DEVELOPMENT AND EVALUATION OF ANTHOCYANIN ENRICHED GINGER CANDY

Thesis

by

MONIKA THAKUR
(H-2017-31-M)

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Dr (Mrs) Manisha Kaushal
Scientist

Department of Food Science and Technology
College of Horticulture
Dr. Yashwant Singh Parmar University of Horticulture & Forestry
(Nauni) Solan (HP)-173 230 India

CERTIFICATE – I

This is to certify that the thesis titled **"Development and evaluation of anthocyanin enriched ginger candy"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science, Food Technology** in the discipline of **Food Science and Technology** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)- 173230 is a record of bonafide research work carried out by **Ms Monika Thakur (H-17-31-M)** daughter of Sh. Heera Singh under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

Manisha

Place: Nauni, Solan
Date: Nov 2019

Dr (Mrs) Manisha Kaushal
Major Advisor

CERTIFICATE - II

This is to certify that the thesis titled, **"Development and evaluation of anthocyanin enriched ginger candy"** submitted by **Ms Monika Thakur (H-2017-31-M)** daughter of Sh. Heera Singh to Dr. Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni) Solan (HP)- 173230 India in partial fulfilment of the requirements for the degree of Master of Science Food Technology in the discipline of **Food Science and Technology** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

Manisha 2/11/19

Dr (Mrs) Manisha Kaushal
(Scientist)
Major Advisor

Anupama 02/11/2019

Dr Anupama Sandal
External Examiner

02/11/2019

Dr NK Bharat
Dean's Nominee

Advisory Committee

1. **Dr Devina Vaidya**
   Principal Scientist
   Deptt. of Food Science &Technology 2/11/19

2. **Dr Neerja Rana**
   Assistant Professor
   Deptt. of Basic Science 2/11/19

3. **Dr Anil Verma**
   Assistant Professor
   Deptt. of Food Science & Technology Anil Verma

(Head of the Department)

Countersigned

Dean of the College

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Place: Nauni, Solan
Date: **(Monika Thakur)**

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ABBREVIATIONS USED

%	:	Per cent
CD	:	Critical difference
Cfu	:	Colony forming units
CRD	:	Completely Randomized Design
cv.	:	Cultivar
EMC	:	Equilibrium moisture content
ERH	:	Equilibrium relative humidity
G	:	Gram
Ha	:	Hectare
hrs/hr	:	Hours
TPC	:	Total plate count
Kg	:	Kilogram
T	:	Time
Mg	:	Milligram
Mg	:	Microgram
min.	:	Minute
Mm	:	Millimeter
MT	:	Metric tones
et al.	:	And more
ºB	:	Degree brix
ºC	:	Degree celsius
ALP	:	Aluminium laminated pouches
Ppm	:	Parts per million
RBD	:	Randomized Block Design
i.e	:	That is
Temp.	:	Temperature
TSS	:	Total soluble solids
SG	:	Solid gain
WL	:	Water loss
WR	:	Weight Reduction

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Chapter-1

INTRODUCTION

Ginger (*Zingiber officinale* Roscoe) is a tropical herbaceous monocotyledonous and perennial rhizome which belongs to the order Scitamineae and family Zingiberaceae. It is native of South East Asia from where it was introduced to Africa and Caribbean regions (Purseglove *et al*., 1981). It is one of the principal spice and an important cash crop of the world (Ajay and Ogunlade, 2014). The total production of ginger in the world is 32, 70,762 tonnes from the total acreage of 4, 07,773 hectares. India, China, Nepal, Nigeria and Thailand are the major producers of ginger in the world (FAO, 2018). In India ginger is grown in an area of 165.00 thousand hectares with a production of 1109 thousand tonnes (NHB, 2018). In Himachal Pradesh, ginger is grown in the mid hill regions covering an area of 3.2 thousand hectares with a production of 7.6 thousand tonnes (Kaushal *et al*., 2017).

Ginger is a spice and medicinal plant gaining attention in the pharmaceutical, food and chemical industries as being an excellent source of several bioactive phenolics apart from other nutritional constituents (Srinivasan, 2016). The pungency of fresh ginger is due to gingerol, which is formed in the plant from phenylalanine, malonate and hexonate (Evans, 2002). Gingerol has potent antimicrobial and antioxidant activity apart from countering liver toxicity by increasing bile secretions (Pawer, 2009), whereas shogaol, a dehydrated product of gingerol significantly attenuate a variety of neuro-inflamatory responses in cortical astrocytes (Shim *et al*., 2011 and El-Ghorab *et al*., 2010).

Ginger is found effective in stimulating digestion, relieve constipation and flatulence by increasing muscular activity in the digestive tract (Polasa and Nirmala, 2003). It is also found effective in treating nausea caused by sea sickness, morning sickness, (Sebiomo *et al*., 2011) diarrhea, asthma, respiratory disorders (Medoua *et al.,* 2009) and treat migraine headache without side effects (Mustafa and Srivastava, 1990).

Ginger is presently used in various forms like fresh, dried as sonth and ginger powder, pickles, ginger preserves or candies, ginger juice for making squashes and appetizers etc. Fresh ginger are perishable in nature and are spoiled due to improper handling, growth of spoilage microorganisms, susceptibility to rhizome rot, wilting and sprouting, action of

naturally occurring enzyme, chemical reactions and structural changes during storage (Baranowski, 1985). Processing ginger into dried product is an important method of reducing perishability and also to increase storage stability (Pezzutti *et al*., 1997).

Plum (*Prunus domestica* L., Rosaceae) is one of the important fruit crops cultivated in temperate regions of the world, consumed mostly as fresh form (Pino and Quijano, 2012). The major world producers of plum include USA, France, Italy, Argentina, Chile and Turkey (Sabarez and Price, 1999). Plum is predominantly grown in Himachal Pradesh, Jammu and Kashmir and Uttarakhand and to some extent in Nilgiri hills of South India (Ravindran *et al*., 2007; Jindal and Chandel, 2002). In Himachal Pradesh, it is mainly grown in Shimla, Solan, Kullu and Mandi districts and covers an area of 18, 000 hectares with an annual production of 1, 20, 000 metric tonnes (Anonymous, 2018). Fresh plum fruits are delicious, nutritious and have a wide variety of size and colour. Plum fruits are an excellent source of antioxidants, calcium, magnesium, iron, potassium and fibre besides substantial amount of vitamin C (Sabarez *et al*., 1997). The perishable nature, short harvest period and sourness of plum fruit is to some extent reducing the acceptability of the fruit by consumers.

Natural pigments have importance in the field of medicine, food and cosmetics industries (Azeredo, 2009). Now-a-days food and beverage industries are more focusing towards the natural colours due to their high colouring properties, non-toxic effects and their antioxidant potential (Kearsley and Katsaboxakis, 2006). Consumers are attracted more towards the natural pigments because of its health benefits than synthetic colours as they do not show any side effect on human body hence, the use of synthetic food colourants is restricted by legal regulations of both international and national authorities (Azeredo, 2006). Anthocyanins, the largest subclass of flavonoids, is a powerful group of antioxidants that comprises of water-soluble phytochemical responsible for the deep rich red to blue purple colours in fruits and vegetables which protect the body from diseases and prevent premature aging. Antioxidants prevent important cells in our body from being oxidized by not only removing the products of oxidation called free radicals, but also by offering themselves up for oxidation instead. Anthocyanins is found in berries like black currant, blueberries, strawberries, plum, prunes, grapes and red apples.

Ginger candy is a traditionally ready to eat intermediate moisture food (IMF) product having a great demand in confectionery industry due to the acceptable sensorial characteristics and appreciable nutrients especially phenols. In the conventional method of

ginger candy preparation, honey may be an effective replacement for sugar which is generally used as a sweetener. Honey is sweeter than table sugar due to high concentration of fructose and glucose which are simple sugars and are easily digestible. The high concentration of fructose and glucose results in increased rate of mass transfer as being low molecular sugar compounds. Honey also serves as a source of natural antioxidants as it prevents deteriorative oxidation reactions and inhibit browning in fruits and vegetables (Oszmianski and Lee, 1990; Mc Lellan et al., 1995; Chen et al., 2000). Thus, the present study undertaken will not only stabilize the prices of ginger but will also reduce post-harvest losses in ginger and plum which will fetch remunerative price to the growers.

Thus the present study entitled **"Development and evaluation of anthocyanin enriched ginger candy."** was undertaken with the following objectives-

i) Standardization of parameters for the development of instant process for ginger candy preparation.
ii) Optimization of process for the preparation of anthocyanin enriched ginger candy.

Chapter-2

REVIEW OF LITERATURE

Ginger (*Zingiber officinale* Roscoe, Zingiberaceae) is an important cash crop and principal spice of world and India (Bartley and Jacobs, 2000). The total world production of ginger is 32, 70,762 tonnes with the total acreage of 4, 07,773 hectares. India, Nigeria China, Indonesia and Nepal are the major ginger producing countries of in the world (FAO, 2018). In India ginger is grown in an area of 165.00 thousand hectares with a total production of 1109.00 thousand tonnes (FAO, 2018). In Himachal Pradesh, ginger is grown in the mid hill regions covering an area of 3.20 thousand hectares with a yield of 7.60 thousand tonnes (Kaushal *et al.,* 2017). Ginger has been used all over the world for a wide array of ailments including sore throats, rheumatism, muscular aches, arthritis, constipation, pains, cramps, sprains, vomiting, hypertension, indigestion, dementia, fever and infectious diseases (Ali *et al.,* 2008; Tan and Vanitha, 2004). Due to its pungency taste it is widely used around the world in food both in fresh and dried form as it adds flavour to the meal (Jayashree *et al.*, 2014). Ginger is presently used in various forms like fresh, dried as sonth and ginger powder, pickles, ginger preserves or candies, ginger juice for making squashes and appetizers etc (Peter, 1996).

Plum (*Prunus domestica* L., Rosaceae) is an important fruit crops cultivated in temperate regions of the world and consumed mostly in a fresh form (Pino and Quijano, 2012). In India, the total area of plum is 24,000 hectares with a total production of 74,000 thousand million tonnes (Anonymous, 2018). Plum is an excellent source of anthocyanins, calcium, iron, potassium, magnesium and fibre besides containing substantial amount of vitamin C (Sabarez *et al.*, 1997). The perishable nature, short harvest period and sourness of plum fruit is to some extent reducing the acceptability of the fruit by consumers. Natural pigments have an important attributes in the field of medicine, food and cosmetic industries (Azeredo, 2009). Now-a-day the food and beverage industries are more focusing towards the natural colours due to their high colouring properties and non-toxic effects (Kearsley and Katsaboxakis, 2006). Anthocyanins is found in berries like black currant, blueberries, strawberries, plum, prunes, grapes and red apples. Anthocyanins, the largest subclass of

flavonoids, comprises of group of water-soluble phytochemical responsible for the deep rich red to blue-purple colors in fruits and vegetables.

Although fresh ginger has many medicinal properties but it is perishable in nature due to susceptibility to rhizome rot, wilting and sprouting and action of naturally occurring enzymes during storage (Baranowski, 1985). Thus, there is an urgent need to standardize a suitable method for preparation of various products for its efficient utilization. Therefore blending of ginger with plum is one of the avenue for immediate exploration to match the challenge of increase production and fluctuating prices thereby augmenting the income of growers. Therefore literature pertaining to present study has been reviewed in this chapter under following heads and subheads:

2.1 PHYSICO-CHEMICAL CHARACTERISTICS

2.1.1 Physical Characteristics

The physico-chemical characteristics of ginger may vary due to land races, variation in maturity stage, time elapsed between harvesting and growing conditions of the ginger.

2.1.1.1 Weight

The average weight of the whole fresh ginger rhizome was found to be 103.45 g (Jayashree and Visvanathan, 2011); 91.88 g (Onu and Okafor, 2002); 38.60 g (Kumar *et al.*, 2013), 37.69 g (Kirtiraj *et al.*, 2013); 116.77 g (Dhiman, 2015); 113.76 g (Hema, 2017) and 150.00 g (Monty and Panda, 1994). Ginger rhizome weight varies between 8.00 to 161.60 g and 20.74 to 122.06 g as reported by Mohanty (1984) and Akhtar *et al.*, (2013) respectively.

Average fruit weight of 'Santa Rosa' variety of plum has been observed as 61.75 g (Mishra and Srivastava, 1970); 52.00 g (Wills *et al.*, 1983); 50.42 g (Sharma and Mahapatra 1997); 33.91g (Lal and Thakur, 1978); 50.36 g (Raj *et al.*, 2012) and 46.28 (Sharma *et al.*, 2011). Gothwal *et al.*, (1998) found fruit weight of 'Santa Rosa', 'Mariposa' and 'Early Transparent Gage' varieties of plum as 27.00 g, 27.40 g and 27.20 g respectively.

From the above review, it emerges that mean weight of the ginger rhizome and plum ranged between 8.00 to 161.60 g and 27.00 to 61.75 g respectively.

2.1.1.2 Size

Size, shape and appearance of ginger rhizome generally varies with the cultivar and growing conditions (Policegoudra and Aradhya, 2007). The tender ginger rhizome is longitudinal in shape with size parameters of length and breadth as 6.18 cm × 3.57 cm (Kirtiraj *et al.,* 2013); 4.80 cm × 3.10 cm (Kumar *et al.,* 2013) and 14.99 cm × 8.17cm (Jayashree and Visvanathan, 2011); 10.01×7.81 cm (Dhiman, 2015) and 10.15 × 7.73 cm (Hema, 2017) respectively. Akhtar *et al.* (2013) found significant difference among 10 selected ginger germplasm in respect of size of rhizome ranging between 5.01 cm to 10.44 cm of length and 1.82 cm to 4.60 cm of breadth.

The size parameters (length and breadth) of 'Santa Rosa' plum was recorded as 3.97 cm × 4.05 cm (Sharma and Mahapatra, 1997); 3.64 cm × 3.59 cm (Lal and Thakur, 1978) and 2.80 cm × 3.00 cm (Raj *et al.,* 2012), 4.81 cm × 4.31 cm (Mishra and Srivastava, 1970) and 3.44 cm × 3.44 cm (Mehta and Jindal, 1984) respectively.

From the above review, it emerges that size parameters of fresh ginger rhizomes ranged between 4.80 to 16.18 cm length and 1.82 to 8.17 cm breadth, and size parameters of fresh plum ranged between 2.80 to 4.81cm length and 3.00 to 4.05 cm breadth.

2.1.1.3 Volume

The average volume of whole ginger rhizome ranged between 64.0 to 85.0 cm^3 as observed by Onu and Okafor (2002) and Jayashree and Visvanathan (2011) and 108.15 cm^3 by Dhiman (2015).

2.1.1.4 Density

The density of ginger rhizome decreased with the increase in fibre and 6-gingerol content (Balladin *et al.,* 1996). Govindarajan, (1982); Dhiman (2015). Hema (2017) reported that density of the ginger rhizome varies from 0.877 to 0.883, while Phoungchandang and Sertwasana, (2010) found that density of 4-12 month old ginger rhizome ranged between 0.98 to 1.02.

2.1.2 Chemical characteristics

The composition of ginger may vary due to varietal difference, variation in maturity stage, time elapsed between harvesting and growing conditions of the ginger.

2.1.2.1 Moisture

The moisture content in freshly harvested ginger rhizome vary between 80.00 to 85.00 per cent (Emehute, 2002); 94.17 per cent (Puengphian and Sirichote, 2008); 86.00 per cent (Policegoudra and Aradhya, 2007); 82.60 per cent (Phoungchandang and Sertwasena, 2010) and 75.20 per cent (Tanveer *et al.*, 2014); 82.39 per cent (Dhiman, 2015) and 82.86 per cent (Hema, 2017) on fresh weight basis.

Moisture content of 'Santa Rosa' variety of plum was recorded 83.40 per cent by Mishra and Srivastava (1970); 85.70 per cent by Westwood (1978); 84.10 per cent by Raj *et al.* (2012); 88.40 g by Dhiman (2015) and 86.80 per cent by Gothwal *et al.* (1998).

From the above review, it emerges that moisture content of the tender ginger rhizome and plum ranged between 75.20 to 94.17 per cent and 83.40 to 88.40 respectively depending on time of harvest.

2.1.2.2 Total soluble solids (TSS)

Increase in total soluble solids may be attributed to the increase in soluble sugars, soluble pectin and soluble organic acids (Bhagwan and Awadhesh, 2014). Fresh ginger rhizome contained 5.00 per cent of total soluble solids as reported by (Krishnapillai, 2005), 3.00 per cent by (Dhiman, 2015) and 2.69 per cent by (Hema, 2017) while, Akhtar *et al.* (2013) reported 3.33 to 6.67 per cent of total soluble solids in the ten germplasms of ginger rhizome.

The total soluble solids in 'Santa Rosa' variety of plum varied from 11.50 to 13.79 per cent as observed by Wills *et al.* (1983) and Mishra and Srivastava (1970) while 14.50 to 16.00 percent of total soluble solids has also been recorded by Lal and Thakur (1978) and Sahni *et al.* (1994).

From the above review, it emerges that total soluble solids of the fresh ginger rhizome and plum ranged between 3.33 to 6.67 per cent and 11.50 to 16.00 per cent respectively.

2.1.2.3 Titratable acidity

The most important function of acids in food is their contribution to sour taste. Besides, they also intensify and modify the taste perception of other flavouring agents (Thomas and Corden, 1970). Titratable acidity (as citric acid) of fresh ginger rhizome has

been found to be 0.16 per cent as reported by Rahman *et al.* (2013) and 2.10 per cent as observed by Shirshir *et al.* (2012).

Titratable acidity (as malic acid) in 'Santa Rosa' variety of plum has been observed as 1.39 per cent (Mishra and Srivastava 1970); 1.89 per cent (Sharma and Mahapatra 1997); 1.53 per cent (Sahni *et al.*, 1994); 2.02 per cent (Lal and Thakur, 1978) and 2.01 per cent (Raj *et al.* (2012). Further, 1.26 per cent, 1.44 per cent and 1.38 per cent of titratable acidity as malic acid was recorded in 'Burbank-A', 'Red Ace' and 'Kanto-5' cultivars of plum respectively by Sharma and Kaushal (1999).

Thus, the range of organic acid as citric acid in fresh ginger rhizome vary from 0.16 to 2.10 per cent and organic acid as malic acid in fresh plum vary from 1.26 to 2.02 per cent.

2.1.2.4 pH

The pH value of a food is a function of the free hydrogen ions present in the food. Acids present in food release these hydrogen ions and gives the food its distinct sour flavor which is a measure of free acidity. The pH value of ginger rhizome varied between 5.23 to 6.72 as reported by Akhtar *et al.* (2013), Shirshir *et al.* (2012), Rahman *et al.* (2013); Dhiman (2015) and Hema (2017). According to U.S. Food and Drug Administration, (2008) approximate pH value of the fresh ginger varied from 5.60 to 5.90.

The pH values of fresh fruits of plum hybrids (*Prunus domestica* L.) ranged from 3.36 to 3.66 (Milosevic and Milosevic, 2011). According to Milosevic *et al.*, (2012) pH value of three plum cultivars like "Jojo", "Hanita" and "Katinka" was observed as 3.80, 3.54 and 3.97 respectively.

Thus, the range of pH value in fresh ginger rhizome and plum vary between 5.23 to 6.72 and 3.36 to 3.97 respectively.

2.1.2.5 Sugars

Carbohydrates are a class of energy yielding substances such as starch, glucose, cane sugar etc which provide most of the energy in almost all human diets. Carbohydrates provide 4 Kcal/g of energy and promote the utilization of fats and reduce the wastage of proteins (Solomos and Latles, 1973). Policegoudra and Aradhya, (2007) reported that freshly harvested ginger rhizome contained total sugar content of 0.95 per cent and reducing sugars

content of 0.42 per cent, while Shankaracharya,(1982) reported 0.80 per cent of total sugar present in the fresh ginger rhizome.

Lal and Thakur (1978) observed the total sugars of 6.54 per cent, while reducing sugars of 3.48 per cent in ‘Santa Rosa' variety of plum. However, in the same cultivar, Mehta and Jindal (1984) recorded 6.75 and 3.70 per cent of total and reducing sugars respectively. Per cent total sugars content as 7.97, 8.02, 9.53 and per cent reducing sugars content as 6.67, 5.92 and 7.86 of were recorded in ‘Burbank-A’, ‘Red Ace’ and ‘Kanto-5’ cultivars of plum respectively by Sharma and Kaushal (1999).

From the above review, it emerges that fresh ginger rhizome contains total sugars content of 0.80 to 0.95 per cent and reducing sugars as 0.42 per cent, whereas total sugars in plum ranged between 6.54 to 9.53 per cent and reducing sugars ranged between 3.48 to 7.86 per cent.

2.1.2.6 Ascorbic acid

Ascorbic acid also known as vitamin C, varies with the type of commodity and its exposure to sun and other growing conditions (Franke *et al.*, 2004). It is generally higher in early fruits than in late fruit (Combes, 2001). The stability of ascorbic acid decreases with increase in temperature and pH (Emese and Nagymate 2008). Fresh ginger rhizome contains 1.04 mg/100 g (Latona *et al.*, 2012); 3.75 mg/100 g (Shahid and Hussain, 2012) and 9.33/100g of ascorbic acid (Shirin and Prakash, 2010) as observed by different authors.

The ascorbic acid content of 'Santa Rosa’ variety of plum has been recorded as 5.30 mg/100 g by Mishra and Srivastava (1970); 4.40 mg/100 g by Mehta and Jindal (1984) and 10.40 mg/l00g by Sahni *et al.,* (1994). A varied range of 4.00 to 11.00 mg/100 g of vitamin C in plum has been observed by Bhutani and Joshi (1995). Further, ascorbic acid content of 9.80 mg/100 g and 9.50 mg/100 g in 'Santa Rosa', 'Mariposa' and 'Early Transparent Gage' respectively has been observed by Gothwal *et al.* (1998).

Thus, the range of ascorbic acid content in fresh ginger rhizome and plum vary between 1.04 to 9.33 mg/100g and 4.00 to 11.00 mg/100g respectively.

2.1.2.7 Total phenols

Phenolic compounds are secondary metabolites, which are widely distributed in plants and plant parts. They are important components of many fruits and vegetables as they not

only influence on sensory qualities of the fruit, but also for their antioxidant, anticarcinogenic, antimicrobial, antiallergic, antimutagenic and anti-inflammatory properties (Cao and Cao, 1999; Eberhardt *et al.* 2000; Joshipura *et al.* 2001; Juranic *et al.* 2005; Duthie, 2007; Alesiani *et al.* 2010). Puengphian and Sirichote (2008) reported that total phenol content of ginger increased after drying due to the conversion of 6-gingerol to 6-shogaol in dried product (Balladin *et al.* 1996; Ali *et al.* 2008). Total phenolic content in fresh ginger was found to be 24.63 mg GAE/100g (Puengphian and Sirichote, 2008); 76.93 mg GAE/100g (Saffa *et al.*, 2010); and 514.02 mg GAE/100g (Oknye *et al.*, 2015). EL-Ghorab *et al.* (2010) found that maximum total phenolic contents were observed in the methanol extract of ginger as 95.2 mg/100 g dry extract) followed by the hexane extract (87.5 mg/100g dry extract). Kaushal *et al.* (2014) observed wide variation in phenol content of ginger procured from different locations of Himachal Pradesh where high phenol content was found in cultivar *Himgiri* (7.09 mg/100 g), procured from university farm (Solan) followed by Pandah (6.5 mg/100 g), while low phenols were found in ginger procured from Dharja area (3.20 mg/100 g) of Solan district.

Voca *et al.* (2009) found the total phenol content in plum cultivars to range between 157.70 to 344.10 mg GAE/100g on fresh weight basis. Similarly, Kim *et al.* (2003) found the total phenolic content in plum fruits range between 174.0 to 375.0 mg GAE/100g for six commercial cutivars of plums. According to Chun *et al.* (2003), amount of total phenolic content in fresh plum ranged from 138.1 mg GAE/100 g for cultivar New York 9 to 684.5 mg GAE/100 g for ‘Beltsville Elite’.

2.1.2.8 Antioxidant activity

Natural antioxidants are of plant origin and these include vitamin, phenolic compounds and flavonoids (Hudson, 1990). Antioxidants are capable of delaying, retarding or preventing flavour deterioration or the development of rancidity which occurs due to oxidation in food. Further antioxidants also prevent oxidative damage caused by free radicals by interfering with the oxidation process by reacting with free radicals, chelating and catalytic metals and also by acting as oxygen scavengers (Shahid and Wanasundara, 1992; Buyukokuroglu *et al.*, 2001). Ginger is reported to be rich in antioxidant content and has been used as a curative medicine since ancient times (Grant and Lutz, 2000). Modern scientific research has revealed that ginger possesses numerous therapeutic properties including antioxidant effects and anti-inflammatory effects (Akoachere, 2002). Antioxidant activity in

fresh ginger rhizome has been reported as 79.19 per cent by Purnomo *et al.* (2010) and 79.0 per cent by Maizura *et al.* (2011). The antioxidant activities of peeled and unpeeled extracts were found to be 73.01 percent and 51.01 per cent respectively (Nwaoha *et al.,* 2013).

Various kinds of antioxidant components in plums play important roles in the combinative or synergistic contribution to total antioxidant capacity (Kim *et al.,* 2003). According to Wang *et al.* (1996) plums exhibits 4.4 times higher total antioxidant capacity than apples despite apples being one of the most commonly consumed fruits in the human diet. Erturk *et al.* (2009) studied antioxidant activity of dark purple, red and yellow skin coloured plum fruits to range between 71.15 to 78.99 per cent.

Thus, the range of antioxidant activity in fresh ginger rhizome and plum fruit varies between 51.01 to 79.19 per cent and 71.15 to 78.99 per cent respectively.

2.1.2.9 Crude fibre

Fibre is the organic residue left after treating the defatted material with boiling dilute solution of acid, alkali, alcohol and ether. The fibre constitutes mainly of cellulose, lignin and hemicelluloses. Aggarwal *et al.,* (2002) reported increase in the content of crude fibre of ginger with age of rhizomes. Cultivars such as ‘Kintoki’ and ‘Nadia’ recorded very less fiber and hence can be exploited for making value added products like slices preserved in syrup, ginger candy (crystallized ginger), jams, cakes etc. whereas the cultivars such as ‘Suruchi’, ‘Oman’, ‘Pulpally, ‘Thodupuzha-2’, ‘Kottayam, ‘Wyanad local’, ‘Vizagapatnam-1’, which recorded high fiber content was found useful for dried ginger products (Kizhakkayil and Sasikumar, 2009).

Wide variations have been observed in fibre content of different varieties of ginger. The mean value of crude fibre content in fresh ginger reported by different authors was 2.40 per cent (Virendra *et al.* 2013), 5.19 per cent (Thomas, 1966), 1.7 to 6.5 per cent (Pearson, 1971) and 4.7 to 9.8 (Chougule and Desai, 1988); 1.40 per cent (Dhiman, 2015) and 1.28 per cent (Hema, 2017). Jogi *et al.* (1974) and Sreekumar *et al.* (1980) found 6.88 per cent crude fibre in Himachal Pradesh variety ‘Himachali selection’ followed by 6.37 per cent in the cultivar Rio-de-Janerio, 5.40 per cent in the cultivar ‘Wynad local’, 4.60 to 6.0 per cent in the cultivar ‘Poona’ and 3.5 per cent in cultivar ‘Tura’.

Crude fibre content in plums were established between 1.4-2.3 per cent (Esehaghbeygi *et al.,* 2013) which were found with the values recorded by Ertekin *et al.* (2006). Calisir *et al.* (2005) also observed values of crude fibre as 2.1 per cent in wild plum.

Thus, the range of crude fibre content in fresh ginger rhizome and plum vary between 1.7 to 10.8 per cent and 1.4 to 2.3 percent respectively.

2.1.2.10 Total ash

Ash is a material that is left after burning the organic residue which comprises of minerals like calcium, phosphorus, iron, traces of iodine, fluorine etc. (Sengupta and Pal, 1971). Panhwar (2005) and Kokate *et al.* (2009) found that the raw ginger rhizome is composed of 6.00 to 6.64 per cent total ash, 1.7 to 5.48 per cent water soluble ash and 0.14 to 2.0 per cent acid insoluble ash respectively. Total ash content in fresh ginger rhizome has been found to be 1.79 per cent (Shahid and Hussain, 2012), 1.20 per cent (Gopalan *et al.*, 1995) and 1.00 per cent by Rahman *et al.* (2013); 1.34 per cent by Dhiman (2015) and 1.61 per cent by Hema (2017).

Total ash content in plum vary between 1.24 to 5.46 per cent as reported by Nisar *et al.* (2015) and (Esehaghbeygi *et al.,* 2013) respectively.

Thus, the range of total ash content in fresh ginger rhizome and plum vary between 1.00 to 6.64 per cent and 1.24 to 5.46 per cent respectively.

2.2 PEELING OF GINGER

Peeling of ginger is an important pre-requisite for carrying out various ginger value addition processes. Ginger is irregular in shape, therefore the peeling process is very tedious, time consuming and labour intensive. Commonly used methods of peeling ginger rhizomes include hand peeling, gunny bag peeling, lye peeling and sand blasting (Joshi *et al.*, 1991). Balakrishan (2005) found that the rhizomes after surface cleaning and manual peeling by scrapping the outer skin of rhizome with bamboo splits having pointed ends which accelerate the drying process. Evaluation of mechanical ginger peeler by Jayashree and Visvanathan (2013) conducted for varying drum loads (5, 6 and 7kg), drum speed (20, 25 and 30 rpm) and different peeling durations (5, 10 and 15 minutes) showed that the optimum machine parameters for maximum peeling with minimum loss was obtained at a drum load of 7 kg per batch at a drum speed of 30 rpm for a peeling duration of 15 minutes, to produce peeled

ginger. The peeling efficiency and material loss at optimum condition were determined as 59.43 per cent and 4.76 per cent respectively. Kaushal *et al.* (2014) evaluated different ginger peeling methods viz; hand peeling, gunny bag peeling, abrasive peeling, lye peeling and mechanical peeling and found that maximum recovery of peeled rhizome was obtained by mechanical peeler with peeling losses of 4.51 per cent as compared to other peeling methods. Conventional hand peeling and gunny bag peeling methods were much time consuming and lye peeling was not recommended as treated rhizome become very soft with dark brown colour and removal of peel after lye peeling was also found difficult. Chemical and enzymatic peeling techniques were also evaluated to enhance the efficiency of ginger peeling process and it was found that the optimum condition for chemical peeling of ginger measured by image analysis techniques was soaking in NaOH solution (1g/100g water) at 80^0C for 60 sec. It was further found that commercially available fruit peeling enzymes also had the potential to be used in ginger peeling where the enzymatic peeling enhanced the efficiency of the peeling by removing the peels of the areas that could not be reached by chemical peeling (Srikaeo *et al.,* 2011).

2.3 PRE-TREATMENTS

Pre-treatments exert significant effect on the quality characteristics of fruits and vegetables. One of the common techniques employed to arrest enzyme activity and associated changes before drying is blanching (Gaiser *et al.,* 1996 and Ihl *et al.,*1998) where peroxidases are the enzymes present in plant tissues that cause oxidation of compounds in presence of oxygen (Murcia *et al.,* 2000). Pre-treatments with chemicals or blanching prior to drying improves the quality of the final product by inhibiting various undesirable enzymatic reactions (Nilinkara *et al.,* 2009). Blanching consist of mild heat treatment in different heating system like steam, hot water and microwave to varying time periods influenced by various factors such as blanching media, temperature, time, physical and physiological characteristics, average size of pieces and uniformity of heat distribution and penetration (Muftagil, 1985; Masure and Campbell, 1944). Dhiman (2015) standardized that blanching of ginger in 1.0 percent citric acid or lime juice (1.0%) solution prior to drying or osmotic dehydration was used to prevent enzymatic browning. Immersion of product in alkaline or acid solutions of oleate esters prior to drying of fruits prevented discoloration as observed by (Hussain *et al.,* 2004 and Sunkja and Ragharan, 2004).

A study conducted by Thuwapanichayanan *et al.* (2014) exhibited greater total phenolic content and higher antioxidant activity in ginger slices pre-treated with blanching or ascorbic acid dip @ 0.1 per cent for varying temperatures due to the inactivation of enzymes responsible for browning. Ravindran and Nirmal (2005) observed that peeled whole or split ginger scalded in water for a couple of minutes before the drying process obtain a good quality product. Garcia-Toledo *et al.* (2015) studied the effect of blanching on quality characteristics of osmotically dried Mexican ginger and observed that within the sucrose concentration range of 35 to 65 per cent at 40-70^{0}C temperature water loss ranged from 34.15 to 58.66 per cent without blanching and 29.42 to 62.38 per cent in blanched ginger. Similar results were obtained by An *et al.* (2013) in Chinese ginger without blanching at different concentrations and temperatures.

2.4 OSMOTIC DEHYDRATION

Osmotic dehydration is an important technique of food processing and preservation in which fruits and vegetables are immersed in the hypertonic aqueous solution, which leads to the loss of water and solid gain from the solution into the food without the phase change (Lenaut, 1992). Moreover, osmotic dehydration is one of the pre-treatment for the drying of fruits and a vegetable as, it reduces drying time and causes less damage to the colour, flavor, texture and nutritional quality of the finished product (Stao and Karadbhajne, 2018; Alakali *et al.*, 2006; Torris *et al.*, 2012; Khan, 2012). The quality and the rate of water removal depends on the several variables and processing parameters like weight loss, temperature of the osmotic solution, immersion time, level of agitation, specific characteristics of the food and solution to food ratio (Fernandes *et al.*, 2011). However, the drying force of osmotic dehydration process is concurrent flow between the fruits and osmotic solution. Koprivica *et al.* (2010) reported that osmotic dehydration is a three ways mass transfer process involving water removal from the food commodity, solvent molecule transfer from the solution into food commodity and leaching of organic solids, minerals and vitamins etc from the food commodity. The third transfer is quantitatively negligible compared with the first two types of transfer, but essential with regard to the composition of the product. As the hypertonic solution has higher osmotic pressure with reduced water activity, it serves as a driving force for water withdrawal from the cells solution to the osmo-active solution. The removal of water during osmotic process is mainly by diffusion and capillary flow, whereas solute uptake or leaching is only by diffusion (Rahman, 2007). Chavan and Amrowicz (2012) recorded that mass exchange takes place at the maximum rate within the first two hours of the osmotic

treatment. The osmotic dehydration of common fruits and vegetables, such as Chinese ginger, banana, pineapple, guava, papaya, kiwi fruit and carrot has been described by An *et al.* (2013), Nowacka *et al.* (2014), Jain *et al.* (2011) and Silva *et al.* (2014). Osmotic dehydration process has been investigated for various fruits and vegetables like papaya (Kalee mullah *et al.*, 2002), mushroom (Kar and Gupta, 2003), beetroot (Manivannan and Rajasimman, 2008), carrot (Sodhi *et al.*, 2006), onion (Sutar and Gupta, 2007), pineapple (Parjoko *et al*., 1996), apple (Conway *et al*., 1983; Janowicz and Lenart, 2010), banana (Pokharkar and Prasad, 1998).

Chaudhary *et al.* (1993) studied by the effect of osmotic solution concentration on mass transfer showed that the syrup strength of 60.0 to 70.0 ^{o}B has been found to be optimum in most fruits during osmotic dehydration process. Further, the increase in the immersion time with constant concentration of solution also resulted in the increase in water loss. The osmo-dried banana slices prepared with sulphur fumigation @ 2g/kg slices for two hours followed by soaking in 60 ^{o}B sugar syrup containing 0.1 per cent KMS with 0.1 per cent citric and 0.2 per cent ascorbic acid was found better with respect to colour and appearance, flavor, taste and overall acceptability with non- stickiness of the product (Chavan *et al.*,2010). However, Gurumeenakshi *et al.* (2005) reported the osmotic concentration process for mango and papaya slices in sugar syrup of 60 ^{o}B took 18 hours for equilibrium to occur. Sereno *et al.* (2001) reported that trearment of apple samples with acqueous sucrose solution produced a dehydration effect on the solid tissue which increased with the osmotic pressure and temperature of the solution.

2.4.1 GEOMETRY OF THE MATERIAL

Size and shape of the food material have a definite effect on the mass transfer process during the osmotic dehydration. The geometry of sample process affects the behaviour of the osmotic concentration due to the variation of the surface area per unit volume (mass) and diffusion length of water and solutes involved in mass transport (Tortoe, 2010). Lerici *et al.* (1985) found that greater surface area and sample shape gave higher water loss and sugar gain value as compared to lower surface area samples. The area and thickness limit higher specific surface area samples such as cubes favoured sugar gain at the expense of lower water loss resulting in lower weight reduction with the highest area and thickness ratio was explained as a result of reduced water diffusion due to the high sugar. Contreras and Smyrl (1981) found that mass reduction increased to about 1.3 times when apple slices thickness

decresed from 10.00 to 5.00 mm. In general, sample size of 3.00 mm to a maximum of 10.00 mm in rectangle, ring or cube shape was suitable for the use in osmotic dehydration process (Rahman, 1992). Satao and Karadbhajne (2018) reported that net solid content of the sample is more for the 5.0 mm size sample than the 10mm thick sample, but it will remain same after 18 hours of osmotic dehydration. Nowakunda *et al.* (2004) standardized 10.00 mm thickness for banana slices for conducting osmotic dehydration in sucrose solutions with varying concentrations of 45, 55 and 65 ^{o}B at 30, 40 and 50 ^{o}C for 20, 40, 60, 120 and 240 minutes.

2.4.2 OSMOTIC AGENT

The osmotic dehydration is a partial removal of water from a given food using a hypertonic solution consisting of either one or more than one solutes (Ponting *et al.,* 1966). The difference in osmotic pressure obtained in a system leads to a flow of water from the food to the solution and opposite flow of solutes from the hypertonic solution to the food material. Generally, low molecular weight osmotic agent penetrates easily into the cell of fruit as compared to high molecular weight osmotic agent (Phisut, 2012). The organoleptic compatibility with the end product, solute cost and additional preservation action by the solute are the factors considered in selecting the osmotic agents. Sugar and salt solutions are the most common choices based on effectiveness, cost convenience and quality (Tortol, 2010). The molecular weight, solubility of the solute in water and ionic state cause differences in the behavior of the osmotic solute. Further, molecular size of the osmotic solute has a significant effect on the water loss to solids gain ratio. The smaller the solute, the larger is the depth and the extent of solute penetration is observed in the food sample during osmotic dehydration. The most commonly used osmotic agents are table sugar for fruits and salt for vegetables while other commonly used osmotic agents are glucose, fructose, lactose, dextrose, maltose, polysaccharides, maltodextrin, corn starch syrup etc. Bolin *et al.* (1983) observed the higher diffusitivty of HFCS (High Fructose Corn Syrup) compared to sucrose during osmotic dehydration of apples. Lenart and Flink (1984) compared various osmotic solutions at constant solid concentration reported that a combination of sucrose and salt solutions showed a greater decrease in water activity of the products compared to pure sucrose solutions, although water transport rates were similar in both. This was attributed to the extensive salt uptake. Ispir and Togrul (2009) studied the effect of various osmotic agents such as sucrose, glucose, fructose, maltodextrin and sorbitol and reported that the highest and the lowest water loss were obtained by maltodextrin and fructose solutions respectively. Sucrose and fructose solutions showed the best results in osmotic dehydration of apricots due

to high water loss and low solid gain. A decrease in the molecular size of the solute enhances the solid gain. Mass transfer of the solute dependes on the effective diffusion coefficient that can be affected by the radius of molecules (Phisut, 2012). Contreras and Smyrl (1981) found water removal from apple rings to be maximum at pH 3.0 using corn syrup. Singh *et al.* (2010) optimized a combination of sucrose and sodium chloride (50˚B + 15% w/v) as osmotic agent for carrot cubes at 54.8 ˚C for 120 minutes as process time. However, Madan and Dhawan (2005) prepared osmo-dried carrot slices by soaking in sugar syrup (65˚B) for 3 hours and drying at 60˚C for 15 hours with higher retention of ß-carotene than the slices which were air dried without osmosis. Sachadev *et al.* (2007) concluded that apple slices treated with KMS for 15 minutes with 50 ˚B osmotic syrup found to be better for retention of fruit color, appearance and taste. Yadav *et al.* (2012) optimized the conditions for osmotic dehydration of peach slices as 69.9 ^{o}B total soluble solids of sucrose, 3.97 hours time of immersion time and 37.63 ^{o}C of process temperature.

2.4.3 IMMERSION TIME

During the process of osmotic dehydration, the loss in water content from the commodity and gain in soluble solids is a function of time. As the time of treatment increases, higher the weight loss occurs but the rate at which this occur decreases with the passage of time. Maximum water loss (50% reduction) takes place within first two to three hours of process depending upon the type of fruits (Ponting *et al.*, 1966; Bongirwar and Sreenivasan, 1977; Farkas and Lazar, 1969; Hawkes and Flink, 1978). Lazarides (1994) observed that within first three hours of osmotic dehydration, the apple slices lost 50.0 percent of its initial moisture and doubleing its total soluble solids content due to uptake of sugar. Equilibrium state between product and osmotic solution is characterized by an equality of water activity and soluble solids concentrations in the product and solution (Lenart and Flink, 1984). Keeping the concentration of the solution constant, increase in immersion time resulted in increase loss of water though the rate at which the water loss occurs decreased subsequently. The optimization of duration of osmosis process indicated that mass exchange took place at the maximal level within the first two hours of the osmotic treatment. Tiwari and Jalali (2004) reported that during osmotic dehydration of mango and pineapple, the increase in osmotic duration resulted in increase in weight loss. Nowakunda *et al.* (2004) found that rate of weight reduction and water removal reduced after 1.5 hours of osmotic treatment in banana slices, similarly Nadia *et al.* (2013) observed higher water loss and solids

gain at 40°C in pears in first two hours of process. Noroes *et al.* (2010) studied that the kinetics of the osmotic dehydration of the guava, water loss and solid gain were higher at the beginning of the osmosis reaching maximum at 3.5 hours at 65°B sugar syrup. Likewise, Morrera and Sereno (2001) has also reported maximum sugar penetration during first two hours of dip in apple slices. Gaspartero *et al.* (2003) and Mauro *et al.* (2004) observed that when banana and apple slices were dipped in osmotic solution of 70 and 50°B respectively, at 50°C temperature, 3 hours immersion time gave optimum water loss and sugar gain.

2.4.4 TEMPERATURE OF THE OSMOTIC SOLUTION

Temperature is the most important parameter affecting the kinetics of mass transfer during the process of osmotic dehydration. Beristain *et al.* (1990) stated that comparatively high temperature of osmotic solution shows increase in water loss whereas solid gain is less influenced by temperature (Tortoe, 2010) as it was limited upto 60°C because higher temperature destroyed the cell membranes as observed by Chavan and Amarowicz (2012). High temperature result in lower viscosity of the osmotic medium and as a result promotes faster mass transfer in the product (Harris *et al.*, 1999). In most of fruits and vegetables increase in temperature results in decreased quality of final product. Ponting *et al.*,(1966) reported that above 49°C temperature, enzymatic browning and flavour reduction starts while the low temperature drying usually preserve as the active components in ginger, are decomposed at higher temperature (Azain *et al.,* 2004). Pokharkar and Prasad (1998) reported that the temperature of the osmotic solution affected the parameters like water and sugar gain of banana slices.

2.4.5 CONCENTRATION OF THE OSMOTIC SOLUTION

The key factor in the osmotic dehydration process is the concentration of osmotic solution. Phisut (2012) stated that increase in concentration of solute results in increased water loss and solid gain rates. Similarly, Conway *et al.* (1983) and Lenaut (1992) also reported that increase in osmotic solution concentration resulted in corresponding increase in water loss to equilibrium level. This was due to the water activity of osmotic solution which decreased with the increases in solute concentration (Marcotte, 1991; Tortoe, 2010). Falade (2007) found that watermelon slabs dipped in 60 ^{0} B hypertonic sucrose solution showed increased water loss and solid gain as compared to the slabs immersed in 40 ^{0} B and 50 ^{0} B sugar solutions. Mundada (2011) studied the effect of sucrose concentrations on mass transfer

of pomegranate arils during osmotic dehydration and reported that the increase in solid gain and water loss is due to the difference in concentration between the osmotic solution and fruit sample which effect the rate of diffusion of water and solute. Increased solution concentration resulted in the increase in the osmotic pressure gradient and higher water loss as advocated by Azoubel and Murr, 2004; Phisut, 2012. Studies by Saurel (1994) showed a dense solute barrier layer formed on the surface of the food material when the concentration of osmotic solution increased which enhance dewatering effect and reduced the leaching of nutrients during the process. Lazarides (1994) concluded that short duration osmosis process under high concentration of immersion solution favoured solute uptake resulting in lower water loss and solids gain ratios. Results on the negative effect of osmosis due to low concentration of sucrose solution on fruits and vegetables have also been reported by Karathanos *et al.* (1995). Similarly, Tortoe (2010) observed that low sucrose concentration solution causes minimal water loss and solid gain ratios. Increased mass transfer of sugar molecules in high concentration solution is possible due to swelling effect the membrane which increases the cell membrane permeability. These results indicate that by choosing a higher concentration medium, some benefits in terms of faster water loss and greater gain of solid could be achieved. However, some authers reported that high concentration of osmotic agent may not enhance the solid gain. Giraldo *et al.* (2003) studied the osmotic dehydration of mango at 30 ^{o}C temperature using 35 ^{o}B, 45^{o}B, 55 ^{o}B and 65 ^{o}B sucrose concentration and reported that water transfer rate increased when the concentration of sucrose up to 45 ^{o}B whereas this effect did not appear between 55 ^{o}B and 65 ^{o}B, the rate constant being slightly greater for the treatment at 55 ^{o}B highest sucrose concentration a case hardening effect is responsible for reduced mass transfer rates. When the immersion solution is concentrated the liquid penetration is limited due to increased viscosity. Additionally, the rigidity of external cell layers increases quickly due to the case hardening effect at high concentrations (Phisut, 2012). The rate of sugar diffusion is affected by sugar concentration and temperature. Rahman and Lamb (1990) stated that with the increase in sugar concentration and temperature the water loss and sugar gain increases linearly. The sugar syrup strength in the range of 60 to 70 ^{o}B has been optimized by Chaudhary *et al.*, 1993 as higher the concentration, faster is the rate of osmosis. Yadav *et al.* (2012) optimized osmotic dehydration conditions of peach slices with sucrose concentration of TSS 69.9^{o}B, immersion time 3.97 hours and temperature 37.63^{o}C. Nowakunda *et al.* (2004) standardized the thickness of banana slices 10.00 mm immersed in sucrose solution of varying concentrations of 45, 55 and 65 ^{o}B at temperature range of 30- 50 ^{o}C for 20 to 240 minutes. The sucrose

concentration in the osmotic solution (25-65 per cent w/w), osmosis time (30 to 390 mintutes) and temperature (20 to 60 ^{o}C) has a linear significant impact on water loss and solid gain (Nadia *et al.,* 2013) for fruit commodity.

2.4.6 AGITATION / CIRCULATION

The use of highly concentrated viscous sugar solutions create major problems like hindering the contact between food material and the osmotic solution, floating of food pieces and reduction in the mass transfer rates and in order to enhance mass transfer process agitation or stirring can be applied during osmotic dehydration (Moreira *et al.,* 2007; Phisut, 2012). Agitation ensure a continuous contact of the sample surface with concentrated osmotic solution, securing a large gradient at the product/solution interface. Moreira *et al.* (2007) compared the effect of agitation and non-agitated treatments and found that the agitated samples exhibited greater weight reduction, consequently water loss, than non-agitated product. Raoult-Wack *et al.*(2002) observed that agitation results in increased water loss even at low temperature (< 30 ^{o}C) during the initial stages of osmosis, while the rate of solid gain decreased with agitation. For short process periods agitation has no effect on the solids gain. For longer process period solids gain decreased drastically with agitation. Similarly, Ponting *et al.* (1966) also stated that in some cases agitation might not beneficial.

2.4.7 OSMOTIC SOLUTION AND FOOD MASS RATIO

In osmotic dehydration an increase in osmotic solution to sample mass ratio results in increase in solid gain and water loss (Ponting *et al.,* 1966). Similarly Rahman and Lamb, 1990 and Palou *et al.,* 1993 reported that both solid gain and water loss increased with the increase of syrup and food mass ratio up to a certain level and then falls off. Even Ponting *et al.* (1966) and Flink (1979) observed that an increase in osmotic solution to sample mass ratio resulted in an increase in both the solid gain and water loss in osmotic dehydration. A large ratio of syrup: food (30:1) was used to avoid significant dilution of the medium and subsequent decrease of (osmotic) driving force during the process. Some investigators used a much lower solution to product ratio (4:1 or 3:1) in order to monitor mass transfer by following changes in the concentration of the sugar solution (Conway *et al.,* 1983).

2.4.8 DRYING BEHAVIOUR OF OSMOTICALLY CONCENTRATED SAMPLE

Drying is a process involving heat and mass transfer phenomenon, frequently used in most food processing industries (Cohen and Yang, 1995). Dehydration is one of the oldest

method of food preservation, which involves water removal to reduce the risk of microbial growth and proliferation. Among drying process, osmotic dehydration is considered a better preservation method that includes removal of moisture from fruit by placing them in hypertonic solution and it provides high quality products by means of water removal without phase change (Lanart, 1966). Osmotic dehydration does not result in a product with moisture content low enough to be considered as shelf-stable. Therefore, osmotic dehydrated products must be further processed by other dehydration techniques to obtain stable products (Vial *et al.,* 1991). Osmo-dried products are processed further (air drying, vacuum drying etc.) to obtain shelf-stable products (Pointing, 1973). Bhuyan and Prasad (1990) found that drying at 60 to70^{0}C air temperature was optimum in maintaining the sensory qualities of dried product, while Richardson (1966) reported a suitable temperature for ginger drying at 57.3 ^{o}C and 83 ^{o}C for spice market and for extraction purposes respectively. Mantri and Agrawal (1991) suggested that ginger may be dried at 85 ^{o}C up to the moisture content of 50.0 per cent (wb) during first stage and at 65 ^{o}C up to moisture content of 12 per cent (wb) for reducing drying time and maintaining quality of ginger. Alakali and Satimehin (2004) studied drying kinetics of ginger slices at varying temperature of 40, 45, 50 and 55 ^{o}C and reported that drying proceeded faster at high temperatures than at lower temperatures but Natarajan *et al.* (1972) found no significant difference in colour of ginger samples dried at temperature between 50 to 60 ^{o}C and reported that the critical temperature of ginger drying is 60 ^{o}C. Drying of ginger flakes by Singh *et al.* (2008) under fluidized bed conditions in the temperature range of 50 to 80 ^{o}C showed that drying rate at 60 ^{o}C air temperature decreased from 0.43 to 0.17 g/s with the change in moisture content from 300 to 10 per cent on dry basis. Further, Jadhav *et al.* (2012) studied the drying characteristics of ginger by employing open air sun drying, solar cabinet drying and mechanical tray drying (65 ^{o}C) methods and drying time required for open air sun drying, peeled treated whole, peeled untreated sliced, peeled untreated whole, unpeeled untreated sliced and unpeeled untreated whole observed as 30.0, 23.5, 31.0, 26.5 and 50.0 hours respectively, whereas in case of solar cabinet drying and mechanical drying it was 12.0, 10.5, 8.0, 11.0, 30.5 hours and 12.5, 5.5, 17.5, 14.0 and 29.5 hours respectively. The minimum drying time and maximum value of drying constant was observed in case of mechanical tray drying for peeled untreated sliced ginger samples.

2.5 CANDY PREPARATION

Candied fruits and vegetables are important and attractive food ingredients produced by soaking fruits and vegetables in hypertonic sugar solutions, yielded products with a fresh-

like character and a sweet taste. Candy preparation is an osmotic dehydration (OD) process which aims at reducing the moisture content and increasing the sugar content of the food sample with a lower water activity and longer shelf-life of the final product. During the osmotic dehydration two simultaneous processes occur between the plant tissue and the surrounding solution which are water loss and sugar uptake, resulting in an increase concentration of sugar in cell sap (Raoult-Wack *et al.,* 2002). Fruits and vegetables like mangoes, ginger, carrots, guava, apples and citrus peels have been used to prepare candies (Mehta and Bajaj, 1984). Joshi and Sagar (2016) prepared papaya candy by boiling raw papaya dices in sugar solution and drying for 2-3 days in solar dehydrator. Kumar *et al.,* 2018 optimized the blanching time (7.81mm) and beetroot pomace extract (9.24%) for the development of antioxidant rich ginger candy.

2.6 CHANGES DURING PRODUCT STORAGE

Water activity is the principal characteristic that controls microbial growth in sugar based products. Candy is intermediate moisture food with increased shelf life even without refrigeration or thermal processing in any sealed container. The osmo-dried ginger flakes showed good storage stability up to six months with minimum changes in sensory and quality characteristics at ambient temperature (Dhiman, 2015).

Fortunately, the water activity in confectionary products generally falls below the critical values for microbial growth, with the exceptions of few items. Therefore, the growth of micro-organisms in confections is generally not an issue of concern. However, the end of shelf life due to moisture loss or gain, with subsequent changes in textural and other properties, is often the main problem in confections. ERH is the relative humidity at which the product do not gain or loose moisture to the air surrounding the confection (Jackson, 1995). If the surrounding atmosphere has a different relative humidity from this value, the confection will either gain or lose moisture as it strives to equilibrate with the air. Many candies are prone to losing moisture to the environment. In candies where a_w is greater than ambient relative humidity, typically about 50%, moisture migrates out of the candy and through the package, causing a decrease in water content in the candy. This decrease in moisture generally leads to hardening of the candy However, some candies, particularly those with low water activity, are prone to picking up moisture from the environment. If ambient relative humidity is high, as in some humid environments, confections such as caramel and

fudge, gums, hard chewy candies, and panned candies may also be prone to moisture uptake (Ergun *et al.*,2010).

2.7 STORAGE STUDIES

Packaging plays an important role in enhancing the shelf-life of processed products. The selection of suitable package to store a particular food depends upon the temperature and relative humidity during storage. The packages for sugar based candies should not be 100 per cent moisture proof but should allow the sugar to breathe slightly and not totally dry it out (Childs, 2007). A cool storage temperature with 50-60 per cent humidity works the best for the storage of confectionary products (Ross, 1975). Common packaging materials for confectionary products are polymer films such as polyethylene, polypropylene and polyvinyl chloride due to their light weight and easy to transport (Ergun *et al.*,2010). Aluminium foils are traditional packing material for chocolate bars as they have good barrier properties for water and other gases apart from being light in weight (Ergun *et al.,* 2010). Plastic films and laminates are the most popular choice as a packaging media, replacing traditional waxed paper and aluminium foil. Sagar and Kumar (2009) found that food sample stored in 200 gauge HDPE pouches retained better reducing and total sugars with a low non-enzymatic browning as compared to 200 gauge LDPE.

2.8 MICROBIOLOGICAL QUALITY

Microorganisms in food products are influenced by inherent characteristics in the food such as moisture content, nutrient composition and pH (Frazier and Westhoff, 1998). Ginger is reported to have antibacterial effect especially against *Staphylococci* species and also exhibits antifungal activity against a wide variety of fungi including *Candida albicans* (Ficker *et al.,* 2003). Osmotic dried fruits and vegetables have low moisture content and low water activity. They are hard, firm and resistant to microbial deterioration. Microbial load plays a very important role in determination of the length of storage till which the product remains consumable. Temperature, oxygen and moisture content are the most important factors that influence the type of microbial growth and spoilage of food during storage.According to a study by Muzzaffar *et al.* (2016) the microbial count of pumpkin candy was found as 1.74–3.2 log cfu/g and the candies were safe for human consumption during storage. Sidhu *et al.* (2016) reported a bacterial count of 1×101, 3×101 and 7×101 cfu/gm in candy with 40 per cent, 50 per cent and 60 per cent sugar solution respectively during storage.

Chapter-3

MATERIALS AND METHODS

The present investigations entitled **"Development and evaluation of anthocyanin enriched ginger candy"** were conducted in the Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the year 2018-2019. The material used, experimental details and techniques employed in the investigation are furnished in this chapter under the following heads.

3.1 RAW MATERIAL

3.2 EXPERIMENTAL DETAILS

3.2.1 Optimization of thickness of ginger slices for osmotic dehydration

3.2.2 Standardization of optimum time-temperature combination for osmotic dehydration of ginger slices

3.2.3 Optimization of process for the development of anthocyanin enriched ginger candy

3.2.4 Storage studies of standardized anthocyanin enriched ginger candy

3.3 QUALITY EVALUATION OF RAW MATERIAL AND PROCESSED PRODUCTS

3.3.1 Physical characteristics

3.3.2 Chemical characteristics

3.3.3 Drying characteristics

3.3.4 Sensory evaluation

3.3.5 Microbial examination

3.3.6 Statistical analysis

3.4 COST OF PRODUCTION OF PROCESSED PRODUCTS

3.1 RAW MATERIAL

Raw material such as tender ginger rhizome (cv *Himgiri*) and plum (cv. *Santa Rosa*) used for conducting study were procured from local market and brought to the Department of

Food Science and Technology, UHF, Nauni, Solan (HP). Honey was procured from the Department of Entomology, UHF, Nauni, Solan (HP).

3.2 EXPERIMENTAL DETAILS

3.2.1 Optimization of thickness of ginger slices for osmotic dehydration

Fresh ginger rhizomes were sorted, washed thoroughly in water to remove adherent foreign material followed by peeling in a mechanical peeler cum polisher machine procured from AICRP on PHET, Maharana Partap University of Agriculture and Technology, Udaipur, Rajasthan. The peeled ginger was sliced (5.0 - 25.0 mm) and blanched in solution of 1.0 per cent lime juice for 15 minutes (Dhiman, 2015) followed by drying in mechanical dehydrator (Widsons Scientific Works, Delhi) at 55±2^{o}C till the moisture content of slices reached around 14.09 per cent (Jayashree *et al.*, 2014). The tray load taken for the following experiment was 500 grams.

The optimum thickness was selected on the criteria of drying time and sensory characteristics as shown in Table 3.1.

Table 3.1. Optimization of thickness of ginger slices for osmotic dehydration

Slice Thickness (mm)	Drying time (h)	Sensory Characteristics				
		Colour	Texture	Aroma	Taste	OA*
5.0						
10.0						
15.0						
20.0						
25.0						

*** OA – Overall acceptability**

On the basis of results obtained from Table 3.1, the thickness range of ginger slices was reduced to a gap of 2.5 mm and was again standardized by comparing 5.0, 7.50 and 10.0 mm.

3.2.2 Standardization of optimum time-temperature combination for osmotic dehydration of ginger slices

In order to optimize the immersion time for preparation of ginger candy by quick method the blanched ginger slices (15 minutes in 1.0 % lime juice) of standardized thickness (Expt 3.2.1) were steeped in hypertonic sugar solution of 70 ^{o}B TSS at 50 ^{O}C temperature maintained in a hot water bath. The slices were dipped for varying process time ranging from

1 to 8 hours with slices: syrup ratio maintained as 1:3 for all the treatments. The best time temperature combination was selected on the basis of different osmotic parameters like weight reduction, moisture loss, solid gain and equilibrium of TSS between slices and syrup as mentioned in Table 3.2. The parameters of osmotic dehydration process are the water loss (WL) and solid gain (SG) which defines the process.

Table 3.2 Treatment detail of osmotic dehydration of ginger slices

Treatments	TSS (^oB)	Temp (^oC)	Steeping Time (h)	Parameters				
				Weight Reduction (%)	Moisture Loss (%)	Solid Gain (%)	TSS of slices (^oB)	TSS of syrup (^oB)
T_1	70	50	1					
T_2	70	50	2					
T_3	70	50	3					
T_4	70	50	4					
T_5	70	50	5					
T_6	70	50	6					
T_7	70	50	7					
T_8	70	50	8					

3.2.3 Optimization of process for the development of anthocyanin enriched ginger candy

The parameters (thickness, blanching time and immersion time) standardized in Expt 3.2.2. was further taken for optimization of process conditions (immersion time and sample: plum pulp) for the development of anthocyanin enriched ginger candy. The blanched ginger slices of optimized thickness (Expt 3.2.1) was immersed in sugar syrup of 70 ^OB maintained 50 ^OC for time period standardized in Expt 3.2.2. Thereafter, the steeped mass was drained followed by dipping in plum pulp in ratio of 1:3 for different time period of 1 to 8 hours to study the osmosis effect. The plum pulp dipped ginger candy was then drained and dried (55±2 ^oC) in a mechanical dehydrator (Widsons Scientific Works, Delhi) and the best treatment was optimized on the results of sensory characteristics and nutritional quality.

The osmotic dehydration process involves the partial removal of water from a given food using a hypertonic solution and an opposite flow of solutes from the syrup to the product. Furthermore, a third flow of solids take place from the food to the solution leading to a meaningful loss of product quality. Thus, in order to minimize the leaching of nutrients by using two consecutive dipping medium (hypertonic sugar solution and plum pulp) a process

protocol was standardized by using a combination of plum pulp with sweetening agent either cane sugar or honey to form a anthocyanin hypertonic solution of 70 ^{o}B and comparing with pure sugar syrup or honey as immersion solutions. The details of different immersion solution is given in Table 3.3 The specification of ginger slices for the development of candy was prepared on the basis of the parameters standardized in Expt 3.2.1 and 3.2.2.

The pre-treated ginger slices were then dipped in the different dipping solutions in the ratio of 1:3 for varying time period. The optimum time period for osmosis was standardized on the results of parameters as detailed in Table 3.3.

Table 3.3 Treatment detail of impregnation of anthocyanin in pre-treated ginger slices

Treatments	Thickness (mm)	TSS (^{O}B)	Temp. (^{O}C)	Steeping time (h)
T_1(Sugar)	Expt. 3.2.1	70	50	1 to 8
T_2 (Plum pulp +sugar syrup)	Expt. 3.2.1	70	50	1 to 8
T_3 (Honey)	Expt. 3.2.1	70	50	1 to 8
T_4 (Plum pulp + honey)	Expt. 3.2.1	70	50	1 to 8

The osmosis process was optimized on the basis of equilibrium state which was determined by the total soluble solid concentration between the product and the osmotic solution followed by draining and drying in a mechanical dehydrator (Widsons Scientific Works, Delhi) at 55±2 ^{o}C.

3.2.4 Utilization of drained dipping solution for value addition

The left over drained syrup was successfully utilized for the preparation of lollipops. Lollipop is a non-crystalline, hard sugar boiled confectionery which contains about 70-90 per cent of the carbohydrates. White sugar is the usual sweetening agent used in preparation of candies. Keeping in view the disadvantages associated with excessive sugar consumption, possibilities of replacing sugar with alternate natural sweeteners has been explored in the present study. The white sugar is partially replaced with plum pulp and honey (20%) as natural sweetener and glucose syrup (20%) as thickner, sweetener and humectants.

Table 3.4 Formulation for preparation of lollipops

Ingredients	Weight
Sugar (g)	40
Glucose syrup (g)	20
Plum pulp + Honey (g)	20
Water (ml)	20

Lollipops were prepared by the recipe by Manjula and Suneetha (2014) to which different concentration of ginger was added. Weighed amount of sucrose (white sugar), glucose syrup (also known as confectioner's glucose) plum pulp and honey and water (Table 3.4) was combined in a saucepan over medium-high heat with continuous stirring till the ingredients get dissolved. The mixture was allowed to boil without stirring until it reaches 120°C which was measured by a laboratory thermometer with range of 0 to 250°C. This is called the hard crack stage. The candy mass was then spooned into the mold cavities to which the lollipop stick was already placed. The lollipops were allowed to cool completely and removed after 15-20 minutes from the mold once hardened.

3.2.5 Storage studies ginger candy

Anthocyanin enriched ginger candy and control ginger candies (sugar syrup and honey dipped) were packed in aluminium laminated pouches (200g) and stored at ambient (24-27 ^{o}C) and refrigerated (3-7^{o}C) temperature for further storage studies. The developed products were evaluated for different quality parameters at 0, 3 and 6 months.

3.3 QUALITY EVALUATION OF PROCESSED PRODUCTS

3.3.1 Physical characteristics

Ten randomly selected samples of fresh ginger rhizome and plum were analyzed for following characteristics:

3.3.1.1 Size

Size parameters comprising of vertical and horizontal diameter of ginger rhizome and plum were recorded with digital vernier calliper.

3.3.1.2 Weight

Ten randomly selected samples of ginger rhizome and plum were taken and weighed on an electronic weighing balance and average weight of a rhizome and fruit was expressed in grams.

3.3.1.3 Volume

Volume of fresh ginger rhizome and plum was determined as true volume by immersing the rhizomes and plum in water contained in a measuring cylinder and determining the volume of water displaced (Mohsenin, 1986).

3.3.1.4 Density

The density of ginger rhizome and plum was determined as the ratio of bulk weight of ginger and plum to the bulk volume.

3.3.1.5 Firmness

Firmness of ginger rhizome and plum fruit was measured by using Effegi Pentrometer with a plunger of 5/16 inch diameter. The result was expressed as kg/cm^2.

3.3.1.6 Thickness (mm)

The thickness in millimeter was measured with the vernier calliper. This process was repeated ten times to get an average value.

3.3.1.7 Yield

Yield of dried ginger slices was calculated by dividing the weight of final dried ginger slices by the initial weight of fresh ginger slices with following formula

$$\text{Yield (\%)} = \frac{\text{Weight of dried ginger slices}}{\text{Weight of fresh ginger slices}} \times 100$$

3.3.2 Chemical characteristics

3.3.2.1 Moisture content

The moisture content of fresh commodity and dried samples was estimated by drying the weighed samples to a constant weight in a hot air oven. The oven dried samples were then cooled desiccator to room temperature in a prior to weighing.

Loss in weight of fresh samples after drying represents the moisture content and is expressed as per cent w/w. Moisture content of the samples was then calculated and expressed as per cent on fresh weight basis (Ranganna, 2009) as given below:

$$\text{Moisture (\%)} = \frac{\text{Weight of fresh sample (g)} - \text{Weight of dried sample (g)}}{\text{Weight of fresh sample (g)}} \times 100$$

3.3.2.2 Total soluble solids (TSS)

TSS of ginger, plum and their processed products was measured by hand refractrometers of 0-32 ^{0}B, 28-62 ^{0}B and 58-92 ^{0}B ranges.

3.3.2.3 Titratable acidity

Titratable acidity was estimated by titrating a known volume of sample against standard NaOH using phenolphthalein as an indicator (AOAC, 2004). The titratable acidity is expressed as per cent as per given formula:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{Volume made} \times \text{Eq. Weight of dominating acid}}{\text{Weight of sample x Volume of aliquot x 1000}} \times 100$$

3.3.2.4 pH

The pH of fresh sample as well as dried sample was taken with pH meter (ELTOP-3030 pH meter). Prior to pH measurement, the instrument was calibrated with buffer solutions of 4.0, 7.0 and 9.0. The pH of the samples was estimated directly (AOAC, 2004)

3.3.2.5 Sugars

Reducing and total sugars in ginger, plum and honey and its products were determined by Lane and Eynon method (1923), Nelson-Somogyi's Colorimetric method (Somogyi, 1951) and Phenol-sulphuric acid method. In Lane and Eynon method a known value of sample was neutralized with NaOH and 2ml of lead acetate (45%) was added in the flask and kept for ten minutes undisturbed. Excess of lead acetate was removed by adding 2ml of potassium oxalate (22%) in 250 ml volumetric flask. After diluting it up to the mark, the solution was filtered and clear filtrate was taken to estimate reducing sugars by titrating against a known quantity of Fehling's A and Fehling's B solutions using methylene blue as an indicator. Total sugars were estimated by adding 5 g of citric acid to 50 ml of calibrated sample (prepared for reducing sugars) and heated for 10 minutes. For complete inversion of sugar samples, NaOH was added and final volume 250 ml was made. Total sugars and reducing sugars were estimated as per cent and calculated as:

$$\text{Total sugars \%} = \frac{\text{*Factor x Dilution}}{\text{Titre value x Weight/Volume of sample}} \times 100$$

*Factor = 0.05

In Nelson-Somogyi's method a known weight of sample was heated with alkaline copper tartrate to reduce the copper from cupric to cuprous state (copper oxide) which reacted

with arsenomolybdate to give blue colour. The blue colour developed was measured calorimetrically at 520 nm. The standard curve was prepared using different concentrations (20-100 µg/ml) of sugar and results were expressed accordingly. In phenol-sulphuric acid method the known weight of aliquot after hydrolysis was made to one ml followed by the addition of one ml of 5 per cent phenol solution and 5 ml of $H_2 SO_4$ (98%). The green colour so developed was measured calorimetrically at 490 nm and the results were expressed as per cent total sugar after comparing with the standard curve.

3.3.2.6 Ascorbic acid

Ascorbic acid content was estimated as per AOAC (2004) method using 2, 6-dichlorophenol- indophenol dye. A known weight of the sample was crushed and blended with 3.0 per cent metaphosphoric acid (HPO_3) separately. A known 100 ml of volume was made up with 3 % HPO_3 which was centrifuged and filtered for further estimations. An aliquot of the HPO_3 extract of the sample was titrated with the dye to a pink colour end point. The results were expressed as mg/ 100g of sample and calculated by using the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made up}}{\text{Aliquot of extract taken} \times \text{weight of the sample}} \times 100$$

3.3.2.7 Crude fibre

Total crude fibre content was estimated by the method given by Gould (1978). 100 g of ground samples was taken and boiled with 200 ml of distilled water along with 25 ml of NaOH concentration, filtered on the screen with stream of water and continued washing until there was only fibrous material remained. The residue was dried for 2 hours at 100^0 C in an oven and further cooled and weighed to calculate per cent fibre by the following formula:

$$\text{Crude fibre (\%)} = \frac{\text{Loss in weight}}{\text{Sample weight}} \times 100$$

3.3.2.8 Total ash

Total ash was determined gravimetrically by taking known weight of fresh and dried samples in tared silica crucibles. The oven dried samples after estimation of moisture were slowly heated at 550°C until the bulk of organic matter was burnt. The crucibles were then

placed in a muffle furnace for ashing to obtain a carbon free white ash with a constant weight. The ash content of samples was then calculated and expressed as per cent on fresh weight basis (Ranganna, 2009) as given below:

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample taken}} \times 100$$

3.3.2.9 Total phenols

Total phenols were estimated on the basis of their reaction with an oxidizing agent phosphomolybdate in Folin-Ciocalteau reagent under alkaline conditions after estimation in 80.0 per cent ethanol. The developed blue colour was measured at 650 nm in a spectronic-20 spectrophotometer (Bray and Thorpe, 1954). The standard curve was prepared using different concentrations (8-32 µg/ml) of catechol was expressed as mg per cent on fresh weight basis.

3.3.2.10 Antioxidant activity

Antioxidant activity (free radical scavenging activity) was measured as per the method of Brand-Williams *et al*. (1995). DPPH (2, 2-diphenyl-1-picrylhydrazyl) was used as a source of free radical. A quantity of 3.9 ml of $6x10^{-5}$ mol/L DPPH in methanol was put into a cuvette with 0.1 ml of sample extract and the absorbance was measured at 515 nm after 30 minutes. Methanol was used as blank. Antioxidant activity was calculated using the following equation:

$$\text{Antioxidant activity (\%)} = \frac{\text{Ab(B)-Ab(S)}}{\text{Ab(B)}} \times 100$$

where,

Ab (B) = Absorbance of blank

Ab (S) = Absorbance of sample

3.3.2.11 Anthocyanins

Total anthocyanins present in all samples were determined by spectrophotometric method given by Ranganna (2009). The procedure involves extraction of anthocyanins with 85 per cent ethanolic HCl and measuring its optical density at 535 nm. Anthocyanins were calculated and expressed as mg/100 ml using the following formula:

$$\text{Titratable acidity (\%)} = \frac{\text{OD of sample at 535nm} \times \text{Volume made up of extract for colour measurement} \times \text{Total volume made}}{\text{Volume of extract used} \times \text{Volume of sample taken}} \times 100$$

$$\text{Total anthocyanins (mg/100 g)} = \frac{x}{100} \times 100$$

*98.20 = Extraction coefficient

3.3.2.12 Colour

The color parameters of anthocyanin enriched ginger candy were measured by using a Hunter Lab Color Flex Colorimeter (Hunter Associates Laboratory Inc., Reston, Virginia, USA). Hunter L value (lightness/darkness), a value (redness/greeness) and b value (yellowness/blueness) were determined. This color system consists of a luminance or lightness compound (L*) and two chromatic compounds: *a** component for green (-a) to red (+a) and the *b** component from blue (-b) to yellow (+b) colors. Colour or appearance properties are critical parameters in defining the uses and acceptability of products. The lightness coefficient, L* ranges from black to white on a scale of 0- 100.

Drying characteristics of ginger slices

3.3.3.1 Parameters for Osmotic Dehydration

The characteristics parameters for osmotic treatment determined as weight reduction (WR), solid gain (SG) and water loss (WL) are calculated as per the equations given below:

3.3.3.1.1 Weight Reduction (WR) (Gupta *et al.*, 2014)

$$\text{WR (\%)} = \frac{\text{Wi} - \text{Wo}}{\text{Wi}} \times 100$$

where, Wi = Initial weight of sample (g)

Wo = Final weight of sample (g)

3.3.3.1.2 Water Loss (WL) (Yadav *et al.*, 2012)

Water loss is the net loss at time (T) on an initial mass basis and expressed as in percentage. Water loss in sample was calculated by using the following formula:

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

where,

Wo = Initial weight of sample

Wt = Final weight of sample

St = Final TSS of sample

So = Initial TSS of sample

3.3.3.1.3 Solid Gain (SG) or (Mass transfer) (Sharma *et al*., 1998)

The solid gain is the net sugar transported into the fruits on an initial mass basis and expressed in percentage.

$$SG\ (\%) = WL\ (\%) - WR\ (\%)$$

3.3.3.2 Drying time

The time taken to dry given tray load was calculated by recording the time (h) required by the material in the tray to attain a constant weight after drying in respective drying mode.

3.3.3.3 Drying rate

The rate of dehydration per unit time was calculated by placing weighed quantity of ginger slices (200g) on a stainless steel tray (30 × 20 cm^2) followed by drying in mechanical dehydrator (55±2^{0}C). The weight loss during dehydration was recorded at periodic intervals and then calculated by plotting the per cent moisture against time in hours (Fellows, 1988).

3.3.3.4 Dehydration ratio

The ratio between fresh sample weight to that of dried weight represented the dehydration ratio of the given sample (Ranganna, 2009).

3.3.3.5 Equilibrium relative humidity (%)

Equilibrium relative humidity is the humidity at which a product will neither gain nor loss moisture and it is of considerable value in the study of the packaging behaviour of low moisture foods. The packaging material is selected according to the required quantity of

the material to be packed for a certain period of storage at a particular temperature and relative humidity as per the standard procedure (Ranganna, 2009). For determining the equilibrium relative humidity (ERH) 5 g of sample was spread evenly on tared petri dishes which were placed in the desiccators containing H_2SO_4 solutions of different concentrations representing relative humidity levels ranging between 0-100 per cent. The loss or gain in weight of sample was recorded at 24 hours till the samples attained the equilibrium. After equilibrium, data were plotted against relative humidities to determine ERH of given samples (Ranganna, 2009). Critical and danger points of different products were calculated according to the weight equilibrium method of Wink (1946).

3.3.2.6 Sensory evaluation

Sensory evaluation of novel products from ginger viz., ginger candy was carried out by the method advocated by Amerine *et al*. (1965). The products were evaluated by panel of 7-9 judges where each judge was given a set of product separately and provided with a glass of fresh water to rinse their mouth after tasting the next sample. Each sample was evaluated for various quality attributes viz., colour, texture, aroma, taste and overall acceptability on 9 Point Hedonic Scale (Annexure-I).

3.3.2.7 Microbial examination

Total plate count (TPC) was calculated by aseptically inoculating one gram of serially diluted samples in total plate count/ standard plate count agar medium prepared according to Ranganna (2009). One ml of sample (ginger candy) after serial dilutions was aseptically inoculated in pre sterilized plates, followed by pouring total plate count agar (10-15 ml) under sterilized environment of laminar air flow. The plates were then incubated at 37ºC for 24 - 48 hours prior counting of microbes. The results of total plate count (TPC) were then expressed as log cfu/ml of the sample.

3.3.3.8 Statistical analysis

The data on chemical characteristics of different fresh and processed products were analyzed statistically by following Completely Randomized Design (CRD) of Cochran and Cox (1987). While data pertaining to sensory evaluation of ginger candy was analyzed according to Randomized Block Design (RBD) as described by Mahony (1985). Triplicate determinations were made for each attributes.

3.4 COST OF PRODUCTION OF PROCESSED PRODUCTS

Cost of production of ginger candy prepared by using different osmotic solution was calculated by taking into accounts the various input costs such as cost of raw material, labour, packaging and processing cost. For calculating the saleable price of product, 20.0 per cent profit margin was added to the cost of production of each product.

Chapter-4

RESULTS AND DISCUSSION

The present investigations entitled **"Development and evaluation of anthocyanin enriched ginger candy"** were carried out in the Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the year 2018-2019. The results recorded in different experiments have been explained under the following heads.

4.1 Physico-chemical composition of fresh ginger and plum fruit

4.1.1 Physical characteristics of fresh ginger rhizome and plum fruit

4.1.2 Chemical characteristics of fresh ginger rhizome and plum fruit

4.2 Product standardization

4.2.1 Chemical characteristics of peeled ginger rhizome (*Zingiber officinale)*

4.2.2(a) Optimization of thickness of ginger slices in relation to osmotic dehydration

4.2.3 (b) Optimization of thickness of ginger slices for osmotic dehydration

4.3 Standardization of optimum time-temperature combination for osmotic dehydration of ginger slices

4.4. Optimization of process for the development of anthocyanin enriched ginger candy

4.4.1. Equilibrium relative humidity of the standardized ginger candy

4.5 Physico-chemical characteristics of fresh honey and sugar

4.6 Changes during storage

4.6.1 Storage studies of anthocyanin enriched ginger candy

4.7 Microbial study of processed products

4.8 Cost of production

4.1 PHYSICO-CHEMICAL COMPOSITION OF FRESH GINGER RHIZOME AND PLUM FRUIT

4.1.1 Physical characteristics of fresh ginger and plum fruit

The observation on physical characteristics of fresh ginger rhizome presented in Table 4.1 revealed that size parameters (Mean ± SD) of ginger rhizome was 10.01 ± 1.61 cm length

and 7.81 ± 3.03 cm breadth with the mean weight and volume observed as 116.77 ± 1.46 g and 108.15 ± 1.52 cc respectively. The density of ginger rhizome was found to be 1.07 ± 0.01 g/cc with the firmness recorded as 11.50 ± 0.10 kg/cm^2. Earlier Dhiman (2015), Akhtar *et al.* (2013), Jayashree and Visvanathan (2011) and Kaushik (2017) also observed almost similar type of physical characteristics of ginger.

Data on physical characteristics of plum fruit (Table 4.1) indicates that average length and breadth of fruit was found to be 4.39 ± 1.55 cm and 3.97 ± 1.57 cm respectively. Almost similar average length and breadth of plum fruit was reported by Mehta and Jindal (1984), Mishra and Srivastava (1970), Sharma and Mahapatra (1997) and Lal and Thakur (1978). Further, mean weight, volume and density of fruit was recorded as 56.62 ± 0.89 g, 53.16 ± 1.53 cc and 1.06 ± 0.01 g/cc respectively which is within the range noticed by Mishra and Srivastava (1970), Wills *et al.* (1983), Sharma and Mahapatra (1997) and Raj *et al.* (2012). Firmness of plum fruit recorded as 2.30 ± 0.18 kg/cm^2 was almost similar to the value recorded by Sharma and Kaushal (1999).

4.1.2 Chemical characteristics of fresh ginger rhizome and plum fruit

The data on chemical characteristics of fresh ginger rhizome (Table 4.1) indicated a moisture content of 82.39 ± 0.05 per cent and total soluble solids of 2.70 ± 0.10 ^{0}B in fresh ginger rhizome. A low titratable acidity of 0.15 ± 0.02 per cent citric acid was observed in ginger rhizome with pH noticed as 6.53 ± 0.02. Thus, broadly our values were in conformity with Phoungchandang and Sertwasena (2010), Policegoudra and Aradhya (2007), Akhtar *et al.* (2013) Dhiman (2015), Hema (2016) and Kaushik (2017). Further the level of reducing and total sugars in ginger rhizome were found to be 0.75 ± 0.21 and 1.26 ± 0.02 per cent respectively which were slightly higher than the values revealed by Kaushal *et al.* (2014). The amount of ascorbic acid, total phenols and antioxidant activity was recorded as 8.48 ± 0.53 mg/100 g, 10.18 ± 0.03 mg/100 g and 37.45 ± 0.60 per cent respectively which was near to the value revealed by Shirin and Prakash (2010), Kaushal *et al.* (2014), Dhiman (2015) and Hema (2016). Crude fibre and mineral represented by total ash was found to be 1.41 ± 0.02 and 1.66 ± 0.02 per cent respectively. These value were in conformity with the result found by Pearson (1971), Shahid and Hussain (2012), Dhiman (2015), Hema (2016) and Kaushik (2017).

Table 4.1 Physico-chemical characteristics of fresh ginger rhizome (*Zingiber officinale*) and plum fruit (*Prunus domestica*)

Characteristics		Mean ± SD*	
		Ginger rhizome	Plum
Size (cm)	Length	10.01 ± 1.61	4.39 ± 1.55
	Breadth	7.81 ± 3.03	3.97 ± 1.57
Weight (g)		116.77 ± 1.46	56.62 ± 0.89
Volume (cc)		108.15 ± 1.52	53.16 ± 1.53
Density (g/cc)		1.07 ± 0.01	1.06 ± 0.01
Firmness (kg/cm^2)		11.50 ± 0.10	2.30 ± 0.18
Moisture (%)		82.39 ± 0.05	86.93 ± 0.09
TSS (^{0}B)		2.70 ± 0.10	11.86 ± 0.41
Titratable acidity (%)		0.15 ± 0.02	2.94 ± 0.02
pH		6.53 ± 0.02	3.36 ± 0.04
Reducing sugars (%)		0.75 ± 0.21	3.67 ± 0.09
Total sugars (%)		1.26 ± 0.02	9.26 ± 0.34
Ascorbic acid (mg/100 g)		8.48 ± 0.53	18.30 ± 1.09
Total phenols (mg/ 100g)		10.18 ± 0.03	52.32 ± 2.89
Antioxidant activity (%)		37.45 ± 0.60	71.6 ± 0.55
Anthocyanin (mg/100g)		--	56.30 ± 1.50
Total ash (%)		1.66 ± 0.02	0.42 ± 0.03
Crude fibre (%)		1.41 ± 0.02	0.07 ± 0.01

*****All values are the mean of 10 observations
* SD = Standard deviation

The data on chemical characteristics of plum depicted in Table 4.1 shows that plum fruit contained moisture content, total soluble solids, titratable acidity (as malic acid) and pH values of 86.93 ± 0.09 per cent, 11.86 ± 0.41^{0}B, 2.94 ± 0.02 per cent and 3.36 ± 0.04 respectively which were near to the value reported by Wills *et al.* (1983), Gothwal *et al.* (1998),Sharma and Kaushal (1999), Mishra and Srivastava (1970), Sharma *et al.* (2002) and Milosevic and Milosevic (2011). The reducing and total sugars in plum fruit were found to be 3.67 ± 0.09 and 9.26 ± 0.34 per cent which were in agreement to the values of reducing sugars and total sugars given by Mehta and Jindal (1984) and Sharma and Kaushal (1999). An appreciable amount of ascorbic acid (18.30 ± 1.09 mg/100 g), total phenols (52.32 ± 2.89 mg/100g) and antioxidant activity (71.60 ± 0.55%) was recorded in plum fruits along with anthocyanin content (56.30 ± 1.50 mg/100g), crude fibre (0.07 ± 0.01 %) and total ash (0.42 ± 0.03%) where these values were in conformity with the results found by Erturk *et al.* (2009) and Dhiman (2015).

4.2 PRODUCT STANDARDIZATION

4.2.1 Quality characteristics of peeled ginger rhizome (*Zingiber officinale)*

The data on chemical characteristics of peeled ginger rhizome presented in Table 4.2 indicated that average moisture content (Mean ± SD) and total soluble solids in the peeled

ginger rhizome was recorded as 84.76 ± 0.05 per cent and 3.99 ± 0.10 ^{0}B respectively. Titratable acidity was observed as 0.16 ± 0.03 per cent citric acid whereas, pH was recorded as 6.44 ± 0.04 in the peeled ginger rhizomes. Data pertaining to nutritional characteristics of peeled ginger rhizome revealed that it contained substantial amount of total and reducing sugars (0.78±0.15 and 1.86± 0.05 %), ascorbic acid (6.36±1.06 mg/100 g), crude fibre (1.40±0.03 %) and total ash (1.34± 0.03 %).

Table 4.2 Quality characteristics of peeled fresh ginger rhizome (*Zingiber officinale*)

Characteristics	Mean ± SD*
Moisture (%)	84.76 ± 0.05
TSS (^{0}B)	3.99 ± 0.10
Titratable acidity (% Citric acid)	0.16 ± 0.03
pH	6.44 ± 0.04
Reducing sugars (%)	0.78 ± 0.15
Total sugars (%)	1.86 ± 0.05
Ascorbic acid (mg/100 g)	6.36 ± 1.06
Total phenols (mg/ 100g)	9.81 ± 0.05
Antioxidant activity (%)	46.60 ± 0.67
Crude fibre (%)	1.40 ± 0.03
Total ash (%)	1.34 ± 0.03

*91.25 per cent peeled rhizome was obtained by mechanical peeler
* All values are the mean of 10 observations
* SD = Standard deviation

The mean total phenols and antioxidant activity of peeled ginger rhizome was recorded as 9.81±0.05 mg/100 g, 46.60 ±0.67 per cent respectively. Following results were in conformity with the results of Dhiman (2015), Hema (2016), Kaushik (2017) and Dhiman (2018) for peeled ginger.

4.2.2 (a) Optimization to thickness of ginger slices in relation to osmotic dehydration

Dehydration is a unit operation whereby heat and mass transfer processes occur simultaneously. The data pertaining to reduction the moisture content in drying time of ginger slices with varying thickness after blanching (1.0 % lime juice for 15 minutes) is presented in Table 4.3 where the mean duration of drying of blanched ginger slices ranged between 4.02 to 10.01 hours. Maximum drying time of 10.01 hours was taken by treatment T_5 (slice thickness 25.00 mm) to reach to a moisture content of 16.69 per cent while it took only 4.02 hours to dry the ginger slices having 5.00 mm thickness to reach to moisture content of 11.51 per cent. The data presented in Table 4.3 clearly shows that with increasing thickness the time taken for drying to specific moisture content increased which was in agreement with the

results of Nath *et al.* (2013) and Aktar *et al*. (2009). Dhiman (2015) reported a drying time of 6.25 hours for drying ginger flakes (3-4x0.4x0.4cm^3) to a moisture content of 15.75 per cent.

Table 4.3: Reduction in moisture content on drying time with varying thickness

Thickness (mm) / Drying time (hrs)	5.00	10.00	15.00	20.00	25.00
0	84.22	84.22	84.22	84.22	84.22
1	65.63	80.91	77.72	77.89	79.90
2	38.69	58.20	59.86	63.45	72.97
3	23.58	42.01	42.24	54.21	64.68
4	11.51	30.55	31.83	39.42	53.17
5	11.50	14.98	20.27	34.23	48.02
6		14.95	16.35	31.60	36.16
7			16.30	25.23	31.45
8				16.37	29.04
9				16.35	23.58
10					16.69
11					16.60

The ginger slices of thickness 10.0, 15.0 and 20.0 mm showed drying time of 5.00, 6.00 and 8.01 hours respectively. The data in Table 4.3 shows that thinner the ginger slice, lesser the time it takes to reach the required moisture content while, thicker the slice, greater is the time taken to dry under similar conditions. Drying process of a material is described as a series of steps in which drying rate plays an important role and the dehydration curve plots the drying rate versus drying time. Drying rate of all treatments was high initially especially in the slices with less thickness when the moisture content was highest, then decreased rapidly. Kaushik (2017) also reported that the rate of moisture loss was slowest during falling rate period than that of constant rate period.

4.2.2 (b) Optimization of thickness of ginger slices for osmotic dehydration

To optimize the thickness of ginger slices for osmotic dehydration, the peeled ginger rhizome was sliced into varying thickness (5.00–25.00 mm) and blanched in a solution of 1.0 per cent lime juice for 15 minutes as standardized by Dhiman (2015) followed by drying in mechanical dehydrator at 55±2^{o}C (Jayashree *et al*. 2014). The slice thickness was optimized

on the basis of sensory characteristics and drying time and the optimized treatment was then taken for further experiments.

The results pertaining to the sensory evaluation of ginger slices (Table 4.4 and Figure 4.1) showed that colour scores obtained was non significantly different among the ginger slices of varying thickness. Texture indicates the characteristics of a food that includes the descriptive parameters like softness, chewiness, hardness, brittleness etc. which has a relationship to the appearance of a product and to its evaluation in the mouth as well. The data pertaining to texture characteristics showed significantly higher scores (7.70) for treatment T_2 (slice thickness 10.00 mm) followed by treatment T_1 (slice thickness 5.00 mm) as 7.00 and minimum score (5.50) for treatment T_5 (slice thickness 25.00 mm). The ginger slices of thickness 15.00 and 20.00 mm recorded texture scores of 6.80 and 6.00 respectively. Further, the taste scores of ginger slices of varying thickness (5.00-25.00 mm) were found to be non-significantly different among the treatments. Aroma is a distinctive typically pleasant smell characteristic of a product and all the treatments with varying thickness received aroma scores above 7.50 where maximum scores of 7.90 was received by treatment T_5 (slice thickness 25.00 mm) followed by treatment T_4 (slice thickness 20.00 mm) with a score of 7.80 while minimum scores for aroma (7.20) was received by treatment T_1 (slice thickness 5.00 mm). On the basis of overall acceptability treatment T_2 (slice thickness 10.00 mm) received maximum score of 7.80 followed by treatment T_1 (slice thickness 5.00 mm) with a score of 7.50. Minimum score for overall acceptability (6.00) was received by treatment T_5 (slice thickness 25.00 mm) followed by treatment T_4 (slice thickness of 20.00 mm) as 6.43.

Thus, on the basis of sensory scores the ginger slices of thickness of 10.00 mm and 5.00 mm were optimized for conducting further experimentations.

Table 4.4: **Sensory score* of dehydrated ginger slices**

Thickness of slices (mm)	Colour	Texture	Taste	Aroma	Overall acceptability
T_1 5.00	7.00	7.00	6.05	7.20	7.50
T_2 10.00	7.05	7.70	6.09	7.50	7.80
T_3 15.00	7.09	6.80	6.10	7.60	7.00
T_4 20.00	7.10	6.00	6.12	7.80	6.43
T_5 25.00	7.12	5.50	6.20	7.90	6.00
$CD_{0.05}$	**NS**	**0.61**	**NS**	**0.07**	**0.08**

*On 9 point hedonic scale

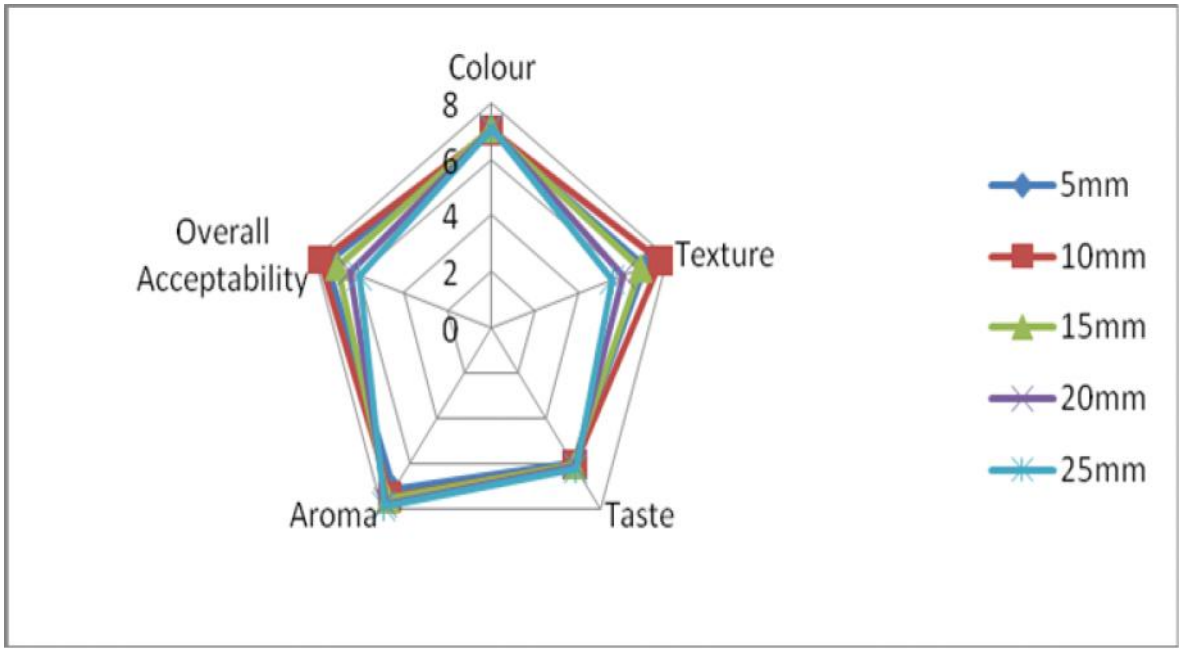


Fig.4.1. Sensory scores for dehydrated ginger slices

In order to optimize the thickness of ginger slices the results of Table 4.3 and 4.4 were taken into consideration and a thickness of 7.50 mm of ginger slice was compared with 5.00 mm and 10.00 mm. The data in Table 4.5 shows that in treatment L_3 (slice thickness 10.0mm) 14.98 per cent of moisture was lost during five hours while, in treatment L_1 (slice thickness 5.00mm) 11.51 per cent of moisture was lost in the 4 hours. The ginger slice of thickness 7.50 mm showed a drying time of (L_2) 4.30 hours to reach to a moisture content of 14.09 per cent. The three major stages of drying in a drying curve are the transient early stage during which the product is heating up, constant rate period where moisture is comparatively easy to remove and falling rate period where moisture is bound within solid matrix. Drying rate of all treatments was high initially especially in the slices with less thickness when the moisture content was highest, then decreased rapidly. Earlier, Thuwapanichayanan *et al.* (2014) also found that drying of ginger slices mostly occurred in falling rate period. Similar to previous findings Kaushik (2017) also reported that the rate of moisture loss was slowest during falling rate period than that of constant rate period. Further Nath *et al.* (2013) observed that the hardness of ginger candy is a function of slice thickness and blanching time where hardness increases with increase in slice thickness. Dehydration curve for ginger slices of varying thickness (Fig. 4.2) shows that greater the surface area, faster the drying especially in the first two hours. Drying process of a material is described as a series of steps in which drying rate plays an important role and the dehydration curve plots the drying rate versus drying time.

Table 4.5 Effect of dehydration on drying behaviour of ginger slices

Thickness of slices(mm)	Drying time (hrs)	Moisture content (%)
L_1 5.00	4.02	11.51
L_2 7.50	4.30	14.09
L_3 10.00	5.01	14.98

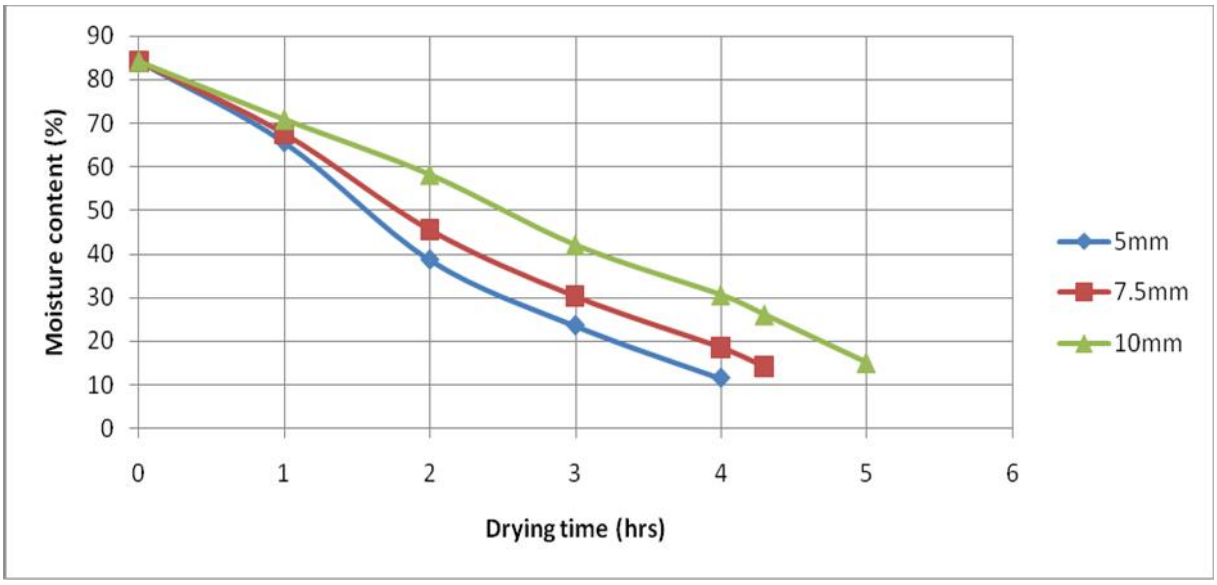


Fig.4.2. Dehydration curve for ginger slices

The results pertaining to the sensory evaluation for optimization of thickness for osmotic dehydration (Figure 4.3) revealed non significant differences in the colour characteristics of ginger slices. Data appended to texture characteristics showed significantly higher scores (8.00) for treatment L_2 (slice thickness 7.50 mm) followed by treatment L_3 (7.70) and minimum score (7.00) for treatment L_1 with a slice thickness 5.00mm. Further, the taste characteristics of ginger slices of the varying thickness (5.00, 7.50 and 10.00mm) was found to be non significantly different among the treatments. Maximum score for aroma was obtained by treatment L_3 (slice thickness10.00mm) followed by treatment L_2 (slice thickness 7.50 mm) and L_1 (slice thickness 5.00 mm) with a score of 7.50, 7.40 and 7.20 respectively.

Table 4.6: **Sensory score* of dehydrated ginger slices**

Thickness of slices (mm)	Colour	Texture	Taste	Aroma	Overall acceptability
L_1 5.00	7.00	7.00	6.05	7.20	7.50
L_2 7.50	7.01	8.00	6.08	7.40	8.00
L_3 10.00	7.05	7.70	6.09	7.50	7.80
$CD_{0.05}$	**NS**	**0.12**	**NS**	**0.06**	**0.08**

*On 9 hedonic point scale



Plate 4.1 : Effect of thickness of ginger slices for osmotic dehydration

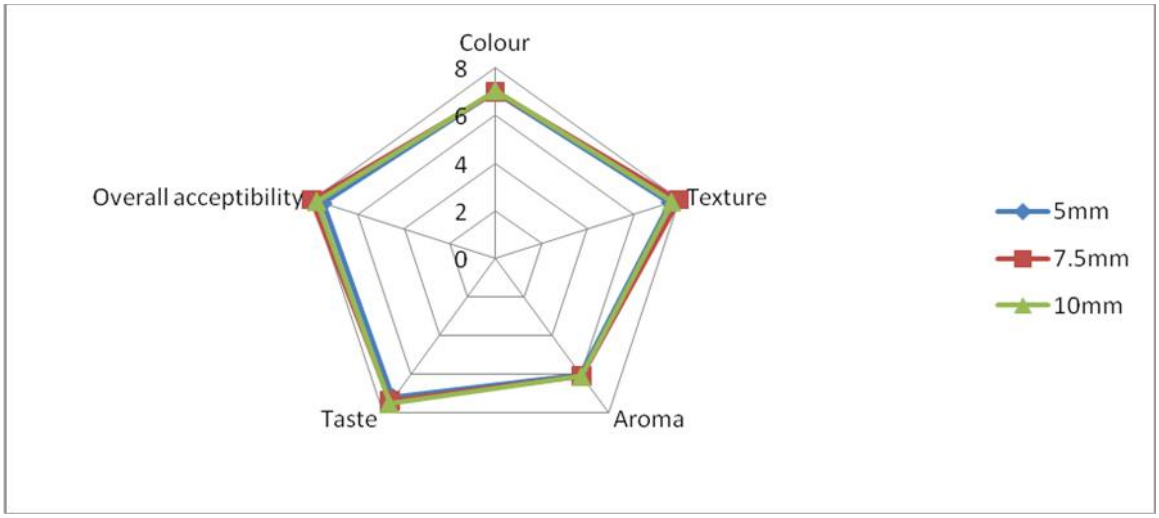


Fig.4.3. Sensory scores of dehydrated ginger slices

On the basis of data in Table 4.6 and Figure 4.3 the maximum overall acceptability scores (8.00) was received by treatment L_2 (slice thickness 7.50 mm) and minimum (7.50) by treatment L_1 (slice thickness 5.00 mm).Similar results were found by Nath *et al.* (2013) for slice thickness and blanching time on different quality attributes of instant ginger candy.

Thus, on the basis of sensory scores and drying behaviour the ginger slices thickness of 7.50 mm was optimized for conducting the osmotic studies.

4.3 STANDARDIZATION OF OPTIMUM TIME-TEMPERATURE COMBINATION FOR OSMOTIC DEHYDRATION OF GINGER SLICES

To optimize the time temperature combination for osmotic dehydration, ginger slices of 7.50mm thickness was blanched and dipped in a hypertonic sugar solution of 70^{o}B TSS maintained at 50 ^{o}C temperature for varying steeping time of 1.0 to 10.0 hours with slices: syrup ratio as 1:3 for all the treatments. The slices were drained out of the syrup after the specific time period and the results pertaining to the osmotically dehydrated ginger slices is presented in Table 4.7 the result showed that the weight of slices was reduced in all the treatments with respect to steeping time (1-10 hours) following osmotic dehydration, as weight reduction, solid gain and water loss are affected by process time (Fito *et al.*, 2001). The amount of water diffuses from the slices to the osmotic solution is the water loss while the solid gain indicates the solid diffusion from the osmotic solution to the slices. Weight reduction, solid gain and water loss increased in the initial hour of osmosis in nearly all treatments and thereafter the values increased with decreasing rate and approached to equilibrium with length of contact. The data pertaining to osmotic parameters in Table 4.7

showed that after 1.0 hour of steeping in osmotic solution of 70 ^{o}B, the ginger slices showed a weight reduction of 9.96 per cent with a corresponding solid gain and moisture loss of 5.92 per cent and 68.51 per cent respectively. The total soluble solid of ginger slices after 1.0 hour of steeping was recorded as 10.15 ^{o}B with a parallel total soluble solid of syrup as 68.85 ^{o}B. After 2.00 hours of steeping time in the osmotic solution of 70 ^{o}B the ginger slices showed a weight reduction of 15.58 per cent with a corresponding solid gain and moisture loss of 6.17 per cent and 60.15 per cent respectively. The total soluble solid of ginger slices after 2.0 hours of steeping was recorded as 14.50 ^{o}B with a parallel total soluble solid of syrup as 63.05 ^{o}B. Similarly, at 3.0, 4.0 and 5.0 hours of steeping time in the osmotic solution of 70 ^{o}B the ginger slices showed a weight reduction of 19.96, 23.08 and 24.20 per cent with a corresponding solid gain and moisture loss of 8.43, 10.60 and 13.00 per cent and 57.90, 55.86 and 52.89 per cent respectively. The total soluble solids of ginger slices after 3.0, 4.0 and 5.0 hours of steeping were recorded as 19.20, 23.05 and 25.02 ^{o}B with a parallel total soluble solid of syrup as 55.02, 47.01 and 45.03 ^{o}B. While after 6.00, 7.00 and 8.00 hours of immersion time a weight reduction of 27.00, 29.60 and 30.00 per cent and a solid gain of 16.60, 16.80 and 17.20 per cent was recorded respectively with a corresponding water loss of 43.60, 44.40 and 47.20 per cent (Fig. 4.4). The equilibrium of total soluble solids between slices and syrup was evident at 8 hours of steeping with a value of (Fig. 4.5) 32.03 oB for slices and 35.10 ^{o}B for syrup.

Table 4.7: Effect of steeping time on osmotic dehydration behaviour of ginger slices

Parameters / Steeping time(h)	Weight Reduction (%)	Solid gain (%)	Moisture loss (%)	TSS of slices (^{O}B)	TSS of syrup (^{O}B)
T_0 0.00	0.00	0.00	84.22	4.02	70.00
T_1 1.00	9.96	5.92	68.51	10.15	68.85
T_2 2.00	15.58	7.17	60.15	14.50	63.05
T_3 3.00	19.96	8.43	57.90	19.20	55.02
T_4 4.00	23.08	10.60	55.86	23.05	47.01
T_5 5.00	24.20	13.00	52.89	25.02	45.03
T_6 6.00	27.00	16.60	47.50	28.01	40.05
T_7 7.00	29.60	16.80	46.83	29.02	38.02
T_8 8.00	30.00	17.20	44.47	32.03	35.10
T_9 9.00	30.00	17.20	44.47	32.05	35.16
T_{10} 10.00	30.02	17.10	44.45	32.04	35.04
$CD_{0.05}$	**0.02**	**0.01**	**0.03**	**0.017**	**0.02**

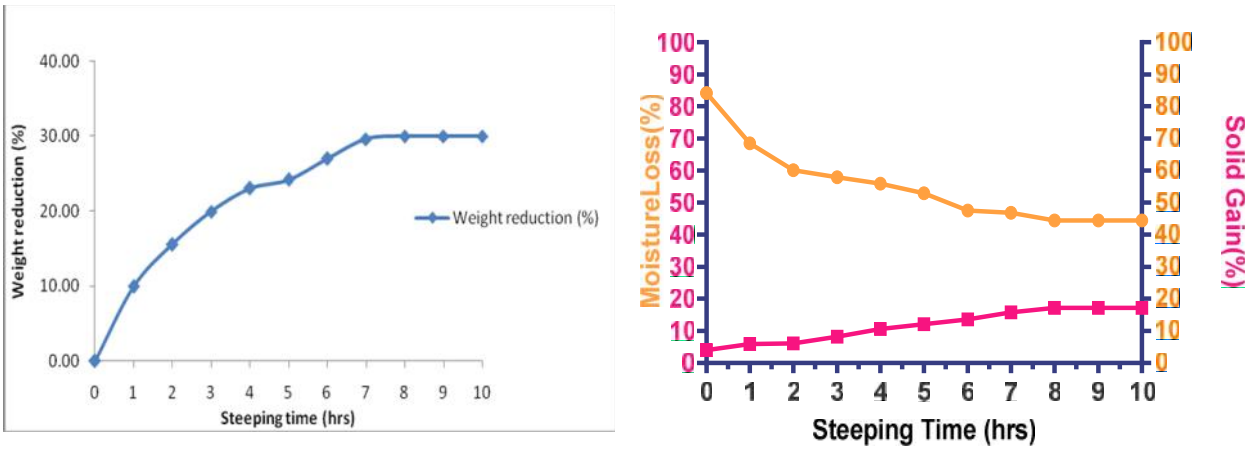


Fig.4.4. Effect of immersion time on per cent weight reduction, water and solid gain of ginger slice

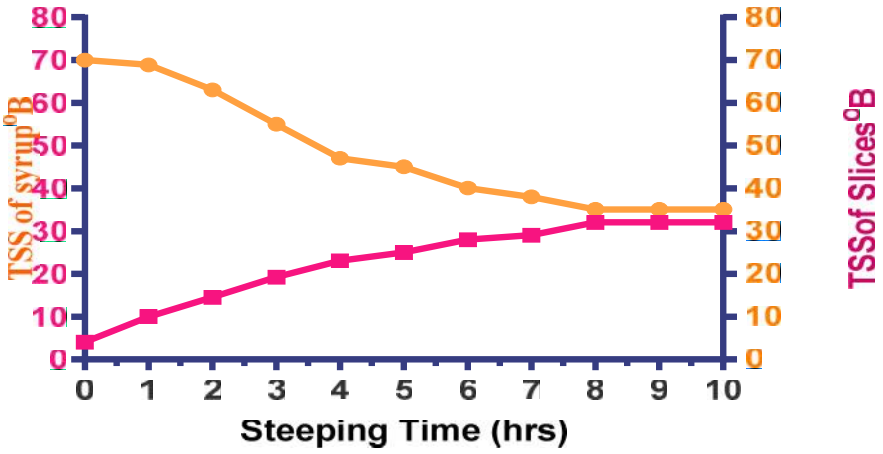


Fig.4.5. Effect of immersion time on TSS of immersion solution and slices of ginger

Aktar *et al.* (2009) reported 28.18 per cent of water loss in first hour of osmosis in a hypertonic sugar solution of 60 ^{o}B with a corresponding solid gain of 5.36 per cent for 5 mm of ginger slices at room temperature. Similarly Gupta *et al*. (2014) found that maximum sugar gain and water loss was attained within 5 hours of immersion of sapota slices in 70 ^{o}B sugar syrup at 60 ^{o}C temperature with syrup: sample ratio of 5:1. Isse and Shubert (1991) reported that during osmosis cell wall pores get smaller which makes diffusion difficult through cellular membranes especially in syrup of higher concentration resulting in less solid gain while, Yadav *et al.* (2012) observed that with the increase in immersion time, water loss at a specific sucrose concentration increased. Sugar uptake results in the development of a concentrated solid layer under the surface of the slices, decreasing the osmotic pressure gradient across the ginger slices interface and thereby decreasing the driving force of water flow.

Thus the steeping time of 8.00 hours (T_8) was optimized on the basis of equilibrium of total soluble solids attained between slices and syrup and was therefore selected for further studies. Thus a steeping time of 8.0 hours in 70 ^oB sugar solution maintained at 50 ^oC was standardized for ginger slices having a thickness of 7.50 mm.

4.4 OPTIMIZATION OF PROCESS FOR THE DEVELOPMENT OF ANTHOCYANIN ENRICHED GINGER CANDY

The anthocyanin enriched ginger candy was prepared by draining the ginger slices from the osmotic solution after a standardized steeping time of 8 hours and dipping in plum pulp in the ratio 1:3 for time period varying from 1 to 8 hours. The ginger slices were then drained at specific time period, and were evaluated on the basis of total soluble solid, antioxidant activity and anthocyanin content. The TSS of the ginger slices after draining from a hypertonic sugar solution was observed as 32 ^oB. The results pertaining to the osmotically dehydrated anthocyanin enriched ginger slices presented in Table 4.8 showed that after 1.00 hours of steeping in plum pulp of 12 ^oB (1:3), total soluble solid of 30.02±0.03 ^oB was observed with a corresponding antioxidant activity of 32.09±0.20 per cent and anthocyanin content of 1.89±0.04 mg/100g was observed. At 2.00 hours of steeping in plum pulp of 12 ^oB (1:3), total soluble solid of 29.41±0.08 ^oB was observed with a corresponding antioxidant activity of 35.13±0.21 per cent and anthocyanin content of 2.02±0.14 mg/100g was observed. Similarly, after 3.00 hours of steeping in plum pulp of 12 ^oB (1:3), total soluble solid of 27.25±0.06 ^oB was observed with a corresponding antioxidant activity of 38.23±0.25 per cent and anthocyanin content of 4.02±0.10 mg/100g was observed. After 4.00 hours of steeping in plum pulp of 12 ^oB (1:3), total soluble solid of 26.10±0.02 ^oB was observed with a corresponding antioxidant activity of 40.10±0.42 per cent and anthocyanin content of 5.64±0.12 mg/100g was observed. Similarly at 5.00 hours of steeping time a total soluble solid of 25.20±0.05 ^oB with a corresponding antioxidant activity of 41.50±0.46 per cent and anthocyanin content of 7.41±0.15 mg/100g was noticed. While after 6.00 hours of steeping time in 12 ^oB plum pulp (1:3) a total soluble solid of 25.50±0.07 ^oB with a corresponding antioxidant activity of 41.52±0.54 per cent and anthocyanin content of 7.57±0.13mg/100g was calculated. However, at 7.00 and 8.00 hours of steeping time a total soluble solid of 25.20±0.09 and a 25.60±0.01 ^oB with a corresponding antioxidant activity of 41.43±0.44 and 41.05±0.41 per cent and anthocyanin content of 7.55±0.06 mg/100g and 7.51±0.04 mg/100g was observed. The decrease in TSS of ginger slices was due to the tendency attained equilibrium between slices and solution.

Table 4.8 Effect of steeping time in plum pulp on nutritional characteristics of osmo dried ginger candy

Slices: Plum pulp	Steeping Time (h)	TSS (^{o}B)	Antioxidant Activity (%)	Anthocyanin Content (mg/100g)
1:3	**1.00**	30.02±0.03	32.09±0.20	1.89±0.04
	2.00	29.41±0.08	35.13±0.21	2.02±0.14
	3.00	27.25±0.06	38.23±0.25	4.02±0.10
	4.00	26.10±0.02	40.10±0.42	5.64±0.12
	5.00	25.20±0.05	41.50±0.46	7.41±0.15
	6.00	25.50±0.07	41.59±0.54	7.57±0.13
	7.00	25.20±0.09	41.55±0.44	7.55±0.06
	8.00	25.60±0.01	41.51±0.41	7.51±0.04

4.4.1 Colour value of the anthocyanin enriched ginger candy

The color parameters Hunter L value (lightness/darkness), a value (redness/greeness) and b value (yellowness/blueness) of anthocyanin enriched ginger candy were measured by using a Hunter Lab Color Flex Colorimeter (Hunter Associates Laboratory Inc., Reston, Virginia, USA) and the data is shown in Table 4.9. The anthocyanin enriched ginger candy was light red with L * value of 25.41, a* 1.21 and b* 6.44 after 4.00 hours of steeping of ginger slices in 12 ^{o}B solution of plum pulp. Similarly at 5.00 hours of steeping in the solution of plum pulp the L* 24.36, a* 1.26 and b* 6.01 values were observed. While after 6.0, 7.0 and 8.0 hours of steeping in plum pulp of 12 ^{o}B L*, a* and b* values were 24.03, 1.42 and 5.32; 23.68, 1.77 and 5.17 and 23.14, 1.93 and 5.03 respectively. Use of plum pulp as immersion solution during osmotic dehydration caused darkening of ginger slices probably due to the uptake of anthocyanins. With longer the dipping time and lower the water content there was a decrease in the lightness (L*) of the samples. The color alteration in dehydrated ginger slices was less pronounced when the osmotic dehydration occurred at sucrose solution, especially without fruit concentrates addition or when it was lower (5%). The use of color solutions (plum pulp concentrates) at 12 ^{o}B resulted in the darkening of samples.

Lab colour value reported by Bhaktaraj *et al*. (2019) in sugar osmotically dehydrated ginger candy and observed lightness (L *) 29.75, greeness (a*) -1.35 and yellowness (b*) 15.01.

This results shows that the osmotic dehydration process involves the partial removal of water from a given food using a hypertonic solution and an opposite flow of solutes from the syrup to the product. Furthermore, a third flow of solid takes place from the food to the

solution due to leaching of the nutrients thus leading to a meaningful loss of product quality (Raoult- Wack *et al*., 2002). Beside this, the cell wall pores of slices gets blocked or smaller during dipping in hypertonic solution for a longer period of time and thus restricts the uptake of plum pulp where only a thin layer of plum pulp was formed at the surface of ginger slices and very little was imbibed.

Table 4.9 Colour value of anthocyanin enriched ginger candy

Slices: Plum pulp	Steeping Time (h)	L* (Lightness)	a* (Redness-greeness)	b* (Yellowness-blueness)
1:3	**4.00**	25.41	1.21	6.44
	5.00	24.36	1.26	6.01
	6.00	24.03	1.42	5.32
	7.00	23.68	1.77	5.17
	8.00	23.14	1.93	5.03
	CD 0.05	**0.019**	**0.018**	**0.018**

Simple sugar candy L= 29.15, a = 0.67 and b = 8.14

Thus, in order to maximize the uptake of anthocyanin and minimize the leaching of nutrients a process protocol was standardized by combining the two medium (i.e sugar and plum pulp) as a single dipping solution for the preparation of anthocyanin enriched ginger candy.

4.4.1 Standardization of protocol for the development of anthocyanin enriched ginger candy

4.4.1.1 Physico- chemical characteristics of honey and sugar

Data of physico-chemical characteristics of honey and sugar is presented in Table 4.10. The total soluble solid of honey and sugar was observed as 70.65 ^{0}B and 94.0±1.15 ^{0}B with the total sugars as 65.34±0.01 per cent and 93.79±0.01 per cent which was more than the values observed by Lakhanpal and Vaidya (2015) and was less than the observations of Kaushik *et al.* (1993). The honey and sugar had a moisture content of 16.50 per cent and 3.40±0.15 per cent with the total ash content of 0.19 per cent and 0.07±0.02 per cent respectively. The fructose and glucose of honey was observed as 36.19±0.93 per cent and 29.25±0.07 per cent respectively which was in the same range as observed by Poncini and Winner (1987); Singh (1994) and Singh *et al*. (1998).

Table 4.10: **Physico- chemical characteristics of honey and sugar**

Characteristics	Honey	Sugar
	Mean ± SD*	Mean ± SD*
Moisture (%)	16.50±0.20	3.40±0.15
Total soluble solids (^oB)	70.65±1.00	94.0±1.15
Total sugars (%)	68.34±0.01	93.79±0.01
Fructose (%)	36.19±0.93	-
Glucose (%)	29.25±0.07	-
pH	3.86±0.02	6.08±0.83
Total ash (%)	0.19±0.010	0.07±0.02

The plum pulp was used as a source for the development of anthocyanin enriched ginger candy whose the TSS was raised to 70 ^oB by adding either cane sugar or honey and compared with hypertonic sugar solution (70 ^oB) and honey (70^oB) as control, the details of which is given in Table 3.3. The blanched ginger rhizome of 7.50mm slice thickness was dipped in these different solutions for 10 hours maintained at 50 ^oC in the ratio of 1:3, and the osmosis process was optimized on the basis of equilibrium state of total soluble solid between the slices and the osmotic solution. Data in Table 4.11 clearly shows that TSS of ginger slices increased with the steeping time while TSS of syrup decreases with time.

Table 4.11 Effect of immersion solution and steeping time on TSS of slices and drained syrup

Treatment / Steeping time (hours)	T_1 Sugar syrup		T_2 Plum pulp+ Sugar		T_3 Honey		T_4 Plum pulp+ honey	
	TSS of slices (^oB)	TSS of syrup (^oB)	TSS of slices (^oB)	TSS of syrup (^oB)	TSS of slices (^oB)	TSS of syrup (^oB)	TSS of slices (^oB)	TSS of syrup (^oB)
1	10.02	63.85	12.04	59.02	11.04	61.50	12.60	58.50
2	14.50	58.05	16.60	55.04	15.60	56.08	17.20	54.50
3	19.20	51.02	23.05	49.03	20.10	50.03	24.10	48.06
4	23.05	47.01	28.80	42.05	24.50	45.80	30.50	41.01
5	25.02	45.03	32.40	35.60	27.20	42.06	34.02	35.02
6	28.01	40.05	33.01	35.14	30.10	38.96	34.90	35.60
7	29.02	38.02	32.02	36.03	32.06	35.24	35.03	36.02
8	32.03	35.10	32.07	36.13	32.04	35.20	35.08	36.48
9	32.00	35.15	-	-	32.08	35.29	-	-
10	32.05	35.17	-	-	32.06	35.25	-	-
CD 0.05	**0.01**	**0.02**	**0.01**	**0.02**	**0.01**	**0.02**	**0.02**	**0.01**

The ginger slices dipped in sugar syrup (T_1) attained equilibrium in 8 hours with TSS of slices as 32.03 and syrup as 35.10 while in honey solution (T_3) the equilibrium was attained in 7 hours with TSS of slices as 32.06 ^oB and syrup as 35.24 ^oB. While both in treatment T_2 and T_4 containing plum pulp the equilibrium between slices and syrup was

attained solution 5 hours with TSS of slices as 32.40 and 34.02 ^{o}B in T_2 and T_4 and TSS of syrup as 35.60 and 35.02 ^{o}B respectively.

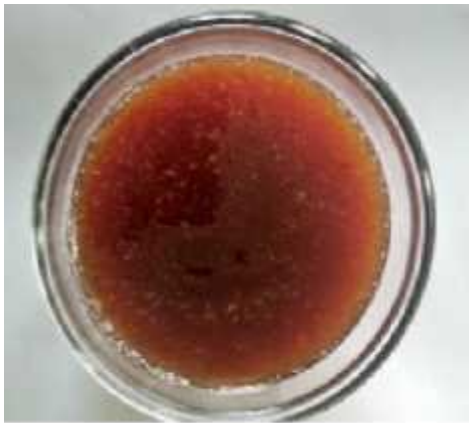
Thus an immersion time of 5 hours was standardized for the preparations of anthocyanin enriched ginger candy. The drained slices from each solution was analyzed for various osmotic parameters and the perusal of data of osmotically drained ginger slices (Table 4.12a) showed that maximum weight reduction was observed in hypertonic solution of the plum pulp and honey (T_4) as 31.50±2.93 per cent followed by pure honey (T_3) as 28.45±3.01 per cent, plum pulp and sugar (T_2) 26.20±2.95 per cent and sugar syrup (T_1) as 24.20±3.02 per cent. Further, a hypertonic solution of plum pulp and honey (T_4) evidenced a maximum water loss (56.50±2.70 %) followed by pure honey (T_3) as 47.00±2.83 per cent, plum pulp and sugar (T_2) 46.00±2.74 and sugar syrup (T_1) as 37.20±2.85 per cent. Similarly, a hypertonic solution of plum pulp and honey (T_4) appended a maximum solid gain of 25.00±0.53 per cent followed by pure honey (T_3) 18.50±0.39 per cent, plum pulp and sugar (T_2) 20.03±0.45 per cent and sugar syrup (T_1) as 13.07±0.34 per cent.

Higher solid gain and water loss were observed in honey treated sample as compared to sucrose-treated sample as honey contains simple sugars like fructose and glucose which low molecular weight osmotic agents thus have enhanced mass transfer during osmotic dehydration. The higher rate of penetration of low molar mass molecules results in the solid enrichment during the process, resulting in the promotion of water loss. Sucrose osmosed slices showed comparably lower solid gain and higher water loss, which is desirable in osmo-dried slices. Further, low molecular weight sugars showed restricted crystallization compared to sucrose treated ones (Chauhan *et al.,* 2011).

Yadav *et al.* (2012) also observed that with the increase in immersion time water loss at a specific sucrose concentration also increased. Nadia *et al*. (2013) concluded that higher water loss and solids gain were observed in pears at 40^{o}C immersion solution while Noroes *et al*. 2010 found that water loss and solid gain were higher at the beginning of the osmosis, reaching maximum at 3.5 hours at 65^{o}B sugar syrup in guava slices. Sagar and Kumar (2009) reported that the concentration of sugar syrup and time of dipping resulted in maximum solid gain after 6 hours in 70^{o}B sugar syrup for mango slices. Similar results were recorded by Lakhanpal and Vaidya (2015) and Mishra (1995) in honey based products.



Sugar Syrup



Plum pulp + Sugar



Honey



Plum pulp + Honey

Plate 4.2 : Standardization of different solutions for osmotic dehydration

Table 4.12 (a): Effect of osmotic solution on osmotic dehydration behaviour of ginger slices

Treatments / Parameter	T_1 Sugar syrup	T_2 Plum pulp + Sugar	T_3 Honey	T_4 Plum pulp + Honey
Weight Reduction (%)	24.20±3.02	26.20±2.95	28.45±3.01	31.50±2.93
Water Loss (%)	37.20±2.85	46.00±2.74	47.00±2.83	56.50±2.70
Solid Gain (%)	13.07±0.34	20.03±0.45	18.50±0.39	25.00±0.53

Table 4.12 (b) shows that nutritionally, the ginger slices immersed in hypertonic solution containing plum pulp contained appreciable amount of anthocyanin content(16.33±0.53 to 18.64±0.63 mg/100g) in treatment T_2 and T_4, antioxidant activity (50.45±0.53 to 52.35±0.60%), total phenols (9.84±0.25 to 13.08±0.28 mg/100g) and ascorbic acid (6.11±0.45 to 6.98±0.49 mg/100g) as against sugar or honey solutions with antioxidant activity, total phenols and ascorbic acid in the range of 42.75±0.51 to 44.25±0.55 per cent, 7.56±0.13 to 11.54±0.12 mg/100g and 3.92±0.35 to 5.32±0.39 mg/100g respectively.

Table 4.12 (b) Effect of osmotic solution on quality characteristics of ginger slices

Treatments / Parameter	T_1 Sugar syrup	T_2 Plum pulp + Sugar	T_3 Honey	T_4 Plum pulp + Honey
Anthocyanin content (mg /100g)	-	16.33±0.53	-	18.64±0.63
Antioxidant activity (%)	22.75±0.51	50.45±0.53	28.25±0.55	52.35±0.60
Total phenol (mg/100g)	7.56±0.13	9.84±0.25	11.54±0.12	13.08±0.28
Ascorbic acid (mg/100g)	3.92±0.35	6.11±0.45	5.32±0.39	6.98±0.49

The above experiment concludes that a dipping time of 5 hours at 50 ^{o}C temperature has been optimized for the preparation of anthocyanin enriched ginger candy in an immersion solution of plum pulp whose TSS in raised to 70 ^{o}B by either sugar or honey while a dipping time of 7 hours has been standardized for ginger slices in honey solution and 8 hours for slices in sugar syrup solution. The ginger slices were then dried in a mechanical dehydrator where the dehydration ratio of 1.99:1 was obtained for ginger slices dipped in sugar syrup (T_1), 1.85:1 for plum pulp and sugar solution (T_2), 1.96:1 honey (T_3) and 1.89:1 plum pulp and honey solution (T_4). Although sugar (sucrose) at 70 ^{o}B is the most suitable osmotic agent however, honey solution could also be used at it improves the flavour considerably. Thus, anthocyanin enriched ginger candy was taken for storage studies comparing with control (sugar syrup or honey).

The color parameters Hunter L value (lightness/darkness), a value (redness/greeness) and b value (yellowness/blueness) ginger candy both anthocyanin enriched ginger candy were measured by using a Hunter Lab Color Flex Colorimeter (Hunter Associates Laboratory Inc., Reston, Virginia, USA) and the data is shown in Table 4.12. The sugar syrup (control) ginger candy showed an L * value of 29.15, a* 0.67 and b* 8.14 while treatment T_2 (plum pulp + sugar) had color values as L* 20.14, a* 6.63 and b* 5.19. While in treatment T_3 using honey as (control) ginger candy dipping solution had L* 21.68, a* 1.32 and b* 6.04 values, as compared in treatment T_4 (plum pulp + honey) where L* 18.36, a* 9.37 and b* 4.39 values was noticed.

Table 4.13 Colour Value of Ginger Candy

Treatments	L* (Lightness)	a* (Redness-greeness)	b* (Yellowness-blueness)
Sugar syrup (T_1)	29.15	0.67	8.14
Plum pulp+ sugar (T_2)	20.14	6.63	5.19
Honey (T_3)	21.68	1.32	6.04
Plum pulp + honey (T_4)	18.36	9.37	4.39
CD $_{0.05}$	**0.02**	**0.019**	**0.019**

Sugar impregnation seemed to maintain lightness resulting in a final product close to that of fresh commodity. The colour parameters L* and a* values correlate well to colour changes in fruit tissues (darkening) due to anthocyanin uptake, L* values decrease with anthocyanin rich solution uptake and a* values increase, the increase in redness and yellowness was clear and seem to be result of solids uptake during osmotic pre-treatment. Similar findings were reported by (Chauhan *et al.*, 2011) where the variations in the colour values of osmotically dehydrated apple slices may be due to the differential solute uptake.

4.4.1.1 Equilibrium Relative Humidity

In order to establish the storage conditions, the ERH studies of ginger candies viz., sugar syrup, honey dipped ginger candy and anthocyanin (plum pulp and sugar, honey) enriched ginger candy were conducted by exposing the product to different relative humidity (0-100 %) in closed desiccators at room temperature.

The data on the relationship between equilibrium moisture content and number of days required for the product to reach equilibrium at particular relative humidity is presented in Table 4.14 and Fig. 4.6 and 4.7.



Ginger rhizome





Packed in aluminium laminated pouches



Peeling and slicing



Osmotically dried ginger candy



Dried anthocyanin enrich ginger candy



Sliced ginger rhizome



Blanching in 1% lime juice (Blanched ginger slices)



Osmotic dehydration



Plum pulp (Anthocyanin)

Plate 4.3 : Flow sheet for the preparation anthocyanin enriched ginger candy

Table 4.14 Equilibrium relative humidity of ginger candy

Sugar syrup (70°B)				Plum pulp + sugar (70°B)		
Relative humidity (%)	**Equilibrium moisture content (%)**	**No. of days to reach equilibrium**	**Remarks**	**Equilibrium moisture content (%)**	**No. of days to reach equilibrium**	**Remarks**
0	0.02	18	Darkened, cracking appears	1.18	22	Colour faded, cracking appears
10	2.70	16	Darkened, cracking appears	2.70	19	Colour faded, cracking appears
20	3.44	15	Darkened, cracking appears	3.07	17	Colour slightly faded, cracking appears
30	4.90	14	Colour darkening, cracking appears	4.90	16	Colour slightly faded, cracking appears
40	7.35	13	Colour slightly faded, cracking appears	6.32	15	Colour slightly faded, cracking appears
50	11.58	11	Colour normal, good texture	8.36	13	Colour normal, good texture and flavour
60	18.71	9	Colour normal, good texture	10.64	12	Colour bright, good texture and flavour
70	28.20	8	Soft, but no mould growth	15.71	10	Colour bright, good texture and flavour
80	36.20	6	Soft, mould growth	25.00	8	Soft, no mould growth
90	44.00	5	Soft and mould growth	36.84	7	Soft and mould growth
100	50.28	4	Soft and mould growth	46.61	5	Soft and mould growth

Results of Fig. 4.6 pertaining to interpolation isotherm showed that for sugar syrup ginger candy had an ERH of 60.0 per cent with equilibrium moisture content of 18.71 per cent while anthocyanin (plum pulp+ sugar) enriched ginger candy showed an ERH of 70.0 per cent with an equilibrium moisture content of 15.71 per cent. Data presented in Table 4.13 and Fig 4.7 further indicated that the product (sugar syrup ginger candy) exposed to 65.0 per cent relative humidity exhibited considerable changes in its texture and colour within 18 days of exposure as compared with anthocyanin (plum pulp+ sugar) enriched ginger candy which exhibited considerable changes in its texture and colour within 22 days of exposure at 75.0 per cent relative humidity.

Thus, the critical point (when candy becomes watery) and danger point (5.0% lower relative humidity than that of critical point) for sugar ginger candy was recorded at relative

humidity of 71.0 and 66.0 per cent, respectively, while for anthocyanin (plum pulp and sugar) enriched ginger candy it was recorded at relative humidity of 80.0 and 75.0 per cent. Singh *et al.* (2001) observed an ERH of 58.0 per cent for dried ginger slices. Thus, it emerges that the anthocyanin (plum pulp and sugar) enriched ginger candy with 70.0 per cent ERH can be stored safely within the relative humidity of 70.0 to 75.0 per cent while sugar syrup dipped ginger candy with 60 per cent ERH is required to be stored within the relative humidity of 60.0 to 65.0 per cent.

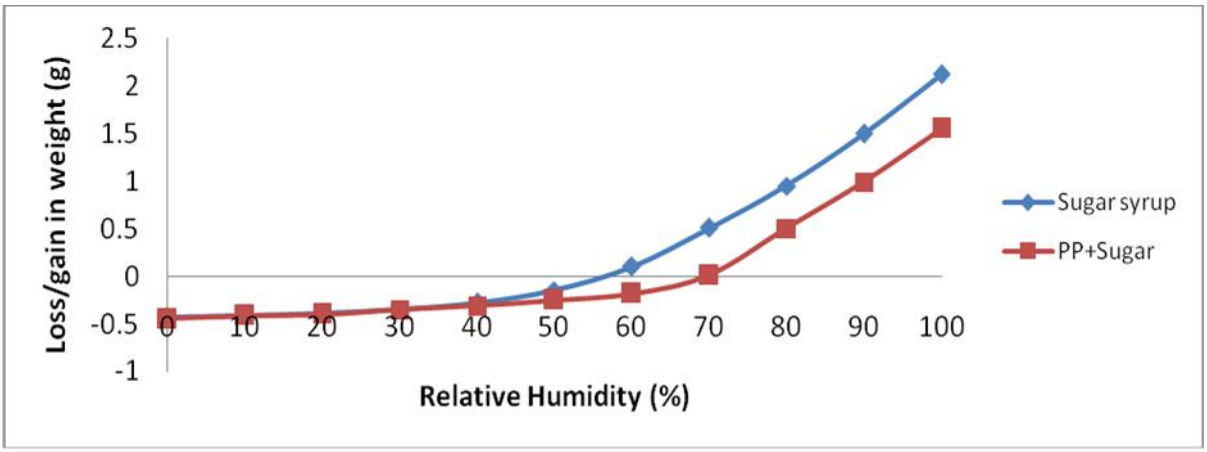


Fig.4.6. Graphical interpolation isotherm for ginger candy

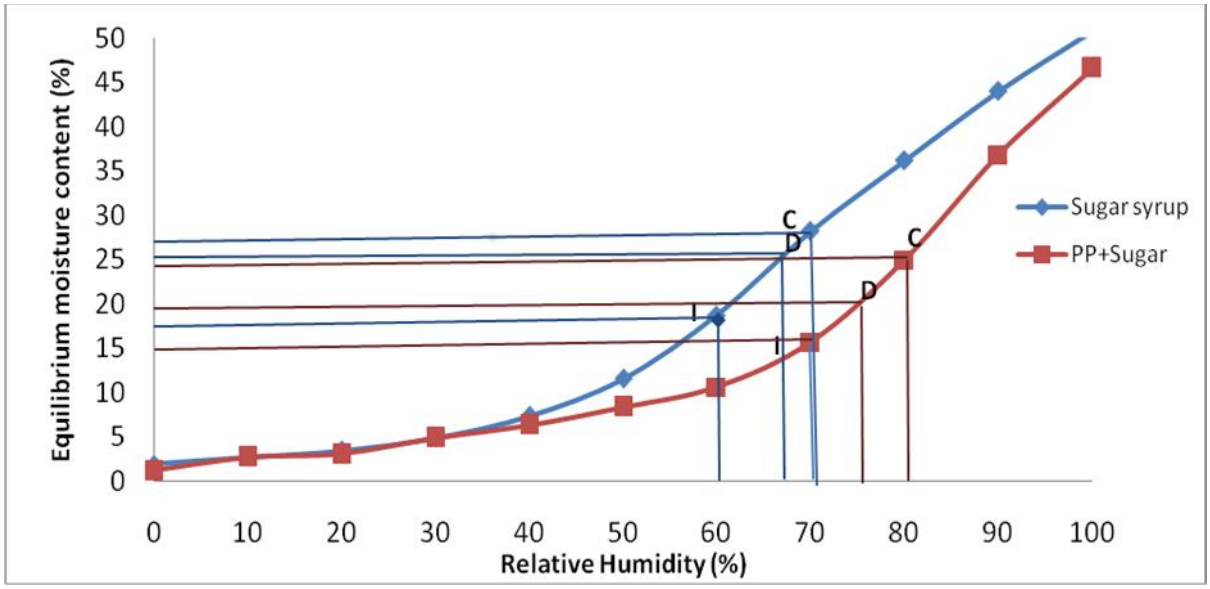


Fig.4.7. Humidity moisture equilibrium curve for ginger candy

Sugar syrup ginger candy I=Initial point (59% RH, 17.71% EMC), D= Danger point (66% RH), C= Critical point (71% RH, 27.10 % EMC)
Plum pulp and sugar ginger candy I=Initial point (70% RH, 15.71% EMC), D= Danger point (75% RH), C= Critical point (80% RH, 25 % EMC)

Similar to the previous study, the ERH studies of honey ginger candy (T_3) and anthocyanin (plum pulp and honey) enriched ginger candy (T_4) were conducted and the data presented in Table 4.15 and Fig. 4.8 and 4.9 showed that pure honey dipped ginger candy had an ERH of 60.0 per cent with an equilibrium moisture content of 14.58 per cent as compared with anthocyanin (plum pulp+ honey) enriched ginger candy with ERH of 70.0 per cent with an equilibrium moisture content of 15.44 per cent. Data presented in Table 4.15 and Fig 4.9 further indicated that the product (pure honey ginger candy) exposed to 70.0 per cent relative humidity, exhibited considerable changes in its texture within 18 days of exposure as compared with anthocyanin (plum pulp+ honey) enriched ginger candy where the product exposed to 80.0 per cent relative humidity, exhibited considerable changes in its texture and colour within 20 days of exposure.

Table 4.15 Equilibrium relative humidity of ginger candy

Honey (70 ^{o}B)				Plum pulp+ Honey (70 ^{o}B)		
Relative humidity (%)	**Equilibrium moisture content (%)**	**Days to reach equilibrium**	**Remarks (Honey)**	**Equilibrium moisture content (%)**	**Days to reach equilibrium**	**Remarks**
0	0.79	18	Darkened, cracking appears	1.56	20	Colour faded, cracking appears
10	3.07	16	Darkened, cracking appears	2.32	18	Colour faded, cracking appears
20	4.18	14	Darkened, cracking appears	3.45	17	Colour slightly faded, cracking appears
30	5.70	13	Darkened, cracking appears	5.26	15	Colour slightly faded, cracking appears
40	8.36	12	Colour slightly faded, cracking appears	6.67	14	Colour normal, good texture
50	10.54	11	Colour normal, good texture	9.35	12	Colour normal, good texture
60	14.58	9	Soft, no mould growth	10.64	10	Colour bright, good texture
70	18.45	8	Soft, lightly mould growth	15.44	8	Colour bright, good texture
80	28	7	Soft and mould growth	26.09	7	Soft, no mould growth
90	36.20	5	Soft and mould growth	42.99	6	Soft and mould growth
100	48.04	4	Soft and mould growth	56.92	4	Soft and mould growth

Thus, the critical point (when candy becomes watery) and danger point (5.0% lower relative humidity than that of critical point) for ginger candy was recorded at relative humidity of 75.0 and 70.0 per cent, respectively as compared with anthocyanin (plum pulp and honey) enriched ginger candy was recorded at relative humidity of 85.0 and 80.0 per cent.

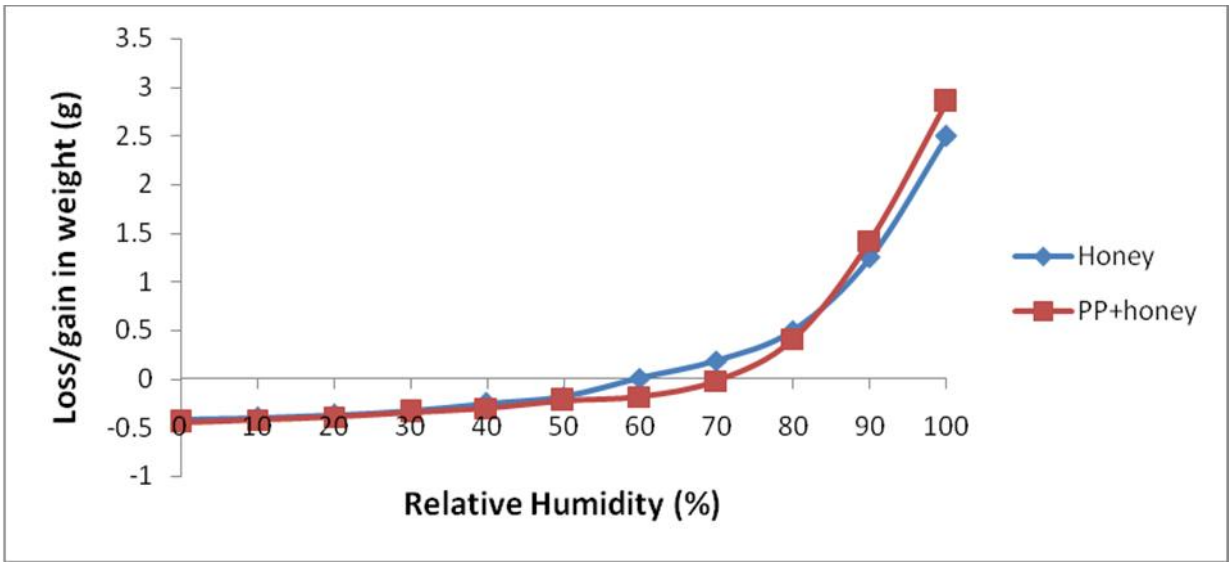


Fig.4.8 Graphical interpolation isotherm for ginger candy

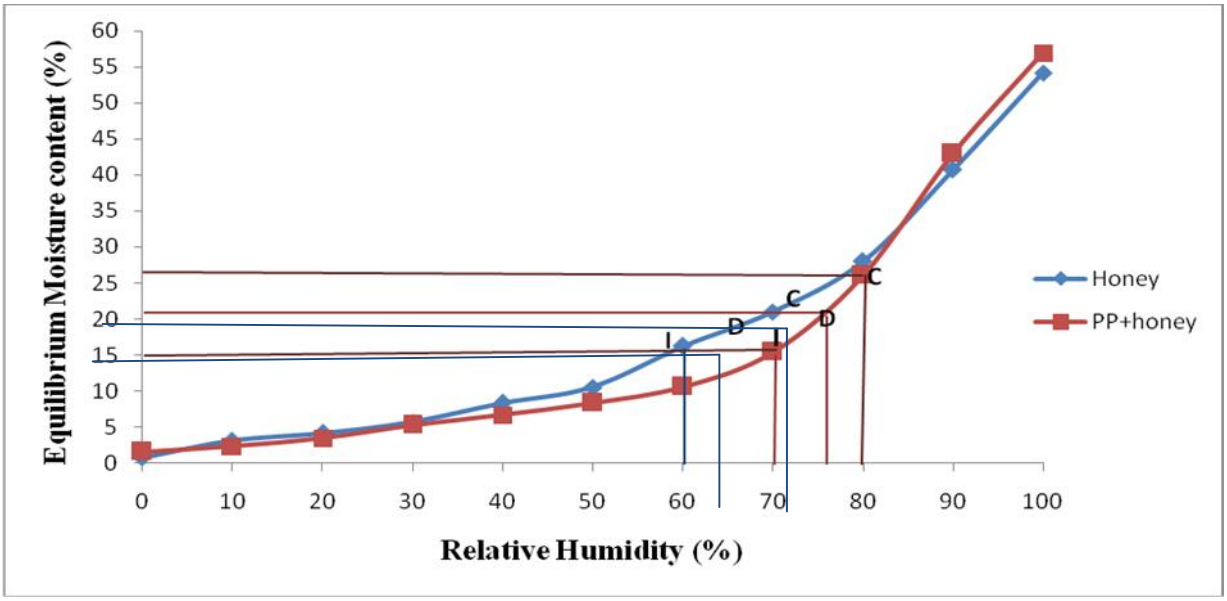


Fig.4.9 Humidity moisture equilibrium curve for ginger candy

Pure honey ginger candy I=Initial point (60% RH, 14.58% EMC), D= Danger point (69% RH), C= Critical point (74% RH, 24 % EMC)
Plum pulp and honey ginger candy I=Initial point (70% RH, 15.44% EMC), D= Danger point (75% RH), C= Critical point (80% RH, 26.09 % EMC)



Mix weighed sugar and water

↓

Add plum pulp and honey and glucose syrup

↓

Heat upto hard crack stage (149°C)

↓

Place lollipop sticks in silicon moulds

↓

Pour hot mix in silicon molds

↓

Cooling at room temperature

↓

Packaging

↓

Storage (ambient)

Ingredients	Weight
Sugar (g)	40
Glucose syrup (g)	20
Plum pulp + Honey (g)	20
Water (ml)	20











Plate 4.4. Flow sheet for the preparation of lollipops

The ginger slices dipped in honey showed good keeping quality due to the presence of phytochemicals like phenols, flavonoids, alkaloids, steroids and terepenoids (Beltagi *et al*. 2019).

4.4.1.2 Utilization of drained dipping solution for value addition

The left over drained syrup was successfully utilized for the preparation of lollipops. Lollipop is a non-crystalline, hard sugar boiled confectionery which contains about 70-90 per cent of the carbohydrates. White sugar is the usual sweetening agent used in preparation of candies. Keeping in view the disadvantages associated with excessive sugar consumption, possibilities of replacing sugar with alternate natural sweeteners has been explored in the present study. The white sugar is partially replaced with plum pulp and honey (20%) as natural sweetener and glucose syrup (20%) as thickner, sweetener and humectants.

4.5 CHANGES DURING STORAGE

The storage stability of anthocyanin enriched ginger candy prepared in a hypertonic solution of plum pulp whose TSS was raised by either sugar syrup or honey was wrapped in aluminium laminated pouches and stored at ambient and refrigerated temperature and compared with control (sugar syrup/honey dipped) ginger candy for analysis at three months interval i.e at 0, 3 and 6 months. The results are presented in Table 4.16 to 4.27 and discussed as under.

4.5.1. Changes in physico-chemical characteristics of anthocyanin enriched ginger candy during storage

4.5.1.1 Moisture

Data pertaining to moisture (Table 4.16) indicate that there was a general decreasing trend in the moisture of dried anthocyanin enriched and control ginger candy during the entire storage period of 6 months. The overall effect of storage interval (S) reveals that moisture content among treatments decreased from 16.05 to 15.35 per cent during 6 months of storage. The overall effect of storage temperature (V) and treatment (T) was found to be non significant. The combined effect of treatment and storage temperature (T x V), treatment and storage interval (T x S), storage interval and storage temperature (S x V) on moisture content of ginger candy was found to be non significant. The combined overall effect of storage temperature, treatments and storage interval (V×T×S) on moisture of anthocyanin enriched ginger candy and control ginger candy was also found to be non significant.

The decrease in moisture might be due to fibrous nature of ginger which reduces the moisture content at ambient temperature and could also be due to evaporation during storage. Similar trend of decreasing moisture content during storage has been reported by Devi (2014) in dehydrated wild pear halves, Chavan *et al*. (2010) in osmo-dried banana slices, Amitabh *et al*. (2000) in osmotically dehydrated mango slices.

Table 4.16- Effect of storage on moisture content (%) of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	15.95	15.45	14.50	**15.30**	15.82	15.55	**15.77**
T_2 (Plum pulp + sugar)	16.01	15.55	15.40	**15.65**	15.90	15.57	**15.83**
T_3 (Honey)	16.10	15.70	15.40	**15.73**	15.85	15.52	**15.82**
T_4 (Plum pulp +honey)	16.15	15.67	15.30	**15.71**	15.92	15.60	**15.89**
Mean	**16.05**	**15.59**	**15.15**		**15.87**	**15.56**	
CD 0.05	**VxTxS - NS**				**T –NS**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	15.95	15.63	15.02	**15.54**
T_2	16.01	15.72	15.48	**15.74**
T_3	16.10	15.77	15.46	**15.78**
T_4	16.15	15.79	15.45	**15.80**
Mean (S)	**16.05**	**15.74**	**15.35**	
CD $_{0.05}$		**S – 0.33**		**TxS- NS**

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	15.30	15.77	**15.54**
T_2	15.65	15.82	**15.74**
T_3	15.73	15.82	**15.78**
T_4	15.70	15.89	**15.80**
Mean (V)	**15.60**	**15.83**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	16.05	16.05	**16.05**
S_2	15.59	15.88	**15.74**
S_3	15.15	15.55	**15.35**
Mean (V)	**15.60**	**15.83**	
CD $_{0.05}$	**SxV – NS**		

4.5.1.2 Total soluble solids (TSS)

Data pertaining to total soluble solid given in Table 4.17 indicate that there was a general increasing trend in the total soluble solid of ginger candy both anthocyanin enriched and control ginger candy during entire storage period of 6 months at ambient and refrigerated temperature. Storage interval (S) exerted a significant overall effect with mean values of increased from 64.12 to 64.47 ^{o}B. The overall effect of storage temperatures (V) and treatment (T) was found to be non significant. The combined effect of treatment and storage temperature (T x V), treatment and storage interval (T x S), storage interval and storage temperature (S x V) was found to be non significant. The combined overall effect of storage

temperature, treatments and storage interval (V×T×S) on total soluble solid of anthocyanin enriched ginger candy was found to be non significant.

Table 4.17- Effect of storage on total soluble solid (^{o}B) of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	64.02	64.06	64.13	**64.07**	64.16	64.46	**64.21**
T_2 (Plum pulp + sugar)	64.05	64.15	64.30	**64.17**	64.20	64.88	**64.40**
T_3 (Honey)	64.17	64.25	64.38	**64.28**	64.30	64.51	**64.33**
T_4 (Plum pulp +honey)	64.26	64.35	64.50	**64.37**	64.43	64.63	**64.44**
Mean	**63.27**	**63.35**	**63.48**		**63.42**	**63.75**	
CD 0.05	**VxTxS - NS**				**T –NS**		

Treatments	Storage (S)			Mean (T)	Treatments	Temperature		Mean (T)
	S_1	S_2	S_3			V_1	V_2	
T_1	64.02	64.11	64.29	**64.14**	T_1	64.07	64.21	**64.14**
T_2	64.05	64.21	64.59	**64.27**	T_2	64.17	64.40	**64.28**
T_3	64.17	64.27	64.39	**64.30**	T_3	64.28	64.33	**64.30**
T_4	64.26	64.39	64.56	**64.40**	T_4	64.37	64.44	**64.40**
Mean (S)	**64.12**	**64.29**	**64.47**		**Mean (V)**	**64.22**	**64.35**	
CD $_{0.05}$		**S – 0.01**		**TxS- NS**	**CD $_{0.05}$**	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	64.12	64.12	**64.12**
S_2	64.20	64.29	**64.25**
S_3	64.33	64.62	**64.47**
Mean (V)	**64.22**	**64.35**	
CD $_{0.05}$ SxV – NS			

The negligible increase in TSS might be due to decrease in moisture content from the packaging material through the sealing pouches. The results of increase in total soluble solids are similar to the findings of Rani and Bhatia (1985) for pear candy, Rani and Bhatia (1985) for pear preserve, Tripathi *et al*. (1988) for aonla preserve, Nath *et al.* (2013) for ginger candy and Sharma *et al*. (1999) for apple candy.

4.5.1.3 Titratable acidity

Data pertaining to titratable acidity given in Table 4.18 indicate that there was a general increasing trend in the titratable acidity of osmotically dried ginger candy during entire storage period of 6 months. Treatment (T) exerted a significant overall effect with mean values of 0.17 per cent in control sugar syrup (T_1), 1.23 per cent in plum pulp and sugar (T_2), 0.19 per cent in control honey (T_3) and 1.25 per cent in plum pulp and honey (T_4).The

overall effect of storage temperatures (V) and storage interval (S) was found to be non significant. The combined effect of treatment and storage temperature (T x V), treatment and storage interval (T x S), storage interval and storage temperature (S x V) was observed non significant. The combined overall effect of storage temperature, treatments and storage interval (V×T×S) on titratable acidity of anthocyanin enriched ginger candy was also non significant.

Table 4.17- Effect of storage on titratable acidity (%) of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	0.16	0.16	0.17	**0.16**	0.17	0.18	**0.17**
T_2 (Plum pulp + sugar)	1.20	1.22	1.24	**1.22**	1.24	1.26	**1.23**
T_3 (Honey)	0.17	0.18	0.20	**0.18**	0.19	0.21	**0.19**
T_4 (Plum pulp + honey)	1.22	1.24	1.26	**1.24**	1.26	1.28	**1.25**
Mean	**0.69**	**0.70**	**0.71**		**0.71**	**0.73**	
CD 0.05	**VxTxS - NS**				**T -0.27**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	0.16	0.17	0.17	**0.17**
T_2	1.21	1.23	1.25	**1.23**
T_3	0.17	0.18	0.20	**0.19**
T_4	1.22	1.25	1.27	**1.25**
Mean (S)	**0.69**	**0.71**	**0.72**	
CD $_{0.05}$		**S – NS**		**TxS- NS**

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	0.16	0.17	**0.17**
T_2	1.22	1.24	**1.23**
T_3	0.18	0.19	**0.19**
T_4	1.24	1.25	**1.25**
Mean (V)	**0.70**	**0.71**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	0.69	0.69	**0.69**
S_2	0.70	0.71	**0.71**
S_3	0.71	0.73	**0.72**
Mean (V)	**0.70**	**0.71**	
CD $_{0.05}$	**SxV – NS**		

An increase in acidity with storage period has also been observed in aonla preserve. Similar findings were also observed by Rani and Bhatia (1985); Tripathi *et al*. (1988) in which the acidity decreases with storage. Similar influence was accounted by Sagar and Khurdiya (1999) in dehydrated mango slices, Raj *et al*. (2006) in dehydrated onion rings and Ahmed *et al*. (2014) in osmo dried peach slices.

4.5.1.4 Ascorbic acid

Data pertaining to ascorbic acid given in Table 4.19 indicate that there was a general decreasing trend in the ascorbic acid content of osmotically dried both anthocyanin enriched

ginger candy and control sugar syrup and honey ginger candy during entire storage period of 6 months. After six months treatment (T) exerted a significant overall effect with mean values of 9.48 mg/100g in control sugar syrup (T_1), 13.96 mg/100g in plum pulp and sugar (T_2), 11.49 mg/100g in control honey (T_3) and 17.46 mg/100g in plum pulp and honey (T_4).

Table 4.19- Effect of storage on ascorbic acid (mg/100g) of ginger candy

Storage periods (S)		**Temperature (V)**					
		Ambient (V_1)			**Refrigerated (V_2)**		
Treatments (T)	**0**	**3**	**6**	**Mean**	**3**	**6**	**Mean**
T_1 (Sugar)	9.79	9.30	9.03	**9.37**	9.60	9.40	**9.60**
T_2 (Plum pulp + sugar)	14.05	13.95	13.80	**13.93**	14.00	13.90	**13.98**
T_3 (Honey)	11.62	11.49	11.27	**11.46**	11.56	11.37	**11.52**
T_4 (Plum pulp +honey)	17.58	17.48	17.25	**17.44**	17.55	17.35	**17.49**
Mean	**13.26**	**13.05**	**12.83**		**13.18**	**13.00**	
CD 0.05	**VxTxS - NS**				**T -0.38**		

Treatments	**Storage (S)**			**Mean (T)**
	S_1	**S_2**	**S_3**	
T_1	9.79	9.45	9.20	**9.48**
T_2	14.05	13.97	13.85	**13.96**
T_3	11.62	11.52	11.32	**11.49**
T_4	17.58	17.51	17.30	**17.46**
Mean (S)	**13.26**	**13.12**	**12.92**	
CD $_{0.05}$		**S – 0.NS**		**TxS- NS**

Treatments	**Temperature**		**Mean (T)**
	V_1	**V_2**	
T_1	9.37	9.60	**9.48**
T_2	13.93	13.98	**13.96**
T_3	11.46	11.52	**11.49**
T_4	17.44	17.49	**17.46**
Mean (V)	**13.05**	**13.15**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	**Temperature**		**Mean (S)**
	V_1	**V_2**	
S_1	13.26	13.26	**13.26**
S_2	13.05	13.18	**13.12**
S_3	12.83	13.00	**12.92**
Mean (V)	**13.05**	**13.15**	
CD $_{0.05}$	**SxV – NS**		

The overall effect of storage temperatures (V) and storage interval (S) was found to be non significant. The combined effect of treatment and storage temperature (T x V), treatment and storage interval (T x S), storage interval and storage temperature (S x V) was found to be non significant. The combined overall effect of storage temperature, treatments and storage interval (V×T×S) on ascorbic acid of anthocyanin enriched ginger candy was found to be non significant.

Loss of ascorbic acid might be due to its oxidation to dehydro-ascorbic acid followed by further degradation to 2, 3- diketogluconic acid and finally to furfural compounds which enter browning reactions (Reynold 1965). Similar result were also noticed by Sra *et al.*

(2014) in dried carrot slices, Sharma *et al*. (2006) in dehydrated apple rings, Muzzaffar (2016) in pumpkin candy and Devi (2014) in glass jar packed wild pear preserve.

4.5.1.5 Total phenol

Data pertaining to total phenols content (Table 4.20) indicate that there was a general decreasing trend in the total phenols content of ginger candy both anthocyanin enriched and control ginger candy during entire storage period of 6 months. Treatment (T) exerted a significant overall effect with mean values of 15.37 mg/100g in control sugar syrup (T_1), 16.47 mg/100g in plum pulp and sugar (T_2), 22.52 mg/100g in control honey (T_3) and 26.95 mg/100g in plum pulp and honey (T_4). After six months of storage the level of total phenol was measured as 20.16 mg/100g from its initial value of 20.48 mg/100g thus exhibiting a net loss of 1.56 per cent. The overall effect of storage temperatures (V) and storage interval (S) was found to be non significant. The combined effect of treatment and storage interval (T x S), treatment and storage temperature (T x V) storage interval and storage temperature (S x V) was found to be non significant. The combined overall effect of storage temperature, treatments and storage interval (V×T×S) on total phenols content of osmotically dried ginger candy was found to be non significant.

Table 4.20- Effect of storage on total phenol (mg/100g) of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	15.56	15.35	15.05	**15.32**	15.50	15.20	**15.37**
T_2 (Plum pulp + sugar)	16.65	16.40	16.20	**16.42**	16.50	16.41	**16.47**
T_3 (Honey)	22.64	22.50	22.35	**22.50**	22.50	22.47	**22.52**
T_4 (Plum pulp +honey)	27.10	26.88	26.75	**26.91**	26.98	26.89	**26.95**
Mean	**20.48**	**20.28**	**20.09**		**20.37**	**20.24**	
CD 0.05	**VxTxS - NS**				**T -0.27**		

Treatments	Storage (S)			Mean (T)	Treatments	Temperature		Mean (T)
	S_1	S_2	S_3			V_1	V_2	
T_1	15.56	15.42	15.12	**15.37**	**T_1**	15.32	15.42	**15.37**
T_2	16.65	16.45	16.30	**16.47**	**T_2**	16.42	16.52	**16.47**
T_3	22.64	22.50	22.41	**22.52**	**T_3**	22.50	22.54	**22.52**
T_4	27.10	26.93	26.82	**26.95**	**T_4**	26.91	26.99	**26.95**
Mean (S)	**20.48**	**20.32**	**20.16**		**Mean (V)**	**20.29**	**20.37**	
CD $_{0.05}$	**S – NS**			**TxS- NS**	**CD $_{0.05}$**	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	20.48	20.48	**20.48**
S_2	20.28	20.37	**20.32**
S_3	20.09	20.24	**20.16**
Mean (V)	**20.29**	**20.37**	
CD $_{0.05}$ SxV – NS			

Osmotically dried ginger candy stored under refrigerated conditions retained more total phenols content which might be due to the slower rate of oxidation reactions under low temperature conditions. Similar trend of decrease total phenolic content was reported by Nadia *et al.* (2013) in effect of osmo-dehydration conditions on the quality attributes of pears.

4.5.1.6 DPPH (2, 2-diphenyl-1-picrylhydrazyl) antioxidant activity

Data pertaining to antioxidant activity content given in Table 4.21 indicate that there was a general decreasing trend in the antioxidant activity of ginger candy both anthocyanin enriched and control ginger candy during entire storage period of 6 months. Treatment (T) exerted a significant overall effect with mean values of 85.08 per cent in control sugar syrup (T_1), 92.12 per cent in plum pulp and sugar (T_2), 86.42 per cent in control honey (T_3) and 97.66 per cent in plum pulp and honey (T_4).

Table 4.21- Effect of storage on antioxidant activity (%) of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	85.42	85.03	84.71	**85.05**	85.20	84.73	**85.11**
T_2 (Sugar + plum pulp)	92.50	92.04	91.60	**92.04**	92.25	91.83	**92.19**
T_3 (Honey)	86.95	86.00	85.75	**86.23**	86.70	86.20	**86.61**
T_4 (Honey +plum pulp)	98.03	97.50	97.12	**97.55**	97.75	97.55	**97.77**
Mean	**90.72**	**90.14**	**89.79**		**90.47**	**90.07**	
CD 0.05		**VxTxS - NS**			**T -0.23**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	85.42	85.11	84.72	**85.08**
T_2	92.50	92.14	90.71	**92.12**
T_3	86.95	86.35	85.97	**86.42**
T_4	98.03	97.62	97.33	**97.66**
Mean (S)	**90.72**	**90.30**	**89.93**	
CD $_{0.05}$	**S – 0.20**			**TxS- NS**

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	85.05	85.11	**85.08**
T_2	92.04	92.19	**92.12**
T_3	86.23	86.61	**86.42**
T_4	97.55	97.77	**97.66**
Mean (V)	**90.22**	**90.42**	
CD $_{0.05}$	**V- NS**		**TxV - 0.16**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	90.72	90.72	**90.72**
S_2	90.14	90.47	**90.30**
S_3	89.79	90.07	**89.93**
Mean (V)	**90.22**	**90.42**	
CD $_{0.05}$ SxV – NS			

After six months of storage the level of antioxidant activity was measured as 89.79 per cent from its initial value of 90.72 per cent thus exhibiting a net loss of 1.02 per cent. The

overall effect of storage temperature (V) was found to be non significant. The combined effect of treatment and storage temperature (T x V) reveal that antioxidant activity of among treatments increased from 85.05 to 97.77 per cent during storage. The combined effect of treatment and storage interval (T x S), storage interval and storage temperature (S x V) was found to be non significant. The combined overall effect of storage temperature, treatments and storage interval (V×T×S) on antioxidant activity of anthocyanin enriched ginger candy was found to be non significant.

Decrease in antioxidant activity has been attributed to decrease in total phenol content during storage (Nisar *et al.* 2015) or due to chemical degradation of polyphenols during Maillard reaction (Scala *et.al*. 2011). The loss of antioxidant activity was lower in the anthocyanin enriched ginger candy stored under refrigerated temperature condition as compared to ambient which might be due to the slower rates of degradation of various antioxidant compounds present in the product which helped in the retention of higher antioxidant activity.

4.5.1.7 Anthocyanins

Data pertaining to change in the anthocyanins in osmotically dried ginger candy have been presented in the Table 4.22. Treatment (T) exerted a significant overall effect with mean values of 48.93 mg/100g in plum pulp and sugar (T_2) and 56.64 mg/100g in plum pulp and honey (T_4). The overall effect of storage temperature (V), storage interval (S) was found to be non significant. The combined effect of treatment and storage temperature (T x V), treatment and storage interval (T x S), storage interval and storage temperature (S x V) was found to be non significant. The combined overall effect of storage temperature, treatments and storage interval (V×T×S) on anthocyanins of anthocyanin enriched ginger candy was found to be non significant.

The increase in plum pulp concentration resulted in the increase in anthocyanins. Faster deterioration of anthocyanins of strawberry jam has been reported by Withy *et al*. (1993) when it was stored at higher temperature. Montefiori *et al*. (2005) has mentioned the effect of oxygen, light and temperature on the colour changes of fruits. Loss of anthocyanins during storage has been attributed to many factors such as pH, acidity, phenolic compounds, sugar degradation and oxygen (Alam *et al*., 2010) for aonla slices and (Nath *et al*., 2013) for ginger candy.

Table 4.22- Effect of storage on anthocyanin content (mg/100g) of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_2 (Plum pulp + sugar)	49.10	48.95	48.50	**48.85**	49.02	48.92	**48.97**
T_4 (Plum pulp +honey)	56.61	56.52	56.21	**56.44**	56.85	56.70	**56.77**
Mean	**26.45**	**26.38**	**26.18**	**26.33**	**26.48**	**26.41**	**26.44**
CD 0.05	**VxTxS - NS**				**T -0.31**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_2	49.10	48.98	48.71	**48.93**
T_4	56.61	56.68	56.45	**56.64**
Mean (S)	**26.45**	**26.43**	**26.30**	
CD $_{0.05}$	**S – NS**			**TxS- NS**

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_2	48.85	48.97	**48.93**
T_4	56.44	56.77	**56.64**
Mean (V)	**26.33**	**26.44**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	26.45	26.45	**26.45**
S_2	26.38	26.48	**26.43**
S_3	26.18	26.41	**26.30**
Mean (V)	**26.33**	**26.44**	
CD $_{0.05}$	**SxV – NS**		

4.5.1.8 Effect of treatments and packaging on sensory characteristics of osmotically dried ginger candy during storage

The most significant factor determining the commercial viability of any product is its sensory quality in terms of appearance colour, body, taste, aroma and overall acceptance.

4.5.1.8.1 Colour

Data pertaining to change in the colour score in osmotically dried ginger candy have been presented in the Table 4.23 showed the treatments exerted a significant effect on colour scores with mean values of 6.69 in control sugar syrup (T_1) and 7.61 in plum pulp and sugar (T_2), 6.79 in control honey (T_3) and 7.81 in plum pulp and honey (T_4) but a non-significant effect of storage interval (S) and storage temperature (V) on colour scores of anthocyanin enriched ginger candy.

The difference in colour scores of treatments was due to the addition of plum pulp in its various forms. The combined effect of treatment and storage temperature (T x V), treatment and storage interval (T x S), storage interval and storage temperature (S x V) was found to be non significant.

Table 4.23- Effect of storage on *colour characteristics of ginger candy

Storage periods (S)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
Treatments (T)	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	6.80	6.70	6.50	**6.66**	6.75	6.60	**6.71**
T_2 (Plum pulp + sugar)	7.70	7.60	7.50	**7.60**	7.65	7.55	**7.63**
T_3 (Honey)	6.90	6.80	6.60	**6.76**	6.85	6.70	**6.81**
T_4 (Plum pulp +honey)	7.90	7.80	7.70	**7.80**	7.85	7.75	**7.83**
Mean	**7.32**	**7.22**	**7.07**		**7.27**	**7.15**	
CD 0.05	VxTxS - NS				T -0.38		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	6.80	6.72	6.55	**6.69**
T_2	7.70	7.62	7.52	**7.61**
T_3	6.90	6.82	6.65	**6.79**
T_4	7.90	7.82	7.72	**7.81**
Mean (S)	**7.32**	**7.25**	**7.11**	
CD $_{0.05}$	S – NS		TxS-NS	

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	6.66	6.71	**6.69**
T_2	7.60	7.63	**7.61**
T_3	6.76	6.81	**6.79**
T_4	7.80	7.83	**7.81**
Mean (V)	**7.20**	**7.25**	
CD $_{0.05}$	V- NS		TxV - NS

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	7.32	7.32	**7.32**
S_2	7.22	7.27	**7.25**
S_3	7.07	7.15	**7.11**
Mean (V)	**7.20**	**7.25**	
CD $_{0.05}$ SxV – NS			

4.5.1.8.2 Texture

Data appended in Table 4.24 elucidate that there was a general decreasing trend in texture scores of anthocyanin enriched ginger candy during storage. Treatments (T) and storage intervals (S) exerted a significant effect on texture scores of anthocyanin enriched ginger candy where scores for treatment plum pulp and honey (T_4) was higher than others. During 6 months of storage scores for texture decreased from 7.37 to 7.02 in anthocyanin enrich ginger candy. The combined effect of storage interval and storage temperature (S×V) highlights that texture scores of osmotically dried ginger candy was found to be non significant. Other interactions like treatments and storage temperature (T×V); storage temperature, storage interval and treatment (V×T×S) were recorded to be non-significant.

However, maximum retention of texture scores of anthocyanin enriched ginger candy in treatments (T_4) might be due to the less intake of moisture as a result of favourable conditions inside the pouch which created barrier to moisture, therefore prevented softening of product, thus led the judges to award the better scores as compared to treatment (T_3).

Maximum texture scores retained under refrigerated storage might be due to the controlled humidity conditions which prevented the softening of product as compared to ambient storage temperature.

Table 4.24- Effect of storage on *texture characteristics of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	7.00	6.80	6.60	**6.80**	6.90	6.70	**6.86**
T_2 (Plum pulp + sugar)	7.60	7.40	7.20	**7.40**	7.50	7.30	**7.46**
T_3 (Honey)	7.10	6.90	6.70	**6.90**	7.00	6.80	**6.96**
T_4 (Plum pulp +honey)	7.80	7.60	7.40	**7.60**	7.70	7.50	**7.66**
Mean	**7.37**	**7.17**	**6.97**		**7.27**	**7.07**	
CD 0.05	**VxTxS - NS**				**T -0.19**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	7.00	6.85	6.65	**6.83**
T_2	7.60	7.45	7.25	**7.43**
T_3	7.10	6.95	6.75	**6.93**
T_4	7.80	7.65	7.45	**7.63**
Mean (S)	**7.37**	**7.22**	**7.02**	
CD $_{0.05}$	**S – 0.16**		**TxS- NS**	

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	6.80	6.86	**6.83**
T_2	7.40	7.46	**7.43**
T_3	6.90	6.96	**6.93**
T_4	7.60	7.66	**7.63**
Mean (V)	**7.17**	**7.24**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	7.37	7.37	**7.37**
S_2	7.17	7.27	**7.22**
S_3	6.97	7.07	**7.02**
Mean (V)	**7.17**	**7.24**	
CD $_{0.05}$	**SxV – NS**		

4.5.1.8.3 Aroma

Data appended in Table 4.25 elucidate that there was a general decreasing trend in aroma scores of anthocyanin enrich ginger candy during storage. Treatments (T) and storage intervals (S) exerted a significant effect on aroma scores of anthocyanin enrich ginger candy where scores for treatment T_4 was higher than others. During 6 months of storage scores for aroma decreased from 7.00 to 6.50 in osmotically dried ginger candy. The combined effect of storage interval and storage temperature (S×V) highlights that texture scores of anthocyanin enriched ginger candy was found to be non significant. Other interactions like treatments and storage temperature (T×V); storage temperature, storage interval and treatment (V×T×S)

were recorded to be non-significant. After six months of storage of osmotically dried ginger candy might be attributed to the loss of aromatic compounds during storage.

Table 4.25- Effect of storage on *aroma characteristics of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	6.50	6.30	6.10	**6.30**	6.40	6.20	**6.36**
T_2 (Plum pulp + sugar)	7.30	6.95	6.45	**6.90**	6.99	6.57	**6.95**
T_3 (Honey)	6.60	6.40	6.20	**6.40**	6.50	6.30	**6.46**
T_4 (Plum pulp +honey)	7.60	7.50	7.00	**7.36**	7.55	7.20	**7.45**
Mean	**7.00**	**6.78**	**6.43**		**6.86**	**6.56**	
CD 0.05	**VxTxS - NS**				**T -0.19**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	6.50	6.35	6.15	**6.33**
T_2	7.30	6.97	6.51	**6.92**
T_3	6.60	6.45	6.25	**6.43**
T_4	7.60	7.52	7.12	**7.40**
Mean (S)	**7.00**	**6.82**	**6.50**	
CD $_{0.05}$	**S – 0.16**			**TxS- NS**

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	6.30	6.36	**6.33**
T_2	6.90	6.95	**6.92**
T_3	6.40	6.46	**6.43**
T_4	7.36	7.45	**7.40**
Mean (V)	**6.74**	**6.80**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	7.00	7.00	**7.00**
S_2	6.78	6.86	**6.82**
S_3	6.43	6.56	**6.50**
Mean (V)	**6.74**	**6.80**	
CD $_{0.05}$	**SxV – NS**		

4.5.1.8.4 Taste

Data appended in Table 4.26 elucidate that there was a general decreasing trend in taste scores of osmotically dried ginger candy during storage. Treatments (T) and storage intervals (S) exerted a significant effect on taste scores of anthocyanin enrich ginger candy where scores for treatment T_4 was higher than others. During 6 months of storage scores for taste decreased from 7.38 to 6.76 in anthocyanin enrich ginger candy. The combined effect of storage interval and storage temperature (S×V) highlights that texture scores of anthocyanin enriched ginger candy was found to be non significant. Other interactions like treatments and storage temperature (T×V); storage temperature, storage interval and treatment (V×T×S) were recorded to be non-significant.

Table 4.26- Effect of storage on *taste characteristics of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	7.00	6.50	6.00	**6.50**	6.85	6.60	**6.81**
T_2 (Plum pulp + sugar)	7.70	7.45	7.00	**7.38**	7.65	7.50	**7.61**
T_3 (Honey)	7.03	6.53	6.40	**6.65**	6.90	6.60	**6.74**
T_4 (Plum pulp +honey)	7.80	7.64	7.05	**7.49**	7.70	7.00	**7.49**
Mean	**7.38**	**7.03**	**6.61**		**7.27**	**6.92**	
CD 0.05	**VxTxS - NS**				**T -0.30**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	7.00	6.67	6.30	**6.65**
T_2	7.70	7.55	7.25	**7.50**
T_3	7.03	6.71	6.50	**6.74**
T_4	7.80	7.67	7.02	**7.49**
Mean (S)	**7.38**	**7.15**	**6.76**	
CD $_{0.05}$	**S – 0.26**			**TxS- NS**

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	6.50	6.81	**6.65**
T_2	7.38	7.61	**7.50**
T_3	6.65	6.84	**6.74**
T_4	7.49	7.50	**7.49**
Mean (V)	**7.00**	**7.19**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	7.38	7.38	**7.38**
S_2	7.03	7.27	**7.15**
S_3	6.61	6.92	**6.76**
Mean (V)	**7.00**	**7.19**	
CD $_{0.05}$	**SxV – NS**		

4.5.1.8.5 Overall acceptability

It is clear from the data (Table 4.27) that treatment T_2 (plum pulp and sugar) and T_4 (plum pulp and honey) scored significantly higher than the treatment T_1 (control sugar syrup) and T_3 (control honey) with mean values of 7.61 in T_2 and 7.81 in T_4, 6.69 in T_1, and 6.79 in T_3 respectively. During storage interval scores for overall acceptability decreased from 7.32 to 7.11 in osmotically dried ginger candy.

The combined effect of storage interval and storage temperature (S×V) highlights that texture scores of anthocyanin enriched ginger candy was found to be non significant. Other interactions like treatments and storage temperature (T×V); storage temperature, storage interval and treatment (V×T×S) were recorded to be non-significant.

The overall acceptability scores of anthocyanin enriched ginger candy exhibited significant decrease during storage which might be due to reduction in colour intensity as a result of degradation of anthocyanin. This might be due to the better colour, flavour, taste and

overall acceptability retained during the storage and not much loss in texture of dried ginger candy in this packaging material at ambient temperature and refrigerated temperature.

Table 4.27- Effect of storage on *overall acceptability of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)	6.80	6.70	6.50	**6.66**	6.75	6.60	**6.71**
T_2 (Plum pulp + sugar)	7.70	7.60	7.50	**7.60**	7.65	7.55	**7.63**
T_3 (Honey)	6.90	6.80	6.60	**6.76**	6.85	6.70	**6.81**
T_4 (Plum pulp +honey)	7.90	7.80	7.70	**7.80**	7.85	7.75	**7.83**
Mean	**7.32**	**7.22**	**7.07**		**7.27**	**7.15**	
CD 0.05	**VxTxS - NS**				**T -0.13**		

Treatments	Storage (S)			Mean (T)
	S_1	S_2	S_3	
T_1	6.80	6.72	6.55	**6.69**
T_2	7.70	7.62	7.52	**7.61**
T_3	6.90	6.82	6.65	**6.79**
T_4	7.90	7.82	7.72	**7.81**
Mean (S)	**7.32**	**7.25**	**7.11**	
CD $_{0.05}$	**S – 0.11**			**TxS- NS**

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1	6.66	6.71	**6.69**
T_2	7.60	7.63	**7.61**
T_3	6.76	6.81	**6.79**
T_4	7.80	7.83	**6.81**
Mean (V)	**7.20**	**7.25**	
CD $_{0.05}$	**V- NS**		**TxV - NS**

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1	7.32	7.32	**7.32**
S_2	7.22	7.27	**7.25**
S_3	7.07	7.15	**7.11**
Mean (V)	**7.20**	**7.25**	
CD $_{0.05}$	**SxV – NS**		

4.7 MICROBIAL STUDY OF DRIED GINGER CANDY

Microbial quality measured in terms of total plate count (TPC) in dried ginger candy preserved in aluminium laminated pouches showed the absence of any microbial growth during the entire period at ambient and refrigerated temperature, thus exhibiting good storage stability of the product. The maximum limit of microbial colonies in dried fruits and vegetable products according to FSSAI (2006) is 42,000 cfu/g.

4.8 COST OF PRODUCTION OF ANTHOCYANIN ENRICHED GINGER CANDY

It is evident from the data (Table 4.28) the cost of production of anthocyanin enriched ginger candy were calculated to be Rs. 72.89 (plum pulp+honey) and Rs. 56.76 (plum pulp+ sugar) per 200g candies packed in aluminium laminated pouches. The cost compared with the

similar products from other fruit and vegetable crops the products were found to be economical and nutritional.

Table 4.28. Cost of production

Particulars	Rate (Rs)	Sugar syrup		Plum pulp + sugar		Honey			Plum pulp + honey
		Quantity	Amount (Rs)	Quantity	Amount (Rs)	Quantity	Amount (Rs)	Quantity	Amount (Rs)
Ginger rhizomes	60/Kg	100 Kg	6000.00		6000.00		6000.00		6000.00
Ginger slices	-	50 Kg							
Labour cost for slicing (2 labour/10 Kg)	250/labour	2	500.00		500.00		500.00		500.00
Lime juice blanching @ 1%	400 lit.		400.00		400.00		400.00		400.00
Sugar	40/Kg	4 / Kg	280.00	8 kg	560.00				
Honey	350/kg					4 /Kg	1400.00	8/kg	2800.00
Yield of dried ginger candy		22 Kg		23.2 Kg		25.2 Kg		26.4 Kg	
Pulp recovery	60/ Kg			4 Kg	240.00		-	4 Kg	240.00
Total cost			**7180.00**		**7700.00**		**8300.00**		**9940.00**
Processing cost charges @ 20%	-		1436.00		1540.00		1660.00		1988.00
Packaging cost :									
Aluminium laminated pouches (200g each)	1/Al pouch	110	110		110		110		110
Labels	1/label	110	110		110		110		110
Total cost of production			**8836.00**		**9460.00**		**10180.00**		**12148.00**
Profit @20%			2054.40		1892.00		2036.00		2429.60
Total cost of final product			10890.00		11352.00		12216.00		14577.60
Sale price/200g			**54.45**		**56.76**		**61.08**		**72.89**

Chapter-5

SUMMARY AND CONCLUSION

The present study entitled **"Development and evaluation of anthocyanin enriched ginger candy"** was carried out in the Department of Food Science and Technology, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the year 2018-19. The main objectives of the study were to standardization of parameters for the development of instant process for ginger candy preparation, optimization of process for the preparation of anthocyanin enriched ginger candy, to study the shelf life of standardized processed products and to work out the cost of production of standardized products. The methods for preparation of osmotically dehydrated anthocyanin enriched ginger candy were developed and standardized. Standardized anthocyanin enriched ginger candy were packed in aluminium laminated pouches. All the packed products were kept at ambient (24-27 ^{o}C) and at refrigerated (3-7 ^{o}C) temperature for further storage studies. The developed products were evaluated for different quality parameters and storage studies were conducted at 0, 3 and 6 months. The cost of production of all standardized products was also worked out to see their economic feasibility. The results obtained in the present study have been summarized and concluded briefly as under:

The study is summarized as under:

- The average length and breadth of fresh ginger rhizomes was 10.01±1.61 cm and 7.81±3.03 cm respectively, while the weight, volume, density and firmness was recorded as 116.77±1.46 g, 108.15±1.52 cc, 1.07±0.01 g/cc and 11.50±0.10 kg/cm^2 respectively.
- The average length and breadth of plum fruit was 4.39±1.55 cm and 3.97±1.57 cm respectively, while the weight, volume, density and firmness was recorded as 56.62±0.89 g, 53.16±1.53 cc, 1.06±0.01 g/cc and 2.30±0.18 kg/cm^2 respectively.
- Fresh ginger rhizome recorded moisture content, total soluble solids, titratable acidity, pH, reducing sugar content, total sugars, ascorbic acid, total phenols and antioxidant activity as 82.86±0.05 per cent, 2.80±0.10 ^{o}B, 0.15±0.02 per cent, 6.53±0.02, 0.75±0.21 per cent, 1.26±0.02 per cent, 8.48±0.53 mg/100g, 10.18±0.03 mg/100g and

37.45±0.60 per cent respectively with total ash and crude fibre as 1.41±0.02 and 1.66±0.02 per cent respectively.

- The plum fruit recorded moisture content, total soluble solids, titratable acidity, pH, reducing sugar, total sugars, ascorbic acid, total phenols, antioxidant activity and anthocyanin of 86.93±0.09 per cent, 11.86±0.41 ºB, 2.94±0.02 per cent, 3.36±0.04, 3.67±0.09 per cent, 9.26±0.34 per cent, 18.30±1.09 mg/100g, 52.32±2.89 mg/100g, 71.60±0.55 per cent and 56.30 ±1.50 mg/100g respectively with total ash and crude fibre were recorded to be 0.42±0.03 and 0.07±0.01 per cent respectively.
- Nutritionally, the peeled ginger rhizome showed a moisture content, total soluble solids, titratable acidity, pH, reducing sugar, total sugars, ascorbic acid, total phenols and antioxidant activity of 84.76±0.05 per cent, 3.99±0.10 ºB, 0.16±0.03 per cent, 6.44±0.04, 0.78±0.15 per cent, 1.86±0.05 per cent, 6.36±1.06 mg/100g, 9.81±0.05 mg/100g and 46.60±0.67 per respectively. The total ash and crude fibre was in peeled ginger rhizome recorded as 1.34±0.03 per cent and 1.40±0.03 per cent respectively.
- Among varying slice thickness (5-25mm), the ginger slice thickness of 7.5 mm was optimized on the basis of sensory scores and drying time for conducting the osmotic dehydration studies. Slice thickness of 7.5 mm took 4.30 hours to dry to moisture content of 14.09 per cent.
- A steeping time of 8.0 hours in 70 ^{o}B osmotic sugar solution maintained at 50 ^{o}C temperature is optimized for ginger slices having a thickness of 7.50 mm after blanching in 1.0 per cent lime juice for 15.0 minutes.
- The process for development of anthocyanin enriched ginger candy was optimized by using plum pulp as a source of anthocyanin with two different sweetening agents i.e sugar and honey to raise the TSS of immersion solution to 70 ^{o}B and compared with hypertonic sugar solution and honey as control. The blanched ginger rhizome of 7.50mm slice thickness was dipped in these different solutions maintained at 50 ^{o}C temperature in the ratio of 1:3, where an immersion time of 5.0 hours was standardized for anthocyanin enrich candy on the basis of equilibrium state of TSS between the slices and the osmotic solution while a dipping time of 7.0 hours has been optimized for ginger slices in dipped honey solution and 8.0 hours for slices in sugar syrup solution.
- The moisture content, total soluble solid, total sugars, total phenols, antioxidant activity, pH and ash content of honey was recorded as 16.50 per cent, 70.00^{0}B,

65.34±0.01 per cent, 65.45±0.02 mg/100g, 56.02±0.10 per cent, 3.86±0.02 and 0.19±0.01 per cent respectively.

- Among the different osmotic solutions, treatment T_4 (plum pulp and honey) showed maximum weight reduction of 31.50 per cent with a solid gain of 25.00 per cent followed by treatment T_2 (plum pulp and sugar) with weight reduction and solid gain of 26.20 and 20.03 per cent respectively.
- The colour quality of anthocyanin enriched ginger candy was L (lightness) value ranging between 18.36 to 20.14, a (redness-greeness) as 6.63 to 9.37 and b (yellowness- blueness) as 4.39 to 5.19 which an anthocyanin content of 16.33 to 18.64 mg/100g after draining from the immersion solution.
- On the basis of ERH studies, the critical point and danger point of anthocyanin enriched ginger candy was observed at 80.0 per cent RH and 75.0 per cent RH while in critical point and danger point of sugar syrup and honey dipped ginger candy was recorded at 71.0 per cent and 66.0 per cent; 74.0 per cent and 69.0 per cent respectively.
- Nutritionally anthocyanin enriched ginger candy prepared by dipping in hypertonic solution containing either plum pulp and sugar or plum pulp and honey possessed appreciable amount of anthocyanin (48.93 and 56.64 mg/100g), ascorbic acid (13.96 and 17.46 mg/100g), total phenols (16.47 and 26.95 mg/100g) and antioxidant activity (92.12 and 97.66 %).
- The anthocyanin enriched ginger candy showed that good storage stability up to 6 months at ambient and refrigerated temperatures.
- No microbial growth was noticed in ginger candy throughout the storage period of 6 months at ambient and refrigerated temperature.
- The saleable cost of osmotically dried anthocyanin enriched ginger candy was calculated as Rs.56.76/200g for plum pulp and sugar, 72.89/200g for plum pulp and honey solution after adding 20 per cent profit and packing in aluminium laminated pouches.

CONCLUSION

Indian confectionary is one of the fastest growing sectors in the world which requires substantial change in nutritional profile of its products. The present study concludes that organoleptic characteristics and chemical composition of conventially osmo-dried ginger candy can be improved by substituting the osmotic solution containing sugar syrup with plum

pulp and honey or enriching sugar syrup with plum pulp which is a source of anthocyanin. The osmo-dried ginger candy can successfully be stored under ambient and refrigerated conditions with minimum changes in their quality characteristics. Thus, the development of anthocyanin enriched ginger candy will have functional and nutritional properties of ginger, plum and honey which seems to be a profitable venture for efficient utilization of fresh ginger rhizome and plum fruits thereby enhancing income of growers along with development of a novel therapeutic confectionary product.

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APPENDIX – I

Hedonic rating test for evaluating sensory quality

Name: _____ Date: _____

Product: _____

Please evaluate the following samples as per standard scale:

Attributes	**Sample**				
	1	**2**	**3**	**4**	**5**
Colour					
Aroma					
Flavour					
Taste					
Overall acceptibility					

Comments:

…….

…….

9- Point Hedonic Scale:

9- Like extremely

8- Like very much

7- Like moderately

6- Like slightly

5- Neither like nor dislike

4- Dislike slightly

3- Dislike moderately

2- Dislike very much

1- Dislike extremely

Signature of evaluator

APPENDIX – II

Effect of storage on chemical characteristics of dried ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)							
T_2 (Sugar + plum pulp)							
T_3 (Honey)							
T_4 (Honey +plum pulp)							
Mean							

Treatments	Storage			Mean (T)
	S_1	S_2	S_3	
T_1				
T_2				
T_3				
T_4				
Mean (S)				

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1			
T_2			
T_3			
T_4			
Mean (V)			

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1			
S_2			
S_3			
Mean (V)			

*__T1__ – Lime juice blanching + 70 percent sugar syrup (1:3), 8 hours

*__T2__ – Lime juice blanching + 70 percent Plum pulp + sugar, 5 hours

*__T3__ **-** – Lime juice blanching + 70 percent honey, 7 hours

*__T4__ – Lime juice blanching + 70 percent plum pulp + honey, 5 hours

APPENDIX - III

Effect of storage on sensory characteristics of ginger candy

Storage periods (S) / Treatments (T)		Temperature (V)					
		Ambient (V_1)			Refrigerated (V_2)		
	0	3	6	Mean	3	6	Mean
T_1 (Sugar)							
T_2 (Sugar + plum pulp)							
T_3 (Honey)							
T_4 (Honey +plum pulp)							
Mean							

Treatments	Storage			Mean (T)
	S_1	S_2	S_3	
T_1				
T_2				
T_3				
T_4				
Mean (S)				

Treatments	Temperature		Mean (T)
	V_1	V_2	
T_1			
T_2			
T_3			
T_4			
Mean (V)			

Storage	Temperature		Mean (S)
	V_1	V_2	
S_1			
S_2			
S_3			
Mean (V)			

*__T1__ – Lime juice blanching + 70 percent sugar syrup (1:3), 8 hours

*__T2__ – Lime juice blanching + 70 percent Plum pulp + sugar, 5 hours

*__T3__ – Lime juice blanching + 70 percent honey, 7 hours

*__T4__ – Lime juice blanching + 70 percent plum pulp + honey, 5

APPENDIX - IV

Mean monthly meteorological data recorded during storage studies of the anthocyanin enriched ginger candy

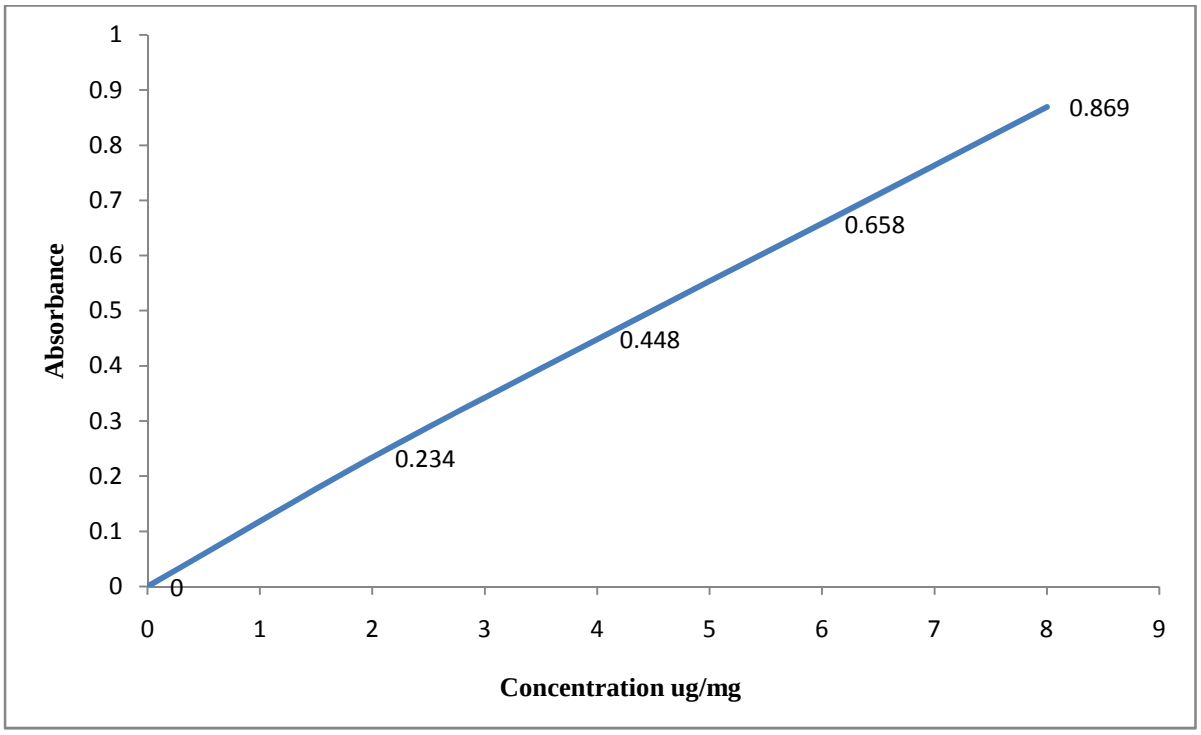
Month	Temperature (°C)	
	Maximum	Minimum
January, 2019	16.40	3.10
February, 2019	21.30	6.10
March, 2019	22.9	7.80
April, 2019	29.30	13.20
May, 2019	30.5	15.80
June, 2019	29.60	19.20

Source: Meteorological Observatory, Department of Environmental Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni

APPENDIX - V

STANDARD CURVE OF PHENOLS

ABSORBANCE OF STANDARD COMPOUND (CATECHOL)



Standard value

1ug= 0.00264

APPENDIX - VI

Anova 1: Optimization of thickness of ginger slices for osmotic dehydration

Source	DF	Mean sum of square (MSS)				
		Colour	Texture	Taste	Aroma	Overall acceptability
Treatment	4	0.007	0.245	0.009	0.225	1.650
Error	10	1.000	0.000	1.000	0.000	0.000

Anova 2: Standardization of thickness of ginger slices for osmotic dehydration on the basis of sensory score

Source	DF	Mean sum of square (MSS)				
		Colour	Texture	Taste	Aroma	Overall acceptability
Treatment	2	0.006	0.790	0.001	0.070	0.190
Error	6	1.000	0.000	1.000	0.000	0.000

Anova 3: Effect of steeping time on osmotic dehydration behaviour of ginger slices

Source	DF	Mean sum of square (MSS)				
		Weight reduction	Solid gain	Moisture loss	TSS of slices	TSS of syrup
Treatment	9	293.276	94.708	834.219	275.801	449.631
Error	20	0.000	0.000	0.000	0.000	0.000

Anova 4: Colour value of anthocyanin enriched ginger candy

Source	DF	Mean sum of square (MSS)		
		L*	A*	B*
Treatment	4	2.163	0.303	1.096
Error	10	0.000	0.000	0.000

Anova 5: Standardization of immersion solution and steeping time on TSS of slices and drained syrup

Source	DF	Mean sum of square (MSS)							
		Sugar syrup		Plum pulp + sugar		Honey		Plum pulp + honey	
		TSS of slices	TSS of syrup	TSS of slices	TSS of syrup	TSS of slices	TSS of syrup	TSS of slices	TSS of syrup
Treatment	9	275.801	449.631	521.623	1225.812	177.710	275.147	602.213	1196.812
Error	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Anova 6: Colour value of ginger candy

Source	DF	Mean sum of square (MSS)		
		L*	A*	B*
Treatment	3	67.492	53.035	7.815
Error	8	0.000	0.000	0.000

Anova 7: Effect of storage on chemical characteristics of ginger candy

Source	Degrees of freedom	Mean sum of square (MSS)						
		Moisture	Total soluble solids	Titratable acidity	Ascorbic acid	Total phenol	Antioxidant activity	Anthocyanin content
Treatment (T)	3	0.776	50.533	6.758	212.951	528.721	598.419	534.933
Storage interval (S)	2	2.905	0.514	0.008	0.710	0.627	3.692	0.411
Storage temperature (V)	1	0.952	0.184	0.001	0.177	0.120	0.666	0.682
TxS	6	0.057	0.016	0.000	0.049	0.017	0.054	0.003
TxV	3	0.126	0.028	0.000	0.036	0.003	0.117	0.101
SxV	2	0.263	0.050	0.000	0.048	0.035	0.225	0.070
TxSxV	6	0.085	0.040	0.000	0.009	0.003	0.077	0.020
Error	48	0.333	0.500	0.167	0.333	0.167	0.126	0.444

Anova 8: Effect of storage on sensory characteristics of ginger candy

Source of Variation	Degrees of freedom	Mean of sum of squares Sensory characteristics				
		Colour	Texture	Aroma	Taste	Overall Acceptability
Treatment (T)	3	17.562	2.685	4.416	3.825	5.854
Storage interval (S)	2	0.279	0.740	1.527	2.308	0.279
Storage temperature (V)	1	0.032	0.080	0.082	0.622	0.031
TxS	6	0.004	0.000	0.075	0.068	0.004
TxV	3	0.000	0.000	0.001	0.079	0.000
SxV	2	0.008	0.020	0.025	0.162	0.009
TxSxV	6	0.001	0.000	0.002	0.042	0.000
Error	48	0.333	0.083	0.083	0.208	0.042

Department of Food Science and Technology
Dr Yashwant Singh Parmar University of Horticulture and Forestry
(Nauni) Solan (H P) - 173 230 India

Title of the Thesis	**:**	**"Development and evaluation of anthocyanin enriched ginger candy"**
Name of student	**:**	Monika Thakur
Admission Number	**:**	H-17-31-M
Major Discipline	**:**	Food Technology
Minor Discipline	**:**	Food Science and Technology
Date of Thesis Submission	**:**	
Total pages of the thesis	**:**	94+vi
Major Advisor	**:**	Dr Manisha Kaushal

ABSTRACT

The present study entitled "**Development and evaluation of anthocyanin enriched ginger candy**" was conducted in the Department of Food Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the year 2018-2019. Ginger candy is a traditionally ready to eat intermediate moisture food (IMF) product having a great demand in confectionary industry due to the acceptable sensorial characteristics and appreciable nutrients especially phenols. In the conventional method of ginger candy preparation, honey may be an effective replacement for sugar which is generally used as a sweetener. The data revealed that the optimized method for preparation of anthocyanin enriched ginger candy (plum pulp and honey) involves 7.5mm slice thickness, blanching in 1.0 per cent lime juice, osmotic dip in 70 per cent immersion solution (plum pulp and honey) for 5 hours, drying in a mechanical dehydrator (55±2^{o}C). The high concentration of fructose and glucose in honey resulted in increased rate of mass transfer other than being a source of natural antioxidants. Nutritionally anthocyanin enriched ginger candy prepared by dipping in hypertonic solution containing plum pulp and honey possessed appreciable amount of anthocyanin (56.64 mg/100g), ascorbic acid (17.46 mg/100g), total phenols (26.95 mg/100g) and antioxidant activity (97.66 %). Study indicated that all these eat intermediate dried products can be successfully stored under ambient and refrigerated storage conditions without significant change in physico-chemical and sensory characteristics. The cost of production of anthocyanin enriched ginger candies was found Rs. 56.76 with plum pulp and sugar and 72.89 with plum pulp and honey per 200g after adding 20 per cent profit. Therefore, formulation of ginger candy by using honey as an osmotic agent along with anthocyanin rich plum pulp was a novel innovation thereby extracting the benefits of both phenols and anthocyanin.

_____ **_____**

Signature of Student **Signature of Major Advisor**
Ms Suman **Dr (Mrs) Manisha Kaushal**
Date: **Date:**

_____
Professor and Head
Department of Food Science and Technology
Dr. Y. S. Parmar University of Horticulture & Forestry
Nauni, Solan (H.P) 173 230

BRIEF BIO-DATA

Name : **Monika Thakur**

Father's Name : Sh. Heera Singh

Mother's Name : Smt. Reeta Devi

Date of Birth : 7 October 1996

Permanent Address : Vill. Badhet P.O. Tikker Teh. Kandaghat Distt. Solan (HP) 173 217 (India)

Academic Qualifications:

Certificate/ degree	Year	School	Board/ University	Division
10^{th} Class	2010	Govt. Sen. Sec. School Chail	H.P. Board	First
12^{th} Class	2012	Govt. Sen. Sec. School Chail	H. P. Board	First
B.Sc. (Horticulture)	2017	Dr.Y.S Parmar university of Horticulture and Forestry	UHF, Nauni, Solan (HP)	First

Fellowship/ Scholarship/Gold medal/Awards/ Any other Distinction : University Stipend

(Monika Thakur)