Effects of Sucrose on the Physicochemical Properties, Organoleptic Qualities and Shelf-Life Stability of Aonla (*Emblica officinalis*) Candy

A THESIS

BY

MUSTAF ISHAK ALI

Registration No. 1605311

Semester: January-June/2017

Session: 2016-2017

MASTER OF SCIENCE (MS)

IN

FOOD PROCESSING AND PRESERVATION

DEPARTMENT OF FOOD PROCESSING AND PRESERVATION

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

JUNE, 2017

Effects of Sucrose on the Physicochemical Properties, Organoleptic Qualities and Shelf-Life Stability of Aonla (*Emblica officinalis*) Candy

A THESIS

BY

MUSTAF ISHAK ALI

Registration No. 1605311

Semester: January-June/2017

Session: 2016-2017

Submitted to the Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur

In partial fulfillment of the requirements for the degree of

Master of Science (MS) in Food Processing and Preservation

DEPARTMENT OF FOOD PROCESSING AND PRESERVATION

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

JUNE, 2017

Effects of Sucrose on the Physicochemical Properties, Organoleptic Qualities and Shelf-Life Stability of Aonla (*Emblica officinalis*) Candy

A THESIS

BY

MUSTAF ISHAK ALI

Registration No. 1605311

Semester: January-June/2017

Session: 2016-2017

Approved as to the Style and Content By

……	……
Supervisor	Co-Supervisor
(Shakti Chandra Mondal)	(Md. Mojaffor Hosain)
Assistant Professor	Assistant Professor
Department of Food Processing and Preservation	Department of Food Processing and Preservation

Examined By

……	……
Member	Member

……

Chairman of the Examination Committee

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

JUNE, 2017

CHAPTER I

INTRODUCTION

Aonla is one of the oldest Indian fruits and considered as "Wonder fruit for health" (Ganachari *et al.*, 2010). It is also known as Indian gooseberry, Amlaki, Amla, Amlet, in different parts of world (Agarwal and Chopra, 2004). India ranks first in the world in area for production of aonla crop (Priya and Khatkar, 2013). Besides India, naturally growing aonla trees are also found in different parts of the world, viz. Sri Lanka, Cuba, Puerto Rico, China, Thailand and Japan. It can grow well in dry region and slightly saline as well as alkaline soils where other fruit crops do not thrive well. In Bangladesh, the fruit is found growing wild or in cultivated form in different parts of the country mainly grown in the hilly regions of Chittagong and Chittagong hill tracts (Haque, 1995).

Aonla is one of the most important medicinal fruits and it is therefore, used as a major constituent in several Ayurvedic preparations (Rajkumar *et al.*, 2001). It is a rich source of vitamin C and its content of ascorbic acid is next to that of Barbados cherry (Singh *et al.*, 2006; Ganachari *et al.*, 2010). About 600–900 mg of vitamin C is found in 100g of aonla pulp (Pokharkar, 2005). The edible fruit tissues of aonla contain about 3 times more protein and 160 times more vitamin C as compared to apple. The fruits contain leuco-anthocyanin or polyphenols which retard the oxidation of vitamin C. Tannins contain gallic acid, elagic acid and glucose, which retards the oxidation of vitamin C and renders its value as anti-scorbutic in fresh as well as dried conditions (Pareek and Kaushik, 2012). Dried fruit is useful in diabetes, jaundice, diarrhoea and cough. It is one of the three ingredients of the famous ayurvedic preparation "triphala" which is given to treat chronic dysentery, biliousness and other disorders, the postharvest losses in aonla vary from 30% to 40% due to its perishable nature, which reduces the market value, moreover, 17% or more of the produce fruits are lost during transport, storage and marketing (Singh *et al*., 1993). Value addition through processing would be the only effective tool for economic utilization of increased production of aonla in the future; processing not only reduces the postharvest losses but also provides higher returns to the growers (Vijaykumar *et al*., 2013). Production of more and better aonla fruit alone is not enough. This nutritious fruit must be delivered to the ultimate consumer through post-harvest system without

nutritional and quality loss, the fresh fruits are generally not consumed as it is highly acidic and astringent; therefore, it is not a popular table fruit and its use is limited. But, it has got great potential in processed forms (Nayak *et al*., 2011). Hence attention has been focused on the preparation of different value added products from aonla and it can be made into various products such as pickles, preserve, sauce, jam, jelly, dried chips, tablets, etc. (Rakesh *et al*., 2004; Singh and Kumar, 2000). Aonla is presently an underutilized fruit, but has enormous potential in the world market. It is almost entirely unknown in the world market and needs to be popularized. In view of the health benefits, there is need to make the fruits more and more amenable to value added products, among the unique products of aonla, the candy has much demand in domestic as well as export point of view (Nayak *et al*., 2011). Candy is a sweet food prepared from fruits or vegetables by impregnating them with sugar syrup followed by draining of excessive syrup and then drying the product to a shelf stable state, fruits and vegetables like apples, ginger, mangoes, guava, carrots and citrus peels have been used to prepare candies (Mehta and Bajaj 1984; Sharma *et al*.,1998; Ribeiro and Sabaa-Srur 1999; Chandu and Prasad 2006). White sugar (mainly sucrose) is the usual sweetening agent used in preparation of candy (Durrani, 2011).

Aonla candies are becoming more and more popular because of high acceptability, minimum volume, higher nutritional value and longer storage life. These have additional advantage of being least thirst provoking and ready to eat snacks (Vikram *et al*., 2014). The dried products save energy, money and space in packaging, storage and transportation (Nayak *et al*., 2012). To strengthen market, storability and superior quality of aonla candy is of prime importance, hence, the attempt to processing aonla to various value added products like aonla candies will be helpful in alleviating distress sale of the aonla fruits often observed in the market when the harvesting reaches the peak.

Objectives

The information so far accumulated, the present study has been attempted to fulfill the following objectives:

I. To develop aonla candy using various sucrose concentration.

II. To investigate the effects of sucrose concentration on the physicochemical properties, organoleptic qualities and shelf-life stability of aonla candy.

CHAPTER II

REVIEW OF LITERATURE

2.1. General Review on Aonla

Aonla (*Emblica officinalis)* also known as Indian Gooseberry is a minor sub-tropical deciduous medium size tree belonging to the family *Euphorbiaceae.* It can be grown successfully in dry and neglected regions outstanding its hardy nature, suitability to various kinds of wasteland. Aonla is grown in an area of about 50,000 ha with a production of around 2,00,000 metric tons in India (Goyal *et al*., 2008).

Aonla is arguably the most important medicinal plant in the Indian traditional system of medicine, the Ayurveda. Various parts of the plant are used to treat a range of diseases, but the most important is the fruit. The fruit is used either alone or in combination with other plants to treat many ailments such as common cold and fever and it possess radiomodulatory, chemomodulatory, chemopreventive effects, free radical scavenging, antioxidant, anti-inflammatory, anti-mutagenic and immune modulatory activities, properties that are efficacious in the treatment and prevention of cancer ,this review for the first time summarizes the results related to these properties and also emphasizes the aspects that warrant future research to establish its activity and utility as a cancer preventive and therapeutic drug in humans (Baliga and Dsouza, 2011).

The embolic fruit is a rare example of an edible material or it has very little table value due to highly acidic taste and bitterness, therefore, it is mainly consumed after processing. This highly nutritious fruit process into a variety of products such as aonla murabba, squash, candy, dried chips, jelly, pickle, toffees, powder, juice, much was, chocolate, chutney, churan, mouth freshener, soap, hair oil, hair dye, shampoo, etc., (Singh *et al.*, 2006).

Processed products of aonla are largely consumed by people as a health invigorating tonic prepared at home as well as cottage scale (Naik and Chundawat, 1996). Devi and Mishra (2009) developed aonla candy by two methods, one was the plain and the other was the candy containing fat. The overall quality and overall acceptability of the plain candy was better than

the fat candy. Candy prepared with 300g of Aonla slices and 300 g of sugar and 2 g of citric acid was recommended. Moreover, 17% or more of the produced fruits are lost during transport, storage and marketing (Singh, *et.al*.,1993). So, modern technologies are needed to reduce the losses. Hence attention has been focused on the preparation of different value added products from aonla fruit while being processed into candy by food processing industry generates a high brix candy syrup which otherwise is a waste and poses burden to environment. This candy syrup was converted into natural vinegar, a nutrient rich value added food product through two successive fermentations: alcoholic and acetic acid fermentations. Diluted candy syrup (20°Bx) supplemented with raisins was fermented to ethanol by using *Saccharomyces cerevisiae* strain 35 which produced 10.5% (v/v) ethanol in 28 days. The ethanol was further used for production of amla-candy syrup vinegar using cells of *Acetobacter acetic.* The wort (supplemented with mother vinegar and nutrients in the form of sulphites and nitrogen substrates) with initial acidity of 2% was fermented by *A. aceti* 7.5% (v/v) and mother vinegar 10% (v/v) at 5L scale. This resulted in production of vinegar with a final acidity of 5.7% (w/v) in 14 days having a fermentation efficiency of 75.5±8.21%, acetification rate of 4.11±0.36g/L/d and a yield factor of 0.95±0.07. The fermented vinegar so produced had 180mg/100ml of total phenols and 390mg/100ml ascorbic acid, making it a value added product from an otherwise amla waste. (Kocher *et al*., 2013)

2.2. Chemical Composition and Nutritive Value of Aonla

Aonla has mineral and vitamin contents include calcium, phosphorous, iron, carotene, thiamine, riboflavin, and niacin. The seeds of aonla contain a fixed oil, phosphatides and an essential oil. The root contains ellagic acid and lupeol and bark contains leucodelphinidin. The seeds yield a fixed oil (16%) which is brownish-yellow in colour. The following fatty acids are present in Amla: linolenic (8.8%), linoleic (44.0%), oleic (28.4%), stearic (2.15%), palmitic (3.0%) and myristic (1.0%). Srivasuki (2012) reported that the ethanol soluble fraction contains free sugars, D-glucose, D-fructose, and D-myo-inositol. The acidic water soluble fraction contains a pectin with D-galacturonic acid, D-arabinosyI, D-rhamnosyl, D-xylosyI, D-glucosyI, D-mannosyl and D-galactosyI residues.

Amla is a rich dietary source of vitamin C, minerals and amino acids, and also contains a wide variety of phenolic compounds. Gelatin hydrolysate, also known as collagen peptide as a functional ingredient, is obtained from animal hide or fish scales. Ingestion of gelatin or collagen peptide affects various functions of the body, including bone, the Achilles tendon, and skin. However, there are few data on the effects of amla extract and collagen peptide on photo-aging in vivo. In the present study, therefore, we administered amla extract and/or collagen peptide to hairless mice that were repeatedly exposed of UVB irradiation, and examined the resulting effects on photo-aging. Collagen peptide, but not amla extract, also enhanced the production of collagen. Researchers demonstrated that amla extract and collagen peptide exerted an additive effect in ameliorating skin dehydration and wrinkle formation, suggesting that they were able to attenuate photo-aging effectively in UVB-irradiated hairless mice mentioned by Fujii *et al.* (2008).

The moisture content varied from 83.76 to 85.35% in aonla cultivars (Ghorai and Sethi, 1996). Premi *et al*. (1999) and Tandon *et al*. (2003) found 87.17 and 86.9% moisture in fresh aonla fruits.

Dahiya and Dhawan (2001) found 80.74% moisture in cv Chakaiya., Pathak *et al*. (2002) reported that moisture content ranged from 85.2 to 87.7% among various aonla cultivars. Singh *et al*. (2012) reported that Banarasi had maximum moisture content (86.90%) followed by NA-7 (86.40%), Chakaiya (86.14%) and Desi (82.10%), respectively.

The moisture content of aonla cultivars differed significantly and ranged from 83.4 per cent (cv. Krishna) to 85.6 % in cv. Chakaiya (Nayak *et al*., 2012). The total sugars of fresh aonla fruits varied in the range of 3.11 to 11.09 % and reducing sugars in the range of 1.04 to 8.48 % (Tripathi *et. al*., 1988; Mehta, 1995; Ghorai and Sethi, 1996). Taeotia *et al*. (1968) reported total sugars ranged from 7 to 9% and reducing sugars from 1 to 4% among various cultivars of aonla.

Singh *et al*. (1993) observed a slightly higher value of reducing sugars in different aonla cultivars and lower values for total sugars. The total and reducing sugars recorded in fresh fruits ranged from 6.8 to 9.1 and 1.5 to 7.7%, respectively. Mehta (1995) reported higher values *i.e.*, 10.87 and 7.91 % of total and reducing sugars, respectively. Gomez and Khurdiya (2005) found

7.04% total sugars in fresh aonla fruits. Singh *et al*. (2012) observed that total sugars and reducing sugars percentage were higher in Chakaiya followed by NA-7, Banarasi and Desi (9.62 and 2.01, 8.2 and 1.08, 8.03 and 1.07, and 7.13 and 1.06), respectively. The total and reducing sugars in fresh aonla fruits were most abundant in cv. Krishna followed by Chakaiya (Nayak *et al*., 2012).

Taeotia *et al*. (1968) reported that the fibre intensity varied from slightly fibrous to highly fibrous. Singh *et al*. (1987), Mehta (1995) and Gopalan *et al*. (1996) found 2.5, 3.2 and 3.4 per cent crude fibre in aonla fruits on fresh weight basis, respectively.

Sharma *et al*. (1989) observed 3 to 4% fibre in aonla fruits, which seemed to be the highest value reported in literature content. Verma *et al*. (2006) reported 2.24 g crude fibre in 100g fresh aonla fruit. Nayak *et al*. (2012) found that fibre content of fruits ranged between 1.10 to 2.00%. The highest fibre content was, however, recorded in cv. Chakaiyaaonla (2.0%) with the lowest being in cv. NA-7 (1.1%). Singh and Pathak (1987) observed 1.5 and 1.2% titratable acidity in Chakaiya and Krishna cultivars of aonla, respectively. Tripathi *et al*. (1988) and Ghorai and Sethi (1996) reported higher values for titratable acidity ranging between 2.17 to 2.82 % in different varieties of aonla. The acidity in fresh fruit was found to be 1.5% (Kalra, 1988 and Mehta, 1995). Acidity was reported to be 1.82% (Dahiya and Dhawan, 2001; Singh *et al*., 2005) and 2.23% (Gomez and Khurdiya, 2005). Nayak *et al*. (2012) reported that titratable acidity in fresh fruit ranged from 1.5 to 1.8%. Organic acids are mainly responsible for sourness of fruits. (Singh, 1982) reported 500 to 750 mg/100 g ascorbic acid in different aonla cultivars. The ascorbic acid content in aonla fruits grown world-wide ranged from 200 to 1800 mg/100 g of fruit pulp.

Ram (1983) and Singh *et al*. (1984) reported that Banarasi contained more ascorbic acid (645.5 mg/100 g) than Desi (540.7 mg/100 g). Ascorbic acid was found to be 454 mg/100 g by Dahiya and Dhawan (2001). Singh *et al*. (2005) reported 349.50 mg/100 g ascorbic acid. Singh *et al*. (2012) reported maximum ascorbic acid (647 mg/100 g) was in Banarasi followed by Chakaiya (627 mg/100 g), NA-7 (640 mg/100 g) and Desi (486 mg/100 g). Fresh fruits of cv. Krishna recorded maximum ascorbic acid content (339 mg/100 g) followed by cv. Chakaiya (309 mg/100 g) The differences in ascorbic acid content of aonla fruits may be attributed to various

factors including mainly agro-climatic conditions in which fruits are grown and the maturity of fruits as reported by Nayak *et al*. (2012).

2.3. Nutritional Quality of Aonla during Processing and Storage

Chauhan *et al.* (2005) conducted a laboratory experiment on the development of aonla blended sauce by using aonla pulp blended with tomato pulp (50:50). The pH, TSS and ascorbic acid content has found decreased while acidity increased after 90 days of storage at room temperature. Tandon *et al.* (2005) studied the development of churan from dried aonla powder and found 1.5gm ginger and 0.5gm ajwain and 1.0 g ginger and 2.5gm mint, apart from other ingredients found to be most acceptable among 14 different combinations of treatments.

The kinetics of ascorbic acid degradation in amla as well as in pure ascorbic acid solutions at initial concentrations present in amla over a temperature range of 50-120^{o}C (steady-state temperature) has been studied. The ascorbic acid degradation followed first-order reaction kinetics where the rate constant increased with an increase in temperature. The temperature dependence of degradation was adequately modeled by the Arrhenius equation. The activation energies were found to be 4.09 kcal/mole for amla and 4.49 kcal/mole for pure vitamin solution.

A mathematical model was developed using the steady-state kinetic parameters obtained to predict the losses of ascorbic acid from the time-temperature data of the unsteady state heating processing method. The results obtained indicate the ascorbic acid degradation is of a similar order of magnitude in all the methods of cooking (Nisha *et al.,* 2004). Hertog *et al.* (1992) and Shadidi and Nazck (1995) had shown that flavonoid content could be affected by different processing techniques.

Singh *et al.* (2005) reported that the processing of aonla fruits with various recipes which were evaluated for commercial processing with an composition of 25% aonla pulp + 5% asparagus root extract + 2% ginger juice with 50% TSS and 1.2% acidity for herbal squash; 50% aonla pulp + 5% asparagus root extract + 2% ashwagandha extract with 68% TSS and 2% acidity for herbal jam; segmented candy with pectin coating; 55% aonla pulp + 2.5% butter + 0.5% custard powder + 42% sugar for toffees was found excellent for preparation of value added products.

Tiwari *et al. (*2005) studied the preservation of aonla fruit pulp. They reported the chemical characteristics of sulphite treated aonla pulp and found that increasing the acidity, reducing sugar, non-reducing sugar and total sugar as well as decreasing TSS during nine-month storage.

Satbhai and Masalkar (2006) reported the extension of shelf life of ready-to-serve (RTS) beverages of aonla and revealed that the treatments of hot filling followed by in bottle pasteurization and hot filling with preservative followed by in bottle pasteurization were superior at both (ambient and cool) the storage conditions with higher retention of ascorbic acid and higher per cent of acidity. The treatment hot filling of RTS with preservative followed by in bottle pasteurization recorded highest general acceptance throughout storage period and highest score for organoleptic evaluation.

Singh *et al*. (2006) conducted an experiment for value addition and recorded that different aonla varieties are suitable for different processed products with their different physico-chemical composition. Kanchan and Krishna variety were suitable for preparation of candy and jam while Chakaiya was suitable for pickle, chutney, beverages (nectar, squash and syrup) and jam. Banarasi was better for drying, candy and pickle preparation. cv. NA-6 recorded lowest fibre content, high pulp and TSS content. While cv. NA-7 showed average physico-chemical composition with high content of ascorbic acid.

Lal (2006) studied on the effect of sugar and citric acid treatment on quality attributes of aonla syrup during storage. He observed that during 9-month storage there was a linear increase in TSS and non-enzymatic browning whereas ascorbic acid, titrable acidity and organoleptic quality decrease with increased duration the storage.

Ray *et al.* (2006) conducted a laboratory experiment for standardization of processing technology for "sweet aonla candy" cv. Gujarat aonla-1. Among all different treatments, aonla pieces treated in 2 per cent brine solution with 75 ^{0}Brix sugar gave maximum final product while treatment of aonla pieces treated in 2 per cent brine with 70 ^{0}brix sugar syrup was found better in taste and ranked first for commercialization as well as marketability.

Mehra (2008) evaluated aonla varieties for chayvanprash processing, and noted that among all the varieties NA-7 and Krishna (NA-5) were found superior in respect of nutritional quality of

fresh fruit of aonla. The maximum TSS, acidity, ascorbic acid, Moisture, total sugar and reducing sugar were recorded in case of variety NA-7 during six-month storage.

Singh *et al*. (2010) studied on "Influence of pre-drying treatments and drying methods on bio-chemical properties of different recipes of aonla. Product preparation noted decreasing trend in ascorbic acid and acidity and increasing trend in total sugar, reducing sugar and non-reducing sugar during four-month storage.

Pawar (2010) evaluated the different aonla varieties for osmo-dehydrated candy product processing, and reported that the significantly higher TSS, total sugar, reducing sugar and ascorbic acid; while lower level of moisture and acidity was found in candy of NA-7 variety. Moreover, organoleptically also NA-7 variety was found best. Considering the behavior of all constituents found increasing in trend except ascorbic acid and all organoleptic character found decreasing trends during six-month storage.

Nutritional quality of food during storage has become increasingly important problem. The loss of some nutrients such as ascorbic acid (vitamin C) might be a critical factor for the shelf life of some products as citrus juice concentrate. Vitamin C content of citrus juices undergoes destruction during storages is stated by Johnson *et al*. (1995). During processing, distribution and storage of frozen vegetables, ascorbic acid oxidizes to dehydroascorbic acid (DHAA), which retains vitamin C activity. Afterwards, it can be irreversibly hydrolyzed to 2, 3-diketogulonic acid (DKGA), which possesses no biological activity. This last oxidation step is found to be much more temperature sensitive than the oxidation of ascorbic acid to dehydroascorbic acid is reported by Belitz and Grosch (1999); Cooke and Moxon (1981); (Giannakourou and Taoukis 2003); (Vieira *et al*., 2000).

Over the years, researchers have optimized time/temperature profiles to minimize the exposure of food to heat. Further, the newer process technologies may have the potential to reduce or even eliminate heat exposure. Some of these processes are not new, but have recently made significant advances towards commercialization are stated by Vikram *et al*. (2005). Mehta (1995) stated that the total tannins were found to be reduced in the dried amla would have happened as the action of enzyme polyphenoloxidase converting tannin into other products. Tripathi *et al*. (1988) reported the chemical changes occurring in Aonla preserve during

processing and storage for 135 days. They observed that most constituents including total soluble solids content, vitamin C, total sugar, pectin, tannin and protein decreased as compared to fresh fruits. Acceptability was observed in Aonla preserve up to 135 days of storage.

Geetha *et al*. (2005) studied the effect of sugar concentration at different temperatures on the kinetics of total sugar gain, moisture loss, ascorbic acid loss, TSS gain in Aonla preserve. They observed that the rate of constant kinetics for all the constituents increased with the increase in sugar concentration and temperature.

2.4. Changes in Organoleptic Quality of Candy during Storage

Singh *et al*. (2008) prepared candy from six cultivars (viz. NA-7, Chakaiya, Francis, Krishna, Kanchan and Banarasi) of aonla. The organoleptic quality was best (8.02 score) in NA-7 and poorest (6.56 score) in Krishna. Organoleptic evaluation revealed that the acceptability of aonla candy decreased with the storage period. The acceptability in terms of organoleptic taste was found better in candy prepared from NA-7, Banarasi, Kanchan, and Krishna than that of Chakaiya and Francis at last interval of storage.

Kumar and Singh (2001) found that a gradual decrease in organoleptic score of different Aonla products during storage at ambient temperature. The acceptable quality of Aonla candy was maintained upto 9 months of storage. (Alam and Singh, 2010) developed sweet Aonla flakes. The Aonla slices of 2 mm thickness were first osmotically pretreated and convectively dried at air temperature of 60 °C to a moisture level of 10 % (wb). The product had high consumer acceptability.

Tripathi *et al.* (1988) observed that most of the nutritive constituents decreased in amla products as compared to the fresh fruit. The loss in ascorbic acid content during processing and storage was very significant in all the products, the acceptability of amla preserve and jam increased, while that of amla candy, juice and the dehydrated product decreased with storage period.

Mishra *et al.* (2011) observed that the scores for overall acceptability of amla candy differed significantly, which may be ascribed to different ratios of rose extract and sugar. It was concluded that the incorporation of rose extract in amla candy was well acceptable and

improved colour and flavour of candy. Amla candy with 20 ml rose extract and 100% sugar gave best with respect to taste, flavour, colour, texture, and overall acceptability.

On the basis of organoleptic evaluation and biochemical characters, it was concluded that the candy prepared from cv. Krishna and flavoured with cardamom powder was found to be the best aonla candy (Nayak *et al*., 2012).

Singh *et al.* (2007) evaluated osmotically dehydrated Aonla fruit segments for their physical, nutritional, organoleptic qualities and shelf life and compared with whole fruit preserve. Osmotic dehydration was carried out using 60 and 70 °Brix sugar syrup with varying steeping time. Steeping in 60°Brix sugar syrup showed less loss of vitamin C in the preserve compared to 70°Brix. Blanched Aonla segments were immersed in 60 °Brix for 24 h and fallen brix was maintained after 24, 48 and 72 h by heating and left for 24 h. The product is nutritionally and organoleptically superior and had a shelf life of three months.

Nath (1999) reported the different types of processed products of aonla *viz.*, preserve (Murabba) and candy as processing whole fruits; pickle and shreds as segments and chopped fruits; pulp, nectar, squash, syrup and jam as pulp and pulp based products and revealed studied the storage life of products at room temperature. Sagar and Kumar (2006) found 200 gauge HDPE most suitable for retention better quality in respect of colour, flavour, texture and overall quality of the shreds for 4 months at room temperature and 6 months at low temperature (7±2 °C) followed by 400 gauge LDPE and 150-gauge PP pouches during the storage (Divya *et al.,* 2014).

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site

The present study was conducted at the Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

3.2 Source of Raw Material

Fully matured and large sized aonla fruits were procured from the local market of Dinajpur district in Bangladesh. Care was taken during the transportation of the fruits so as to prevent any damage. Fruits having crack or skin injuries and specks were rejected. The selected fruits were washed with potable water to remove any extraneous matter adhering to the fruits. After washing the fruits were stored in refrigerator for further use.

3.3 Physical Parameters for Fresh Aonla Fruits

Ten fruits were selected randomly and following observations were recorded:

3.3.1 Fruit Size

Fruit size in terms of length (cm) and diameter (cm) of ten fruits was measured by digital gauge meter and their average was calculated.

3.3.2 Fruit Weight

Weight of ten fruits was taken on electronic balance and average weight per fruit was calculated and expressed in grams.

3.3.3 Pulp Weight

Initial weight of randomly selected fruits was recorded on electronic balance. These fruits were deseeded and separate pulp was weighed. The pulp weight was expressed in percent.

3.4 Preparation of Aonla Candy

Aonla candies were prepared by blanching the fruits in boiling water for 10 min. at 70^{o}C and were placed on a dry cloth and excess water was allowed to drain off. The pricked and blanched

aonla were made into segments and were soaked over-night in sucrose (white sugar) solution with varying concentration (80%, 70%, 60%, 50%, and 40%). Next day, the aonla segments were taken out from the syrup. The product was kept again for 24 hrs. Next day, the pieces were dried at 50^{o}C temperature in a cabinet dryer till they become non-sticky. Fresh aonla candy without sugar was used as control. The prepared candies were packed in glass jar and stored for 4 months and data were obtained at 2-months interval.

Table 3.1: Different ratios of aonla fruit pulp and sugar for different samples

Samples	Fruit pulp (gram)	Sugar(gram)
Sample-1	Fresh Aonla	----
Sample-2	20	80
Sample-3	30	70
Sample-4	40	60
Sample-5	50	50
Sample-6	60	40

Figure 3.1: Preparation of sample.

3.5 Proximate Analysis

3.5.1 Determination of Moisture Content

AOAC (2000) method was used to determine the moisture content of aonla samples. Sample (3gm) was weighed and taken in a clean, dry and pre-weighted petridish. Then the petridish with sample was transferred to oven and dried at 105ºC for 24 hours. After that it was cooled at desiccator and weighed. Moisture content was calculated by following formula:

$$\% \text{ Moisture} = \frac{W_1 - W_2}{W} \times 100$$

Where,

W_1 = weight of sample with crucible

W_2= weight of dried sample with crucible

W = weight of sample

3.5.2 Determination of Protein Content

Principle

Protein content can be measured by estimating the nitrogen content of the material and then multiplying the nitrogen value by 6.25. This is referred to as crude protein content, since the non-protein (NPN) content present in the material was taken into consideration in the present investigation. The estimation of nitrogen was made by modified Kjeldahl method (Ranganna, S.1992), which depends on the fact that organic nitrogen, when digested with concentrated sulphuric acid (H_2SO_4). In the presence of a catalyst, is converted into ammonium sulphate $(NH_4)_2SO_4$. Alkali is added to the sample to convert ammonium (NH_4^+) to ammonia (NH_3). The ammonia is steam is distilled into a receiver flask containing boric acid and titrated with a standard acid solution. This determines % of N that is multiplied by 6.25 to give the value of crude protein.

Digestion Mixture

Potassium sulphate (K_2SO_4) and dehydrated copper sulphate ($CuSO_4.5H_2O$) in a ratio of 5:1 were powdered with mortar and pestle and mixed well. Concentrated HCl was used for titration.

Sodium hydroxide (40%)

Sodium hydroxide (NaOH) 40g was dissolved in distilled water and the volume was made up to 100ml.

Receiver solution

10g of boric acid was added in 500ml deionized water in a one-liter volumetric flask, heated it gently until the boric acid was dissolved. An amount of 0.02g bromocresol green was dissolved with 4 ml ethanol in a separate beaker. An amount of 0.014g methyl red was dissolved with 4 ml ethanol in another beaker. Some bromocresol green and methyl red solution mixture was then transferred into that volumetric flask and 0.5 ml 1N NaOH was added when the total volume was made 1000 ml with deionized water.

Procedure

The Kjeldahl method consists of following steps:

i. Digestion of sample
ii. Distillation
iii. Titration

Digestion of sample

The aonla sample (5g) was taken in weighing paper and measured carefully. This sample was poured into a 100 ml clean and dry Kjeldahl flask, to which 10g of digestion mixture and 25 ml of concentrated HCl were added. To avoid frothing and bumping 2-5 glass beads was placed inside the flask. A blank was carried with all reagents except sample material for comparison. The flask was then heated in a fume hood digestion chamber at 400°C until the solution become colorless. At the end of the digestion period, the flask was cooled and diluted with 100 ml distilled water. A small piece of litmus paper was placed in the solution and the reaction was found to be acidic.

Distillation

The distilling set of Kjeldahl apparatus was thoroughly washed with distilled water before starting the distillation. In a measuring cylinder 60 ml of 40% NaOH was taken and it was carefully poured down the side of the Kjeldahl flask. The mouth of the flask was closed with a stopper containing connective tube, which was ultimately connected to the ammonia receiving flask containing 25 ml receiver solution.

The mixture was boiled at such a rate that water and ammonia distilled over at a steady moderate rate. The heating was too slow so that the receiver solution might be sucked into the Kjeldahl flask and not to fast so that the distilling ammonia did not escape the receiver solution without absorption.

Titration

The ammonia absorbed in the receiving flask containing receiver solution was titrated with 0.1 N HCl. Similarly, a reagent blank was distilled and titrated.

Calculation

Protein content of the sample on the percentage basis was calculated by the following formula:

$$\% \text{ Protein (g)} = \frac{(c-b)\times d \times 14 \times 6.25}{a} \times 100$$

Where, a = Sample weight (g); b = Volume of the sodium hydroxide required for the blank titration; c = Volume of the sodium hydroxide required for the blank and to neutralize 20 ml of 0.1 NH_2SO_4 (for blank); d = Normality of NaOH used for titration; the conversion factor of nitrogen to protein is 6.25 and atomic weight of nitrogen is 14.

3.5.3 Determination of Fat Content

To determine the fat content of aonla samples the AOAC (2000) method was used with some modification. Sample (3g) was taken into the thimble. Then the thimble was attached to the Soxhlet apparatus which was attached with a round bottom flask containing 250 ml petroleum ether. The fat was extracted for 6 hours. After that petroleum ether was evaporated at 80ºC until the flask completely dried. Fat content was calculated by following formula:

$$\% \text{ Fat} = \frac{W_1 - W_2}{W} \times 100$$

Where,

W_1= weight of evaporated flask with fat

W_2= weight of empty flask

W= weight of sample

3.5.4 Determination of Ash Content

Total ash content of aonla samples was measured by AOAC (2000) method. Sample (3gm) was weighed and transferred into a clean, dry and pre-weighted crucible. Then the crucible was kept into muffle furnace at 550ºC for 6 hours. Turn off muffle furnace and wait to open it until the temperature has dropped to at least 250 °C, preferably lower. Open door carefully and cooled ignited powder at desiccator and weighed. The ash content was calculated by the following formula:

$$\% \text{ Ash} = \frac{W_1 - W_2}{W} \times 100$$

Here,

W_1= weight of ash with crucible

W_2 = weight of empty crucible

W = weight of sample

3.5.5 Determination of Total Carbohydrate

The total carbohydrate of the samples was determined as total carbohydrate by difference, which is by subtracting the measured moisture, ash, fat, and protein from 100, (Pearson, 1970).

3.5.6 Determination of Fiber Content

The sample was taken for crude fiber analysis by adopting the procedure mentioned in AOAC (2000) Method. 5g sample was used to determine crude fiber of aonla samples. Samples were boiled for 30 minutes in 200 ml of 1.25% H_2SO_4 and then filtered and washed. Then the sample was again boiled in 200 ml of 1.25% NaOH for 30minutes and then filtered and washed. The resultant residue was dried at 110ºC for 2 hours and weighed. The dried residue was ignited at 550±15ºC, cooled and reweighed. The crude fiber was calculated according to following expression:

$$\% \text{ Fiber} = \frac{\text{Loss in weight on ignition}}{\text{weight of sample}} \times 100$$

3.6 Determination of Titrable Acidity

Titrable acidity (TA) was determined by titration of a known quantity of sample (5g) against 0.1 N sodium hydroxide using 1% phenolphthalein solution as an indicator. The endpoint was denoted by the appearance of pink color. The titration was repeated thrice and the average value was recorded (Shrivastava and Kumar, 1994). The results were expressed as percent using the following equation:

$$\% \text{ Acidity} = \frac{\text{Titre} \times 0.1 \times 0.064 \times 100}{\text{Weight of sample taken} \times 1000}$$

3.7 Determination of Vitamin C by Indophenol Method (AOAC, 2000)

(a) Principle

Aliquots of samples in oxalic acid solution are titrated with standardized sodium 2-6 dichlorophenol dye to a faint pink colour that persists for 5 to10 seconds. This method is limited to juices of light colour because red pigments obscure the end point.

Reagents

(i) **Indophenol dye 0.04 %:** 0.2 g of sodium 2, 6 dichlorophenol indophenol was weighed and dissolved in about 200 ml water.

(ii) **Oxalic acid 0.4 %:** 4 g oxalic acid was weighed and dissolved in distilled water and made up to 1000 ml mark.

(b) Standardization of dye

2 g of potassium iodide was weighed and dissolved in about 5 ml distilled water in 50 ml Erlenmeyer flask in triplicates. 15 ml of the dye was pipetted and added and then 10 ml 1N HCl. This was mixed thoroughly and made to stand for 2 minutes. The solution was titrated

with freshly prepared 0.01N sodium thiosulfate from a micro burette using 2 ml starch, until there is no change in colour when one drops or less is added.

(c) Procedure

Ten grams of each sample was weighed and this was macerated in a porcelain dish or mortar. Twenty-five ml of distilled water was added onto the macerated sample to form a solution. Twenty ml of the solution was pipetted into 100 ml volumetric flask and this was made up to the mark with 0.4% oxalic acid and filtered through Whatman filter paper to clarify the solution. Ten ml of the filtrate (aliquot) was pipetted and 15 ml of oxalic (0.4 %) was mixed with the filtrate and this was titrated in a 50 ml Erlenmeyer flask with dye (0.04 % 2,6 dichlorophenol indophenol) to a faint pink end point lasting for 5 to 10 seconds. Titration was completed within one minute. The measurements were taken in triplicate and results were averaged. Ascorbic acid (Vitamin C) was calculated as follows:

$$\text{Ascorbic acid (mg /100gm)} = \frac{\text{Titre} \times \text{ Dye factor} \times \text{ Volume made up}}{\text{Volume of filtrate taken} \times \text{ weight of sample}} \times 100$$

3.8 Determination of total phenolic content

The total phenolic content of the sample was determined by Folin-Ciocalteau method (Slinkard and Singleton 1977) with slight modification using gallic acid as a standard compound. The extracted solution was obtained using 1g sample mixed with 40 ml 100% methanol in separate glass beaker and stirred for 4-5 minutes. Then the mixtures were concentrated to 10 ml by heat using hotplate stirrer followed by adding 10ml of 100% methanol to concentrated samples solution. From these mixtures, aliquots of 1 ml of each sample were taken in glass test tubes to which 0.2 ml 10% Folin-Ciocalteau reagent was added. These mixtures were vortexed for 3 minutes. Then 0.8 ml of 7.5% Na_2CO_3 was added to the mixture and allowed to stand at dark place for 1-2 hours before measuring the absorbance at 760 nm using spectrometer (T80 UV/VIS Spectrometer, PG Instruments LTD.) against the blank (contained the same mixture solution without the sample extract). Standard gallic acid was used for constructing the standard curve. Concentration range of standard gallic acid was of 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30 mg/ml. The regression line in relation to absorbance (y) and gallic acid content (x) was $y = 0.208x + 0.143$ at $R^2 = 0.985$. The total phenolics were determined using the following formula

by a comparison of the values obtained with the standard curve of gallic acid. The results were expressed as mg gallic acid/100g of sample.

$$\text{Total Phenol (mg Gallic acid/100g)} = \text{X (mg/ml)} \times \frac{\text{Volume made (ml)}}{\text{Sample taken (g)}} \times 100$$

3.9 Determination of Sugar Content

3.9.1 Determination of Reducing Sugar

This was determined by modifying the methods described in Ranganna (2002), the reagent used for the estimation of reducing, non-reducing and total sugar were follows:

1. Fehling's solution (A)
2. Fehling's solution (B)
3. Methylene blue indicator
4. 45% Neutral lead acetate solution
5. 22% Potassium oxalate solution

Standardization of Fehling's solution

10 ml of both Fehling's solutions A and solution B were mixed together in a beaker. 10 ml of mixed solution was pipetted into a 250 ml conical flask and 25 ml distilled water was added to it Standard sugar solution was taken in a burette. The conical flask containing mixed solution was heated on a hot plate. When the solution began to boil, three drops of methylene blue indicator solution was added to it. Mixed solution was titrated by standard sugar solution. The end point was indicated by decolourization of the indicator. Fehling's factor was calculated by using the following formula:

$$\text{Fehling Factor} = \frac{\text{Titre} \times 2.5}{1000}$$

Preparation of the sample

10 gm of sample and 100 ml of distilled water mixed in homogenizer and transferred to 250 ml volumetric flask. It was neutralized with O.1N NaOH and added 2 ml of lead acetate solution

and stand for 10 minutes. Add 5 ml potassium oxalate solution and made a volume of 250 ml. Then filtered and made the dilution.

Titration for reducing sugar

10 ml of mixed Fehling's solution was taken in a conical flask and 25 ml of distilled water was added to it. Filtered sample was taken in a burette. Conical flask containing mixed Fehling's solution was added to the flask when boiling started and titrated with solution taken in the burette at the same time. The end point was indicated by decolorization of indicator. Percent reducing sugar was calculated by using the following formula:

$$\% \text{ Reducing sugar} = \frac{\text{I} \times \text{D} \times 100}{\text{T} \times \text{W} \times 1000}$$

Where,

I = mg of invert sugar required to reduce known volume of Fehling's solution

D = Dilution factor

T = Titration

W = Weight of sample

3.9.2 Non-Reducing Sugar

50 ml of purified solution was taken a conical flask. 50 ml of distilled water and 5gm of citric acid were, added to it Then the conical flask was heated for 10 minutes for insertion of sucrose and finally cooled. The sample was then neutralizing by 0.1N NaOH solution using phenolphthalein indicator. The volume was made up to 100 ml with distilled water. The mixed Fehling's solution was titrated using similar procedure followed as in the case of reducing sugar. The percent invert sugar is then calculated by the following formula:

$$\% \text{ Invert sugar} = \frac{\text{I} \times \text{D} \times 100}{\text{T} \times \text{W} \times 1000}$$

The percent non-reducing sugar was calculated by using the following way:

$$\% \text{ Nonreducing sugar} = \% \text{ Invert sugar} - \% \text{ Reducing sugar}$$

3.9.3 Estimation of Total Sugar

Total sugar can be calculated by using the following way:

$$\% \text{ Total sugar} = \% \text{ Reducing sugar} + \% \text{ Nonreducing sugar}$$

3.10 Sensory Evaluation

Sensory evaluation of developed aonla candy samples was conducted through a taste testing panel using 9-point hedonic scale (Bergara-Almeida *et al*., 2002). The panelists were selected from among those students and employees of the Department of Food Processing and Preservation, HSTU who frequently take part in such evaluation. The panelists (10) were asked to assign appropriate numerical score to each product for characteristics color, flavor, texture, taste and overall acceptability of amla candy. The hedonic scale arranged was such that; 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like or dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely.

3.11 Statistical Analysis

Each experiment was repeated in triplicate. The obtained data were analyzed by SPSS (version 20.0). The results were expressed as mean ± standard error mean (SEM). Significant differences between the groups were assessed by one-way Analysis of Variance (ANOVA) test and means were separated by Duncan's Multiple Range Test (DMRT) at the 95% confidence level. Microsoft office excel (2013) was used for plotting graphs.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Physical Characteristics of Fresh Aonla Fruits

The data pertaining to physical characteristics of fresh aonla fruits have been presented in Table 4.2. The fruit length, fruit diameter, fruit weight, and pulp weight were found to be 3.83 cm, 4.38 cm, 43.67 g, and 94.76 %respectively.

Table 4.1: Physical characteristics of fresh fruits of aonla.

Characteristics	Data obtained
Fruit length (cm)	3.83 ± 0.03
Fruit diameter (cm)	4.38 ± 0.02
Fruit weight (g)	43.67 ± 0.05
Pulp weight (%)	94.76 ± 0.04
All values are mean ± SEM	

4.2 Chemical Characteristics of Fresh Fruits of Aonla

The fresh aonla fruits were evaluated for various chemical characteristics and the results recorded have been presented in Table 4.2. On fresh wet basis, moisture, protein, fat, ash, carbohydrate, total fiber content and value of fresh fruits was found to be 80.18 %, 1.94%, 1.07 %, 0.31 %, 16.50 % and 2.31 %, respectively.

Titratable acidity was analyzed to be 1.46 %, whereas vitamin C, total phenol, reducing sugars, non-reducing sugars and total sugars were found to be 649.92 mg/100g, 24.58 mg/100g, 8.88%, 1.86% and 10.74 %, respectively.

Table 4.2. Physicochemical characteristics of fresh fruits of aonla.

Parameters	Composition
Moisture (%)	80.18 ± 0.98
Protein (%)	1.94 ± 0.07
Fat (%)	1.07 ± 0.01
Ash (%)	0.31 ± 0.01
Carbohydrate (%)	16.50 ± 1.70
Total Fiber (%)	2.31 ± 0.01
Titrable acidity (%)	1.46 ± 0.05
Vitamin C (mg/ 100g)	649.92 ± 1.54
Total Phenol (mg/100 g)	24.58 ± 1.23
Reducing Sugar (%)	8.88 ± 0.04
Non-reducing Sugar (%)	1.86 ± 0.24
Total Sugar (%)	10.74 ± 0.27
All values are mean ± SEM of three replicates.	

4.3 Changes in Proximate Composition of Aonla Candy during Storage

4.3.1 Moisture Content

The change in moisture content of various treatments of aonla candy during storage is summarized in Fig.4.1. The data revealed that the moisture contents of the aonla candies were statistically significant ($P < 0.05$) with respect to various concentration of sugar concentration. The moisture content aonla candy on zero day ranged from 14.63 to 12.02% being maximum in sample-1 (14.63%) and minimum in sample-2 (12.02 %). The moisture content in aonla candy decreased significantly with progressive increase in storage period. After 120 days of storage, moisture content of aonla candy ranged from 13.97 to 11.21% being maximum in sample-1 (12.93%) and minimum in sample-3 (11.09 %). The moisture content here was also found to decrease with an increase in storage period. The decrease in moisture content in the various aonla candies with an increase in storage period might be due to the evaporation of moisture from the product. Decrease in moisture with storage of candies was also reported by

Tripathi *et al.* (1988) in aonla candy, Mehta *et al*. (2005) in gal gal peel candy and Rani and Bhatia (1985) in pear candy.

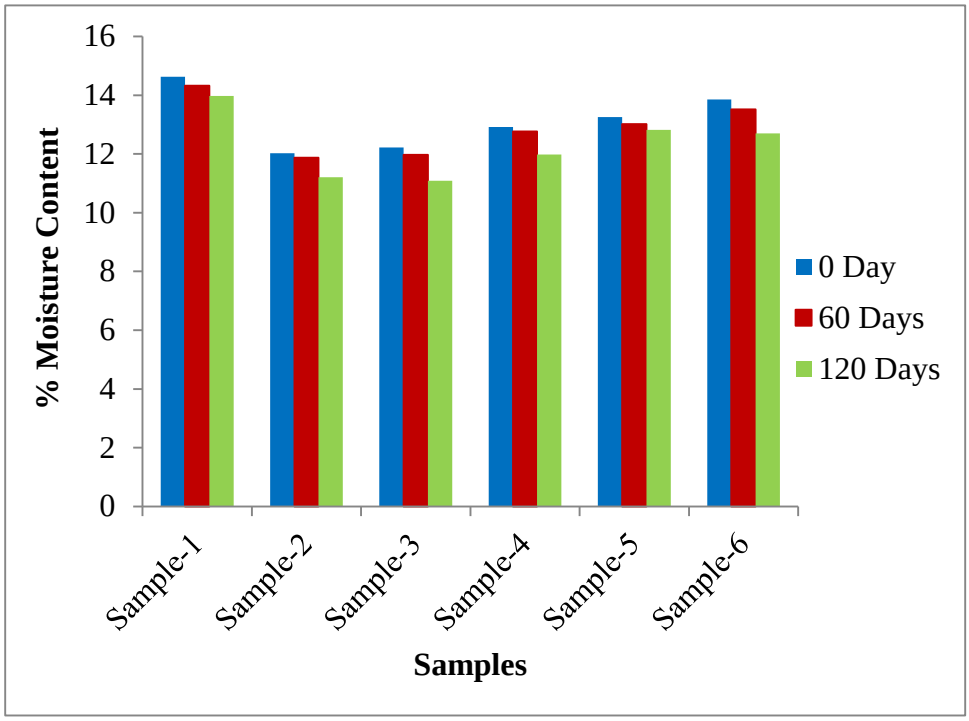


Figure 4.1: Effects of sucrose on moisture content of aonla candy during storage.

4.3.2 Fat Content

The percent fat content of aonla candies prepared with different sugar concentration was recorded during storage as shown in Fig.4.2. The data revealed that the variations of fat content to various aonla candies were statistically significant ($P< 0.05$) with respect to sugar concentration. The fat content increased with an increase in storage period. After 120 days of storage, the fat content increased from an initial range of 1.04 to 4.69 % to a final of 1.13 to 4.84%.

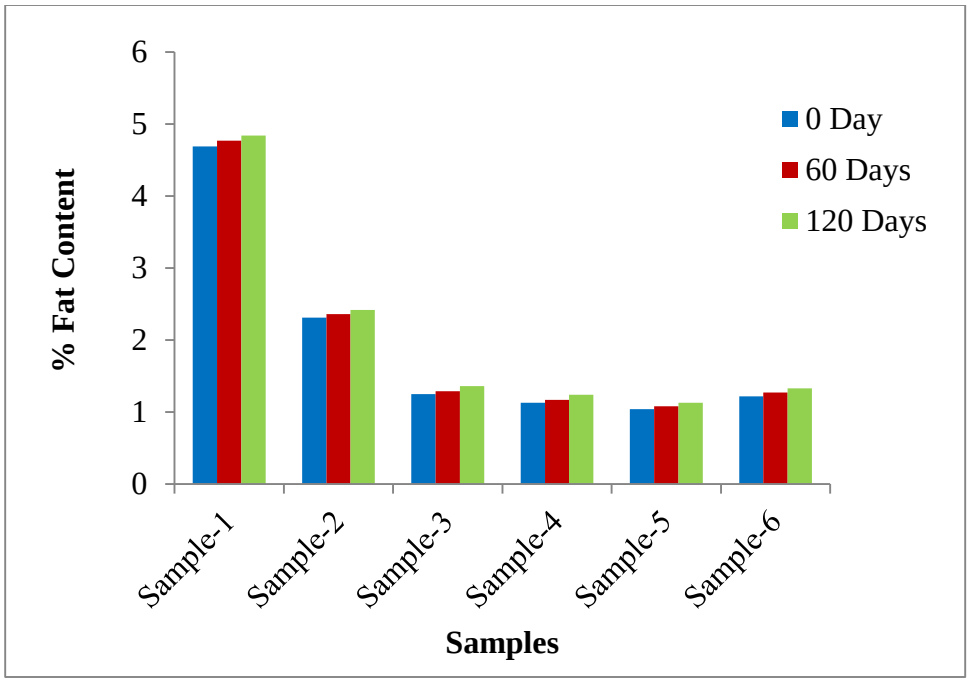


Figure 4.2: Effects of sucrose on fat content of aonla candy during storage.

4.3.3 Ash Content

The change in ash content of various treatments of aonla candy during storage is summarized in Fig.4.3. The data revealed that the ash contents of the aonla candies were statistically significant with respect to various concentration of sugar concentration. The ash content aonla candy on zero day ranged from 0.24 to 1.88 % being maximum in sample-1 (1.88 %) and minimum in sample-6 (0.24 %). The ash content in aonla candy increased significantly with progressive increase in storage period. After 120 days of storage, ash content aonla candy ranged from 0.29 to 1.95 % being maximum in sample-1 (0.29 %) and minimum in sample-6 (1.95 %). The ash content of aonla candy obtained in this study was higher than that reported by Hasanuzzaman *et al*. (2014) for tomato candy (0.87%).

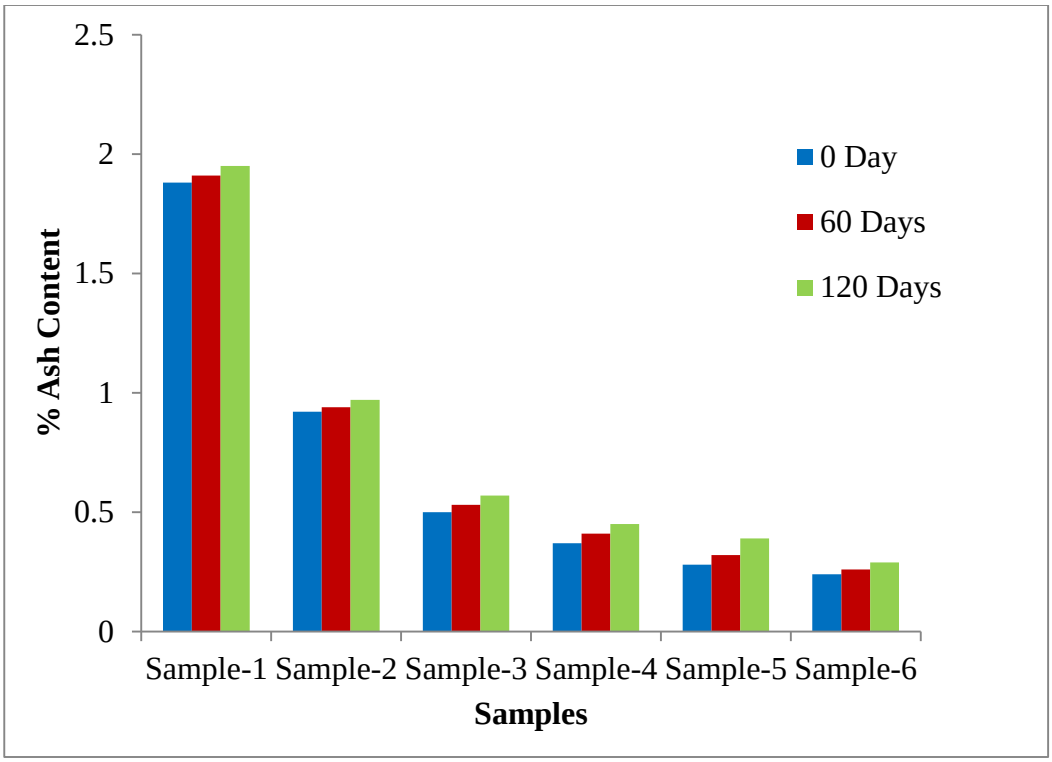


Figure 4.3: Effects of sucrose on ash content of aonla candy during storage.

4.3.4 Protein Content

The data pertaining to effect of various sugar treatments and storage on protein content of candy prepared from aonla fruits have been given in Fig.4.4. The protein content aonla candy on zero day ranged from 3.98 to 4.91 % being maximum in sample-2 (4.91 %) and minimum in sample-1 (3.98 %). The protein content in aonla candy increased significantly with progressive increase in storage period. After 120 days of storage, protein content aonla candy was ranged from 4.98 to 4.19% being maximum in sample-2 (4.98 %) and minimum in sample-1 (4.19 %).

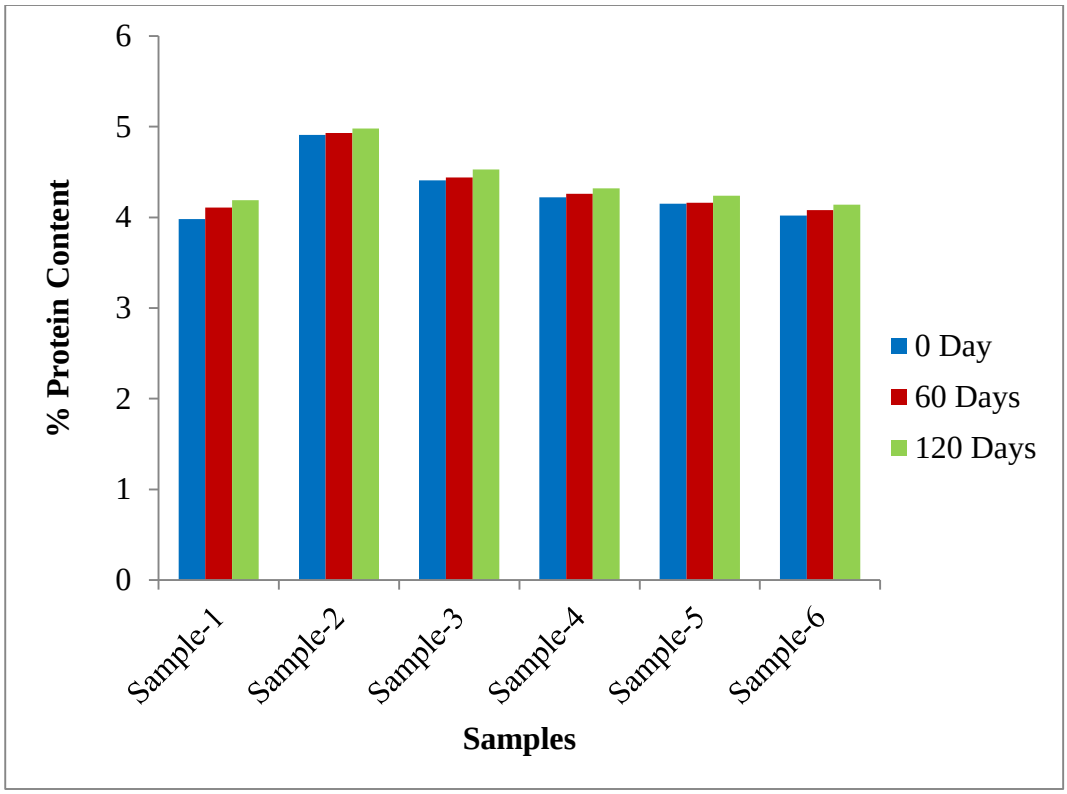


Figure 4.4: Effects of sucrose on protein content of aonla candy during storage.

4.3.5 Carbohydrate Content

The change in carbohydrate content of various treatments of aonla candy during storage is summarized in Fig. 4.5. The data revealed that the variation of carbohydrate contents of the aonla candies were statistically significant ($P < 0.05$) with respect to various concentration of sugar concentration. The carbohydrate content aonla candy on zero day ranged from 81.62 to 74.82 % being maximum in sample-3 (81.62 %) and minimum in sample-1 (74.82 %). The carbohydrate content in aonla candy increased significantly with progressive increase in storage period. After 120 days of storage, carbohydrate content of aonla candy ranged from 82.45% to 75.05 % being maximum in sample-3 (82.45 %) and minimum in sample-1 (75.05 %). Variation in carbohydrate content may be due to the compositional changes among the samples.

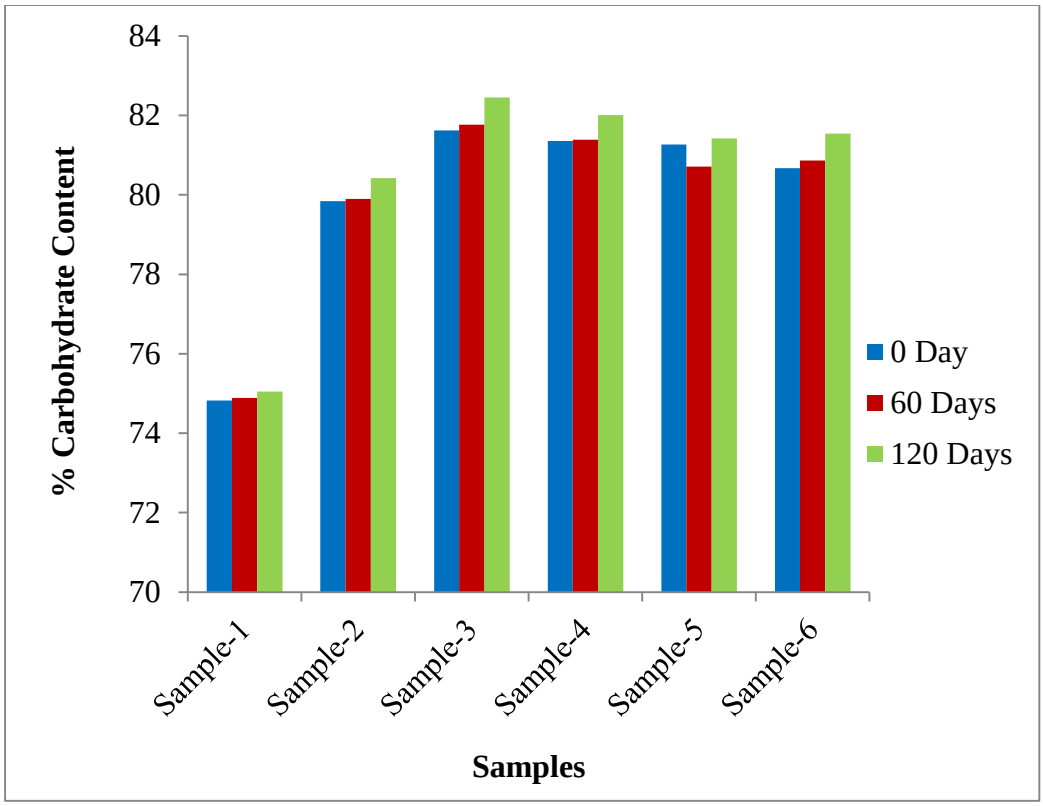


Figure 4.5: Effects of sucrose on carbohydrate content of aonla candy during storage.

4.3.6 Total Fiber Content

During storage, changes in total fiber content of aonla candy prepared with different concentration of sugar are presented in Fig. 4.6. The results showed that total fiber content varied significantly ($P < 0.05$) among the samples of aonla candy stored at ambient temperature throughout the storage period from the processing day upto 120 days of storage. The total fiber content of the of aonla candy prepared with varying concentration of sugar was ranged between 2.81 to 13.69 % on the processing day while after 120 days of storage, this content was varied between 2.71 to 13.56 %. The variation in total fiber content of aonla candy during storage may be due to the compositional difference of the samples.

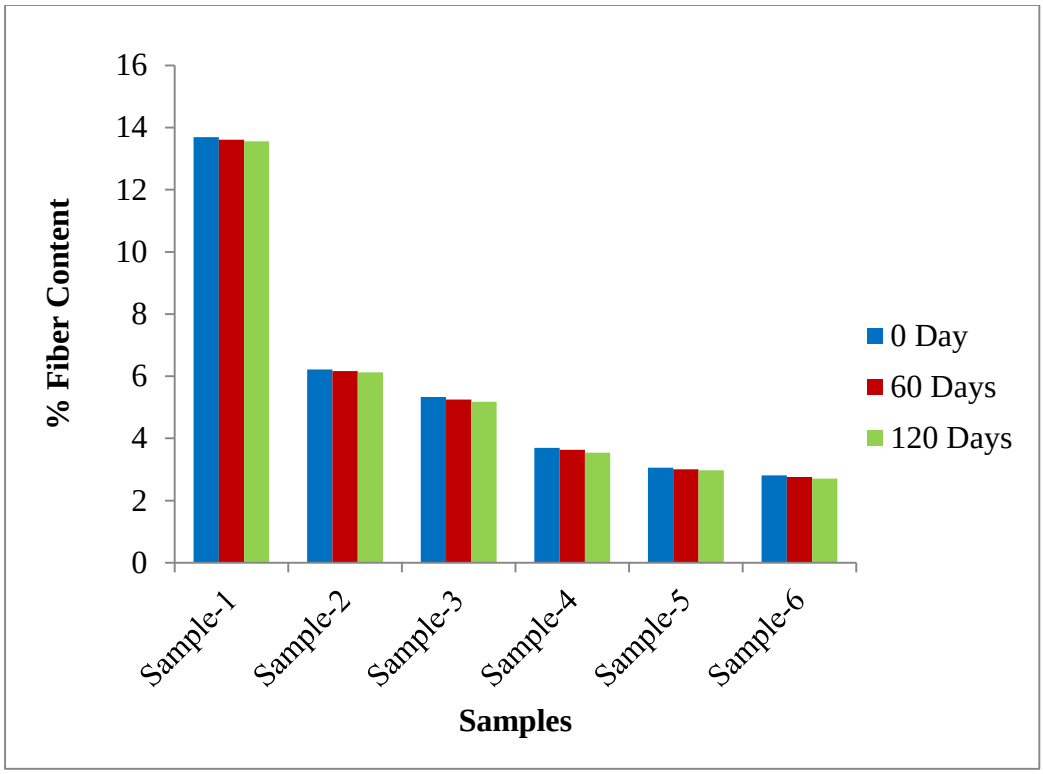


Figure 4.6: Effects of sucrose on fiber content of aonla candy during storage.

4.5 Titrable Acidity

The data with respect to effect of various sugar concentrations and storage on titratable acidity of candy prepared from aonla fruits is presented in Table 4.3. The variation of titratable acidity of aonla candy increased significantly with the progressive increase in storage time. It was varied with storage period as from initial 0. 35 - 1.75 % to final value of 0.54 – 1.81 %. There were significant differences among various sugar treatments as far as titratable acidity of aonla candy is concerned. In aonla candy, sample-1 showed maximum titratable acidity (1.75 %) with minimum value being in sample-2 (0.53 %) on the processing day while titratable acidity was maximum in sample-1 (1.81 %) and minimum in sample-2 (0.54 %) after 120 days of storage.

Acidity content did not change in the beginning of storage, there after it increased during storage. Pectic acid has been reported to increase the acidity in fruit products, hence, degradation of pectic substances into soluble solids might have contributed towards an increased in acidity of aonla products. An increase in acidity with storage period has also been

observed in aonla preserve. Similar findings were also observed by Sethi (1980); Kumar and Singh (2001) in aonla products. These results were contrary to the results obtained by Divya *et al*. (2014); Rani and Bhatia (1985); Tripathi *et al*. (1988) in which the acidity decreases with storage.

4.6 Ascorbic Acid (Vitamin C) Content

Aonla is rich in ascorbic acid content which is very sensitive and decrease with heat treatment. The change in ascorbic acid content during storage of aonla candy prepared using various concentration of sugar has been presented in Table 4.3. The data revealed that storage had significant effect on ascorbic acid content of aonla candy. A significant decrease in ascorbic acid content of aonla candy was observed with enhancement of storage period. On zero day of storage, the ascorbic acid in aonla candy ranged from 135.83 to 250.35 mg/100g being maximum of ascorbic acid (250.35 mg/100g) recorded in sample-1 with minimum value being in sample-4 (135.83 mg/100g). At the end of 120 days of storage, maximum ascorbic acid (189.77 mg/100g) was observed in aonla candy of sample-1 and it was minimum (102.11 mg/100 g) in sample-5.

The decline in ascorbic acid concentration could be due to thermal destructions during processing and subsequent oxidation during storage (Brock *et al*., 1998). Both ascorbic acid and dehydro-ascorbic acid are highly volatile and unstable forms of vitamin C (Divya *et al*., 2014). Reduction in vitamin C could be due to oxidation by trapped oxygen in the high density polythene pouch which results information of dehydro-ascorbic acid. Similar findings were also observed by Kumarand Singh (2001) and Tripathi *et al*. (1988) in aonla products.

4.7 Total Phenolic Content

The principal antioxidant constituents of natural products are phenolic compounds which composed of phenolic acids and flavonoids that are potent radical terminators (Shahidi and Wanasundara, 1992, Ghasemnezha *et al*., 2011). It is reported by Riccardo *et al*. (2012) that a strong relationship between total phenolic content and antioxidant activity in fresh fruits which have a great importance for industrial use.

There was no significant difference in total phenolic content of aonla candy prepared with varying concentration of sugar stored at ambient temperature throughout the whole storage period except sample-6 which was significantly different from others (Table 4.3). Initially, total phenolic content varied between 7.17 to 7.82 mg/100g while it was found to be in the range of 7.06 to 7.69 mg/100g towards the end of 120 days of storage. Thus it was found that total phenolic content of all aonla candy samples decreased with the advancement of storage period. Many researchers also reported that total phenolic content was decreased after drying (Wiriya *et al*., 2009, Arnnok *et al*. 2012). The decrease in total phenolic content during storage might be due to their condensation into brown pigments (Fennema, 1976; Mehta, 1995).

4.8 Sugar Content

4.8.1 Reducing Sugar Content

The data pertaining to effect of various concentrations of sugar and storage on reducing sugars of candy prepared from aonla fruits have been presented in Table 4.3. The reducing sugar of aonla candy increased significantly with increase in storage period of 120 days. The sugar treatment had significant effect on reducing sugars of aonla candy. Sample-2 showed maximum reducing sugars (38.41%) and minimum in sample-1 (22.39 %) on the processing day while at the end of 120 days of storage, maximum reducing sugar (40.77 %) was in sample-2 and minimum in sample-1 (24.16 %).

Increase in reducing sugar during storage of products is a general phenomenon as observed by many workers, Nayak *et al*. (2012) in amla candy, Vijay Jain *et al*. (2005) inamla, squash and Vanilla, Gupta *et al*. (1980) in ber candy.

Table 4.3: Effects of processing methods on functional compounds of prepared candy during storage.

Samples	Storage Period (Days)	Composition					
		Titrable Acidity (%)	Vitamin C (mg/100g)	Total Phenol (mg/100g)	Reducing Sugar (%)	Non-reducing Sugar (%)	Total Sugar (%)
Sample-1	0	1.75 ± 0.02^{a}	250.35 ± 0.33^{a}	7.49 ± 0.02^{ab}	22.39 ± 0.24^{f}	17.15 ± 0.23^{c}	39.54 ± 0.21^{f}
	60	1.76 ± 0.02^{a}	222.69 ± 0.42^{a}	7.41 ± 0.01^{ab}	23.33 ± 0.19^{f}	16.28 ± 0.17^{d}	39.61± 0.19^{d}
	120	1.81 ± 0.02^{a}	189.77 ± 0.24^{a}	7.35 ± 0.03^{ab}	24.16 ± 0.17^{f}	15.79 ± 0.21^{c}	39.95± 0.28^{d}
Sample-2	0	0.53 ± 0.01^{f}	151.05 ± 0.25^{c}	7.82 ± 0.01^{a}	38.41 ± 0.11^{a}	27.62 ± 0.16^{b}	66.03 ± 0.31^{a}
	60	0.53 ± 0.01^{f}	123.05 ± 0.26^{b}	7.73 ± 0.01^{a}	39.76 ± 0.12^{a}	27.51 ± 0.13^{b}	67.27 ± 0.33^{a}
	120	0.54± 0.01^{f}	100.67 ± 0.33^{c}	7.68 ± 0.03^{a}	40.77 ± 0.05^{a}	27.31 ± 0.18^{b}	68.08 ± 0.22^{a}
Sample-3	0	0.65 ± 0.01^{e}	142.38± 0.23^{e}	7.80 ± 0.05^{a}	36.12 ± 0.31^{b}	29.18 ± 0.22^{a}	65.30 ± 0.23^{b}
	60	0.66 ± 0.01^{e}	127.18 ± 0.20^{e}	7.74 ± 0.04^{a}	36.86± 0.46^{b}	28.91± 0.27^{a}	65.77± 0.20^{b}
	120	0.66 ± 0.01^{e}	115.66 ± 0.13^{b}	7.69 ± 0.04^{a}	37.35 ± 0.29^{b}	28.03± 0.22^{a}	65.38± 0.22^{b}
Sample-4	0	0.71 ± 0.01^{d}	135.83 ± 0.02^{d}	7.61 ± 0.01^{a}	35.63 ± 0.34^{c}	29.07 ± 0.29^{a}	64.70 ± 0.04^{c}
	60	0.72 ± 0.01^{d}	121.81 ± 0.02^{c}	7.56 ± 0.01^{a}	36.55± 0.27^{c}	28.62 ± 0.24^{a}	65.17± 0.04^{b}
	120	0.74± 0.01^{d}	109.98 ± 0.04^{c}	7.49 ± 0.01^{a}	37.21 ± 0.15^{c}	27.80 ± 0.16^{b}	65.01 ± 0.10^{b}
Sample-5	0	0.75 ± 0.01^{c}	151.22 ± 0.11^{c}	7.54 ± 0.01^{a}	34.46 ± 0.21^{d}	27.38 ± 0.34^{b}	61.84 ± 0.32^{e}
	60	0.76 ± 0.01^{c}	119.57 ± 0.15^{b}	7.49 ± 0.01^{a}	35.38 ± 0.20^{d}	26.75 ± 0.28^{b}	62.13 ± 0.28^{c}
	120	0.77± 0.01^{c}	102.11 ± 0.06^{c}	7.41 ± 0.01^{a}	36.34± 0.14^{d}	26.06 ± 0.05^{c}	62.40± 0.16^{c}
Sample-6	0	0.83 ± 0.01^{b}	175.26 ± 0.07^{b}	7.17 ± 0.25^{b}	34.33 ± 0.09^{e}	27.91 ± 0.19^{b}	62.24 ± 0.19^{d}
	60	0.84 ± 0.01^{b}	133.94 ± 0.09^{b}	7.12 ± 0.25^{b}	35.51 ± 0.02^{e}	27.05 ± 0.13^{bc}	62.56 ± 0.18^{c}
	120	0.85 ± 0.01^{b}	115.32 ± 0.06^{b}	7.06 ± 0.25^{b}	36.36± 0.05^{e}	26.61 ± 0.06^{b}	62.97± 0.13^{c}

All values are mean ± SEM of three replicates.

$^{a\text{-}f}$The test values along the same column carrying different superscripts for each composition contents are significantly different ($p < 0.05$).

Sample_1: Without sugar; **Sample_2:** 80% sugar; **Sample_3:** 70% sugar; **Sample_4:** 60% sugar; **Sample_5:** 50% sugar; **Sample_6:** 40% sugar;

4.8.2 Non-Reducing Sugar Content

The data regarding effect of various concentration of sugar and storage on non-reducing sugars of candy prepared from aonla fruits have been presented in Table 4.3. Non-reducing sugars of aonla candy decreased significantly with increase in storage period. On the processing day, maximum non-reducing sugar was observed in sample-3 (29.18 %) and minimum in sample-1 (17.15 %). On the other hand, maximum non-reducing sugar was observed in sample-3 (28.03%) and sample-1 (15.79 %)at the end of 120 days of storage.

Decrease in non-reducing sugar due to inversion of non-reducing sugar to reducing is caused by acid present in products (Divya *et al*., 2014). Enzyme (invertase) would also contribute to this in version to a little extent; the rate of inversion was rapid initially in all the products which might be due to availability of more substrate for inversion at initial stages (Jain *et al*.,1984).

4.8.3 Total Sugar Content

The data regarding effect of various concentration of sugar and storage on total sugars of candy prepared from aonla fruits have been presented in Table 4.3. The total sugars of aonla candy increased significantly with increase in storage period. Maximum total sugar was observed in sample-2 (66.03 %) and minimum in sample-1 (39.54 %) on the processing day while it was maximum in sample-2 (68.08 %) and minimum in sample-1 (39.95 %) after 120 days of storage.

Increase in total sugar content was found during storage of aonla candy which could be due to the hydrolysis of polysaccharides resulting in conversion of soluble compounds like sugars. Total sugar content of products was dependent on the total soluble solids. It was reported by Roy and Singh (1979) in squash hand nectar prepared from bael fruits. Choudary *et al*. (2006) also reported the increase in reducing and total sugar. The increased levels of total sugars were probably due to conversion of starch into simple sugars (Divya *et al*., 2014).

Table 4.4: Effects of processing methods on organoleptic quality of prepared candy during storage.

Samples	Storage Period (Days)	Sensory Attributes				
		Colour	Flavour	Texture	Taste	Overall Acceptability
Sample-1	0	8.20 ± 0.20^{e}	8.0 ± 0.20^{a}	7.60 ± 0.20^{a}	7.80 ± 0.20^{a}	7.90 ± 0.12^{d}
	60	7.80 ± 0.20^{a}	7.90 ± 0.20^{a}	7.50 ± 0.20^{a}	7.80 ± 0.20^{a}	7.75 ± 0.08^{d}
	120	7.70 ± 0.18^{a}	7.80 ± 0.20^{a}	7.40 ± 0.20^{a}	7.70 ± 0.20^{a}	7.65 ± 0.08^{e}
Sample-2	0	8.90 ± 0.21^{ab}	8.60 ± 0.16^{a}	7.90 ± 0.12^{a}	8.70 ± 0.13^{a}	8.52 ± 0.21^{a}
	60	8.80 ± 0.13^{ab}	8.40 ± 0.13^{a}	7.80 ± 0.16^{a}	8.60 ± 0.12^{a}	8.40 ± 0.21^{a}
	120	8.70 ± 0.11^{a}	8.30 ± 0.13^{a}	7.80 ± 0.13^{a}	8.60 ± 0.13^{a}	8.35 ± 0.20^{a}
Sample-3	0	8.80 ± 0.16^{b}	8.50 ± 0.23^{a}	7.90 ± 0.18^{ab}	8.70 ± 0.21^{ab}	8.47 ± 0.20^{a}
	60	8.70 ± 0.13^{b}	8.40 ± 0.16^{a}	7.80 ± 0.15^{b}	8.60 ± 0.21^{b}	8.37 ± 0.20^{a}
	120	8.60 ± 0.16^{bc}	7.90 ± 0.16^{c}	7.70 ± 0.12^{a}	8.50 ± 0.15^{b}	8.17 ± 0.22^{b}
Sample-4	0	8.70 ± 0.16bc	8.20 ± 0.13^{a}	7.70 ± 0.21^{a}	8.60 ± 0.13^{a}	8.30 ± 0.22^{ab}
	60	8.50 ± 0.13^{a}	8.10 ± 0.12^{a}	7.70 ± 0.16^{a}	8.60 ± 0.15^{a}	8.22 ± 0.20^{b}
	120	8.50 ± 0.10^{ab}	7.90 ± 0.13^{a}	7.60 ± 0.21^{a}	8.50 ± 0.17^{ab}	8.12 ± 0.22^{c}
Sample-5	0	8.60 ± 0.20^{c}	8.20 ± 0.26^{b}	7.70 ± 0.26^{b}	8.50 ± 0.22^{b}	8.25 ± 0.20^{b}
	60	8.50 ± 0.17^{ab}	7.90 ± 0.21^{b}	7.60 ± 0.21^{ab}	8.50 ± 0.20^{ab}	8.13 ± 0.22^{c}
	120	8.40 ± 0.20^{c}	7.80 ± 0.19^{b}	7.50 ± 0.13^{a}	8.40 ± 0.15^{b}	8.03 ± 0.22^{d}
Sample-6	0	8.50 ± 0.20^{d}	8.10 ± 0.20^{a}	7.60 ± 0.20^{a}	8.40 ± 0.20^{a}	8.15 ± 0.20^{c}
	60	8.40 ± 0.18^{a}	8.0 ± 0.20^{a}	7.60 ± 0.20^{a}	8.30 ± 0.20^{a}	8.08 ± 0.17^{c}
	120	8.10 ± 0.19^{a}	7.90 ± 0.20^{a}	7.50 ± 0.20^{a}	8.30 ± 0.20^{a}	7.95 ± 0.17^{d}

All values are mean ± SEM of three replicates.

$^{a\text{-}e}$The test values along the same column carrying different superscripts for each composition contents are significantly different ($p < 0.05$) within days.

Sample_1: Without sugar; **Sample_2:** 80% sugar; **Sample_3:** 70% sugar; **Sample_4:** 60% sugar; **Sample_5:** 50% sugar; **Sample_6:** 40% sugar;

4.9 Changes in Organoleptic Quality of Aonla Candy during Storage

The data with pertaining to the effect of different sugar concentration and storage on sensory scores (9-point hedonic scale) for attributes like colour, flavour, texture, taste and overall acceptability of candy prepared from aonla fruits have been presented in Table 4.4.

The mean scores for colour, flavour, texture, taste and overall acceptability of aonla candy on day zero ranged from 8.20 to 8.9, 8 to 8.6, 7.60 to 7.90, 7.80 to 8.70 and 7.90 to 8.52, respectively.

From Table 4.4 it is seen that there was a significant decrease in mean score for sensory attributes of aonla candy during four months (120 days) of storage. Sample-2 had the highest (8.35) overall acceptability score while sample-1 had lowest (7.65) score.

CHAPTER V

SUMMARY AND CONCLUSION

The present research entitled “Effects of Sucrose on the Physicochemical Properties, Organoleptic Qualities and Shelf-Life Stability of Aonla (*Emblica officinalis*) Candy” was conducted at the Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

The research was conducted with a view to find out the most suitable concentration of sugar for the preparation of aonla candy. In this research, six sets of aonla candy samples were made with varying syrup concentration (80 %, 70 %, 60 %, 50 % and 40 %) using sucrose and fresh aonla candy was used as control. The shelf-life stability of aonla candy was studied for 120 days at ambient temperature.

The results obtained from the study revealed that moisture and total fiber content of aonla candy decrease with storage time while protein, fat, ash, total carbohydrate were increased. Ascorbic acid and total phenol content was found to decrease with increasing storage period. However, sufficient amount of ascorbic acid was retained in all samples. Titrable acidity was increased with progressive increase of storage. Reducing sugar and total sugar were found to increase while non-reducing sugar decreased with the advancement of storage time. Almost all samples had good sensory acceptance towards potential customers in terms of colour, flavour, texture, taste and overall acceptability.

On the basis of the results obtained in the present investigation, it can be drawn that application various concentration of sugar syrup significantly affect the quality parameters of aonla candy like moisture, fat, protein, ash, fiber, carbohydrate, ascorbic acid acidity, total sugars phenolic contents and sensory attributes.

Although the present research tried to maintain a sound methodology and analysis of data, it is not free from limitations as we only used sucrose syrup. Therefore, the present study paved the ways for further research supplemented with others treatments to improve the quality of aonla candy during storage at different conditions.

For this present study it may be concluded that:

- Sample prepared using 80% of sucrose with 120 days of storage and 70% of sucrose with 120 days of storage has produced the highest protein and carbohydrate, respectively.
- According to the moisture content, fat, ash and total fiber, without sucrose yielded the highest amount.
- Irrespective of composition, the highest functional compounds such as titrable acidity and vitamin C were found in fresh aonla candy (control) and the highest total phenol, reducing sugar and total sugar were obtained from 80% of sucrose.
- In terms of organoleptic quality, the highest colour, flavour, texture, test and overall acceptability was rated in 80% of sucrose with zero-day storage.

So it may be recommended to the producers to use 80% of sucrose with storage of 120 days. This study will help the food producer or the confectionary manufacturer to select the appropriate concentration of sugar solution for making aonla candy and at the same time consumers can reduce the spoilage of aonla by preserving them through making aonla candy, which is nutritious.

REFERENCES

A.O.A.C. (2000). Official Methods of Analysis. Association of Official Analytical Chemists.17th edn. U.S.A: Gaithersburg.

Agarwal, S. and Chopra, C.S. (2004). Studies on changes in ascorbic acid and total phenol in making aonla products. *Beverage & Food World* 31(5): 32-34.

Alam M.S. and Singh A. (2010). Optimization of osmotic dehydration process of aonla fruit in salt solution. *International Journal of Food Engineering*, 6(1): 4-24.

Anand, J. C. (1970). Retention of added Vitamin C in amla preserves. *Indian Food Packer* 24 (5): 19-20.

Anonymous (1988). Annual Report, AICRP (All India Coordinated Research Project) on arid fruits, *Technical Document No.* 18.

Arnnok, P., Ruangviriyachai, C., Mahachai, R., Techawongstien, S., and Chanthai, S. Determination of total phenolics and anthocyanin contents in the pericarp of hot chilli pepper (*Capsicum annuum* L.). *International Food Research Journal* (2012). 19, 235-243.

Baileri, L.H (1917). The standard encyclopedia of Horticulture, The Mac Million Co., London.

Baliga, M.S., and Dsouza, J. J. (2011). Amla (*Emblica officinalis Gaertn*), a wonder berry in the treatment and prevention of cancer. *European Journal of Cancer Prevention: The Official Journal of the European Cancer Prevention Organisation (ECP),* 20, 225–239.

Barthakur, N.N. and Arnold, N.P. (1991). Chemical analysis of emblica (*Phylanthus emblica* L.) and its potential as a food source. *Science. Horticlture.*, 47: 99-105.

Belitz, H. and Grosch, W. (1999): Vitamins. Food Chemistry (pp. 383−387). (2nd ed.).

Bergara-Almeida, S., Aparecida, M. and Da Silva, A.P. (2002). Hedonic Scale with Reference: Performance in Obtaining Predictive Models. *Food Quality. Preference*. 13, 57–64.

Bring, S., Hofstrand, J. and Willard, M.J. (1964) Total Ascorbic Acid in Potatoes raw, fresh mashed and reconstituted granules. *Journal America. Dieted Association*. 45: 149.

Brock, V.D., Ludikhuyze, L., Weemaes, C., Van, L.A. and Hendrickx, M. (1998), Kinetics forisoberic isothermal degradation of L-Ascorbic acid. *Journal Agriculture Food Chemistry*., 46(5): 2001-2006.

Chandu, N. and Prasad, M. (2006). Development of guava candies. *Journal Food Science Technology*, 43:210–212.

Chauhan, O. P.; Shrivastava, S; Pandey, P. and Rai, G. K. (2005). A study on the development of aonla blended sauce. *Beverage Food World*, 32 (5): 31-32.

Choudary, MadanLal, S.N. Dikshit and Sharma, H.G. (2006), Studies on preparation and biochemical changes in guava RTS beverage storage. *Indian Journal Arid Horticulture*, 1 (1): 78-79.

Cooke, J. and Moxon, R. (1981). Detection and measurement of vitamin C. *International Journal Counsell*, 167-168

Dahiya, S.P. and Dhawan, S.S. (2001). Physicochemical characteristics of aonla (*Emblica officinalis* Garten.) cv. Chakaiya. *Beverage & Food World*, 54(3): 133-136.

Dar, B.N., Ahsan, H., Wani, S.M. and Dala, M.R. (2011). Effect of $CaCl_2$, citric acid and storage period on physicochemical characteristics of cherry candy. *Journal of Food Science and Engineering*, 1:154-160

Devi, S. and Mishra, P. (2009). Development of amla candy. *Beverage and Food World*, 36(9): 43-44.

Divya, A. R., Jayashree, S., and Bhogi, B. (2014). Effect of Storage Methods on the Nutritional Quality of Sapota Candy. *Asian Journal of Dairy & Food Research*, 104–108.

Durrani, A.M. and Verma, S. (2011). Preparation and quality evaluation of honey amla murrabba.

Esteve, M.J., Farré, R., Frigola, A. and Garcia-Cantabella, J.M. (1997): Determination of ascorbic and dehydroascorbic acids in blood plasma and serum by liquid chromatography. *Journal of Chromatography B: Biomedical Sciences and Applications*, 688 345−349.

Fenemma, O.R. (1976). *Priniciples of Food Science. Part-I. Food Chemistry.* Marcel Dekker Inc., New York and Basel, pp. 80-81.

Fujii, T., Wakaizumi, M., Ikami, T., and Saito, M. (2008). Amla (*Emblica officinalis Gaertn*.) extract promotes procollagen production and inhibits matrix metalloproteinase-1 in human skin fibroblasts. *Journal of Ethnopharmacology*, *119*(1), 53–57.

Ganachari, A., Thangavel, K., Mazara ali, S., Nidoni, U. and Ananthacharya. (2010). Physical propertiesof Aonla fruit relevant to the design of processing equipments. *International Journal ofEngineering Science and Technology*, 2(12): 7562-7566.

Geetha, N.S., Kumar, S. and Garg, M.K. (2005). Osmotic concentration kinetics of aonla preserve. 32th *Annual Convention of Indian Society of Agricultural Engineers*. 39: 278.

Ghasemnezha, M., Sherafati, M. and Payvast, G. A. (2011). Variation in phenolic compounds, ascorbic acid an antioxidant activity of five coloured bell pepper (*Capsicum annum*) fruits at two different harvest times. *Journal of Functional Food*, 3, 44-49.

Ghorai, K. and Sethi, V. (1996). Varietal suitability of amla (Desi and Banarasi) fruits for storage and preservation. *Indian Food Packer*, 50(1): 11-18.

Giannakourou, M.C. and Taoukis, P.S. (2003): Kinetic modeling of vitamin C loss in frozen green vegetables under variable storage conditions. *Food Chemistry*, 83: 1, 33-41.

Gomez, S. and Khurdiya, D.S. (2005). Quality changes in aonla pulp under different storage conditions. *Indian Food Packer* 59(4): 54-57.

Gopalan, C., Ramasastry, B.V. and Balasubramanian, S.C. (1996). *Nutritive value of Indian Foods*, National Institute of Nutrition, Hyderabad, India, p. 63.

Goyal, R.K., Patil, R.T., Kingsly, A.R.P., Walia, H. and Kumar, P. (2008). Status of post-harvest technology of aonla-A review.*American Journal of Food Technology*, 3(1): 13-23.

Gupta, O.P., Kainsa, R.L. and Chauhan, (1980), Post-harvest studies on ber fruits and preparation of candy. Haryana agric. Univ. J. Res., 10(2): 163-165.

Haque, M.A. (1995): Phul-Shobjir Chash O PustiPorichiti (In Bengali). *Department of Agricultural Extension, Khamarbari, KrishiKhamarSarak,* Dhaka-15. pp. 34.

Hasanuzzaman, M., Kamruzzaman, M., Islam, M.M., Khanom, S.A.A., Rahman, M.M., Lisa, L.A. and Paul, D.K. (2014) A Study on Tomato Candy Prepared by Dehydration Technique Using Different Sugar Solutions. *Food and Nutrition Sciences*, 5:1261-1271.

Hertog, M.G.L., Hollman, P.C.H. and Katan, M.B. (1992). Contents of potentially anticarcinogenic flavonoids of 28 vegetables and 9 fruits commonly consumed in the Netherlands. *Journal of Agricultural and Food Chemistry*; 45:1152–55

Hooker, J.D. (1973). The Book of Flora of British India. Vol. VI. 1st Indian Reprint, Periodical Experts, Delhi.

Jain, S.P., Tripati, V.K. and Ram, H.B., (1984). Studies on storage behaviour of orange, lemon and bael squashes. *Indian Food Packer,* 38(5): 33-39.

Johnson, J.R., Braddock, R.J. and Chen, C.S. (1995): Kinetics of ascorbic acid loss and nonenzymatic browning in orange juice serum: Experimental rate constants. *Journal of Food Science*, 60(3) 502−505

Kalra, C.L. (1988). The chemistry and technology of amla (*Phyllanthus emblica*)- a resume. *Indian Food Packer,* 42(4): 67-82.

Kocher, G. S., Dhillon, H. K., Bakshi, D. K., and Arora, J. K. (2013). Development of a fermentation process for utilization of *Emblica officinalis Gaertn* (amla) candy waste for production of natural vinegar. *Current Nutrition and Food Science*, *9*(4): 310–314.

Kumar, S. and Singh, I.S. (2001). Storage studies of aonla fruit products at ambient temperature. *Horticulture Programming,* 33(2): 169-173.

Lal, G. (2006). Studies on the effect of sugar and citric acid treatment on quality attributes of aonla syrup during storage. *Program Horticulture,* 38(1):109-13.

Mehra, S. K. (2008). Evaluation of aonla (*Emblica officinalis* Gaertn.) varieties for chavyanprash processing. M.Sc. thesis submitted to N.A.U., Navsari.

Mehta, S. (1995). Evaluation of different cultivars of aonla *(Emblica officinalis Garten)*) for processing. M.Sc. Thesis. Chaudhary Charan Singh Haryana Agricultural University. Hisar.

Mehta, A., Ranote, P.S. and Bawa, A.S. (2005). Processing of kandi lemon (Galgal) peel waste candy making. *Indian Food Packer,* 59(1&2): 67-74.

Mehta, G. L. and Tomar, M. C. (1979). Studies on simplification of preserve making II. Amla (*Phyllanthus emblica* L.) *Indian Food Packer,* 33 (5): 27-30.

Mehta, U. and Bajaj, S. (1984). Changes in the chemical composition and organoleptic quality of citrus peel candy during preparation and storage. *Journal Food Science Technology,* 21:422–424.

Mishra, S., Verma, A., Prasad, V.M. and Sheikh, S. (2011). Development of value added amla candy with rose extract. *The Allahabad Farmer,* 66(2): 134-136.

Naik, A. G. and Chundawat B. S. (1996). Storage behavior of various Aonla products made from 'Gujarat Amla'-1 variety. *Journal Applied Horticulture.*, 2 (1&2): 40-43.

Nath, V. (1999). Delicacies of aonla, *Indian Horticulture*, 44 (3): 15.

Nayak, P., Bhatt, D.K., Shukla, D.K. and Tandon, D.K. (2011). Evaluation of aonla (*Emblica Officinalis* G.) segments-in-syrup prepared from stored fruits. *Research. Journal. Agriculture Science*., 43(2).

Nayak, P., Tandon, D.K. and Bhatt, D.K. (2012). Study on changes of nutritional and organoleptic quality of flavored candy prepared from aonla (*Emblica officinalis* G.) during storage. *International Journal of Nutrition and Metabolism*, 4(7):100-106.

Nisha, P., Ali, R.S. and Pandit AB (2004): A study on degradation kinetics of ascorbic acid in amla (*Phyllanthus emblica L.*) during cooking. *International Journal of Food Sciences and Nutrition*, 55 415−422.

Pareek, S. and Kaushik, R.A. (2012). Effect of drying methods on quality of Indian gooseberry (*Emblica officinalis* Gaertn.) powder during storage. *Journal of Scientific and Industrial Research*, 71(11): 727-732.

Pathak, R.K., Pandey, D., Hasseb, M., Tandon, D.K. and Mishra, A.K. (2002). Aonla. CISH, Lucknow, P. 36.

Pawar, M. B. (2010). Evaluation of different aonla (*Emblica officinalis* Gaertn.) varieties for osmodehydrated candy product processing. M.Sc. thesis submitted to N.A.U., Navsari.

Pearson, D. (1970). "The Chemical Analysis of Foods" (Seventh Edn.). Churchill Lavingstone, New York.

Pokharkar, S.M. (2005). Development and performance evaluation of aonla shredding machine.*Beverage & Food World* 32(3): 52-53.

Premi, B.R., Sethi, V. and Maini, S.B. (1999). Effect of steeping preservation on the quality of aonla (*Emblica of ficinalis* Gaertn.) fruits during storage. *Journal of Food Science and Technology*, 36(3): 244-247.

Priya, M.D. and Khatkar, B.S. (2013). Effect of processing methods on keeping quality of aonla (*Emblica officinalis* Gaertn.) preserve. *International Food Research Journal*, 20(2): 617-622.

Rajkumar, N.V., Theres, M. and Kuttan, R. (2001). *Emblica officinalis* fruits afford protection against experimental gastric ulcers in rats. *Pharmaceutical Biology*, 39(5): 375-380.

Ram, S. (1983). Aonla (*Emblica officinalis* Gaertn.). Aonla Bulletin, Directorate of Extension, GB Pant University of Agriculture and Technology, Pant Nagar, Nainital.

Ranganna, S. (1992). "Hand Book of Analysis of Fruit and Vegetable Products". Tata Mc Grow Hill Co. Ltd. New Delhi. 30 pp.

Ranganna, S. (2002) Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw- Hill, New Delhi.

Rani, U. and Bhatia, B.S. (1985). Studies on pear candy processing. *Indian Food Packer*, 29(4) 40-46.

Ray, N.R., Kikani, K.P., Patel, K.M. and Patel, R.B. (2006). Value added product of aonla "Sweet aonla candy" cv. 'Gujarataonla-1'. Paper presented in National seminar on production and processing of aonla (*Emblica officinalis* G.), pp. 24, held at AAU, Anand, Gujarat.

Ribeiro, M.S. and Sabaa-Srur, A.U.O. (1999). Mango (*Mangifera indica* L.) cv. 'Rosa Saturation' with sugars. Cien Technol Aliment; 19:118–122.

Riccardo, N. Barbagalloa, Chisari, M. and C. Patané. (2012). Polyphenol oxidase, total phenolics and ascorbic acid changes during storage of minimally processed California Wonderan Quadratod Asti sweet peppers, *food sciences and technology,* 49(2), 192–196.

Roy, S.K. and Singh, R.N. (1979).Bael fruit (*Aegle marmelus*). *A potential fruit for processing.Economic Botany,* 33(2):203-212.

Sagar, V.R. and Kumar R. (2006). Preparation and storage of ready-to-eat dehydrated gooseberry (aonla) shreds. *Journal of Food Science and Technology*, 43(4): 349- 352.

Satbhai, R. D. and Masalkar, S. D. (2006). Extention of shelf life of ready-to-serve beverage of aonla. *Paper presented in National seminar on production and processing of aonla* (*Emblicaofficinalis G.*), pp. 33,

Sethi, V. (1980). Studies on preparation and storage of some semi dry preserve (Murrabba), Ph.D.Thesis, *Indian Agricultural Research Institute*, New Delhi, India.

Shadidi, F. and Nazck M. F. (1995). Food phenolic sources chemistry effects applications. Lancaster-Basel: Technomic Publishing Company.

Shahidi, F. and Wanasundara, P.K.J.P.D. (1992). Phenolic antioxidants. *Critical Review Food Science Nutrition*, 32, 67-103.

Sharma, S., Dhaliwal, Y.S. and Kalia, M. (1998). Candied apple: a new perspective. *Journal Food Science Technology*, 35:79–82.

Sharma, S.S., Sharma, R.K. and Yamdagni, R. (1989). Studies on the yield and quality of fruit of aonla cultivars (*Emblica officinalis* Gaertn.) under rain fed condition of Haryana. *Research Development Department,* 6(1): 41-43.

Shrivastava, R.P. and Sanjeev Kumar. (1994). Fruit and Vegetable Preservation Principle andPractices. International Book Distributing Company, Lucknow.229-232 pp.

Singh, N., Saini, A. and Gupta A.K. (2007). Nutritional quality of osmotically dehydrated aonla (*emblica Officinalis*), fruit segment. *Indian Journal of Agricultural Biochemistry*, 20(2): 89-91.

Singh, S., Singh, A.K. and Joshi, H.K. (2006). Standardization of maturity indices in Indian gooseberry (*Emblica officinalis Gaertn*) under semi-arid conditions of Gujarat. *Indian Journal Agriculture Science,* 76:591–595.

Singh, B., Panesar, P.S. and Nanda, V. (2008). Osmotic dehydration kinetics of carrot cubes in sodium chloride solution. *International Journal of Food Science and Technology*, 43(8): 1361-1370.

Singh, B.P., Pandey, G., Pandey, M.K. and Pathak, R.K. (2005). Shelf life evaluation of aonla cultivars. *Indian Journal of Horticulture,* 62(2): 137-140.

Singh, B.P., Singh, I.P., Singh, S.P. and Kumar, K.A. (1987). Physicochemical composition of different cultivars of aonla. *Indian Food Packer,* 41(2): 7-10.

Singh, D; Mathur, A. K; Prahalad, V. C. and Wangchu, L. (2006). Processing and value addition in Indian gooseberry (*Emblica officinalis* G). *Paper presented in National seminar on production and processing of aonla* (*Emblica officinalis G.*), pp. 25, held at AAU, Ananad, Gujarat.

Singh, I.S. (1982). Techno-economic aspects of fruit beverage industry. Paper presented at national seminar on strategy to meet the challenges of rural unemployment and underemployment, Allahabad, pp. 22-23.

Singh, I.S. and Pathak, R.K. (1987). Evaluation of aonla (*Emblicao fficinalis* Gaertn.) varieties for processing. *ActaHorticulturae*208(1): 173-177.

Singh, I.S., Pathak, R.K., Dwivedi, R. and Singh, H.K. (1993). Aonla production and post-harvest technology. Technolgy. Bulletin, Narendra Deva Univiversity. Agriculture and Technology, Kumarganj, Faizabad.

Singh, J., Joon, M.S. and Daulta, B.S. (1984). A note on physico-chemical characteristics of fruit in two cultivars of aonla (*Phyllanthus emblica* Linn.). *Haryana Journal of Horticulture Sciences* 13(3&4): 133-34.

Singh, J., Koul, R., Bhat, A., Sood, M. and Bandral, J.D. (2012). Comparative studies on compositional changes in aonlasupari (*Emblica officinalis*) during storage. *Annals of Food Science and Technology* 13(1): 19-24.

Singh, R. and Kumar, S. (2000). Studies on the effect of post-harvest treatments on decay loss and biochemical changes during storage of aonla (*Emblica officinalis* G.) fruit cv. Chakaiya. Haryana *Journal of Horticultural Sciences* 29 (3): 178-179.

Singh, S.; Parmar B. R.; Bhalerao, M. P.; Ahir M. P. and Tank R. V. (2010). Influence of pre-drying treatments and drying methods on bio- chemical properties of different recipes of aonla (*Emblica officinalis* Garrtn.) Product preparation. *The Asian Journal. Horticulture.*, 5(1): 199-202.

Singh, V; Singh, H. K. and Chopra, C. S. (2005). Studies on processing of aonla fruits. *Beverage Food World*, 32 (12): 50-52.

Slinkard, K. and Singleton, V.L. (1977). Total phenol analyses: automation and comparison with manual methods. *American Journal of Enology and Viticulture*. 28: 49-55.

Srivasuki, K.P. (2012): Nutritional and healh care benefits of Amla. *Journal of Pharmacognosy 3(2)* pp.147-151.

Taeotia, S.S., Singh, D.B., Singh, R.D. and Singh, R.N. (1968). Studies on some important varieties of aonla (*Phyllanthus Emblica* L.) of eastrn UP. *The Punjab Horticulture Journal* 8: 241-244.

Tandon, D.K., Dikshit, A. and Kumar, S. (2005). Development of churan from dried aonla powder. *Beverage Food World*, 32 (12): 53-54.

Tandon, D.K., Yadav, R.C., Sood, S., Kumar, S. and Dikshit, A. (2003). Effect of Blanching and lye- peeling on the quality of aonla candy. *Indian Food Packer* 57(6): 147-152.

Tiwari, S.; Chopra, C. S. and Santosh, K. (2005). Studies on preservation of aonla (*Emblicaofficinalis*Gaertn.) fruit pulp. *Beverage Food World,* 32 (12): 21-23.

Tripathi, V.K., Singh, M.B. and Singh, S. (1988). Studies on comparative compositional changes in different preseved products of Aonla (*Emblica Officinalis* Gaertn.) var. Banarasi. *Indian Food Packer* 42(4): 60-66.

Verma, R., Kalia, M. and Sharma, H.R. (2006). Effect of method of preparation and storage on the chemical characteristics of peel candy of Darunj (*Citrus medica*). *Journal of Dairying Foods* 25(2): 113-116.

Vieira, M.C., Teixeira, A.A. and Silva, C.L.M. (2000): Mathematical modeling of the thermal degradation kinetics of vitaminC in cupuaçu (Theobromagrandiflorum) nectar. *Journal of Food Engineering* 43 1−7.

Vijay, J., Prabhakar, S. and Singh, A.K. (2005), Screening of aonla cultivars for making squash. *Indian Journal. Arid Horticulture*., 1(1): 44-46.

Vijaykumar, T. K., Lembisana, H.D.E.V.I. and KABIR, J. (2013). Packaging, storage and value addition of aonla, an underutilized fruit, in India. Fruits, 2013, vol. 68, p. 255–266.

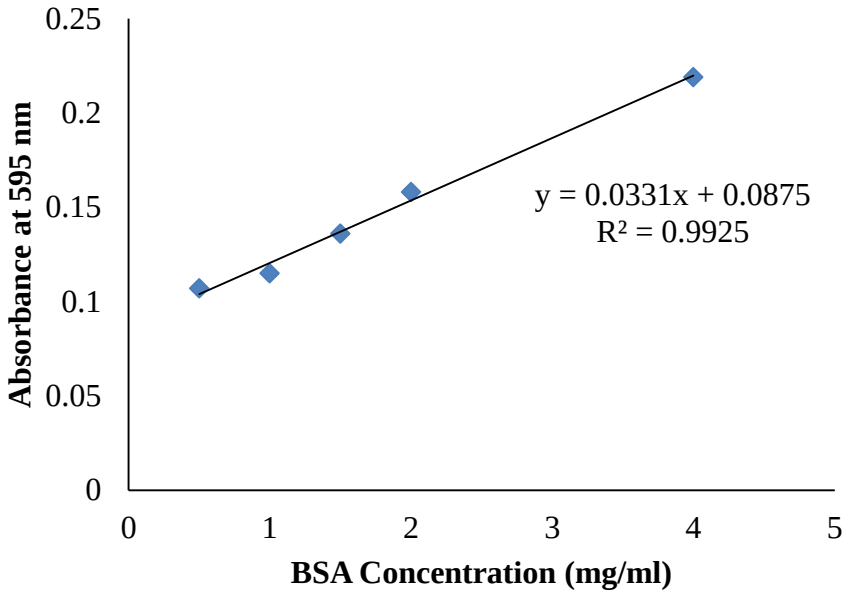
Vikram, B., Prasad, V.M. and Saroj, P.L. (2014). Comparative study of varieties, honey coating and storage durations on aonla candy. *Indian Journal Horticulture*. 71(1): 104-108.

Vikram, V.B., Ramesh, M.N. and Prapull, S.G.F.Y. (2005): Thermal degradation kinetics of nutrients in orange juice heated by electromagnetic and conventional methods. *Journal of Food Engineering* 69 31−40.

Wiriya, P., Paiboon, T., and Somchart, S. (2009). Effect of drying air temperature and chemical pretreatments on quality of dried chilli. *International Food Research Journal*, 16, 441-454.

APPENDICES

Appendix I. Bovine Serum Albumin (BSA) standard curve for estimation of protein.



Appendix II. Gallic Acid (GA) standard curve for estimation of total phenolic content