected for storage studies.

Organoleptic evaluation conducted at monthly interval showed that the total score increased from 58.02 to 58.47 (Table 16).

Table 15. Mean sensory score of sweet lovi-lovi preserve

Accessions	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
Acc. 1	5.09 (2.23)	5.73 (2.27)	6.27 (2.32)	5.91 (2.14)	6.91 (2.95)	6.82 (2.55)	6.27 (2.41)	6.09 (2.27)	49.09
Acc. 2	6.09 (3.27)	6.45 (3.55)	7.54 (3.86)	7.27 4.14)	7.27 (3.64)	8.00 (4.32)	7.54 (4.09)	7.86 (4.59)	58.02
Acc. 3	6.73 (4.09)	6.54 (3.59)	7.36 (3.45)	7.18 (3.82)	7.18 (3.41)	7.54 (3.36)	7.18 (3.73)	7.36 (3.86)	57.07
Acc. 4	5.36 (2.64)	5.82 (2.50)	6.82 (2.55)	6.00 (2.36)	6.54 (2.41)	6.73 (2.41)	6.27 (2.36)	6.36 (2.41)	49.90
Acc. 5	5.64 (2.77)	6.18 (3.09)	6.36 (2.82)	6.18 (2.55)	6.64 (2.59)	6.45 (2.36)	6.09 (2.41)	5.91 (1.86)	49.45
Kendal's W	0.25	0.18	0.28	0.39	0.29	0.34	0.41	0.61	

Table 16. Effect of storage on organoleptic qualities of sweet lovi-lovi preserve

	Initial								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 2	6.09	6.45	7.54	7.27	7.27	8.00	7.54	7.86	58.02
Kendal's W test	0.25	0.18	0.28	0.39	0.29	0.34	0.41	0.61	
	1 MAS								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 2	7.13	7.37	7.23	7.23	7.13	7.73	7.67	7.5	58.99
Kendal's W test	0.32	0.19	0.19	0.19	0.13	0.13	0.15	0.17	
	2 MAS								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 2	6.57	6.9	7.67	7.5	6.77	7.83	7.25	7.9	58.39
Kendal's W test	0.23	0.15	0.23	0.10	0.05	0.10	0.05	0.05	
	3 MAS								
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 2	6.47	6.37	7.37	7.63	7.0	8.3	7.5	7.83	58.47
Kendal's W test	0.23	0.10	0.10	0.03	0.10	0.15	0.05	0.10	

MAS : Months after storage

4.3.1.3 *RTS beverage*

Sweet lovi-lovi RTS beverage prepared from five accessions were organoleptically evaluated by 15 semi trained judges on a nine point hedonic scale using score cards for eight attributes namely appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability.

Highest mean score for appearance (7.44), colour (7.12), texture (7.44), taste (7.81), and overall acceptability (7.78) was recorded for RTS beverage prepared from Accession 3 whereas the RTS beverage prepared from Accession 5 bagged highest mean score for flavour (7.37), odour (7.25), and after taste (7.37) (Table 17). The Accession 3 attained highest mean score (59.09) followed by Accession 5 (58.30), Accession 4 (56.55), Accession 2 (54.36) and least acceptance was for Accession 1 (51.55). Thus RTS beverage from Accession 3 (*Flacourtia cataphracta*) was selected for three months storage and sensory evaluation was conducted on monthly intervals. It was evident from the Table 18 that, on storage, all the attributes showed a reducing trend and the total score reduced from 59.09 to 55.43 after three months. The extend of decrease in mean score over three month storage was appearance (7.44 to 6.9), colour (7.12 to 6.86), flavour (7.19 to 6.9), texture (7.44 to 6.9), odour (7.12 to 6.83), taste (7.81 to 7.27), after taste (7.19 to 6.87) and overall acceptability (7.78 to 6.9).

4.3.2 Microbial load – initial and three months after storage

Monitoring the storage behaviour is as important as its acceptability testing with respect to a new product. In this study, the shelf life quality of the products was assessed on the basis of their changes in organoleptic qualities and microbial status.

4.3.2.1 *Wine*

The yeast count of sweet lovi-lovi wine made from the best accession (Accession 5) was assessed initially and at the end of storage (Table 20) (Plate 5).

Table 17. Mean sensory score of sweet lovi-lovi RTS beverage

Accessions	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
Acc. 1	7.00 (2.94)	6.75 (2.66)	6.25 (2.12)	6.75 (2.66)	6.69 (2.56)	6.12 (1.56)	5.87 (1.78)	6.12 (2.12)	51.55
Acc. 2	6.87 (2.53)	6.81 (2.75)	6.75 (2.59)	6.87 (2.62)	6.69 (2.69)	7.06 (2.72)	6.50 (2.75)	6.81 (2.28)	54.36
Acc. 3	7.44 (3.59)	7.12 (3.34)	7.19 3.38)	7.44 (3.59)	7.12 (3.12)	7.81 (3.97)	7.19 (3.66)	7.78 (3.94)	59.09
Acc. 4	7.06 (3.03)	7.00 (3.03)	7.12 (3.38)	7.12 (3.16)	7.06 (3.19)	7.19 (3.06)	6.75 (2.97)	7.25 (3.19)	56.55
Acc. 5	7.00 (2.91)	7.12 (3.22)	7.37 (3.53)	7.00 (2.97)	7.25 (3.44)	7.69 (3.69)	7.37 (3.84)	7.50 (3.47)	58.30
Kendal's W	0.09	0.06	0.22	0.10	0.09	0.43	0.34	0.27	

Table 18. Effect of storage on organoleptic qualities of sweet lovi-lovi RTS beverage

Initial									
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 3	7.44	7.12	7.19	7.44	7.12	7.81	7.19	7.78	59.09
Kendal's W test	0.09	0.06	0.22	0.10	0.09	0.43	0.34	0.27	
1 MAS									
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 3	7.28	7.07	7.28	7.43	7.13	7.37	7.08	7.41	58.05
Kendal's W test	0.10	0.10	0.19	0.17	0.10	0.07	0.19	0.23	
2 MAS									
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 3	6.97	7.03	7.23	7.27	7.00	7.30	7.13	7.2	57.13
Kendal's W test	0.38	0.17	0.06	0.07	0.04	0.20	0.15	0.05	
3 MAS									
	Appearance	**Colour**	**Flavour**	**Texture**	**Odour**	**Taste**	**After taste**	**Overall acceptability**	**Total score**
Acc. 3	6.9	6.86	6.9	6.9	6.83	7.27	6.87	6.9	55.43
Kendal's W test	0.13	0.10	0.10	0.05	0.10	0.10	0.28	0.15	

MAS : Months after storage

The yeast population was found nil during initial month and a count of 6 cfu/g x 10^3 was witnessed after three months of storage.

4.3.2.2 *Preserve*

The initial and final microbial population of sweet lovi-lovi preserve (Accession 2) were estimated and given in the Table 21 (Plate 5). In the initial month, the bacterial population was nil and during final month the count was 18 cfu/g x 10^6. The yeast population was found to be insignificant during initial and final month. The fungal population was found to be nil during initial month and the count is 2 cfu/g x 10^3 three months after storage.

4.3.2.3 *RTS beverage*

The microbial population of the stored sweet lovi-lovi RTS beverage (Accession 3) was assessed initially and after three months and the results are presented in Table 22 (Plate 5). In initial and final month the bacterial and yeast population were found insignificant in RTS beverage prepared from sweet lovi-lovi fruits. The fungal population was nil during initial month and the count was 1 cfu/g x 10^3 three months after storage. The *E. coli* count of RTS beverage prepared from Acc. 3 was checked out initially and at the end of storage, since pathogenic *E. coli* was found to cause illness through contaminated water. The *E. coli* population was nil during the initial and final month of storage.

Table 19. Effect of storage on biochemical constituents of sweet lovi-lovi wine (Accession 5)

Biochemical constituents	Initial	3 MAS
TSS (°brix)	24	23
Phenol content (mg/g)	0.22	0.33
Alcohol content (%)	8.06	8.71

Table 20. Effect of storage on yeast population of sweet lovi-lovi wine (Accession 5)

Product	Initial	3 MAS
	Yeast (10^3 CFU/g)	Yeast (10^3 CFU/g)
Wine	0	6

Table 21. Effect of storage on microbial population of sweet lovi-lovi preserve (Accession 2)

Product	Initial			3 MAS		
	Bacteria (10^6 CFU/g)	Yeast (10^3 CFU/g)	Fungi (10^3 CFU/g)	Bacteria (10^6 CFU/g)	Yeast (10^3 CFU/g)	Fungi (10^3 CFU/g)
Preserve	0	0	0	18	0	2

Table 22. Effect of storage on microbial population of sweet lovi-lovi RTS beverage (Accession 3)

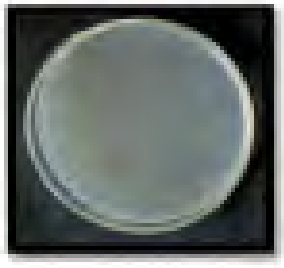
Product	Initial				3 MAS			
	Bacteria (10^6 CFU/g)	Yeast (10^3 CFU/g)	Fungi (10^3 CFU/g)	*E. coli*	Bacteria (10^6 CFU/g)	Yeast (10^3 CFU/g)	Fungi (10^3 CFU/g)	*E. coli*
RTS beverage	0	0	0	0	0	0	1	0

MAS : Months after storage

Initial

3 MAS

Yeast population of sweet lovi-lovi wine

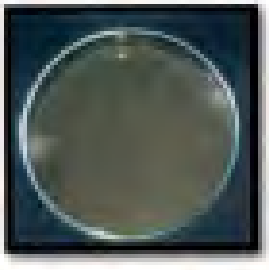


Initial

3 MAS

Bacterial population of sweet lovi-lovi preserve

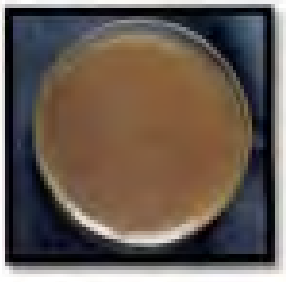
Initial



3 MAS

Fungal population of sweet lovi-lovi preserve

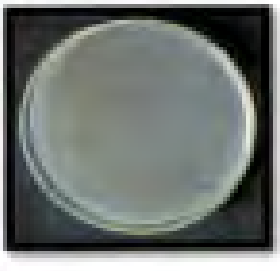
Initial



3 MAS

Yeast population of sweet lovi-lovi preserve

Initial



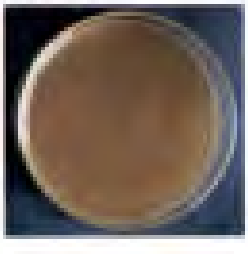
3 MAS

Bacterial population of sweet lovi-lovi RTS beverage

Initial

3 MAS

Fungal population of sweet lovi-lovi RTS beverage



Yeast population of sweet lovi-lovi RTS beverage

***E. coli* population of sweet lovi-lovi RTS beverage**

Plate 5. Microbial population of value added products from sweet lovi-lovi

Discussion

5. DISCUSSION

Underexploited fruits play a significant role in nutrition, pharmaceuticals, food security and income generation. Due to nutritive, therapeutic and medicinal values, these fruits hold potential for value addition through processing. Momin *et al.*, (2016) opined that *Flacourtia indica* have a great importance in the indigenous system of medicine as well as tribal dietary requirements and these edible fruits have great economic value and are highly linked with socio economic development of the tribal communities. Dubey and Pandey (2013) reported that fruits of *Flacourtia jangomas* can be exploited as dessert, made into juice, syrup, jam, marmalade and pickles and also used in chutneys. It also contains anthocyanin, alkaloids, flavonoids, phenolic compounds, tannins and saponins which prove its high antioxidant potential. Now a day's need has been arisen to find such plants, which possess both, nutritional and medicinal properties, such plants are known as neutraceutical plants.

Even though sweet lovi-lovi is having these many advantages, its utilization is limited in processing sector mainly due to the fruit's short shelf life and limited availability. These limitations can be overcome by adopting proper post harvest technology and processing the fruits into number of value added products. Hence, the study on "Post harvest characterisation and value addition of sweet lovi-lovi (*Flacourtia* spp.)" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 2015-2017.

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

5.1 Evaluation of genotypes

5.2 Packaging and storage studies

5.3 Studies on value addition of sweet lovi-lovi

5.1 EVALUATION OF GENOTYPES

Sweet lovi-lovi accessions of *Flacourtia cataphracta* and *Flacourtia montana* collected from three centers located at Vellanikkara were characterized based on physico-morphological and biochemical parameters.

5.1.1 Physical parameters

The physical parameters help in the judicious selection of fruits from various accessions for value addition. The appearance is the primary character looked into during the process. This is contributed by length, weight, colour, pulp content, juice content etc.

5.1.1.1 *Fruit length (cm)*

Among different sweet lovi-lovi accessions collected from various locations, Acc. 1 had the highest fruit length (1.59 cm) and the lowest (1.30 cm) was recorded in Acc. 5. Mundade (2002) reported a fruit length of 3.04 cm in aonla cv. Desi. Hazarika (2014) reported a fruit length of 2.5 to 7.5 cm in ber (*Ziziphus mauritiana* Lam.). Fruit length of chinese jujube (*Ziziphus jujuba*) was reported to be 1.5 to 2.3 cm (Sharma, 2014). Fruit length of *Zizyphus spina-christi* was reported to be 1.43 cm (Norouzi *et al.*, 2017).

5.1.1.2 *Fruit diameter (cm)*

Among different sweet lovi-lovi accessions collected from various locations, Acc. 2 had the highest fruit diameter (1.87 cm) and the lowest (1.44 cm) was recorded in Acc. 5. Morton (1987) recorded that governor's plum (*Flacourtia ramontchi*) fruits have a diameter of 1.25 - 2.5 cm. Mundade (2002) reported a fruit diameter of 3.37 cm in aonla cv. Desi. Sharma (2014) reported a fruit diameter of 1 cm for *Ziziphus lotus*, a minor cultivated species of jujube. Singh *et al.* (2014) stated

that fruits of phalsa (*Grewia subinaequalis*) are 1.0 to 1.9 cm in diameter. Fruit diameter of *Zizyphus spina-christi* was reported to be 1.58 cm (Norouzi *et al.*, 2017).

5.1.1.3 *Fruit weight (g)*

Significant variation in fruit weight was observed among different accessions collected from various locations. Acc. 2 recorded highest fruit weight (3.92 g) and the lowest (2.29 g) was recorded in Acc. 5. Singh *et al.* (2014) reported a fruit diameter of 0.5 to 2.2 g in phalsa (*Grewia subinaequalis*). Kumar *et al.* (2016) observed a fruit weight of 5.72 g for the plum genotype Prune. Jorquera-Fontena *et al.* (2017) reported 2.58 g fruit weight in Legacy cultivar of blueberry (*Vaccinium* spp.). Fruit weight of *Zizyphus spina-christi* was reported to be 2.02 g (Norouzi *et al.*, 2017).

5.1.1.4 *Fruit volume (ml)*

Considerable variation in fruit volume was observed among different accessions. Acc. 4 had the highest fruit volume (3.6) and the lowest (1.95) was recorded in Acc. 5. Naderiboldaji *et al.* (2008) reported fruit volume of Mashad cultivar of sweet cherry as 3.96 cm^3. Milosevic and Milosevic (2011) reported a fruit volume of 3.48 cm^3 in sour cherry cultivar Oblacinska. Kumar *et al.* (2016) observed a fruit volume of 6.00 cm^3 for the plum genotype Prune.

5.1.1.5 *Specific gravity*

Among different sweet lovi-lovi accessions collected from various locations, Acc. 5 had the highest specific gravity (1.30) and the lowest (1.05) was recorded in Acc. 3. Pawar (1988) reported that ripe fruits of karonda have a specific gravity of 1.08. Pawar *et al.* (2010) assessed a specific gravity of 1.07 in ripe sapota fruits. Bakshi (2015) reported a specific gravity value of 1.13 in aonla cv. Desi.

5.1.1.6 *Colour of rind*

Rind colour is an important visual criteria determining the quality of fruit. The skin colour was determined using Universal Colour Language (UCL) and it was deep pink in Acc. 1, Acc. 2 and Acc. 3, whereas it was deep yellowish pink in case of Acc. 4 and strong pink in Acc. 5. The studies conducted on the colour analysis have revealed that fruits belonging to *Flacourtia* spp. have attractive colour of rind. Morton (1987) observed that fruits of *Flacourtia rukam* are dark purple red, *Flacourtia jangomas* are dark-maroon to nearly black and *Flacourtia inermis* is bright red in colour. The colour of ripe fruits of *Flacourtia cataphracta* is dark red to purple (Joy, 2003). Pawar *et al.* (2010) reported colour of ripe sapota fruits as brown. According to Sharma (2014) fruits of chinese jujube (*Ziziphus jujube*) are dark reddish brown to black in colour. Gjamovski *et al.* (2016) observed yellow skin colour in Ohridska Zolta Rana, Bela Docna and Bela Cresa cultivars of sweet cherry and yellow with blush in Dalbazlija and Rozeva Cresa cultivars.

5.1.1.7 *Colour of flesh*

The rind colour was analysed using Universal Colour Language (UCL). Pale yellow was commonly observed colour in all accessions but with varying intensities. Pale yellow (18 C) was noticed in Acc. 1 and Acc. 4, pale yellow (19 D) in Acc. 2, pale yellow (18 D) in Acc. 3, and pale yellow (20 C) in Acc. 5. Morton (1987) observed that the colour of flesh in *Flacourtia jangomas* as greenish to white or amber whereas, flesh colour of *Flacourtia inermis* as whitish tinged with pink. Colour variation of bael fruit pulp was observed in some trees by Mitra *et al.* (2010) and it varied from deep yellow to golden yellow.

5.1.1.8 *Colour of juice*

The juice colour of sweet lovi-lovi accessions collected from various locations was determined using Universal Colour Language (UCL). Vivid purplish red was

commonly observed colour in all accessions. Ber fruits of turning-brown stage give dull yellow colour juice (Desai, 1991). Singh *et al.* (2014) reported colour of phalsa (*Grewia subinaequalis*) fruit juice as deep, crimson red.

5.1.1.9 *Seed number*

Presence of seeds in fruits can be considered as an undesirable quality for fresh consumption as well as for product development. Significant variation was observed among sweet lovi-lovi accessions in seed number. Acc. 3, belonging to *Flacourtia cataphracta* had the lowest number of seeds (10.30) and highest was recorded in Acc. 5 (*Flacourtia montana*) (11.90).

Morton (1987) recorded that fruits of rukam (*Flacourtia rukam*) contains four to seven flat seeds and seeds are six to ten in governor's plum (*Flacourtia ramontchi*) and four to 14 in lovi (*Flacourtia inermis*). He also noted that the drought-tolerant and salt-resistant keiapple tree (*Dovyalis caffra*) has fruits with five to 15 seeds arranged in double rings in the center. Bhowmick (2011) reported that fruits of *Flacourtia jangomas* are many seeded with eight to ten in number.

5.1.1.10 *Physical composition (%)*

Physical composition of sweet lovi-lovi accessions differed significantly (Fig 1). Acc. 2 belonging to *Flacourtia cataphracta* had highest pulp percentage (78.77 %) and lowest (70.12 %) was seen in Acc. 5. Skin percentage was maximum (11.09 %) in Acc. 1 and the minimum (8.18 %) was observed in Acc. 5. Also, seed percentage was lowest (12.38 %) in Acc. 2, whereas, the highest was (21.69 %) recorded in Acc. 5. Similar studies conducted in aonla (*Phyllanthus emblica* L.) also revealed that varieties with high pulp percentage was suitable for processing. Pulp percentage of 89.3 per cent was reported by Barthakur and Arnold (1991), 93.32 per cent in cultivar Krishna by Mundade (2002) and 92.28 per cent in cultivar Kanchan

by Singh *et al.* (2016). High pulp percentage with low skin and seed content increase the acceptability of fruits.

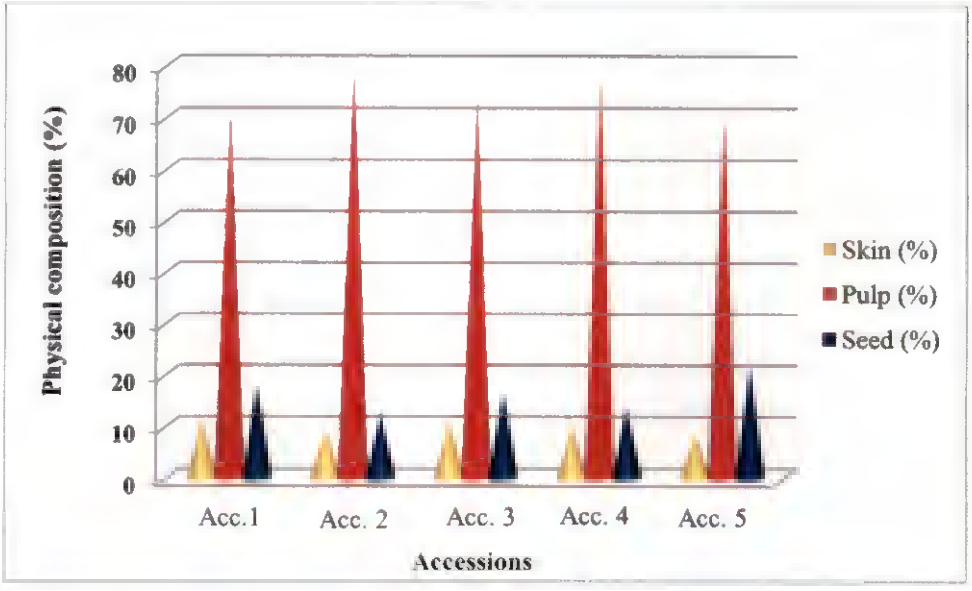


Fig 1. Physical composition of sweet lovi-lovi accessions

5.1.2 Biochemical parameters

Srivastava *et al.* (2009) reported that *Flacourtia jangomas* has edible juicy fruits with good amount of carbohydrate's sugars, proteins, fats, minerals and vitamins. To evaluate the available accessions for their quality, biochemical parameters were studied.

5.1.2.1 *Total soluble solids (TSS) (°Brix)*

Significant variation in TSS was noticed among different sweet lovi-lovi accessions evaluated and it ranged from 17°Brix in Acc.4 to 21.33°Brix in Acc. 5. The present study is in accordance with the findings of Prasad (1998) who reported 20°Brix for sweet lovi-lovi fruits and George (1999). According to him, the TSS content of sweet lovi-lovi ranges from 17°Brix to 19°Brix. Mundaragi and Thangadurai (2015) reported that *Flacourtia montana* contain 21.20°Brix.

Other fruits used for fresh consumption as well as for value addition have similar TSS content. Morton (1987) observed a TSS content of 17.4° Brix to 23.7°Brix in fruits of sapodilla (*Manilkara zapota* van Royen). Aonla cv. Desi was found to contain a TSS of 15.2°Brix (Mundade, 2002). Pawar *et al.* (2010) reported that ripe sapota fruits have a TSS of 23.6°Brix. Ali *et al.* (2011) reported a TSS content of 20°Brix in apricot (*Prunus armeniaca* L.) cultivar Habi. Sharma (2014) reported a TSS content of 17 to 20°Brix in different cultivars of Indian jujube (*Ziziphus mauritiana* Lam.). The TSS of small and big jamun fruits are recorded as 11.10°Brix and 12.30°Brix respectively (Singh *et al.*, 2014). Norouzi *et al.* (2017) reported a TSS of 16.68°Brix in *Zizyphus spina-christi*, 20.90°Brix in *Zizyphus nummularia* and 19.22°Brix in *Zizyphus oxyphylla*.

5.1.2.2 ***Acidity (%)***

Significant variation in titrable acidity was observed among sweet lovi-lovi accessions. Lowest acidity (0.92 %) was recorded in Acc. 3 and both Acc. 1 and 5 had the highest titrable acidity (1.42 %). The acidity present in *Flacourtia ramontchi* and *Flacourtia rukam* is 1.78 per cent and 1.29 per cent respectively (Morton, 1987). According to Joy (2003) the titrable acidity of sweet lovi-lovi is 1.86 per cent. Mundaragi and Thangadurai (2015) opined that fruits of *Flacourtia montana* has an acidity of 0.25 per cent.

The titratable acidity of apricot (*Prunus armeniaca* L.) was reported to be 0.86 per cent in Neeli variety (Ali *et al.*, 2011). Joshi *et al.* (2012) reported that jamun fruits have an acidity of 1.19 per cent. The full ripe fruits of wood apple contain 1.74 per cent acidity (Sharma *et al.*, 2014).

5.1.2.3 ***Total sugar, reducing and non reducing sugars (%)***

The sweetness of the fruit depends on the sugar present in the form of reducing sugar (glucose and fructose) and non reducing sugar (sucrose). Reducing,

non reducing and total sugar content in sweet lovi-lovi accessions varied significantly.

The maximum total sugar content (12.81 %) was recorded in Acc. 1 and 2 while the lowest (7.36 %) was recorded in Acc. 5. This result is in concordance with the study conducted by George (1999) who reported a total sugar content of 11.40 to 13.60 per cent in sweet lovi-lovi fruits. Dubey and Pandey (2013) reported a total sugar content of 9.85 per cent in ripe fruits of *Flacourtia jangomas.*

Mortan (1987) reported a total sugar content of 5.4 to 10.5 g $100g^{-1}$ in Indian Jujube (*Ziziphus mauritiana* Lam.), 10.27 per cent in Phalsa (*Grewia subinaequalis*) and 7.68 per cent in *Flacourtia ramontchi.* Ber fruits of turning-brown stage have a total sugar content of 13.98 per cent (Desai, 1991). Singh *et al.* (2008) reported that guava variety Allahabad safeda have a total sugar value of 8.65 per cent during winter season. Joshi *et al.* (2012) reported that jamun fruits have a total sugar content of 12.44 per cent.

The reducing sugar content ranged from 6.68 per cent (Acc. 5) to 12.13 per cent (Acc. 1). Similar observations were made in other studies also. Morton (1987) observed a reducing content of 4.32 per cent in *Flacourtia rukam.* George (1999) reported a reducing sugar content of 10.80 to 12.08 per cent in sweet lovi-lovi fruits. Mundaragi and Thangadurai (2015) reported that *Flacourtia montana* contain 9.88 per cent reducing sugar.

The fruits of ber is reported to have a reducing sugar content of 10.13 per cent (Desai, 1991). Pawar *et al.* (2010) reported that ripe fruits of sapota have a reducing sugar content of 11.08 per cent. According to Joshi *et al.* (2012) the reducing sugar content of jamun fruits is 8.60 per cent. Singh *et al.* (2014) also observed similar results in jamun.

The highest non reducing sugar content (1.33 %) was recorded in Acc. 2 and lowest (0.67 %) was recorded in Acc. 5. George (1999) reported a non reducing sugar content of 0.57 to 2.56 per cent in sweet lovi-lovi fruits.

Ber fruits of turning-brown stage have a non reducing sugar content of 3.85 per cent (Desai, 1991). Bakshi (2015) reported a non reducing sugar content of 2.19 per cent in aonla cv. Neelam. A non reducing sugar content of 1.26 per cent was noticed in Frontier cultivar of plum (Kumar *et al.*, 2016). It was reported by Vinita and Punia (2016) that non reducing sugar content of date palm (*Phoenix dactylifera* L.) variety Shamran is 5.28 per cent.

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

Ascorbic acid, a powerful antioxidant protects the cell from the free radicals generated by the toxins and pollutants. No significant difference was observed among sweet lovi-lovi accessions in this study. George (1999) reported that ascorbic acid content of sweet lovi-lovi fruits ranged from 14.30 to 17.40 mg 100g^{-1}. According to Joy (2003) the ascorbic acid content of sweet lovi-lovi fruit is 20.26 mg 100g^{-1}. Mundaragi and Thangadurai (2015) reported that the ascorbic acid content was 23.30 mg 100g^{-1} in *Flacourtia montana.*

Morton (1987) reported an ascorbic acid content of 23.9 to 25.0 mg 100g^{-1} in fresh arils of durian (*Durio zibethinus* L.). Lee and Kader (2000) stated that Apricot cultivar Tilton and peach cultivar Elberta, in ripe stage have an ascorbic acid content of 14.3 mg 100g^{-1} and 12.20 mg 100g^{-1}. Musinguzi *et al.* (2007) observed that goose berry (*Physallis minima*) contain 29 mg 100g^{-1} of ascorbic acid. Chadha (2001) reported an ascorbic content of 43 mg 100g^{-1} for egg fruit (*Pouteria campechiana*).

5.1.2.5 *Anthocyanin (mg 100g^{-1})*

Anthocyanin the pigment responsible for the colour of the fruit, contribute to its anti oxidant property as well. Significant variation in anthocyanin content was observed among sweet lovi-lovi accessions. Acc. 2 with deep pink colour for rind had the highest anthocyanin content (0.04 mg 100g^{-1}) and the lowest (0.03 mg 100g^{-1}) was recorded in Acc. 5. Anthocyanin content of sour lovi-lovi (*Flacourtia inermis*) was estimated as 108 mg cyanidin-3-glucoside equivalents per 100 g of fresh fruits by Alakolanga *et al.* (2015).

Anthocyanin pigment contributes to colour in phalsa (*Grewia subinaequalis*) (Singh *et al.*, 2014) and jamun (*Syzygium cumini*) (Khurdiya and Roy, 1985) and in phalsa the compound is recognized as delphinidin-3-glucoside and cyanidin-3-glucoside.

5.1.2.6 *Tannin (mg 100g^{-1})*

High tannin content is a desirable character as it reduces the degradation of vitamin C during storage and processing (Pandey *et al.*, 2014). Hence the tannin content has significant effect on the quality of products. Tannin content differed significantly among sweet lovi-lovi accessions. Acc. 2 had the lowest tannin content (0.21 mg 100g^{-1}) and the highest (0.27 mg 100g^{-1}) was recorded in Acc. 3. Dubey and Pandey (2013) reported that ripe fruits of *Flacourtia jangomas* contain 8 μg g^{1} of tannin.

Ber fruits of turning-brown stage have a tannin content of 0.12 per cent (Desai, 1991). Chowdhury and Ray (2007) reported a tannin content of 1.9 g 100g^{-1} in jamun (*Syzgium cumini* L.) fruits. Pawar *et al.* (2010) reported a tannin content of 0.18 mg 100g^{-1} in ripe sapota fruits. According to Singh *et al.* (2014) the tannin content of small and big jamun fruits are 428.26 and 386.25 mg 100g^{-1} respectively.

5.1.2.7 *Antioxidant value (µg ml^{-1})*

The highest antioxidant value was noticed for Acc. 3 (0.23 µg ml^{-1}) and the lowest (0.16 µg ml^{-1}) was noticed in Acc. 4. Dubey and Pandey (2013) has made extensive studies on ripe fruits of *Flacourtia jangomas* and reported that it possess alkaloids (254 µg g^{-1}), tannin (8 µg g^{-1}), phenols (3.4 µg TA), and flavonoids (250 µg g^{-1}) resulting in its antioxidant activity. The study revealed a total antioxidant activity of 0.043 µg ml^{-1} in 25 per cent concentration of unripe fruits of *Flacourtia jangomas*. Significant radical scavenging antioxidant activity against DPPH free radical was observed by Alakolanga *et al.* (2015) in ethanolic and methanolic extracts of sour lovi-lovi (*Flacourtia inermis*). IC_{50} values for DPPH radical scavenging activity of the ethanolic and methanolic extracts of *Flacourtia inermis* fruits are 66.20 ppm and 212.95 ppm respectively.

5.1.2.8 *Carotenoids (mg 100g^{-1})*

The carotenoids prevent vitamin A deficiency, due to its provitamin activity and will counteract oxidative damage to biomolecules (Halliwell, 1996). Significant variation in carotenoid content was observed in sweet lovi-lovi fruits. Acc. 2 had the highest carotenoid content (582.55 mg 100g^{-1}) and the lowest (347.02 mg 100g^{-1}) was recorded in Acc. 4. Dubey and Pandey (2013) reported ripe fruits of *Flacourtia jangomas* as good source of β carotene (2100 µg g^{-1}).

5.1.2.9 *Minerals*

Most of the fruits contain the important minerals like Ca, Mg and Fe, which are the important factors contributing to its nutritive value.

5.1.2.9.1 *Calcium (mg 100g^{-1})*

Calcium in fruit tissue is one of the mineral believed to be an important factor governing fruit storage quality (Lechaudel *et al.*, 2005).

The fruits of different sweet lovi-lovi accessions under investigation, showed high content of calcium ranging from 193.33 mg $100g^{-1}$ in Acc. 1 to 213.33 mg $100g^{-1}$ in Acc. 4. This is in concurrence with the study conducted by George (1999) in which the calcium content was 218 mg $100g^{-1}$ after 80 days from fruit set. In sour lovi-lovi (*Flacourtia inermis*) fruits, the calcium content is reported to be 34.50 mg $100g^{-1}$ by Joy (2003).

The calcium content of emblic (*Phyllanthus emblica* L.) was noted by Barthakur and Arnold (1991) as 27.6 mg $100g^{-1}$. Noomrio and Dahot (1996) reported a calcium content of 116.0 mg in rose apple (*Eugenia jambosa*) fruit. A study by Musinguzi *et al.* (2007) also indicated that calcium content of goose berry (*Physalis minima*) is 25 mg $100g^{-1}$. Ali *et al.* (2011) reported a calcium content of 124.80 mg $100g^{-1}$ in Alman variety of apricot (*Prunus armeniaca* L.). It was reported by Vinita and Punia (2016) that calcium content of date palm (*Phoenix dactylifera* L.) variety Shamran is 195.33 mg $100g^{-1}$.

5.1.2.9.2 *Magnesium (mg $100g^{-1}$)*

Among different sweet lovi-lovi accessions, Acc. 3 had the highest magnesium content (13.55 mg $100g^{-1}$) and the lowest (10.35 mg $100g^{-1}$) was recorded in Acc. 5. The magnesium content of sweet lovi-lovi is also comparable to other fruits as shown in various reports. Morton (1987) reported magnesium content of kiwi fruit as 30 mg $100g^{-1}$ and Feijoa (*Feijoa sellowiana* Berg.) as 8 mg $100g^{-1}$. The magnesium content of emblic (*Phyllanthus emblica* L.) was noted by Barthakur and Arnold (1991) as 11.8 mg $100g^{-1}$. Singh *et al.* (2014) reported a magnesium content of 44 mg $100g^{-1}$ in fresh fruits of pomegranate. Bhaskar and Shantaram (2013) reported that mature fruits of carambola (*Averrhoa carambola*) contain 11.85 mg $100g^{-1}$ of magnesium.

5.1.2.9.3 *Iron (mg 100g^{-1})*

Sweet lovi-lovi accessions fruits contain considerable quantity of iron. Acc. 2 had the highest iron content (33.23 mg 100g^{-1}) and the lowest (25.08 mg 100g^{-1}) was recorded in Acc. 1. George (1999) reported an iron content of 32 mg 100g^{-1} after 80 days from fruit set in sweet lovi-lovi accessions.

The iron content of apricot (*Prunus armeniaca* L.) was reported by Ali *et al.* (2011) as 12.20 mg 100g^{-1} in Alman variety. Maity *et al.* (2017) reported that pomegranate cv. Bhagwa had an iron content of 13.09 to 20.78 mg 100g^{-1} at fruit maturity.

5.1.2.10 *Crude fibre (g 100g^{-1})*

Fruits consumed as dessert, is rated good depending on its fibre content. Sweet lovi-lovi accessions is found to have crude fibre content from 1.2 g 100g^{-1} in Acc. 5 to 2.92 g 100g^{-1} in Acc. 2. Joy (2003) reported that sweet lovi-lovi contains 1.10 g 100g^{-1}. It was reported by Dubey and Pandey (2013) that ripe fruits of *Flacourtia jangomas* contain 9.6 g 100g^{-1} of crude fibre.

Phalsa (*Grewia subinaequalis*) which is eaten fresh as dessert contain 1.77 per cent crude fibre (Mortan, 2004). Bhaskar and Shantaram (2013) reported that mature fruits of carambola (*Averrhoa carambola*) contain 1.01 g 100g^{-1} of crude fibre. Vinita and Punia (2016) reported a crude fibre content of 1.96 per cent in date palm (*Phoenix dactylifera* L.) variety Medjool.

5.1.2.11 *Starch (g 100g^{-1})*

The starch content varied significantly among the different sweet lovi-lovi accessions. Acc. 5 had the highest starch content (4.6 g 100g^{-1}) while the lowest (2.73 g 100g^{-1}) was recorded in Acc. 2. According to Joy (2003) the starch content of sweet lovi-lovi fruit is 2.97 g 100g^{-1}.

Morton (1987) observed a starch content of 2.98 to 6.40 per cent in sapodilla (*Manilkara sapota* van Royen) fruits. Barthakur and Arnold (1991) reported a starch content of 0.18g $100g^{-1}$ in emblic (*Phyllanthus emblica* L.). Starch content of jack fruit selection SMG-23 was 3.11 per cent (Jagadeesh *et al.*, 2007).

5.1.2.12 *Protein (g $100g^{-1}$)*

Significant variation in protein content was observed among sweet lovi-lovi accessions. Acc. 5 had the highest protein content (2.33 g $100g^{-1}$) and the lowest (0.80 g $100g^{-1}$) was recorded in Acc. 3. According to Joy (2003) the protein content of sweet lovi-lovi fruit is 0.51 g $100g^{-1}$. The protein content of ripe fruits of *Flacourtia jangomas* is 6.16 g $100g^{-1}$ (Dubey and Pandey, 2013). Mundaragi and Thangadurai (2015) reported that *Flacourtia montana* fruits has a protein content of 5.11 per cent.

Morton (1987) reported that protein content of fruits of barbados cherry ranged from 0.68 to 1.8 g $100g^{-1}$ and governor's plum (*Flacourtia ramontchi)* contain protein content of 0.69 per cent. The full ripe fruits of wood apple contain 1.96 per cent protein (Sharma *et al.*, 2014). Vinita and Punia (2016) reported a protein content of 1.88 per cent in date palm (*Phoenix dactylifera* L.) variety Medjool.

Sweet lovi-lovi accessions screened for physico-chemical attributes showed that Acc. 2 collected from college orchard is having good processing attributes like highest fruit weight, pulp percentage and lesser seed percentage. With regard to biochemical parameters, highest total sugar (12.81 %), non reducing sugar content (1.33 %), anthocyanin content (0.04 mg $100g^{-1}$), carotenoid content (582.55 mg $100g^{-1}$), iron content (33.23 mg $100g^{-1}$), crude fibre content (2.92 g $100g^{-1}$) and lowest tannin (0.21 mg $100g^{-1}$) was observed in Acc. 2. Hence Acc. 2 (*Flacourtia cataphracta*) was selected for further storage studies.

5.2 PACKAGING AND STORAGE STUDIES

As a living system, fruits respire and transpire before and after partition from the parent plant. Before harvest, losses due to respiration and transpiration are replaced by water, photosynthates and minerals from the plant. But after harvest, losses of respirable substrates and moisture are not replaced; therefore, deterioration occurs, followed by total death. Sweet lovi-lovi fruits are non climacteric fruits that can be picked only at fully ripen stage to obtain the best eating quality. These fruits decay rapidly after harvest due to its high respiration rate. Loss of firmness also shortens the storage potential. Extension of shelf life in sweet lovi-lovi even for a day or two will go a long way in improving marketability and consumer acceptance. Therefore to enhance the shelf life and to improve the market value an attempt was done by adopting different packaging under three different storage conditions *viz*, ambient, refrigerated and cold storage. Ambotu (2011) opined that post harvest losses of fruits can be minimized by adopting various technologies like modified atmosphere packaging, cold storage and dipping of fruits in chemicals. Storage at low temperature immediately after harvest reduces the rate of respiration resulting in reduction in vital heat, thermal decomposition, and microbial spoilage and also helps in retention of quality for a long period (Sharma and Azad, 2000).

Sweet lovi-lovi fruits harvested from Accession 2 were selected for further storage studies as it had promising characters among the accessions evaluated. Collected fruits were washed in 100 ppm sodium hypochlorite solution prior to packing. Kazemi *et al.* (2013) reported a reduction in weight loss (29.74 %) for pomegranate fruits sanitized with 10 % sodium hypochlorite against fruits (35.80 %) washed with distilled water. Aglar *et al.* (2017) opined that both pre and post harvest treatments have inevitable role in improving the quality and shelf life of produce.

5.2.1 Physiological loss in weight (PLW) (%)

Physiological loss in weight (PLW) increased in all the treatments during storage under ambient, refrigerated and cold storage condition. An increase in PLW of fruits in all the treatments with increasing period of storage was due to the loss of moisture by evapo-transpiration and loss of reserved food material by respiration. PLW of fruits kept unwrapped (control) remained significantly higher during storage in different packages under three different storage conditions. On comparing the three storage conditions, fruits packed in polythene cover (200 gauge) without ventilation in cold storage at 10°C to 14°C have least PLW (0.02 %), followed by shrink wrapped fruits in areca plate stored under refrigerated condition (3°C to 7°C) (Fig. 2). The maximum PLW was recorded for ambient stored fruits with no package (10.64 %).

Under ambient storage, minimum PLW (0.25 %) was observed in fruits packed in areca plates wrapped with polyolefin film of 15μ thickness and unwrapped fruits (control) sample had maximum PLW (10.64 %) after one day of storage. The same trend was observed in refrigerated condition in which the minimum PLW (0.04 %) was recorded in areca plates containing fruits wrapped with polyolefin film of 15μ thickness and maximum PLW (4.54 %) was for unwrapped fruits (control) sample. The rate of physiological processes like transpiration and respiration may be low when wrapping is done with polyolefein film. Under cold storage condition the minimum PLW (0.02 %) was noticed in fruits stored in polyethylene cover (200 gauge) without ventilation and maximum PLW (1.78 %) was recorded for unwrapped sample.

Pahel (2013) reported that different types of wrapping materials have significant effect on PLW of sapota fruits during storage.

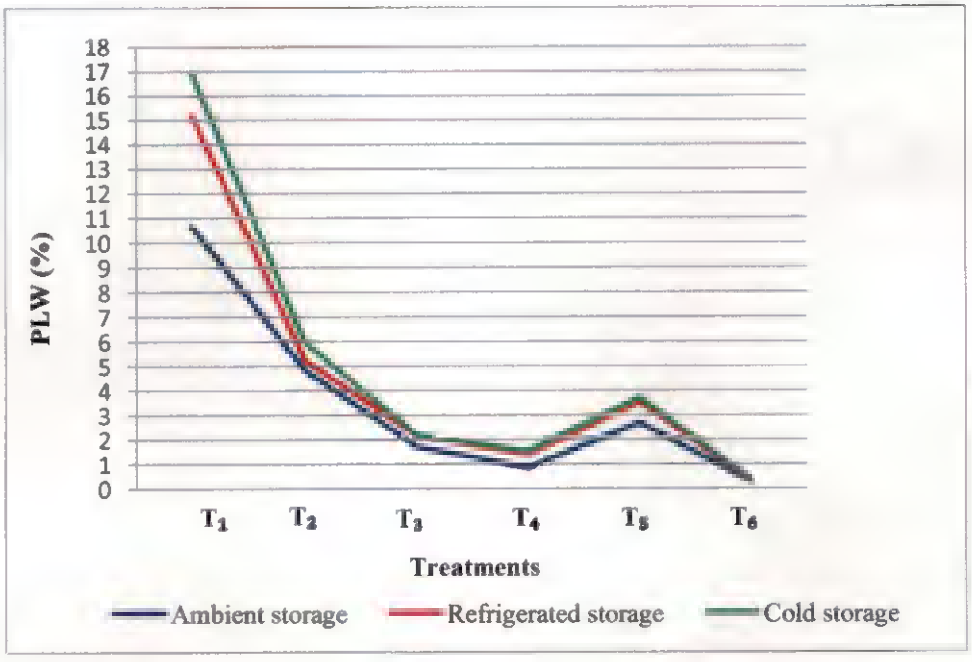


Fig 2. Effect of packaging and storage condition on PLW (%) of sweet lovi-lovi fruits

5.2.2 Shriveling / Browning (%)

Browning occurs when phenolic compounds and anthocyanins are oxidized by polyphenol oxidase and peroxidase (Hajizadeh and Kazemi, 2012). The sensitivity of fruit to minor bruises results in enzymatic browning which adversely affects the eating quality of the fruit, making it unfit for consumption and aggravates the problem of marketing. Joy (2003) reported that scarlet colour of *Flacourtia cataphracta* is lost within one hour of harvest and shriveling occurs from second day onwards.

On considering the three storage conditions, fruits packed in polythene cover (200 gauge) without ventilation stored under refrigerated condition (3°C to 7°C) developed least browning (15.68 %), followed by fruits stored in polypropylene punnets in cold storage condition (10°C to 14°C) (Fig 3). The fruits packed in

polythene cover (200 gauge) with ventilation stored in cold storage developed maximum browning (83.33 %).

The lowest percentage of browning (39.21 %) was observed in polythene cover (200 gauge) without ventilation which is significantly on par with unwrapped fruits (control) and fruits stored in polythene cover (200 gauge) with ventilation, whereas the highest percentage of browning (73.81 %) was noticed in fruits packed in polystyrene box covered with cling film which is on par with fruits shrink wrapped in areca plate and fruits stored in polypropylene punnets under ambient condition.

The lowest browning percentage (15.68 %) under refrigerated storage was noticed in polythene cover (200 gauge) without ventilation, and the highest browning percentage (75 %) was recorded for unwrapped (control) fruits whereas fruits packed in polypropylene punnets had lowest browning percentage (22.67 %) and fruits packed in polythene cover (200 gauge) with ventilation recorded highest browning percentage (83.33 %) under cold storage condition. Prasad (1998) observed that the reduction in quality of sweet and sour lovi-lovi fruits was gradual in refrigerated storage as compared to room conditions.

5.2.3 Shelf life (days)

On comparing the three storage conditions, areca plates containing fruits wrapped with polyolefin film of 15μ thickness and fruits packed in polythene cover (200 gauge) without ventilation stored under cold storage was found to have longest shelf life followed by cold storage of fruits in polystyrene box covered with cling film and refrigerated storage of fruits in polythene cover (200 gauge) without ventilation. All the packages stored under ambient condition and fruits stored in refrigerated condition without any package were found to have shortest shelf life (1 day) (Fig. 4).

Fruits stored in polythene cover (200 gauge) without ventilation had the longest shelf life (2 days) and unwrapped fruits (control) had shortest shelf life (1

day) under refrigerated condition. Storage of fruits under cold storage condition increased the shelf life significantly, in which fruits stored in polythene cover (200 gauge) without ventilation and shrink wrapping on areca tray gave significantly longer shelf life (3 days) as compared to unwrapped fruits (control) and polythene cover (200 gauge) with ventilation (1 day). Fruits are living systems that age due to respiration and transpiration and are still alive after harvest and continue their physiological activities. This involves many enzymatic reactions which increase exponentially with increase in temperature and described mathematically by use of temperature quotient. The rate of a chemical reaction approximately doubles with each 10°C rise in temperature (Wills *et al.*, 1996). The increased shelf life of sweet lovi-lovi fruits in refrigerated and cold storage condition may be due to this reason. Prasad (1998) reported that deterioration of fruits started from the first day of storage in sweet lovi-lovi and the loss was more under room conditions rather than those kept under refrigerated conditions.

Fruits packed in polythene cover creates a modified atmosphere with more carbondioxide and less oxygen than in air. This could extend the storage life (Dalal and Subramanyam, 1970). Under refrigerated condition (3°C to 7°C) a shelf life of three days was observed for ripe barbados cherry (*Malpighia punicifolia* L.) fruits and three to four days in karonda (*Carissa carondas* Auct.) fruits under room temperature (Morton, 1987). Rai *et al.* (2011) also reported that the respiration of fruits decreases with the progress of storage under low temperature due to the accumulation of carbondioxide in packages. This will protect the fruit from physiological, pathological and physical deterioration in the marketing channel and retains its freshness. Al-Ati and Hitchkiss (2003) also reported that the modified atmospheric storage enhance the shelf life of produce by reducing the respiration rate, delaying senescence, and inhibiting the growth of many spoilage organisms. Pelayo *et al.* (2003) reported a shelf life of seven and nine days respectively for Aromas and Selva cultivar of strawberry at 5°C. According to Singh (2012) higher temperature

aggravates respiration leading to breakdown of glucose and organic compounds metabolized in the tissues. This study is in accordance with the findings that highest shelf life was obtained in low temperature and cold storage conditions. Fully ripe fruits of phalsa (*Grewia subinaequalis*) can hardly be stored upto one day at room temperature (Singh *et al.*, 2014).

5.2.4 Biochemical analysis

5.2.4.1 *Total Soluble Solids (°Brix)*

On comparing the three storage conditions, fruits in areca plates wrapped with polyolefin film of 15μ thickness stored under cold storage (10°C to 14°C) was found to be best for preserving TSS (17.27°Brix) which is on par with fruits packed in polythene cover (200 gauge) without ventilation. The least retention of TSS was found in fruits stored in ambient condition without any package (16.03°Brix) (Fig. 5).

Under ambient storage condition, fruits packed in polypropylene punnets (T_4) had the highest TSS (16.73°Brix) and lowest (16.03°Brix) was observed in unwrapped fruits (control) samples after one day of storage. Whereas under refrigerated and cold storage conditions, highest TSS (16.93°Brix and 17.27°Brix) was observed for shrink wrapped fruits on areca trays and lowest (16.23°Brix and 16.33°Brix) was noticed in unwrapped fruits after one day of storage. Prasad (1998) reported that TSS of sweet lovi-lovi fruits declined from 20.4 to 12.6°Brix after three days of storage under refrigerated condition.

Pelayo *et al.* (2003) reported a reduction in TSS of three per cent on storage at 5°C for strawberry cultivar Aromas, whereas the reduction was 10 per cent in cultivar Selva after nine days. Mishra and Kar (2014) reported a significant decrease in TSS of 30 per cent in Chandler and 24 per cent in Camarosa cultivars of strawberry with advancement of storage at 5°C for 9 days.

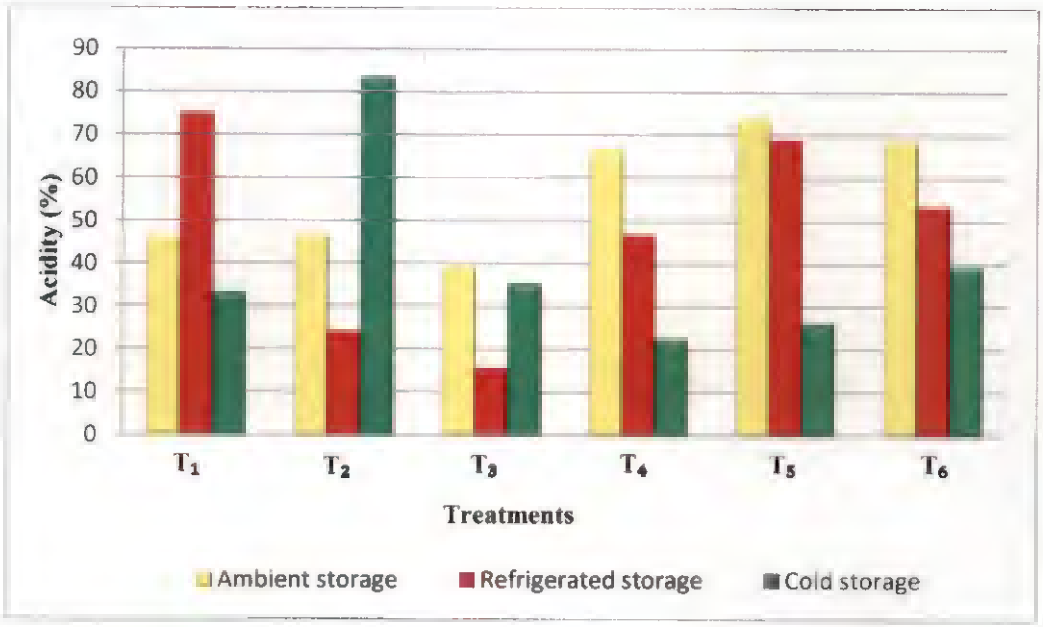


Fig 3. Effect of packaging and storage condition on browning (%) of sweet lovi-lovi fruits

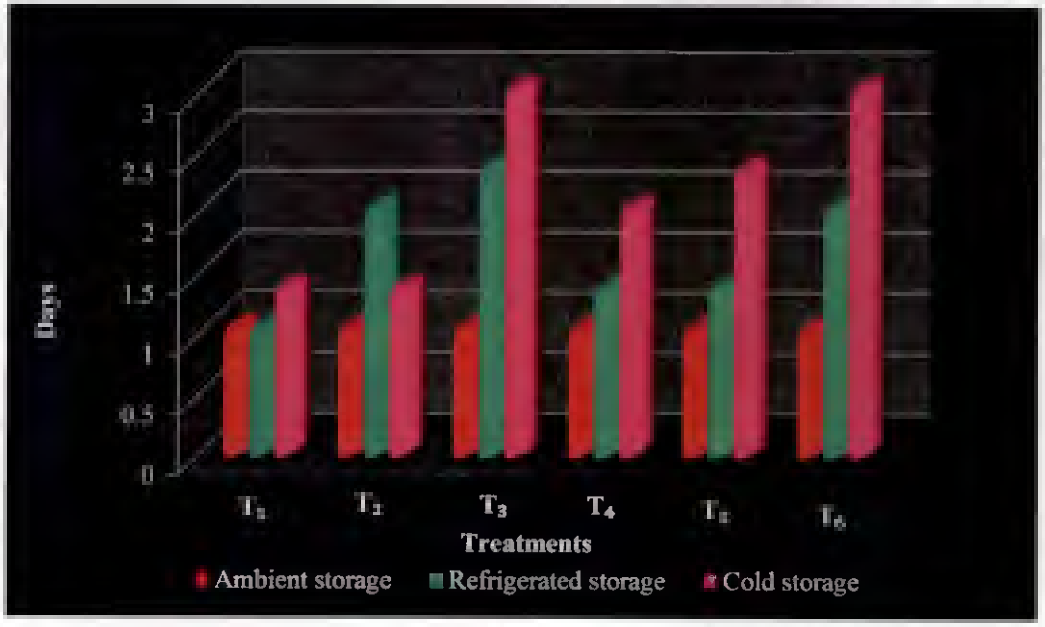


Fig 4. Effect of packaging and storage condition on shelf life (days) of sweet lovi-lovi fruits

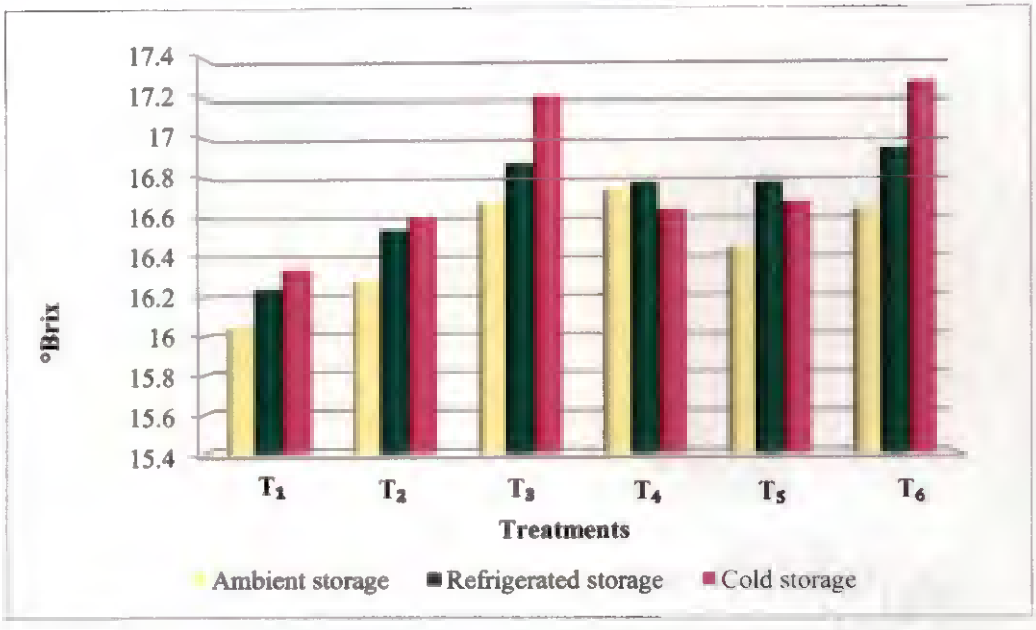


Fig 5. Effect of packaging and storage condition on TSS (°Brix) of sweet lovi-lovi fruits

5.2.4.2 *Acidity (%)*

Comparison of the three storage conditions revealed that, the fruits packed in polystyrene box covered with cling film stored under cold storage had lowest acidity (1.35 %) after one day of storage. High acidity which is an undesirable attribute was recorded in fruits stored in ambient condition without any package (1.77 %) (Fig 6).

After one day of storage, lowest acidity (1.49 %) was noticed in polythene cover (200 gauge) without ventilation and in polystyrene box covered with cling film which is on par with other treatments and unwrapped fruits (control) retained significantly highest acidity (1.77 %) under ambient storage. Pelayo *et al.* (2003) reported an increment in acidity of four per cent on storage for 13 days at 5°C for strawberry cultivar Selva. The increase in acidity may be due to the increase in loss of moisture during storage.

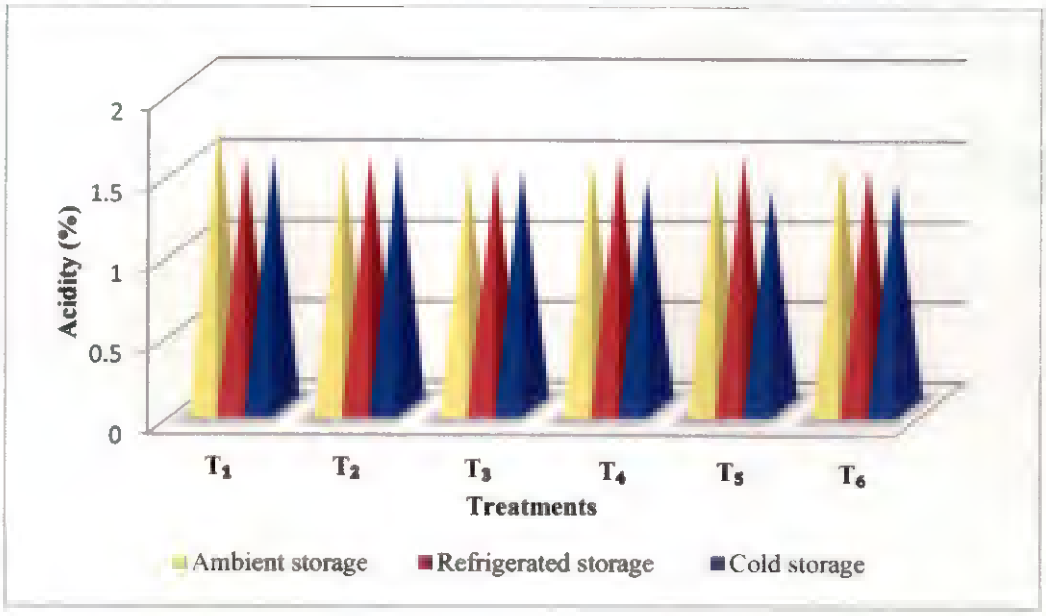


Fig 6. Effect of packaging and storage condition on acidity (%) of sweet lovi-lovi fruits

5.2.4.3 *Sugars (%)*

Evaluation of the three storage conditions, indicated that fruits shrink wrapped in areca plates in cold storage was best for retension of sugar (12.74 %). This was on par with polythene cover (200 gauge) without ventilation in cold storage, polystyrene box covered with cling film in cold storage, unwrapped fruits (control) in refrigerated storage, polypropylene punnets in cold storage, polythene cover (200 gauge) without ventilation in refrigerated storage and polythene cover (200 gauge) with ventilation in cold storage. The lowest total sugar was observed in fruits stored in ambient condition without any package (12.22 %) (Fig 7).

After one day of storage in ambient condition, the highest total sugar content (12.51 %) was noticed in polythene cover (200 gauge) without ventilation and lowest (12.22 %) was seen in control (no package) sample. Under refrigerated storage, no significant difference was observed among treatments in total sugar content.

Whereas, under cold storage condition shrink wrapped fruits in areca plates had significantly higher total sugar content (12.74 %) and lowest (12.58 %) was recorded in control (no package) sample after one day of storage. Pelayo *et al.* (2003) reported a reduction in total sugar content of eight per cent on storage at 5°C for strawberry cultivar Aromas, whereas the reduction was three per cent in cultivar Selva after nine days. Mishra and Kar (2014) reported a significant decrease in total sugar of 9 per cent in Chandler and 10 per cent in Camarosa cultivars of strawberry on storage at 5°C for 9 days. Under low temperature storage biochemical reactions will be less, and ambient temperature accelerated the biochemical reactions, which increases the hydrolysis of complex sugars.

Of the three storage conditions, the highest retention of reducing sugar after one day was seen in fruits shrink wrapped in areca plates in cold storage (11.46 %) and least content of reducing sugar (11.12 %) was observed in fruits stored in polypropylene punnets under ambient condition.

After one day of storage in ambient condition, the highest reducing sugar content (11.31 %) was noticed in polythene cover (200 gauge) without ventilation and lowest (11.12 %) was seen in polypropylene punnets. No significant difference in reducing sugar content was observed among treatments under refrigerated storage. Under cold storage condition shrink wrapped fruits in areca plates had significantly higher reducing sugar content (11.46 %) and lowest (11.37 %) was recorded in control sample after one day of storage.

The shrink wrapped fruits in areca plates in cold storage performs best in preserving non reducing sugar (1.27 %) on comparing the three storage condition, followed by fruits stored in polythene cover (200 gauge) without ventilation in cold storage and the lowest non reducing sugar was observed in fruits stored in ambient condition without any package (1.07 %).

Highest non reducing sugar content (1.2 %) was noticed in polythene cover (200 gauge) without ventilation and lowest (1.07 %) was observed in unwrapped fruits (control) after one day of storage in ambient condition. No significant difference in non reducing sugar content was observed among treatments in refrigerated storage. Under cold storage condition, after one day of storage highest non reducing sugar content (1.27 %) was noticed in shrink wrap packaging in areca plates and lowest (1.21 %) was observed in unwrapped fruit (control) sample.

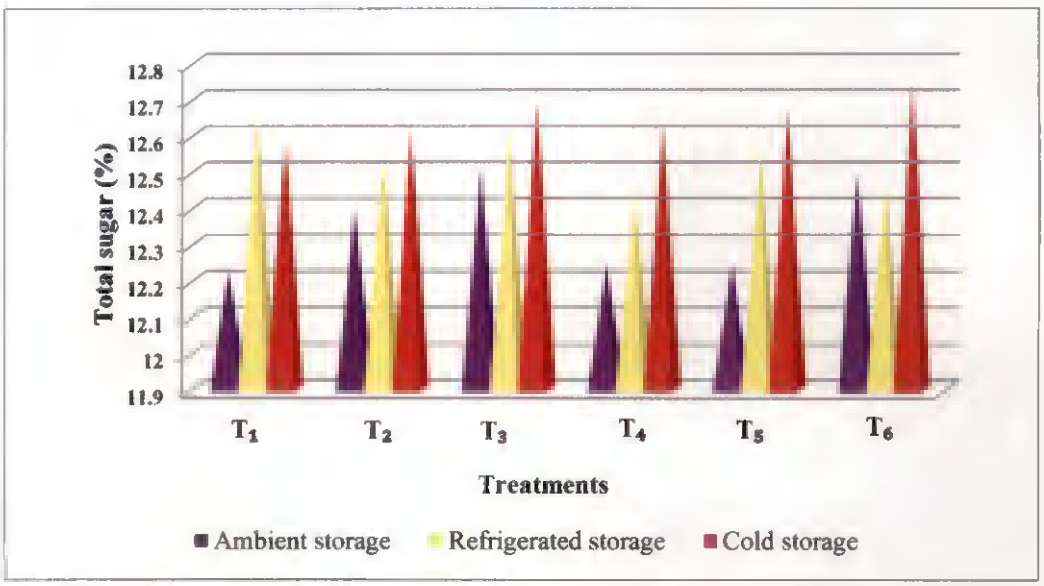


Fig 7. Effect of packaging and storage condition on total sugar content (%) of sweet lovi-lovi fruits

5.2.4.4 *Ascorbic acid (mg 100g^{-1})*

Among the three storage conditions, the fruits packed with cling film in polystyrene box in refrigerated storage (18.11 mg 100g^{-1}) retained the ascorbic acid best, followed by shrink wrap packaging in areca plates in refrigerated storage (17.87

mg $100g^{-1}$) and lowest retention of ascorbic acid (9.67 mg $100g^{-1}$) was recorded in fruits stored under ambient storage with no packing (Fig 8).

Under ambient storage, significantly higher ascorbic acid content (11.00 mg $100g^{-1}$) was observed in fruits stored in polystyrene box covered with cling film and lowest ascorbic acid content (9.67 mg $100g^{-1}$) was noticed in unwrapped fruits (control) after one day of storage. Fruits stored in polystyrene box covered with cling film had highest ascorbic acid content (18.11 mg $100g^{-1}$) under refrigerated storage and lowest (14.95 mg $100g^{-1}$) was observed in polythene cover (200 gauge) with ventilation after one day of storage. However, no significant difference in ascorbic acid content was observed in treatments under cold storage condition. Elevated enzymatic activity due to cellular disruption by cutting or bruising of tissue leads the enzymes to come in contact results in rapid loss of vitamin C (Klein, 1987). Tissue damage arise due to separation of pedicel during harvesting of sweet lovi-lovi fruits accounting for the increased water loss and exposure of ascorbic acid to oxidation which accelerated the declining of the ascorbic acid content on storage. The decrease in ascorbic acid content was attributed to the activity of ascorbate oxidase which converts ascorbic acid to dehydro ascorbic acid (Lee and Kader, 2000).

Chebrolu *et al.* (2012) observed vitamin C degradation losses of 0.5 to 7 per cent for organically produced grapefruits (*Citrus paradisi*) during storage at room temperature. Mishra and Kar (2014) reported that the ascorbic acid content of Chandler cultivar of strawberry decreased (15 %) with advancement of storage at 5°C for 9 days.

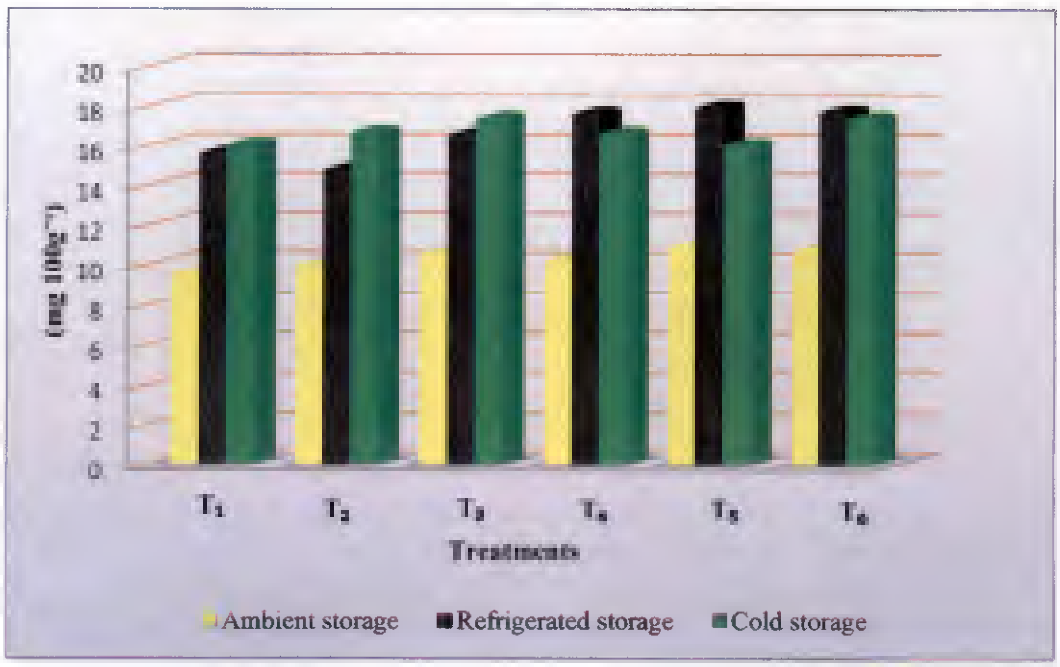


Fig 8. Effect of packaging and storage condition on on ascorbic acid content (mg $100g^{-1}$) of sweet lovi-lovi fruits

5.3 STUDIES ON VALUE ADDITION OF SWEET LOVI-LOVI

Sweet lovi-lovi is a highly perishable fruit with a shelf life of one day in ambient condition. Most of the production goes waste due to poor market demand and less number of processing centers. There is a great scope for the processed products not only because of their exotic flavour but also due to their nutraceutical impotance and therapeutic values. Morton (1987) reported that fruits of governor's plum (*Flacourtia ramontchi*) can be exploited for the production of jelly, without squeezing the jelly bag to ward off astringency. Most of the berries and fruits contain flavonoids and other phenolic compounds which add to its antioxidant activity and these compounds will present also in berry and fruit products, such as juices (Heinonen *et al.*, 1998). Prasad (1998) analysed and reported that ripe fruits of sweet lovi-lovi have high quantities of TSS, total sugars, reducing and non reducing sugars

which will be highly useful for developing products like marmalades, jam and preserves. If processed properly, these products might have multiple advantages of being hygienic, free from pathogens, tastier and healthier.

5.3.1 Sensory evaluation

5.3.1.1 *Wine*

Ripe sweet lovi-lovi is delicious in taste and contains fermentable sugars, which can be utilized for alcoholic fermentation. In recent times, the consumption of wine is gaining momentum owing to its phenolic antioxidant compounds and ability to avert coronary heart diseases (Joshi *et al.*, 2009). The capacity to provide phytochemicals besides basic nutrients, vitamins and minerals makes wine a functional food (Gordon and Brannon, 2013).

The mean rank scores for flavour (7.43), texture (7.13), odour (7.37), taste (7.33) and after taste (7.30) were highest for Accession 5. Accession 3 and Accession 4 bagged highest score (7.57 and 7.47) for appearance and colour respectively (Fig 9). The overall acceptability was also maximum for Accession 5 (7.50) with a total score of 58.09. Thus sweet lovi-lovi wine prepared from Acc. 5 was selected for storage studies. On storage, all the attributes showed an increasing trend and the total score raised from 58.09 to 61.77 after three months. Kalyani (2011) reported that the overall acceptability of karonda (*Carissa carandas* L.) wine increased during storage due to the development of pleasant colour, improvement of aroma, taste and reduction in acidity and phenols.

The wine made from Acc. 2 was screened initially and three months after storage for biochemical characters like TSS, phenol and alcohol content.

5.3.1.1.1 *TSS (°Brix)*

Interaction of various components during maturation brings about precipitation of soluble solids which might be the reason for decrease of TSS on storage (Sharma and Joshi, 2003).

The TSS was 24°Brix in the beginning, which was reduced to 23°Brix after three months of storage. TSS of karonda (*Carissa carandas* L.) wine showed a decrease from 9.25°Brix to 7.83°Brix four months after storage (Kalyani, 2011). Joshi *et al.* (2013) reported that TSS of wine made from coloured grape variety Banglore blue showed a declining trend upon aging. Initial TSS 10.04°Brix was reduced to 9.01°Brix after aging. The study also revealed a reduction in TSS upon storage for wine made from colourless variety of grape Thompson seedless, 8.96°Brix to 7.59°Brix.

5.3.1.1.2 *Phenol content (mg $100g^{-1}$)*

During wine making, changes in phenolic composition of raw material occur at fermentation and ageing step and this phenolic compound will be effectively extracted into berry and fruit wines (Heinonen *et al.*, 1998). Phenolic compounds have an important impact on organoleptic properties of wine (Lorrain *et al.*, 2013) and reported to have multiple biological activities, including cardioprotective, anti-inflammatory, anti-carcinogenic, antiviral and antibacterial properties attributed mainly to their antioxidant (Teissedre *et al.*, 1996) and antiradical activity. The phenol content of sweet lovi-lovi wine increased during storage which witnessed 0.22 mg $100g^{-1}$ initially and 0.33 mg $100g^{-1}$ three months after storage. A phenol content of 0.22g $100ml^{-1}$ was reported in jamun (*Syzgium cumini* L.) wine (Chowdhury and Ray, 2007).

5.3.1.1.3 ***Alcohol content (%)***

In this study the alcohol content of 8.06 per cent was noticed initially and it elevated to 8.71 per cent three months after storage. Chikkasubbanna *et al.* (1990) reported that the alcohol percent of the grape wine increased due to a decrease in total soluble sugars due to the activity of yeast during fermentation. Depending on cultivar used, the ethanol content of jamun (*Syzygium cumini*) wine made using *Saccharomyces cerevisiae* was found to increase from 10.93 to 11.23 per cent (Shukla *et al.*, 1991). Bhajipale (1997) reported that wine prepared from mature green and over ripe fruits of karonda (*Carissa carandas* L.) gave 8.40 per cent and 8.26 per cent alcohol respectively. Ulla (2011) reported that pomegranate wine prepared using arils and 20 per cent sugar syrup yield 7.28 per cent alcohol initially which rise to 7.41 per cent three months after storage. Whereas, the pomegranate wine prepared using arils and 30 per cent sugar syrup yields 9.35 per cent alcohol initially, which show an increment of 11.14 per cent. Joshi *et al.* (2013) reported that the alcohol content of 8.49 per cent in Pusa Navrang variety of grape increased to 9.36 per cent after aging. Patidar (2014) reported that karonda (*Carissa carandas* L.) wine prepared under optimum incubation temperature of 27°C and incubation period of 168 hour gives 7.8 per cent alcohol.

5.3.1.2 ***Preserve***

The preserve or murrabba industry, one of the most important sectors of the fruit and vegetable preservation industry in India has its grounds in indigenous systems of medicine particularly the Unani system (Siddappa and Sastry, 1959). The murrabbas which is preserved by its high sugar concentration principle is valued for its medicinal and curative properties achieved by its long term storage. The medicinal value is attributed to the polyphenolic substances present in them. The study states that amla, quince and pear preserves imparts energy to heart and brain, apple preserve

acts as stimulant for heart and brain, and pineapple preserve as a tonic and remedies mental diseases.

Initially highest mean scores for flavour (7.54), texture (7.27), odour (7.27), taste (8.00), after taste (7.54) and overall acceptability (7.86) were recorded for Accession 2 and for appearance and colour highest mean score were noticed in Accession 3 (Fig 10). Highest score (58.02) for preserve was recorded in Accession 2, followed by Accession 3 (57.07), Accession 4 (49.90), Accession 5 (49.45) and least score (49.09) was noticed in Accession 1. Hence preserve prepared from Accession 2 was selected for storage studies.

Organoleptic evaluation conducted at monthly interval showed that the total score increased from 58.02 to 58.47 out of 72. Joy (2003) reported that mean scores for flavour, texture, taste and overall acceptability of lovi-lovi preserve increased during storage for six months, whereas mean scores for appearance and colour was found to decrease.

Bhatia and Siddappa (1956) reported that the preserves are rich in sugar and calcium. Apple preserves stored for 40 weeks yielded 64 per cent total sugar and 130.80 mg calcium in fruit whereas aonla preserve stored for 13 weeks gave an out turn of 59.37 per cent total sugar and 72 mg calcium. Morton (1987) opined that Surinam cherry (*Eugenia uniflora* L.) fruits can be preserved whole in syrup. Mundade (2002) reported that aonla preserve made from the cultivar NA-6 scored highest for colour (8.90), appearance (8.60) and flavour (8.40) against Krishna, NA-10, NA-7 and local cultivar. Bael (*Aegle marmelos*) fruits of 1.5 cm thick after removing the hard rind can be used to prepare preserves by keeping in sugar syrup and gradually raising the strength to 70°Brix (Singh *et al.*, 2014).

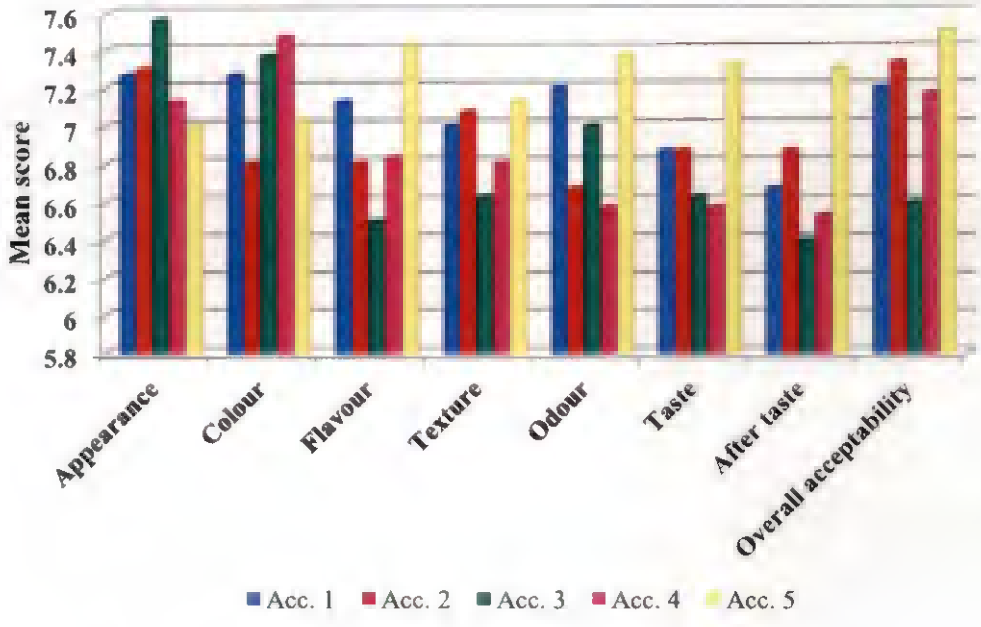


Fig 9. Sensory rank scores of sweet lovi-lovi wine from five accessions

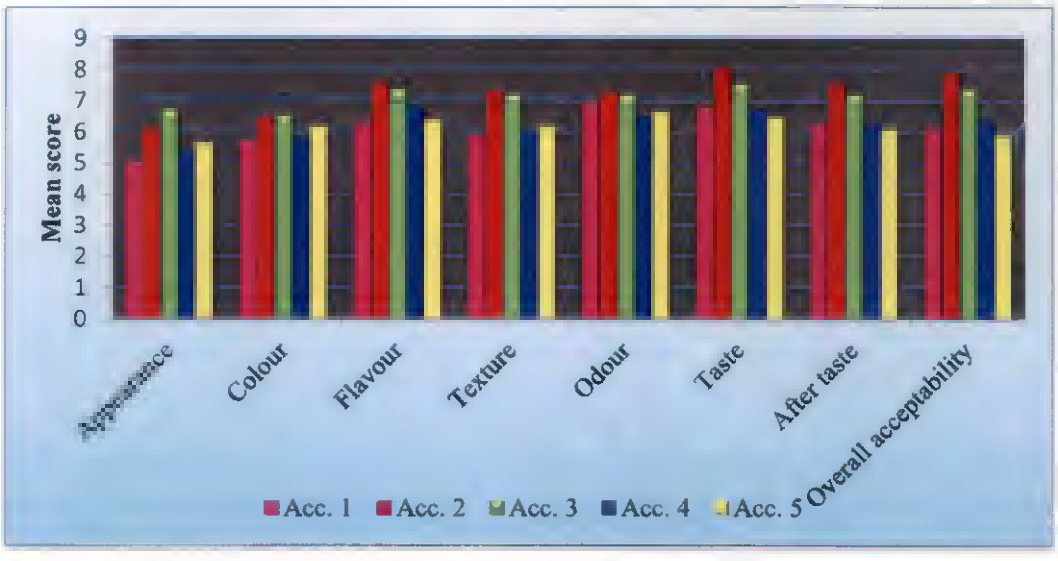


Fig 10. Sensory rank scores of sweet lovi-lovi preserve from five accessions

5.3.1.3 *RTS beverage*

Highest mean score for appearance (7.44), colour (7.12), texture (7.44), taste (7.81), and overall acceptability (7.78) was recorded for RTS beverage prepared from Acc. 3 whereas the RTS beverage prepared from Acc. 5 bagged highest mean score for flavour (7.37), odour (7.25), and after taste (7.37) (Fig 11). The RTS beverage prepared from Acc. 3 attained a total score of 59.09 which was highest and were selected for three months storage. On storage, all the attributes showed a reducing trend and the total score reduced from 59.09 to 55.43 after three months. Organoleptic evaluation of jamun RTS beverage standardized by Hema (1997) have shown that the colour, taste, appearance, flavour and overall acceptability were more when the beverage was prepared from 25 per cent juice. Chandana (2009) reported a decline in overall acceptability of pomegranate RTS beverage stored at 10°C. Kavitha (2011) reported that ber RTS beverage prepared using 15 per cent pulp with 15°Brix TSS stored at low temperature was rated excellent for organoleptic qualities, but the overall acceptability was found reduced during storage. The loss of flavour and conversion of vitamin C and polyphenols into di or polycarbonyl compounds may be contributing towards decreasing trend in organoleptic scores. Sree (2012) assessed the appearance, taste, consistency, flavour and overall acceptability of sweet orange RTS beverage during three months storage and reported that it showed a slight declining trend. Singh *et al.* (2013) reported a similar trend in custard apple RTS beverage.

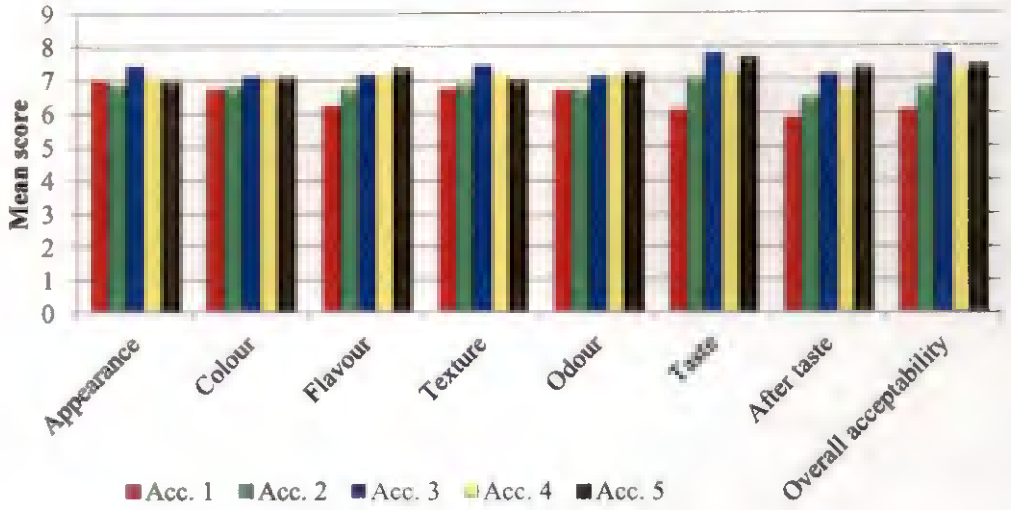


Fig 11. Sensory rank scores of sweet lovi-lovi RTS beverage from five accessions

5.3.2 Microbial load – initial and three months after storage

5.3.2.1 *Wine*

The yeast population was found nil during initial month and a count of 6 cfu/g x 10^3 was witnessed after three months of storage. Kalyani (2011) reported presence of yeast count in wine made from karonda (*Carissa carandas* L.) supplemented with Di-ammonium hydrogen orthophosphate two months after storage which was nil initially.

5.3.2.2 *Preserve*

In the initial month, the bacterial population was nil and during final month the count was 18 cfu/g x 10^6. The yeast population was found to be insignificant during initial and final month. The fungal population was found to be nil during initial month and the count is 2 cfu/g x 10^3 after three months storage.

Joy (2003) observed no visible presence of microflora in lovi-lovi preserve in sugar after six months of storage.

5.3.2.3 *RTS beverage*

In the initial and final month the bacterial and yeast population were found insignificant in RTS beverage prepared from sweet lovi-lovi fruits. The fungal population was nil during initial month and the count was 1 cfu/g x 10^3 three months after storage. The *E. coli* count of RTS beverage prepared from Acc. 3 was checked out initially and at the end of storage, since pathogenic *E. coli* was found to cause illness through contaminated water. The *E. coli* population was nil during the initial and final month of storage. Kalyani (2011) reported an increase in fungal count from 21st to 28th day in RTS beverage from karonda (*Carissa carandas* L.). Sree (2012) reported no fungal contamination in the sweet orange RTS beverage during two months of storage (0) and fungal count was found increasing (24) with increase in storage upto three months.

Summary

6. SUMMARY

Investigation on "Post harvest characterisation and value addition of sweet lovi-lovi (*Flacourtia* spp.)" was carried out in the Department of Processing Technology during 2015-17.

The sweet lovi-lovi accessions were collected from the college orchard of Department of Fruit Science - College of Horticulture, Central nursery and National Bureau of Plant Genetic Resources, Regional Station, Vellanikkara.

The physico-chemical parameters observed in sweet lovi-lovi accessions showed significant difference in characters like fruit length, fruit diameter, fruit weight, fruit volume, seed number and physical composition. Acc. 2 scored maximum for fruit diameter, fruit weight, pulp percentage and minimum for seed percentage. Biochemical characters also varied significantly among sweet lovi-lovi accessions. The highest total sugar (12.81 %), non reducing sugar (1.33 %), anthocyanin (0.04 mg $100g^{-1}$), carotenoids (582.55 mg $100g^{-1}$), iron (33.23 mg $100g^{-1}$), crude fibre (2.92 g $100g^{-1}$) and lowest tannin (0.21 mg $100g^{-1}$) was observed in Acc. 2 collected from college orchard. Hence ripe sweet lovi-lovi fruits from Acc. 2 was selected for shelf life studies.

The surface sanitised fruits were subjected to five different packing *viz.*, packing in polythene cover (200 gauge) with ventilation, polythene cover (200 gauge) without ventilation, polypropylene punnets, polystyrene box covered with cling film, shrink wrapping in areca plate and one without any package is used as control. Each package was stored in ambient, refrigerated (5 ± 2°C) and cold storage (12 ± 2°C) conditions. Observations on physiological loss in weight, browning, shelf life and various biochemical characters were recorded at daily intervals during storage under three conditions.

On comparing the three storage conditions, areca plates containing fruits wrapped with polyolefin film of 15μ thickness and fruits packed in polythene cover (200 gauge) without ventilation stored under cold storage were found to have longest shelf life (3 days). Storage at low temperature immediately after harvest reduces the rate of respiration resulting in reduction of building up of the respiratory heat, thermal decomposition, and microbial spoilage and also helps in retention of quality and freshness for a long period. This might be the reason for increased shelf life under refrigerated and cold storage condition. The areca plates containing fruits wrapped with polyolefin film of 15μ thickness stored under cold storage was found to be best for preserving TSS after one day of storage (17.27° Brix).

As the keeping quality of the whole fruit is very less, improvement in the post harvest processing is done by developing value added products like wine, preserve and Ready To Serve beverage.

Sweet lovi-lovi wines were prepared from five accessions and the mean rank scores for flavour (7.43), texture (7.13), odour (7.37), taste (7.33) and after taste (7.30) were highest for Acc. 5. The overall acceptability was also maximum for Accession 5 (7.50). Thus sweet lovi-lovi wine prepared from Acc. 5 was selected for storage studies. On storage, all the attributes of wine showed an increasing trend and the total score raised from 58.09 to 61.77 after three months. The TSS of the wine from Acc. 5 decreased with the advancement of storage period whereas, the phenol content and alcohol content increased with storage.

Among the preserve prepared from five accessions of sweet lovi-lovi fruits highest mean scores for flavour (7.54), texture (7.27), odour (7.27), taste (8.00), after taste (7.54) and overall acceptability (7.86) was recorded for Acc. 2 and for appearance and colour highest mean score were noticed in Acc. 3. During storage the total score increased from 58.02 to 58.47 for preserve from Acc. 2.

Among the RTS beverage prepared from five accessions the highest mean score for appearance (7.44), colour (7.12), texture (7.44), taste (7.81), and overall acceptability (7.78) was recorded for RTS beverage prepared from Acc. 3 whereas the RTS beverage prepared from Acc. 5 bagged highest mean score for flavour (7.37), odour (7.25), and after taste (7.37). On storage, all the attributes show a reducing trend and the total score reduced from 59.09 to 55.43 after three months of storage of Acc. 3.

The microbial population was found within permissible limits during initial month and three months after storage.

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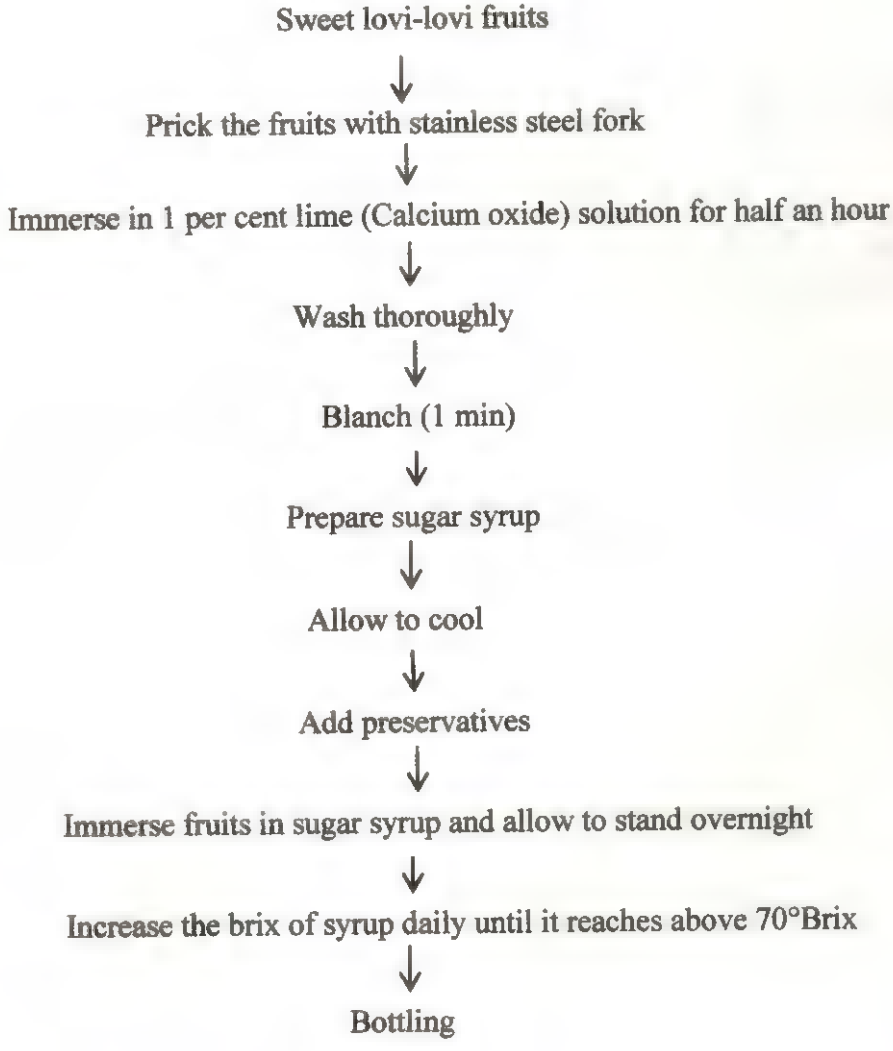
Appendices

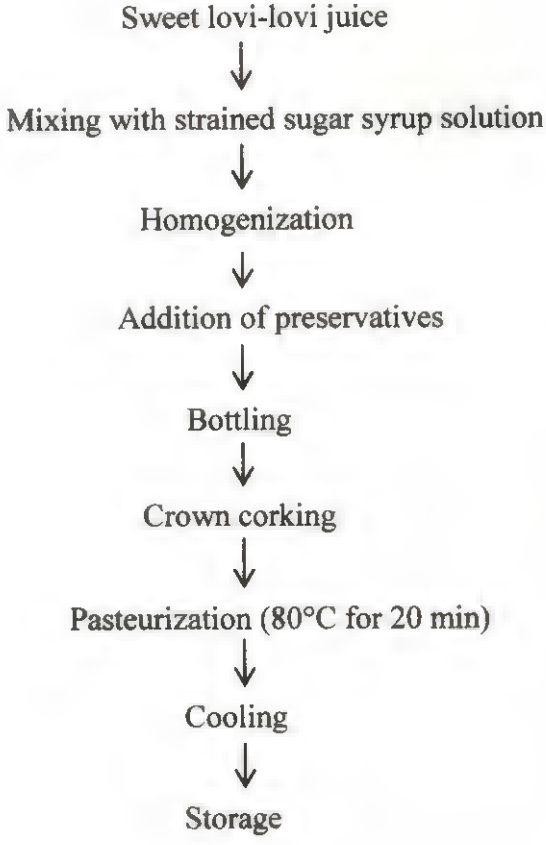
APPENDIX I

Preparation of sweet lovi-lovi preserve



APPENDIX I (a)

Preparation of sweet lovi-lovi RTS beverage



APPENDIX - II

Score card for organoleptic evaluation of sweet lovi-lovi products

Name of the judge:

Date:

Characteristics	Score				
	Acc. 1	Acc. 2	Acc. 3	Acc. 4	Acc. 5
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 III

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. ROSE BENGAL AGAR MEDIA (FOR FUNGUS)

Papaic digest of soyabean meal	: 5 g
Dextrose	: 10 g
Monopotassium phosphate	: 1 g
Magnesium sulphate	: 0.50 g
Rose Bengal	: 0.05 g
Agar	: 15 g
pH	: 5.6

3. SABAURAUD DEXTROSE AGAR (FOR YEAST)

Mycological peptone	: 10 g
Dextrose	: 40 g
Agar	: 15 g
Distilled water	: 1000 ml
pH	: 5.6

POST HARVEST CHARACTERISATION AND VALUE ADDITION OF SWEET LOVI-LOVI (*Flacourtia* spp.)

by

KARISHMA SEBASTIAN
(2015 -12-014)

ABSTRACT OF THE THESIS

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DEPARTMENT OF PROCESSING TECHNOLOGY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR – 680 656
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2017

ABSTRACT

The present study entitled "Post harvest characterisation and value addition of sweet lovi-lovi (*Flacourtia* spp.)" was undertaken with the objectives of characterising sweet lovi-lovi accessions based on physico-chemical and nutritional attributes, to enhance shelf life through packaging and value addition.

The sweet lovi-lovi accessions were collected from three centers located at Vellanikkara namely, college orchard of Department of Fruit Science, Central nursery and Regional station of National Bureau of Plant Genetic Resources.

The physico-chemical characters showed significant variation among the sweet lovi-lovi accessions. The desirable post harvest qualities like high fruit weight, pulp percentage, less seed content along with highest total sugar (12.81 %), non reducing sugar (1.33 %), anthocyanin (0.04 mg $100g^{-1}$), carotenoid (582.55 mg $100g^{-1}$), iron (33.23 mg $100g^{-1}$), crude fibre (2.92 g $100g^{-1}$) and lowest tannin (0.21 mg $100g^{-1}$) was observed in Acc. 2 collected from college orchard. Hence ripe sweet lovi-lovi fruits from Acc. 2 were used for shelf life studies.

Standardisation of packaging and storage requirements were done in Acc. 2 by subjecting fruits to five methods of packaging *viz*., packing in polythene cover (200 gauge) with ventilation, polythene cover (200 gauge) without ventilation, polypropylene punnets, polystyrene box covered with cling film, shrink wrapping in areca plate. Each package was stored in ambient, refrigerated (5 ± 2°C) and cold storage (12 ± 2°C) conditions.

Shelf life of sweet lovi-lovi fruits was longer when stored under cold storage condition than fruits stored in ambient and refrigerated condition. Areca plates containing fruits wrapped with polyolefin film of 15µ thickness (T_6) and fruits packed in polythene cover (200 gauge) without ventilation (T_3) in cold storage were found to

have longest shelf life (3 days). The physiological loss in weight (PLW %) was significantly highest and shelf life was shortest in unwrapped fruits under the three different storage conditions. The treatment T_6 showed highest TSS (17.27 °Brix) and total sugar (12.73 %) after one day of storage at 12 ± 2°C.

To increase the utilisation of sweet lovi-lovi fruits, value added products like wine, preserve and Ready To Serve beverage were prepared and evaluated.

Among the wine prepared from five accessions, the overall acceptability was maximum for Acc. 5 (7.50). All the attributes of wine showed an increasing trend on storage and the total score raised from 58.09 to 61.77 after three months. The highest mean scores for flavour (7.54), texture (7.27), odour (7.27), taste (8.00), after taste (7.54) and overall acceptability (7.86) were recorded for Acc. 2 among the preserve prepared from five accessions of sweet lovi-lovi. During storage, the total score for organoleptic attributes increased from 58.02 to 58.47 for preserve prepared from this accession. RTS beverage prepared from Acc. 3 recorded highest mean score for appearance (7.44), colour (7.12), texture (7.44), taste (7.81), and overall acceptability (7.78). All the attributes showed a declining trend and the total score decreased from 59.09 to 55.43 after three months of storage. Thus accessions 2, 3 and 5 were found to be ideal for preparation of preserve, RTS beverage and wine respectively. The microbial population was least during the initial month and increased slightly on storage but was within the permissible limit in all the products.

The results of the study indicated that sweet lovi-lovi has good nutritional potential almost similar to other minor fruits like jamun, blackberry etc. The extension of shelf life to three days also help in better utilization of the fruit and prospects for value addition is high for sweet lovi-lovi.