DEVELOPMENT OF PROTOCOL FOR SPICED DEHYDRATED *AONLA* (*Phyllanthus emblica* L.) SEGMENTS

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By

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Affectionately

Dedicated to Almighty

My beloved Parents

JAYARAJAN, O. R.,

SUJATHA, M. R.

& My Guide

Dr. R.B. TIWARI

DEPARTMENT OF POSTHARVEST TECHNOLOGY
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CERTIFICATE

This is to certify that the thesis entitled "**DEVELOPMENT OF PROTOCOL FOR SPICED DEHYDRATED *AONLA* (*Phyllanthus emblica* L.) SEGMENTS** " submitted by **Ms. SUJAYASREE, O.J., ID No: UHS14PGM533**, in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (Horticulture)** in **POSTHARVEST TECHNOLOGY** to the University of Horticultural Sciences, Bagalkot, is a record of *bona-fide* research work carried out by her during the period of her study in this University, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar titles.

Bengaluru**,**

July, 2016

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DEVELOPMENT OF PROTOCOL FOR SPICED DEHYDRATED *AONLA* (*Phyllanthus emblica* L.) SEGMENTS

SUJAYASREE.O.J

ABSTRACT

The Indian gooseberry (*Phyllanthus emblica* L.), is a sub-tropical deciduous tree with very high ascorbic acid, polyphenols contents and antioxidant properties. The fresh fruits are not popular as a table fruit due to their high astringency and its storability is limited due to its perishability. Among different dehydration techniques, osmotic dehydration has potential to retain better colour, texture, flavour, nutrients, prevention of microbial spoilage and ensure its availability round the year. The objective of this work was to standardize the processing procedure, evaluate the physico-chemical, sensory, packaging and storage qualities by using Krishna variety. One set of blanched segments and another set of blanched-frozen segments were subjected to osmotic treatment in 60° Brix sugar syrup with three varied spice levels and slice to sugar syrup ratio of 1:2 (W/V) for 24 hrs and 4 hrs respectively followed by draining, drying for comparison in hot air oven and solar drier and packing in air-tight punnet boxes gave best quality product at room temperature with a shelf life of four months. Ascorbic acid content was higher in cabinet dried samples than solar dried samples with a mean value ranged from 95.64 to 179.97 mg/ 100 g. Treatment T_6 showed superiority because of improvement in its microstructure by freezing which enhanced its texture and also the use of spice level-1 which contain 10 ml/ l of ginger extract + Black pepper 1 % + Cumin 5 % + Salt 2 % which given a mild flavour of these spices along with aonla flavour.

SUJAYASREE, O.J.	**R.B.TIWARI**
(Signature of student)	(Signature of Major Advisor)

ಮಸಾಲೆಯೊಂದಿಗೆ ಶುಷ್ಕಗೊಳಿಸಿದ ಬೆಟ್ಟದ ನೆಲ್ಲಿಯ (ಫಿಲ್ಲಾಂಥಸ್ ಎಂಬ್ಲಿಕಾ ಎಲ್.) ತುಣಕುಗಳಿಗೆ ಮಾರ್ಗಸೂಚಿಯ ಬೆಳವಣಿಗೆ

ಸುಜಯಶ್ರೀ ಒ.ಜೆ

ಸಾರಾಂಶ

ಭಾರತೀಯ ನೆಲ್ಲಿಕಾಯಿಯ, ಸಮಶೀತೋಷ್ಣ ವಲಯದಲ್ಲಿ ಬೆಳೆಯುವಂತಾಗಿದ್ದು ಅದರಲ್ಲಿ ಲಭ್ಯವಿರುವ ಹೆಚ್ಚಿನ ಪ್ರಮಾಣದ ವಿಟಮಿನ್, ಪಾಲಿಪಿನಾಲ್ಸ್ ಮತ್ತು ಆ್ಯಂಟಿ ಆಕ್ಸಿಡೆಂಟ್ಗಳಿಂದಾಗಿ ಪೋಷಕಾಂಶಗಳು ಮತ್ತು ಔಷದೀಯಗಳನ್ನು ಹೊಂದಿದ್ದು ಬಹು ಉಪಯೋಗಿಯಾಗಿರುತ್ತದೆ. ಹಸಿ ನೆಲ್ಲಿಕಾಯಿಗಳು ಅದರಲ್ಲಿನ ಹೆಚ್ಚಿನ ಒಗರುವಿನಿಂದ ಹಸಿಯಾಗಿ ತಿನ್ನಲು ಸೂಕ್ತವಾಗಿರುವುದಿಲ್ಲ ಮತ್ತು ಹೆಚ್ಚು ದಿನಗಳ ಕಾಲ ಸಂಗ್ರಹಿಸಿಡುವುದು ಕಷ್ಟಕರವಾಗಿರುತ್ತದೆ. ನೆಲ್ಲಿಕಾಯಿಗಳನ್ನು ಒಣಗಿಸಿ ಸಂಗ್ರಹಣೆ ಮಾಡುವುದರಿಂದ ವರ್ಷದ ಎಲ್ಲಾ ಕಾಲದಲ್ಲೂ ಲಭ್ಯವಾಗುವಂತೆ ನೋಡಿಕೊಳ್ಳಬಹುದು. ಇತ್ತೀಚಿನ ದಿನಗಳಲ್ಲಿ ಆಸ್ಮಾಟಿಕ್ – ತಂತ್ರಜ್ಞಾನ ಬಳಸಿ ಒಣಗಿಸುವಿಕೆಯು ಹೆಚ್ಚು ಪ್ರಚರಿತವಾಗುತ್ತಿದ್ದು, ಹಣ್ಣಿನ ಗುಣ ವಿಶೇಷಗಳನ್ನು ಉಳಿಸಿಕೊಳ್ಳಬಹುದಾಗಿರುತ್ತದೆ. ಈ ಸಂಶೋಧನೆಯ ಮುಖ್ಯ ಉದ್ದೇಶವು ಕೃಷ್ಣ ತಳಿಯ ನೆಲ್ಲಿಕಾಯಿಗಳನ್ನು ಸಂಸ್ಕರಿಸಿ ಒಣಗಿಸುವ ತಂತ್ರಜ್ಞಾನವನ್ನು ಉತ್ತಮಗೊಳಿಸುವುದರ ಜೊತೆಗೆ ಸೂಕ್ತ ಪ್ಯಾಕಿಂಗ್ ಮತ್ತು ಸಂಗ್ರಹಿಸಿದ ಸಮಯದಲ್ಲಿ ಒಣ ಪದಾರ್ಥದ ಗುಣ ೩ ವಿದದ ಮಸಾಲೆ ಪದಾರ್ಥಗಳನ್ನು ಉಪಯೋಗಿಸಿದರೆ ಇನ್ನೊಂದು ವಿದಾನದಲ್ಲಿ ಪ್ರೀಜ್ ಮಾಡಿದ ನೆಲ್ಲಿಕಾಯಿ ಹೋಳುಗಳನ್ನು ೩ ವಿದದ ಮಸಾಲೆಗಳನ್ನು ಉಪಯೋಗಿಸಲಾಯಿತು. ಅಂತಿಮ ಹಂತದ ಒಣಗಿಸಲು ಕರೆಂಟ್ ಡ್ರೈಯರ್ ಅಥವಾ ಸೋಲಾರ್ ಡ್ರೈಯರ್ ಬಳಸಲಾಯಿತು. ಒಣಗಿದ ಪದಾರ್ಥಗಳನ್ನು ಪ್ರೀಜ್ ಮಾಡಿ, ಆಸ್ಮೋಸಿಸ್ ಮಾಡಿದ ಹಾಗೂ ಮಸಾಲೆ ಪದಾರ್ಥಗಳಾದ ಶುಂಠಿ ರಾಸಾಯನಿಕ (೧೦ ಮಿ. ಲೀ / ಲೀಟರ್), ಕಪ್ಪು ಮೆಣಸು (೧%), ಜೀರಿಗೆ (೧ %) + ಉಪ್ಪು (೨ %) ನ್ನು ಸಕ್ಕರೆ ಪಾಕದಲ್ಲಿ ಉಪಯೋಗಿಸಿದ ಹಾಗೂ ಗಾಳಿಯಾಡದಂತಹ ಡಬ್ಬಗಳಲ್ಲಿ ಪ್ಯಾಕ್ ಹೊಂದಿದ್ದು ೪ ತಿಂಗಳುಗಳ ಕಾಲ ಕೆಡದಂತೆ ಶೇಖರಿಸಿಡ ಬಹುದಾಗಿರುತ್ತದೆ.

ಸುಜಯಶ್ರೀ	**ಆರ್.ಬಿ. ತಿವಾರಿ**
(ವಿದ್ಯಾರ್ಥಿಯ ಸಹಿ)	**(ಮಾರ್ಗದರ್ಶಕರ ಸಹಿ)**

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I. INTRODUCTION

The Indian gooseberry (*Emblica officinalis* Gaertn. or *Phyllanthus emblica* L.), is a sub-tropical deciduous tree belonging to the family Euphorbiaceae. It is nutritionally and medicinally important due to its very high ascorbic acid and polyphenols contents and antioxidant properties (Kalra, 1988). *Aonla* is an important fruit crop indigenous to Indian sub-continent, which can be grown successfully in dry and neglected regions. It is a hardy plant which grows without much care and hence its cultivation is ideally suitable for dry regions (Singh *et al*., 1963). The area under *aonla* has been expanding rapidly in the last couple of years especially in South Indian states. *Aonla* is one of the oldest Indian fruits and considered as "*Wonder fruit for health*" because of its unique qualities.

The proximate composition of *aonla* fruit are 89 to 94 per cent pulp, 0.8 to 2 per cent fiber, 10 to 14 per cent total soluble solids, 1.4 to 2.4 per cent acidity, 370 to 500 mg /100 g vitamin C, 2.4 to 3.1 per cent pectin and 2 to 3 per cent phenols (Singh *et al.,* 1993). *Aonla* is indeed, the key ingredient in the popular ayurvedic recipe, *Chyavanaprasha.* More than anything, it may be called as "King of *Rasayana*" [rejuvenation], owing to its multiple health benefits (Singh *et al*., 2011).

It is one of the oldest oriental medicines mentioned in Ayurveda as potential remedy for various ailments. The fruit is rich in quercetin, phyllaemblic compounds, gallic acid, tannins, flavonoids, pectin, and vitamin C and also contains various polyphenolic compounds. A wide range of phytochemical components including terpenoids, alkaloids, flavonoids, and tannins have been shown to possess useful biological activities. Many pharmacological studies have demonstrated the ability of the fruit to comprise antioxidant, anticarcinogenic, antitumour, antigenotoxic, antiinflammatory activities, supporting its traditional uses (Krishnaveni and Mirunalini, 2011).

Recently, the cultivation of *aonla* becomes more popular in the semi arid regions of Maharashtra, Gujarat, Rajasthan, Karnataka, Tamil Nadu and other states. The important cultivars of *aonla* grown in different parts of India are Banarasi, Chakaiya, Francis, Krishna, Kanchana, NA6, NA7, and NA8 (Singh *et al.,* 2003).

The fresh *aonla* fruits are not popular as a table fruit due to their high astringency and its limited storability after harvesting due to its high perishable nature (Kumar and Nath 1993). It is sour, astringent, occasionally eaten raw and is generally consumed after processing in the form of jams, jellies, pickles, preserves, candies and in dried form. Unlike other fruits/vegetables, the vitamin C content of *aonla* fruit is not destroyed much on dehydration due to the protection of the vitamin by tannins containing gallic acid, ellagic acid and/or glucose present in it.

Dehydration of *aonla* is an important technique which can be applied efficiently to make the fruits available round the year and also to avoid market glut in the peak harvest. However due to its astringent taste and high acidity the dried products are usually not acceptable. Hence, applications of certain pre treatments are essential to make the product acceptable to consumers. The process of drying can be carried out in different ways, like solar drying, mechanical drying, osmotic drying and so on. (Pragathi *et al*., 2001). Studies have been carried out to prepare dried whole fruit and flakes (Verma and Gupta, 2004), shred (Sager and Kumar, 2006), slices (Alam *et al*., 2011). It is noted that over 20 % of the world perishable crops are dried to increase shelf-life and promote food security.

Recently, osmotic dehydration technique has gained more attention due to its potential application in the food processing industry. The main advantages of osmotic dehydration include better colour, texture, flavour, nutrient retention and prevention of microbial spoilage. The product obtained by osmotic dehydration is more stable during storage due to low water activity imparted by solutes gain and water loss (Tiwari, 2005).

The important objectives of including the osmotic process in conventional dehydration method are ; i) quality improvement in terms of product transformation towards improved acceptability (Pointing *et al*.,

1966) and ii) Energy savings. Osmotically dehydrated products fall under the group of intermediate moisture foods (IMF). Therefore, addition of preservatives, air drying, vacuum drying, freeze drying, dehydro-freezing and dehydro-canning have been used to stabilize them (Tiwari, 2005). Osmotic dehydration is an efficient form of moisture removal from solid food to inhibit the growth of microorganisms, besides preventing a large part of biochemical reactions, causing no change in phase of the water. It also facilitates infusion of small quantity of solutes or sugar resulting in changed sugar acid blend with highly acidic fruits.

Incorporation of spices in product formulation will help in the development of diversified products by imparting characteristic flavor besides its antimicrobial action and ability to retain the bioactive constituents. The hypocholesterolemic and antioxidant properties of a few specific spices have far-reaching nutraceutical value. These beneficial physiological effects also have the potential for inducing therapeutic application in a variety of disease conditions (Srinivasan, 2005). Incorporation of physiologically active compounds such as minerals, phenolic compounds, probiotics and vitamins into food tissue without destroying the initial food matrix have already been attempted by many researchers.

Infusion of bioactive compound through osmotic treatment into solid food matrix without altering its natural structure has been demonstrated in model food system with grape phenolics (Rozek *et al*., 2008), coconut and raw banana slices with curcuminoids (Bellary *et al*., 2011, Bellary and Rastogi, 2012 & 2014) as well as watermelon rind with anthocyanin (Bellary *et al*., 2015). The addition of compounds into a food matrix could protect them against deteriorating reactions (Betoret *et al*., 2011) and aid to modulate the release of these compounds capable to influence on their assimilation (Ribeiro *et al*., 2006).

Drying is a suitable alternative for post harvest management especially in countries like India where exist poorly established low temperature distribution and handling facilities. Major quality parameters associated with dried fruits and vegetables include colour, visual appeal, shape of product, flavour, microbial load, retention of nutrients, porosity-bulk density, texture, rehydration properties, water activity, freedom from pests, insects and other contaminants, preservatives, and freedom from taints and off-odours.

Convective hot air drying is still the most popular method applied to reduce the moisture content of fruits and vegetables. Energy consumption and quality of dried products are critical parameters in the selection of drying process. Fruits can be dried whole, in halves, or as slices, or alternatively can be chopped after drying. The residual moisture content varies from small (3–8 %) to large (16–18 %) amounts, according to the type of fruit. Hot air in convective drying has a low value of water vapor pressure at high temperature, which creates a vapor pressure gradient between the moisture present in the food and the moisture in air and this gradient is responsible for the moisture migration or the mass transfer phenomenon. Hot air oven drying is more convenient method of lowering moisture from the product on commercial scale.

Over the last few decades, open-air drying has gradually become more and more limited because of the requirements for a large area, the possibilities of quality degradation, pollution from the air, infestation caused by birds and insects, and inherent difficulties in controlling the drying process. These problems can be solved by using either oil-fired or gas fired or electrically operated dryers. However in many rural locations of India, the electricity is either not available or too expensive for drying purpose. Alternatively, fossil powered dryer can be used but it poses such financial barriers due to large initial and running cost that these are beyond the reach of small and marginal farmers. In the present day crisis, it is desirable to apply a little solar technology for dehydration of fruits and vegetables, so the gas, oil and electricity can be saved.

The solar radiation in Bangalore in the month of December increases from 2.6 kWhm^{-2} day^{-1} to 4.5 kWhm^{-2} day^{-1} and during summer *i.e.* March to May; the value ranges from 5.0 to 6.5 kWhm^{-2} day^{-1}. Electrical/fuel fired dryers help the farmers in drying their products at a relatively faster rate, but they do not reach the poor farmers in most of the developing countries due to their high initial cost. Electricity, though cost rich, is not available in the rural areas and comes uninterrupted. Hence it has been established that solar drying of fruits and vegetables is technically feasible, economically viable and can be popularized in the rural areas.

India's diverse climate ensures availability of all varieties of fresh fruits & vegetable. Even though the production is high, due to the perishable nature of fruit and vegetables, inadequate postharvest handling techniques, improper processing and storage technology, poor infrastructure as well as poor marketing systems, postharvest losses of fruits and vegetables are very high (25-30 %) in India. Hunger and extreme poverty can be eliminated through a combination of social protection measures and targeted pro-poor investments in productive activities. Therefore, it is imperative that, besides employing reliable storage systems, post-harvest methods such as drying can be implemented hand-in-hand to convert these perishable products into more stabilized products that can be preserved and subsequently utilized during off season or made available in the areas of scarcity. FAO assist countries in improving the design of their rural economic diversification strategies and policies that promote decent employment creation and skills training for rural workers, especially youth and women. Food preservation is the need of the hour to reduce the food loss and solar drying is widely accepted as an important tool in the direction to the monitoring of the sustainable development goals related to rural poverty by supporting the empowerment of smallholders and family farmers for improved access to and sustainable management of natural resources, better access to markets, technologies and services to increase their productivity and income generation (FAO, 2016).

On the basis of above background this investigation will focus on processing of *aonla* by osmotic treatments as well as incorporating spices, optimum process parameters for standardizing the product, drying and quality evaluation of products with the following objectives.

1. Standardization of processing procedure for spiced *aonla* segments.
2. Physico-chemical & sensory qualities evaluation of the products dehydrated under solar drier and cabinet drier.
3. Packaging and storage quality evaluation.

II. REVIEW OF LITERATURE

Aonla is highly nutritious and is an important dietary source of vitamin C, minerals and amino acids. *Aonla* fruits are highly perishable in nature and hence its storage in atmospheric conditions after harvesting is very limited, which is accompanied by browning of the skin, loss of glossiness and vitamin C content. Due to its highly acidic and astringent nature, the fruit in fresh form or as a table fruit is not popular and consequently, it is used in the preparation of various ayurvedic tonics like chayvanprash, triphala, etc. However, *aonla* fruits are processed into a number of food products like preserve, jam, jelly, candy, toffee, pickle, sauce, squash, juice, RTS beverage, cider, shreds, dried powder, etc. Osmotic dehydration techniques not only enables the storage of the fruits for a longer period, but also preserves flavour, nutritional characters and prevents microbial spoilage.

A brief review of literature relating to development of protocol for conversion of fruit into economically feasible, viable, safe, stable, tasty nutritious product by use of osmotic dehydration of spiced dehydrated *aonla* (*Phyllanthus emblica* L.) segments is presented in this chapter. Also studied the efficiency of cabinet drier which is small and versatile for drying product in which heat from drying medium to food is transferred by convection. Also presented the utility of solar drying can be considered as an elaboration of sun drying and is an efficient system of utilizing solar energy. Reviews regarding integrated energy/technology approach *i.e.* solar drying in the sense of utilizing the solar energy for drying of *aonla* fruits has also been incorporated.

The research work carried out by the various researchers, as related to the problem under study has been reviewed under the following headings:

2.1. *Aonla* fruit and its composition

2.2. Osmotic dehydration

2.3. Pretreatments
    2.3.1. Different osmotic agents that can be used in osmotic dehydration & Post osmosis processing.
    2.3.2. Various pretreatments before osmotic dehydration.
    2.3.3. Freezing

2.4. Spices

2.5. Drying
    2.5.1. Solar drying.
        2.5.1.1. Types of solar driers
        2.5.1.2. Performance of solar driers
        2.5.1.3. Solar drying of different commodities
    2.5.2. Cabinet drying.

2.6. Specific studies on *aonla*.

2.7. Physico-chemical changes in osmotically dehydrated products & sensory qualities.

2.8. Packaging and storage of osmotically dehydrated product.

2.1. *Aonla* fruit and its composition

Pragati *et al*. (2001) evaluated the fresh *aonla* fruits and Chakaiya for their physical and chemical characteristics. The fresh *aonla* fruits were found to be very rich source of ascorbic acid (454.40 mg/100 g) and appreciable source of total sugars (7.43 g/100 g), calcium (14.91 g/100 g), iron (0.62 mg/100 g) and phosphorus (11.81 mg/100 g) and have great potential for processing.

Aonla is rich in polyphenols, minerals and is regarded as one of the richest source of vitamin C (200-900 mg per 100 g of edible portion). The phytochemicals of this plant include hydrolysable tannins (Emblicanin A, Emblicanin B, punigluconin, pedunculagin), flavonoids (Kaempferol 3 O alpha L (6” methyl) rhamnopyranoside, Kaempferol 3 O alpha L (6” ethyl) amnopyranoside), alkaloids (Phyllantidine and phyllantine) (Singh *et al*.,2011).

Aonla fruits are globose, fleshy, pale yellow with six obscure vertical furrows enclosing six trigonous seeds in two seeded three crustaceous cocci (Dasaroju and Gottumukkala, 2014).

2.2 Osmotic dehydration

For osmotic dehydration of mango slices osmotic treatment in 65 per cent sugar concentration for 6 hour at temperature 35 ^{o}C was best (Madamba and Lopez, 2002)

Osmotic dehydration of acerola was carried out in an incubator at temperatures of 25 and 60 °C and constant agitation and best conditions found were: a binary solution with 60 % (w/w) of sucrose and a ternary solution of 50 % (w/w) of sucrose plus 10 % (w/w) of salt, both at a temperature of 60 °C (Alves *et al.* (2005).

Osmotic dehydration is considered as a process in which many simultaneous mechanisms, acting at different levels, are responsible for mass transport. Compositional-structural profiles that are developed with gas-liquid exchanges in the tissue during osmotic process have a significant impact on physical (optical), textural and chemical properties (e.g., flavour profile) of the final product, which is in part influenced by the differences in the number of cells that are altered and unaltered during the treatment (Falade *et al*., 2007).

Sapata *et al*. (2009) carried out osmotic dehydration of mandarins (*Citrus reticulata* Blanco) cv Clementina Nova, using a 60 °Brix sucrose solution, conducted in thermo- -stabilized baths, at 45 °C, 16 h, 40 oscillations per minute and a fruit: solution ratio of 1:2 (m/m) and found that osmotic dehydration process is a good option to improve mandarin’s stabilization, after pasteurization, increasing added value.

Germer *et al*. (2010) investigated on process variables in the osmotic dehydration of sliced peaches and concluded that the process conditions in the range from 50 to 54.1 °C and from 45 to 65 °Brix led to greater water losses and better sensory performances.

Rodriguez *et al*.(2012) studied the osmotic dehydration of nectarines using a hypertonic solutions of glucose syrup and sorbitol (40 and 60 % w/w) during 2 h of process at temperatures of 25 and 40 °C, with fruit/osmotic agent ratio of 1:4 and 1:10. Water loss and solids gain showed significant differences depending on the type and concentration of the osmotic agent, process time and fruit/solution ratio. The concentration interacted significantly with all variables; in addition, there was an interaction between the type of osmotic agent and the relationship between fruit and the osmotic agent.

An osmotic-dehydration process protocol for carambola was developed by Roopa *et al*. (2012). The optimized levels of the process variables were achieved at 70 °Brix, 48 °C and 144 min for soak solution concentration, soaking temperature and soaking time, respectively.

Osmotic dehydration (OD) conditions of peach slices were optimized using response surface methodology (RSM) .The optimized conditions were sucrose concentration-69.9 °B, time-3.97 h and temperature-37.63 °C in order to obtain WL of 28.42 (g/100 g of fresh weight), SG of 8.39 (g/100 g of fresh weight) and RR of 3.38 (Yadav *et al*., 2012).

Kumar *et al*. (2012) studied the effect of osmotic dehydration on mass transfer properties in order to determine the usefulness of this technique as pre-treatment for further drying of litchi pulp. About 80 %

of the water loss occurred between 4-6 h under most of the conditions and the pulp was dried in a tray dryer at 70 °C for 10 h and found that osmotic treatment was responsible for increasing drying rate in a subsequent convective tray drying.

Osmotic dehydration of honeydew papaya was carried out to evaluate the effect of process parameters on mass transfer using response surface methodology and found that optimization process for the maximum WL and the minimum SG obtained at the temperature of 57 °C, concentration of 65 %, 2.76 h duration/time and agitation of 14999.80 Re (Gheybi *et al*.,2013).

Oladejo *et al*. (2013) investigated on kinetics, modeling and optimisation of osmotic dehydration of mango (*Mangifera indica* L). Optimised conditions of 53.5 °Bx sucrose concentration 30.0 °C temperature and immersion time of 160.0 min removed about 42.6 % water content with minimum solute gain of 6.3 % of the sample solid content. At the predicted optimum points, the observed water loss and solute gain were found to be 41.87 and 10.65 % of the initial sample content respectively.

Osmotic dehydration is an operation used for the partial removal of water from plant tissues by immersion in a hypertonic solution, sugar and/or salt solution, to reduce the moisture content of foods before actual drying press. This technique is a partial dehydration process to give the product a quality improvement over the conventional drying process (Akbarian et *al*., 2014).

Osmotic dehydration method allows maintaining good organoleptic and functional properties in the finished product. Obtaining the desired degree of dehydration or saturation of the material with an osmoactive substance often requires elongation of time or use of high temperatures (Chwastek, 2014).

Thipanna and Tiwari (2015) conducted an experiment on quality changes in osmotically dehydrated banana var. 'Robusta' and 'Ney Poovan' as affected by syrup concentration and immersion time and found that the inclusion of osmotic process in conventional dehydration has two major advantages of quality improvement and energy savings. Osmotic pretreatment of 70 °Brix syrup for 24 h resulted in maximum reducing sugar (53.78 %), non-reducing sugar (19.93 %) and total sugar (73.73 %) in banana slices. Samples from 'Robusta' had higher acidity (1.31 %) than the 'Ney Poovan' (1.00 %).

Osmotic dehydration of apricot fruits consisting of dipping prepared fruits in 70° Brix sucrose syrup containing 2,000 ppm potassium metabisulphite (KMS) for 24 h followed by cabinet air drying (55 °C) to desired moisture (20±0.5 %) gave better dried product with good colour and appeal (Raj *et al*., 2015).

Derossi *et al*. (2015) reported that desirability approach allowed defining the best operative conditions; specifically, when the overall quality of osmotized cherry tomatoes was considered as equilibrium of values of a_w, consistency and red index, a maximum desirability of 0.736 could be obtained by using mass fractions of sucrose and NaCl respectively of 55.62 and 2.45 % and a treatment time of 22 h.

2.3 Pretreatment

2.3.1 Different osmotic agents that can be used in osmotic dehydration & post osmosis processing

Imtiaz *et al.* (2004) investigated the combined effect of sucrose glucose solution in ratio 1:1 and 7:3 for 72 hours on osmotic dehydration of banana slices and found that the increase in the time and concentration of solids resulted in decrease of sensory color score.

Singh *et al*. (2007) reported that steeping in 60 °Brix sugar syrup showed less vitamin C loss in the preserve than in 70 °Brix syrup in osmotically treated *aonla* segments.

Konopacka *et al*. (2008) did a study to check the usefulness of concentrated fruit juices as osmotic agents which could replace sucrose in production of osmo-convectively dehydrated dried fruit in sour cherry fruit using following osmotic solutions: concentrated apple juice (AJ), mixture of concentrated apple and sour cherry juices (AJ + SCJ), deacidified concentrated apple juice (DeAAJ) and sucrose solution (S) as a control. Results showed that in all the combinations investigated dry matter increases during osmotic drying were similar as in the control and allowed to produce osmo-convectively dried fruit of comparable, decent texture properties.

Moraga *et al*. (2011) studied osmotic dehydration (OD) of grapefruit (55 °Brix sucrose solution, 30 °C) to obtain 75 g water/100 g sample in the final product. Although the grapefruit was replaced each time, the osmotic solution was reused for five OD cycles, with or without pasteurization. During OD, a partial loss of the natural soluble substances present in the fruit was observed and also it is possible to reuse the osmotic solution in up to 5 OD, without any re concentration treatment.

2.3.2 Various pretreatments before OD.

Sethi (1986) reported reduced drying period for blanched *aonla*. He mentioned that blanched whole *aonla* fruit required 7 days drying period as compared to 8 and 5 days in case of unblanched whole and raw *aonla* pulp respectively.

Devaraju (2001) reported that recovery of dehydrated ber slices was maximum (31.75 %) in pre-treatment of blanching + slicing + steeping in 60 °Brix syrup for 24 hours.

Verma and Gupta (2004) reported that potassium metabisulfite did not affect vitamin C retention in *aonla*. However, the pricking and blanching treatments enhanced the ascorbic acid loss. The blanching treatment was carried out by boiling the sample in a sodium chloride solution for 7 min.

Doymaz *et al*. (2004) reported that the pretreatment also effected the moisture movement from the plum slices. The treated samples dried in less time than the control samples. Similar effect of various pretreatments was reported in drying of apricots and grapes.

The combining of gamma irradiation treatment with osmotic pretreatment resulted in increased mass transfer rates during air dehydration, offering a feasible solution for satisfactorily enhancing the mass transfer rates as a result of an increase in cell wall permeabilization, leading to softening of tissue, which in turn resulted in faster dehydration (Rastogi *et al*., 2006).

The effect of osmotic dehydration on mass fluxes (water loss, solids gain and weight reduction) was investigated by Lombard *et al.* (2007) using pineapple cylinders of 2 cm in diameter and 1 cm thick were immersed in sucrose solutions of 45, 55 and 65 °Brix at 30, 40 and 50 °C for 20, 40, 60, 20,180 and 240 min. Applying a vacuum pulse facilitated water loss and the yield was improved as mass loss was less in those cases especially at the highest concentration and temperature. Temperature affected mostly the water loss while the concentration of the solution affected mostly the solids gain.

Garcia *et al*. (2010) investigated on effects of chitosan coating on mass transfer during osmotic dehydration of papaya and found that chitosan coatings improved the efficiency of osmotic dehydration process in both ripening stages, increasing the water loss and decreasing the solids gain.

A study was designed to evaluate the effects of sulphiting and osmotic pretreatments on effective diffusion coefficient (Deff) of air drying pineapple slices at 50 °C and 70 °C temperatures. The combination of sulphiting and osmotic pretreatments exhibited significant impact on the Deff value, ranging between 5.13 to 8.42 x 10^{-6}, though not as pronounced as with the single pretreatment method. Furthermore, drying at 70 °C influenced the Deff value more than drying at 50 °C with both pretreatment methods. The study, therefore, showed that pretreatment methods improved the Deff of the pineapple slices, with the sulphiting pretreatment at 2500 ppm having the highest value **(**Karim, 2010).

Applying ultrasound pre-osmotic treatment in 70 °Brix prior to hot-air drying reduced the drying time by 33 %, increased the effective diffusivity by 35 %, and decreased the total colour change by 38 %. A remarkable decrease of hardness to 4.2 N obtained was also comparable to the fresh guava at 4.8 N (Kek *et al*., 2013**).**

Silva *et al.* (2014) studied on the effect of calcium on the osmotic dehydration kinetics and quality of pineapple and found that it reduced the water content of the product and solute incorporation rate, inhibiting sucrose impregnation and increasing process efficiency. The addition of 4 % calcium lactate to the solution increased all diffusivities in comparison to the addition of 2 % but not in relation to treatments with no added calcium.

2.3.3 Freezing

The extent of cell membrane permeabilisation due to high intensity electric field pulses (HELP) and freezing on mass transfer and vitamin C content during osmotic (50 ° Brix sucrose at 40 °C) and convective air (60 °C, 1 m/s for 5 h) dehydration of red bell peppers was studied. Result showed that freezing resulted in total pore area of almost 6 times as greater as the highest value from the HELP process (Ade-Omowaye *et al*., 2003).

Kinetic study of the effect of the osmotic dehydration pre-treatment to the shelf life of frozen cucumber showed that dehydrofrozen samples exhibited significantly improved stability, with the rates of colour change being reduced up to 36.7 % for osmotically pre-treated cucumbers, compared to the untreated samples (Dermesonlouoglou *et al*., 2008).

Floury *et al*. (2008) investigated on three-dimensional numerical simulation of the osmotic dehydration of mango and effect of freezing on the mass transfer rates. Measurements showed that freezing of the fruit significantly reduced cell diameter and tortuosity for extracellular mass transfer, and increased the rate of water loss but the relative effect on sugar gain was lower.

Ramallo and Mascheroni (2010) evaluated the effect of osmotic dehydration and hot air-drying, applied previous to the freezing process, on the end quality of pineapple slices. Results showed that the time necessary for pineapple samples freezing got reduced.

The osmotic dehydration prior to freezing demonstrated to be useful for limiting drip loss and, in some cases, to decrease colour change and improve texture. The choice of the dehydrating agent and the usefulness of the pre-treatment depend on the application intended for the final product (Marani *et al*., 2011).

Ketata *et al*. (2013) investigated the impact of liquid nitrogen pretreatments on osmotic dehydration kinetics of two blueberry species, *Vaccinium corymbosum* L. and *Vaccinium angustifolium* A. it, and found that a reduction of dehydration time from 45 % to 65 % was obtained for liquid nitrogen treated samples when compared to control blueberries.

Tandon and Chaurasia (2013) evaluated nutritional quality of *aonla* during freeze-drying for 90 days storage. The retention of ascorbic acid and polyphenols was maximum in freeze dried segments, in all the varieties tried, after 90 days of storage. Krishna was found to be least suitable for freeze drying among the varieties tested.

Nowicka *et al*. (2015) revealed that the decrease of water loss to solid gain (WL/SG) ratio during OD of frozen sour cherries in apple concentrate associated with increased values of WL/SG was considerably enhanced by stone removal and the process of thawing. It was found that the best variant of pretreatment of sour cherries, to be used for OD in apple concentrate, was freezing the fruits without stones. These fruits were characterized by a high content of polyphenols, high antioxidant activity, and the largest WL/SG ratio during OD process.

2.4. Spices

Nain *et al*. (2009) studied on properties and utility of commonly used natural spices and stated that spices are considered to act as natural preservative and attributed to some active antimicrobial and antioxidant principles contained in their oils.

Abraham *et al.* (2010) conducted an experiment on effect of dried ginger powder, fennel powder, cumin powder and fresh ginger extract addition on supari from *aonla*. *Aonla supari* was prepared by osmotic dehydration (OD) process by placing fresh *aonla* fruit in various concentration of brine solution (2, 3 and 4 % (W/V)). Based on the overall acceptability and the physicochemical analysis, the sample with 2 % salt concentration with 5 g/ 100 ml of cumin powder, 2 g/100 ml of dry ginger powder and 2 g/100 ml of fennel powder) and sample with (3 % salt concentration with 5 g/100ml of cumin powder, 2 g/100 ml of dry ginger powder and 2 g/100 ml of fennel powder) were optimized for further studies.

Value added dried Indian gooseberry (*aonla*) shreds were prepared using *aonla* fruits of cv. 'NA-7'. Common salt, black salt and ginger juice were mixed for enhancing sensory quality of the product. In case of different recipes, shreds with 3 % common salt were more acceptable followed by shreds with 3 % common salt + 10 % ginger juice (Prajapati *et al*., 2011).

A study on effect of selected pretreatments on impregnation of curcuminoids and their influence on physico-chemical properties of raw banana slices concluded that osmotic treatment can be a feasible technology for the infusion of functional ingredients into foods without altering its matrix. The treatments such as ultrasound, vacuum and combination of vacuum and blanching with ultrasound, the increase in surrounding solution concentration from pure water to 10 % NaCl resulted in higher curcuminoid infusion compared to control for both pure water and 10 % NaCl osmotic treatments. The blanching treatment resulted in lower infusion of curcuminoids as compared to that of control due to the gelatinisation of starch present in banana (Bellary and Rastogi, 2014).

Rehman *et al*. (2015) presented therapeutic potential of black pepper and piperine as promising candidates for the development of nutraceuticals and functional food ingredients to treat airways disorders.

Osmotic dehydration assisted impregnation of curcuminoids in coconut slices was carried out by Bellary *et al*. (2011) using ultrasound pretreatment and concluded that osmotic dehydration is a feasible technology for impregnation of functional ingredients into foods without altering its matrix.

On the basis of organoleptic evaluation and biochemical characters Nayak *et al*. (2012) concluded that the candy prepared from cv. Krishna and flavored with cardamom powder found to be the best *aonla* candy when the segments of *aonla* cultivar (Krishna, NA-7, NA-10 and Chakkaiya) were stepped for 24 h in successively increasing concentration of sugar syrup (50 to 70 $^{\circ}$B) for three days and added flavors of ginger and cardamom in syrup.

Osmotic treatment for the impregnation of anthocyanin in candies from Indian gooseberry (*Emblica officinalis*) was studied by Adsare *et al*. (2016). When the surrounding solution concentration was minimum the infusion of anthocyanin was higher. With an increase in the concentration of surrounding solution, the time required to reach moisture and solid equilibrium was reduced. The entire process for anthocyanin infused *aonla* candy could be achieved in 24 h of immersion time compared to conventional method of candy making 120 h (5 days). Result concluded that osmotic treatment could be a feasible technology for impregnation of bioactive compounds for candy making without significantly altering the cellular integrity of the solid food matrix.

Anthocyanins from *Garcinia indica* was impregnated in watermelon rind through osmotic dehydration. The process was enhanced by application of pretreatments like vacuum and sonication (from 24 to 32 mg/100 g) which helped in changing the tissue architecture of the watermelon rind which helps in retaining the infusate during candy making process (Bellary *et al*., 2016).

Application of high pressure was shown to be a feasible technique to enhance the infusion of bioactive compound (e.g., anthocyanin) in solid food matrix (apple) without significantly altering its natural solid food matrix (George *et al*., 2016).

2.5 Drying

2.5.1 Solar drying

2.5.1.1 Types of solar driers

Condori *et al. (*2001) designed and developed a low cost tunnel greenhouse dryer under force convection mode and tested on sweet pepper and garlic. It was made of a plastic transparent wall with a manually driven line of carts with several staked drying trays including exhaust fan. Drying tray received the solar radiation though the transparent plastic wall of the dryer. Experimental results, in clear sky conditions showed good drying behaviour with a good drying rate with an acceptable limit of final moisture content and colour of the dried product.

Shahi Navin *et al*. (2009) fabricated a solar poly tunnel dryer (SPTD) for fruits and vegetables for Kashmir valley. As compared to conventional dryer, the SPTD had low cost and it was helpful in decreasing the time consumption by 50–70 % for dehydration.

Abur *et al.* (2014) found that for nutrient preservation of dried products and superior drying speed, the indirect forced convection type solar dryers are preferred but power requirement increase the cost of drying as well as limit their use in the rural areas. Natural-circulation type solar tunnel dryers, wind ventilated type solar dryers with heat storage units and greenhouse dryers are more suitable for rural applications. The use of solar collector’s performance enhancement techniques accelerates drying rates and promotes overall efficiency of drying systems. Solar-biomass hybrid dryers overcome the limitations of solar drying during cloudy conditions and night hours. It is also suggested that computer simulated models should be adapted as a tool in the design and optimization of solar dryers for short and long time benefits while low initial capital cost, operational procedure and effectiveness in promoting better product quality should be consider in the design and production of solar drying systems.

2.5.1.2 Performance of solar drier

Yaldiz and Ertekin (2001) used a solar cabinet dryer to dry pumpkin, green pepper, stuffed pepper, green bean, and onion in thin layers and the results were compared with natural sun drying method. The results revealed that drying air temperature could increase up to 46 $^{\circ}$C and the drying air velocity had an impact on the drying process. They reported that the drying time was reduced (30.29-90.43 h) in solar drying as compared to open sun drying (48.59 and 121.81 h) for different vegetables.

Bala *et al.* (2005) investigated a field performance of a solar tunnel drier for drying jackfruit bulbs and leather. The drier had a loading capacity of 120–150 kg of fruits. The use of a solar tunnel drier led to a considerable reduction in drying time and dried products of better quality in comparison to products dried under the sun. A multilayered neural network approach was used to predict the performance of the solar tunnel drier.

Hossain *et al*. (2007) designed and fabricated solar tunnel type dryer with loading capacity of 80 kg of fresh chilies. It took 20 h in solar tunnel drier compared to 32 h in case of improved and conventional sun drying method.

Demir and Sacilik (2010) recorded that the use of solar tunnel drier led to considerable reduction in drying time in comparison to open sun drying apart from the protection of tomatoes from insects and dust.

Dhanushkodi *et al*. (2014) conducted a study to develop an efficient indirect forced convection solar dryer for the purpose of drying 40 kg of cashews per batch. The performance study indicates that the required moisture reduction from 10 % to 5 % was achieved within 6 hours in active mode, 10 hours in passive mode and 14 hours in open sun drying. Thermal efficiency of the solar collector varied between 65-70 % in active mode and 30-45 % in passive mode.

2.5.1.3. Solar drying of different commodities

Nahar, 2009 investigated on processing of vegetables in a solar dryer in arid areas. He found that the initial moisture content of vegetables reduced to the safe storage level within 2 to 4 days of exposure in solar dryer. It took 20 percent more time in drying of vegetables in In-direct mode and the efficiency of the dryer was found to be 17.95 percent and the use of solar dryer will be a great boon for farmers.

Comparative studies of different types of solar dryers such as solar tunnel dryer, improved version of solar tunnel dryer, roof-integrated solar dryer and greenhouse type solar dryers which have demonstrated their potentialities for drying fruits, vegetables, spices, *etc*. in the tropics and subtropics. Results showed that solar drying leads to considerable reduction of drying time in comparison to sun drying and the product obtained from solar drier was superior in quality than sun dried products (Bala and Janjai, 2009).

Farkas (2011) studied on integrated use of solar energy for crop drying and stated that during the drying of agricultural materials it has to be taken into account the energy saving, quality of end-products and also environmental aspects.

The effect of different drying methods such as freeze, spray, solar, cabinet and sun drying on physico-chemical properties of aonla powder in terms of solubility in water, colour, ascorbic acid and polyphenols contents has been evaluated.Spray drying took least time for powder preparation (1 l/h) but yield was not satisfactory (6.3 % only), while cabinet drying had best yield (14.6 %) and moderate drying time (6 h). In terms of quality parameters, the order of different drying methods is as follows: spray drying > freeze drying > cabinet drying > solar drying > sun drying (Bhattacherjee *et al*., 2012).

Priyanka (2015) investigated on design and development of tunnel type solar dryer for dehydration of onion and *aonla*. In solar tunnel dryer, the drying required 12-15 h and 13-14 h for various pretreated *aonla* segments and onion slices to reduce from moisture content of 422.32-521.46 per cent (d.b.) to a safe moisture content of 17.01-17.39 per cent (d.b.) and from moisture content of 572.92 - 797.29 per cent (d.b.) to attain a safe moisture content of 6.08-6.24 per cent (d.b.), for *aonla* and onion, respectively. The payback period for *aonla* is 6 months and for onion it is 9 months. The results showed that the rehydrated products could be well utilized for substituting the fresh product in off season.

2.5.2 Cabinet drying

Amitabh *et al*. (2000) reported that osmotically dehydrated mango slices were further dried in a cross flow cabinet drier at 60 °C for 4-7 hours.

A study was undertaken to see the possibility of combining partial osmotic dehydration followed by oven drying at 50 °C for producing dehydrated banana. Osmotic dehydration of ripe whole Karpuravalli banana fruits in sugar syrup of 60 °C followed by drying in a hot air oven at 50 °C for 24 hours resulted in highly acceptable banana during storage period up to 60 days. (Narayana *et al*., 2003).

Sharma *et al*. (2010) found that the *aonla* powder processed from mechanically dried samples was superior to sun-dried samples and Banarsi cultivar was found to be the most suitable variety for powder making with acceptable quality attributes when pre-treated prior to mechanical drying

The osmo-dehydrated product prepared from carambola at optimized conditions showed a shelf-life of 10, 8 and 6 months at 5 °C, ambient (30 ± 2 °C) and 37 °C, respectively (Roopa *et al*., 2012).

Demiray *et al.* (2013) studied on degradation kinetics of lycopene, b-carotene and ascorbic acid in tomato quarters of Rio Grande variety were determined during hot air drying. Tomato quarters were dried at five different temperatures (60, 70, 80, 90 and 100 °C) in a cabinet drier at an airflow rate of 0.2 m/s and 20 % relative humidity. The most effective temperature change in tomatoes was from 70 to 80 °C for lycopene and b-carotene degradation, while it was from 60 to 70 °C for ascorbic acid degradation.

Precoppe *et al*. (2014) investigated on batch uniformity and energy efficiency improvements on a cabinet dryer suitable for small holder farmers. On each trial 144.5 kg of peeled and deseeded litchis were placed at the dryer's 17 trays that were stacked atop each other. Moisture content (wet basis) was reduced from 87 to 23 % in about 15.5 h. It was found that a low-cost modification to the dryer chamber's air inlet was able to improve heat distribution and increase the uniformity of the fruit's moisture content.

Karpoora *et al*. (2014) studied on drying kinetics of Tamarind (*Tamarindus indica* L.). It was observed that the mechanical drying of tamarind at 70 °C had highest moisture removal rate followed by mechanical drying at 60 °C

2.6 Specific works on aonla

Kustagi (2002) reported that blanching pre-treatments of the whole *aonla* fruit followed by steeping the slices in 50 °Brix syrup containing 0.2 per cent KMS for 24 hours and drying under sun was found to be best among the various treatments tried.

Pragati *et al*. (2003) conducted the experiment to know the effect of drying methods on composition of dehydrated *aonla* fruit during storage. The osmo-air drying method was found to be the best method for drying of *aonla* because of better retention of nutrients like ascorbic acid and sugars, lower level of antinutrients like tannins was also found because of leaching, minimal browning and satisfactory nutrient content after 90 days of storage.

Osmotic dehydration of *aonla* fruit segments (ODAFS) were carried out in 60 and 70 °Brix sugar syrup with varying steeping time. Osmo dehydrated *aonla* fruits segments showed better Vitamin C retention than in whole fruit preserve. Content of reducing and total sugar in the product increased with increasing sugar syrup concentration and steeping time. Both acidity and tannin content were less in ODAFS than in whole fruit preserve (Singh *et al*., 2007).

Naik and Chundawat (2009) conducted a study to evaluate the value added product of amla, among different product like Murrabba, *Chyavanprash*, pickle, dried flakes (sun drying) and brine preserved, it is observed that dried flakes, was found to be the most preferred product due to high retention of ascorbic acid, tannin and acidity with lowest moisture content in storage.

Shafiq *et al*. (2010) used response surface methodology to investigate the effect of sugar concentration (50–70 °Brix), solution temperature (30–60 °C), solution to fruit ratio (4:1–8:1) and immersion time (60–180 min) on the water loss, solute gain, rehydration ratio, vitamin-C loss, colour change and sensory overall acceptability of Indian gooseberry (*aonla*) slices. The optimum process parameters obtained by computer generated response surfaces, canonical analysis and contour plot interpretation were: sugar concentration, 59 °Brix solution temperature 5 °C, solution to fruit ratio 4:1 and immersion time of 60 min.

Prajapathi *et al*. (2010) conducted a study on effect of pretreatment and drying methods on quality of value-added dried *aonla* (*Emblica officinalis* Gaertn) shreds. Two blanching methods (hot water and potassium metabisulphite (KMS) at 0.1 %) and two drying methods (solar and hot air oven drying) were tried for the production of aonla shreds. The best product was obtained with KMS blanching and drying in solar dryer with added common salt at 3 %. The most acceptable product had ascorbic acid content 298.3 mg/100 g, tannin 2.4 %, acidity 2.6 %, reducing sugar 3.0 %, non-reducing sugar 21.0 % and total sugar 24.0 %. The recovery was 8.0–8.5 %.

Alam and Singh (2011) conducted an experiment on development of a product, sweet *aonla* flakes of high consumer acceptability, the *aonla* slices of 2mm thickness were first osmotically pretreated and then convectively dried at constant air temperature of 60 °C to safe moisture level of 10 % wet basis. The optimum process parameters obtained were: 70 °B of sugar concentration, 60 °C of solution temperature, 6.8:1 of solution to fruit ratio and 72 min of immersion time.

Singh *et al*. (2012) conducted an investigation on comparative study of anola cultivars viz. Banarsi, Chakaiya, NA-7 and Desi were carried out to identify the best suited cultivar for processing into commercially acceptable *aonla supari* and to assess its storability. Retention of ascorbic acid in supari was highest in Banarsi cultivar (42.8 %) followed by Chakaiya and NA-7 *i.e.* 41.07 and 40.06 per cent respectively.

Preethi and Tiroutchelvame (2013) conducted study on osmotic dehydration of *aonla* slices in a combination of sugar (25- 60 °Brix) and salt (5 %, 7.5 % and 10 %) solution at temperature of 30 °C in 4:1 and 8:1 ratio and they were dried in tray dryer at temperature 50 °C. It was observed that the weight reduction, solid gain and weight loss increased with increase of the parameters like time, concentration of the sugar solution and ratio of the solution to sample.

The effect of hot water blanching treatment on thin layer drying kinetics of aonla shreds was studied by Gupta *et al.* (2014) at drying air temperatures of 50, 55 and 60 °C with the air velocity of 1.2 m/s. The drying time decreased with the increase in air temperature and blanching and the drying process was observed in falling rate. Drying after blanching reduced the vitamin C content of *aonla* shreds by 69.36 % whereas it decreased by 27.78 % in unblanched shreds.

2.7 Physio-chemical changes of osmotically dehydrated products & sensory qualities

The storage studies showed that keeping the osmotically dehydrated mango slices above 64.8 and below 75.5 per cent relative humidity should be conductive to the retention of colour, flavour, taste and texture of the product (Amitabh *et al*., 2000).

Lakkond (2002) reported that sapota slices steeped in 50 °Brix sugar syrup containing 0.1 percent KMS and 0.5 per cent citric acid for 12 hours received higher organoleptic scores for colour and appearance (4.03), taste (4.00), flavour (3.39) and overall acceptability (3.80) as compared to other treatments.

Narayana *et al*. (2003) reported that the organoleptic quality of banana developed by combining partial osmotic dehydration (60 °Brix) followed by oven drying at 50 °C was unaffected up to 60 days of storage. No growth of undesirable microorganisms like bacteria or mould was found during storage.

Ade-Omowaye *et al*. (2003) reported that the order of magnitude of vitamin C retention in osmotic and convective air dried red bell pepper was untreated frozen HELP (high intensity electric field pulses) pretreated samples. The reduction in vitamin C content of HELP treated samples after convective drying ranged from approximately 11 to 24 % while freezing resulted in approximately 24 % decrease compared to the untreated samples

Riva *et al*. (2005) reported that osmo-dehydrated apricot cubes showed the lowest structure collapse, retaining a better superficial appearance, colour attributes and ascorbic acid content. The incorporation of sugars improved the colour stability during air dehydration.

Osorio *et al*. (2007) conducted a study on colour and flavour changes during osmotic dehydration of fruits in andes berry (*Rubus glaucus* Benth.) and tamarillo (*Solanum betaceum* Cav., dark-red strain) fruit were separately submitted to osmotic dehydration with three different osmotic agents: sucrose (70 %), sucrose (70 %)-glycerol (65 %) 1:1, and ethanol. This process decreased the water activity in the fruits and promoted the transfer of main pigments (anthocyanins) and flavour constituents to the osmotic solutions.

Konopacka *et al*. (2008) reported that application of concentrated fruit juices (apple juice and mixture of concentrated apple and sour cherry juices) slightly intensified sensation of cherry taste and aroma and allowed adjusting the flavour profile according to consumer's preferences and destination of the final product of osmotically dehydrated sour cherry.

Dermesonlouoglou *et al*. (2008) indicated that osmodehydrofrozen compared to conventionally frozen sliced cucumbers showed improved firmness for prolonged storage period. Sensory evaluation also showed good organoleptic quality in osmodehydrofrozen cucumber slices

Agnieszka and Andrzej (2010) investigated the impact of osmotic dehydration on the mechanical properties (*i.e.*, structural changes and shrinkage) of freeze-dried strawberries. Results revealed that osmotic dehydration process strengthened the fruit structure by increasing their cell wall thickness, limited the shrinkage of the strawberries by about 50 %, while the compression force required for 25 % deformation of the dried material was almost 2-3 times greater in comparison to the fruit not subjected to osmotic dehydration, dependent on the type of osmotic solution used.

In *aonla* Gudapaty *et al*. (2010) reported nutritional quality and rehydration characteristics of CRIDA drier dried products were higher and free from contamination. Drying time was shortest for blanched and osmotically dehydrated segments dried in CRIDA drier and the product had better vitamin C retention, rehydration characteristics and sensory acceptability compared to sun or cabinet drier dried product.

Storage study of osmotic dehydration of sulphur fumigated banana slices showed that there was marginal decrease in moisture content and organoleptic quality and increase in TSS, total sugars and reducing sugars content of osmodried banana slices. The products were found microbiologically safe and sensorily acceptable up to 6 months storage at ambient condition (Chavan *et al*., 2010).

Singh *et al*. (2012) investigated on compositional changes in *aonla supari* during storage and found that acidity declined slightly, a gradual decrease in moisture content and water activity and ascorbic acid content significantly declined in all the four cultivars during 135 days storage. Highest overall mean scores for colour, texture, taste and overall acceptability was observed in *supari* prepared from Banarsi cultivar followed by Chakaiya and NA-7.

Sumitha *et al.* (2013) reported that an increase in reducing sugar, total sugars, and partial reduction in non-reducing sugar content of the osmo-dried aonla product during storage. Among different treatments, significantly low non enzymatic browning (0.043 OD at 440 nm) was recorded in product stored in PET jar at low temperature and rated the best during the sensory evaluation.

The moisture content and water activity of intermediate moisture *aonla* segments decreased significantly and total soluble solids (TSS) increased significantly (37.9 to 48.9 %), while ascorbic acid of IMF *aonla* segments decreased significantly (427 to 185 mg/100 g) during six months storage period. Maximum retention of ascorbic acid was recorded in intermediate moisture *aonla* segments when steeped in 60 per cent glycerol. Organoleptically 60 per cent sucrose treatment to the intermediate moisture *aonla* segments cv. Banarasi was evaluated most effective in maintaining the overall quality of the product followed by 60 per cent sucrose-glycerol (1:1) and 60 per cent glycerol (Panwar *et al*., 2013).

Ketata *et al*. (2013) found that liquid nitrogen pretreatments on osmotic dehydration of blueberries showed a decrease in the cuticle thickness, dewaxing of the skin surface and the presence of micro-fissures facilitating moisture and sugar transfer during the osmotic process.

Abrol *et al*. (2014) used solar tunnel drying is done to evaluate the effect of drying on physico-chemical and antioxidant activity of mango, banana and papaya fruits at 60 ± 2 °C for 6 h under solar tunnel drier. During drying the removal of moisture content increased the physico-chemical properties viz. total soluble solids, acidity, reducing and total sugars of all the fruits. The antioxidant compounds, total phenols and total carotenoids were increased while heat sensitive vitamin C decreased. However, the antioxidant activity, after drying, was increased in mango from 68.6 to 86.3 %, in papaya from 64.1 to 80.4 % and in banana from 59.5 to 73.2 %, respectively.

Osmotic dehydration method allows maintaining good organoleptic and functional properties in the finished product (Chwastek, 2014).

Osmotic pretreatment with 60 °Brix sugar syrup for 24 h banana var. 'Robusta' and 'Ney Poovan' resulted in best quality products with a sensory score of 83.5 as compared to 65.0 in control. Osmotically dehydrated slices of 'Robusta' were significantly superior than 'Ney Poovan' (Thippanna and Tiwari, 2015).

Chemical analysis of solar tunnel dried *aonla* and onion indicates that the quality of solar tunnel dried products are superior to open sun dried products and the vitamin-C retention was found to be highest (125.68 mg/100 g) in untreated amla samples dried in solar tunnel dryer. The highest total phenolics, FRAP was found to be 325.09 (μg/g) and 1617.09 (μg/g), respectively in 0.25 per cent KMS pre-treated onion dried in solar tunnel dryer (Priyanka, 2015).

Moisture sorption dynamics and isotherms of fresh, osmotically-pretreated and dried papayas at temperatures of 30, 50 and 70 °C and water activity in the range of 0.113–0.907 were investigated by Udomkun *et al*. (2015). Results showed that the time required to reach equilibrium moisture content was mainly dependent on temperature, water activity level and processing method. The difference in moisture sorption characteristics between fresh, pretreated and dried papayas was attributed to (i) changes in the contents of sugars after osmotic dehydration and (ii) structural modifications caused by drying, which were corroborated by examination of micrographs.

Mongi *et al*. (2015) investigated the effects of solar drying methods [Cabinet direct (CDD), cabinet mixed mode (CMD) and tunnel (TD) drying] on total phenolic content (TPC) and antioxidant capacities of commonly consumed fruits and vegetable in Tanzania. The results revealed that tunnel dried samples have lower decline in TPC and antioxidant activities than cabinet dried samples due to higher drying temperature and shorter drying rate.

Indian gooseberry (*Emblica officinalis*) *aonla* candies impregnated with anthocyanin through osmotic treatment was highly acceptable with higher sensory attributes compared to control sample (Adsare *et al.,* 2016).

2.8 Packaging and storage of osmotically dehydrated products

Illeperuma and Jayathunge (2001) standardized a procedure for osmotic dehydration of banana by dipping in 70 ^{o}Brix sucrose solution in a fruit syrup ratio of 1:4 at 50 °C and air dried at 65 °C for 18 hours. It reduced the moisture content from about 38 - 3.5 per cent and water activity from 0.80-0.59. Increase in TSS, decrease in crude protein. The product is packaged in pouches made out of aluminium foil laminated with low density polyethylene and stored for 8 months without any changes in water activity and product colour.

Hymavathi and Vijaya (2005) stated that among the mango powders, Baneshan, Suvarnarekha and their blends contained good amount of β-carotene even after storage and can be safely stored in metalized polyester/polyester poly packaging for a period of up to six months.

Sagar and Kumar (2006) proposed a procedure to prepare best quality of ready-to-eat dehydrated *aonla* shreds which are light in weight and can be eaten without any prior preparation. Among the packaging material 200 gauge HDPE was suitable for retaining better quality in respect to colour, flavour, texture and overall quality of shreds for 4 months at room temperature and 6 months at low temperature (7+2 °C) followed by 400 gauge low density polyethylene (LDPE) and 150 gauge poly propylene (PP) pouches during the storage.

Vijayanand *et al*. (2007) reported that gooseberry powder prepared from Chakaiya, Krishna packed in 100 microns LDPE or MPP metalized polyester polyethylene pouches remained acceptable during 6 months of storage at 25 ± 2 $^{\circ}$C without significant change in their quality. MPP pouches had better retention of color and flavor. Gooseberry powder remained free from spoilage throughout the storage period of 6 months.

Kumar and Sagar (2009) reported that among the three packaging material 200 g HDPE, 200 g aluminum laminated polyethylene and 250 g co-extruded (COEX) pouches with 2 modes of pack in air and in nitrogen, the COEX with nitrogen and Low temperature (7 ± 1 °C) storage was good for osmo-vac dehydrated *aonla* segments up to 6 months as compared to room temperature as the former resulted in higher ascorbic acid, sugar content, rehydration ratio, sensory score and less moisture, tannin and non-enzymatic browning in the finished product.

The osmo-dehydrated product prepared from carambola at optimized conditions showed a shelf-life of 10, 8 and 6 months at 5 °C, ambient (30±2 °C) and 37 °C, respectively (Roopa *et al*., 2012).

Sumitha *et al*. (2013) studied on suitability of packaging and storage conditions for osmo-air dried *aonla*. Results revealed that samples packed in PET jar and stored at low temperature retained highest ascorbic acid and acidity. Results concluded that packing the produce in PET jar and storing them under low temperature is a promising way to improve the storage life of osmo-air dried aonla segments.

Moisture sorption study of watermelon rind impregnated with anthocyanins from *Garcinia indica* product was quite stable at ambient temperature up to 75 % RH. Storage of the sample in LDPE (low density polyethylene pouches) and PET/LDPE (Polyethylene terephthalate/low density polyethylene pouches) did not show any significant difference in moisture content, anthocyanin degradation, texture, taste and appearance of the product. The WMR product was stable for 90 days at ambient storage conditions (Bellary *et al*., 2016).

III. MATERIAL AND METHODS

The material used and the methodologies adopted during the present investigation on Development of protocol for spiced dehydrated *aonla* (*Phyllanthus emblica* L.) segments were furnished in this chapter.

3.1 Location

The experiment was conducted at the Processing Laboratory of Division of Post-harvest Technology, ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru during the year 2015-16.

3.2 Materials

Krishna (NA-5) -It is a seedling selection from Banarasi. The fruits are large, triangular, and conical: skin is smooth, whitish green to apricot yellow with red spot on exposed portion. Flesh is pinkish green, less fibrous and highly astringent. It is a early maturing variety (mid Oct.-mid Nov.)

3.3 Procurement of fruits

Freshly harvested *aonla* fruits of commercial variety Krishna of appropriate maturity procured from IIHR farms. Fresh mature fruits with uniform size, free from injuries, bruises, insect damages and diseases were used in this experiment.

3.4 Preparation of *aonla* segments

The selected aonla fruits were washed with potable water, blanched in water (85 to 90 ^{o}C for 8-10 minutes to reduce the enzyme activity and also for easy removal of seeds and then dipped in 2 per cent salt solution to remove the astringency. Out of single blanched aonla fruit, 5-6 segments were made by pressing it manually. By doing like this blanched fruit had broken down to simplest size and made easy seed removal. Seeds and segments were removed manually and subjected to different treatments for osmotic dehydration.

FLOW CHART FOR OSMOTIC DEHYDRATION OF SPICED AONLA SEGMENTS

FRESH FRUITS

BLANCHING OF FRUITS

AONLA SEGMENTS

SUGAR SYRUP

OSMOTIC TREATMENT

DRYING OF SLICES

PLATE -1

For combined process set of treatments, blanched aonla segments were frozen in freezer at -20 °C before subjecting to osmotic dehydration.

3.5 Sugar syrup preparation

Sugar syrup of 60 °Brix was prepared using 1.2 kg of sugar and 0.8 kg of water. While boiling the sugar syrup solution, 0.3 per cent of citric acid was added. After cooling the syrup around 45 °C, 0.1 per cent each of potassium metabisulphite and sodium metabisulphite as a preservative was added to sugar syrup after dissolving in little drinking water when the syrup was cooled. In this investigation slice to sugar syrup ratio was maintained 1:2 (W/V)

3.6 Spice mixture preparation

Pre-standardisation of spice mixes containing salt, ginger extract, cumin and black pepper were done in three different combinations as follows:

Spice level -1= 10ml/lit of ginger extract + Black pepper 1 %+ Cumin 5 % + Salt 2 %

Spice level-2= 10ml/lit ginger extract + Black pepper 2 %+ Cumin 5 %+ Salt 2 %

Spice level-3= 20ml/lit ginger extract + Black pepper 5 %+ Cumin 5 %+ Salt 2 %

Preparation of different spice levels: one part of ginger was diluted to two part of water for getting 100 % pure extract. It has been done by preparing one liter of ginger extract by taking 1000 g of ginger paste to one liter of water. And later used as extract of different quantity to incorporate to various spice levels. Whole black pepper seeds and cumin seeds were grinded to powder and then added to the syrup. For making spiced aonla segments of level -1 20ml of ginger extract, 20 g Black pepper powder, 50 g Cumin powder and 20 g salt was added in 2 litre of sugar syrup. Similarly level-2 spices content was 20 ml of ginger extract, 40 g Black pepper powder, 50 g Cumin powder and 20 g salt was added in 2 litre of sugar syrup. For level-3 spices content was 40ml of ginger extract, 100 g Black pepper powder, 50 g Cumin powder and 20 g salt was added in 2 litre of sugar syrup. The mixture was allowed to stay for 1hr to get it extracted. Finally syrup was filtered using muslin cloth before using for osmotic dehydration treatments.

3.7 Osmotic treatment

Prepared *aonla* segments were dipped in sugar-spice solution for 24 hours for one set of treatment and 4 hours for combined process treatment at room temperature (20-30 °C). During the process of osmosis, water flows out of the aonla segments to the syrup and fraction of solute also moves in to the aonla segments. At the end of the treatment for a particular osmotic duration, the aonla segments were drained out of the osmotic solution. These osmosed *aonla* segments were weighed to know the extent of weight reduction after osmosis (Plate 2).

3.8 Dehydration

Drying of aonla segments was done in two types of driers (Plate 3)

1. After taking samples for analysis, known weight of osmosed segments of one set of treatment of aonla were spread thinly on stainless steel trays which were kept in a cabinet tray drier for dehydration. *Aonla* segments were thoroughly air dried at 55-60 °C temperature till the fruits reached the desired moisture content and product quality.
2. Another set of treatments were dried in a solar tunnel drier. A gable roof even span type solar tunnel dryer having a floor area of (6 m x 3 m) was used and height of 2.7 m which was convenient height for a person to enter into the dryer and carry out the operations such as loading and unloading of the

material to be dried. The center length of the dryer was 3.3 m. The solar tunnel dryer was a galvanized iron framed structure and oriented in north-south direction. The structure was covered with ultra violet stabilized polythene sheet of 200 micron size. Two fresh air inlets, each of 0.6 m x 0.3 m were installed at the rear side of the dryer and at 0.15 m height from the ground level for entry of fresh air. Two each of 50 watt axial flow exhaust fans were fitted (9'' diameter) at the front side of the dryer at 2 m height from the ground level, for easy escape of moisture ladden air from the dryer, for obtaining higher drying rate. The structure was raised on concrete floor. Aonla segments were dried in platform having a dimension of 2.7 m x 1 m x 0.96 m (L x W x H).

OSMOTIC TREATMENT OF SPICED AONLA SEGMENTS

PLATE -2

CABINET DRYING AND SOLAR DRYING OF SPICED AONLA SEGMENTS

HOT AIR OVEN DRYING

SOLAR TUNNEL DRYING

PLATE -3

3.9 Packaging and storage

After dehydration, the dried *aonla* segments were weighed packed in flexible packaging (plastic punnets) and stored for 4 months at room temperature (28-30 ^{o}C).

Flow chart for osmotic dehydration of *aonla* is given in figure 3.1

Plate 1: Flow chart for osmotic dehydration of spiced *aonla* segments

SELECTION OF FRUITS

↓

WASHING

↓

BLANCHING

↓

REMOVAL OF SEEDS

↓

SYRUP PREPERATION

↓

ADDITION OF SPICE MIXTURE TO SYRUP

↓

ALLOW IT TO STAND FOR ONE HOUR

↓

FILTRATION OF SYRUP AND DIPPING OF SEGMENTES

↓

OSMOTIC TREATMENT

↓

DRAINING OUT

↙ ↘

CABINET DRYING **SOLAR DRYING**

↓

PACKAGING

↓

STORAGE

3.10 Treatment details

The laboratory experiment was carried out by using a Factorial Completely Randomized Design (Factorial CRD) with 18 treatments given in Table 3.1. Each treatment was replicated thrice with two types of different drying methods.

Table 3.1: Treatment combination

TREATMENTS	**CABINET DRYING**
T_1	Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup
T_2	Aonla segments with spices level-1 with OD in 60 °Brix sugar syrup for 24 hrs.
T_3	Aonla segments with spices level-2 with OD in 60 °Brix sugar syrup for 24 hrs.
T_4	Aonla segments with spices level-3 with OD in 60 °Brix sugar syrup for 24 hrs
T_5	Control: Aonla segments with combined processing (CP-blanching + freezing + drying)
T_6	Aonla segments with spices level-1(CP) with OD in 60 °Brix sugar syrup for 4 hrs
T_7	Aonla segments with spices level-2(CP) with OD in 60 °Brix sugar syrup for 4 hrs
T_8	Aonla segments with spices level-3(CP) with OD in 60 °Brix sugar syrup for 4 hrs
T_9	Control (3 % salt dip only for overnight with blanched aonla flakes)
	SOLAR DRYING
T_{10}	Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup
T_{11}	Aonla segments with spices level-1 with OD in 60 °Brix sugar syrup for 24 hrs.
T_{12}	Aonla segments with spices level-2 with OD in 60 °Brix sugar syrup for 24 hrs.
T_{13}	Aonla segments with spices level-3 with OD in 60 °Brix sugar syrup for 24 hrs
T_{14}	Control:Aonla segments with combined processing (CP) (blanching + freezing + drying)
T_{15}	Aonla segments with spices level-1(CP) with OD in 60 °Brix sugar syrup for 4 hrs
T_{16}	Aonla segments with spices level-2 (CP) with OD in 60 °Brix sugar syrup for 4 hrs
T_{17}	Aonla segments with spices level-3(CP) with OD in 60 °Brix sugar syrup for 4 hrs
T_{18}	Control (3 % salt dip only for overnight with blanched aonla flakes)

3.11 Observations

Sample of fresh fruits, prepared segments and dried product at initial as well as stored samples at two months intervals will be analyzed for various physio-chemical parameters. Samples will also be subjected to sensory quality evaluation.

3.11.1 Physical parameters

Mass transfer parameters like weight reduction, solid gain, water loss and other physical parameters like yield and dehydration ratio were analysed by following equations. (Silva *et al*., 2012)

1. Weight Reduction (WR %) =

$$\frac{\text{Initial weight – weight at time 't'}}{\text{Initial weight}} \times 100$$

2. Water loss (WL %) =

$$\frac{\text{Initial moisture – moisture at time ' t'}}{\text{Initial weight}} \times 100$$

3. Solid gain (SG %) = Moisture loss (%) – weight loss (%)

4. Yield (%) =

$$\frac{\text{Weight of prepared fruit segments}}{\text{Weight of fresh fruit segments}} \times 100$$

5. Dehydration ratio =

$$\frac{\text{Weight of fresh slices}}{\text{Weight of dehydrated slices}}$$

6. Moisture content (%)

Moisture content of fresh slices, osmosed slices as well as osmotically dehydrated samples was determined on percentage basis. Ten grams of sample was taken in a pre-weighed China dish and kept in a hot air oven (65-70 $^{\circ}$C) for overnight and then the weight was recorded using electronic balance. Moisture content was determined (Ranganna, 1991).

Calculation

$$\text{Moisture content (\%)} = \frac{\text{Moisture loss}}{\text{Sample weight}} \times 100$$

7. Water activity (a_w)

In the aqua lab (water activity measurement instrument) a sample is placed in a sample cup which is sealed against a sensor block inside the sensor and an infrared thermometer. It gives the water activity level in the food (Ranganna, 1991).

8. Rehydration ratio

Rehydration means refreshing the dehydrated or dried products in water. Six beakers of each 500 ml capacity were taken and 150 ml of water and 5 g of dried sample were poured into each beaker and kept for 50 or 60 min for presoaking. The samples were transferred to another six beakers with 150 ml boiling water. When boiling started, counting of time started. After the eating of this liquid portion was drained off and solid content were transferred to a Buchner funnel of 4 inch diameter separately fitted with filter paper. The excess water was removed by applying a gentle suction for a few seconds. The rehydrated materials were removed from the funnel and the weights taken individually (Ranganna, 1991) and finally the following relations were found out:

$$\text{Rehydration ratio} = \frac{\text{Wt. of rehydrated material}}{\text{Wt. of dehydrated material}}$$

3.11.2 Chemical parameters

1. Total soluble solids (TSS)

The total soluble solids of fresh segments were recorded in °Brix by using a Hand Refractometer (0-32 °Brix). (Make: Erma Optical Works Ltd., Tokyo, Japan) after making necessary temperature corrections.

2. Total titratable acidity (%)

Titratable acidity was analyzed by titrating a known aliquot of sample against standard 0.1N NaOH using phenolpthalein as indicator and was expressed as per cent citric acid.

Calculation

$$\text{Total acid } (\%) =$$

$$\frac{\text{Titre value} \times \text{N of alkali} \times \text{Vol. made up} \times \text{Eq.wt. of acid} \times 100}{\text{Vol. of sample taken for estimation} \times \text{wt. or vol. of sample taken} \times 1000}$$

3. Ascorbic acid

Ascorbic acid content was estimated with the help of volumetric method (Ranganna, 1991).

PROCEDURE: Ten gram of sample was homogenized with 0.4 % oxalic acid. The volume was then made up to 100 ml with 0.4 % oxalic acid. The solution was filtered using Whatman No.1 filter paper and the filtrate was used for analysis. 10 ml of extract were taken in a conical flask and titrated against the standard dye solution. The end point was light pink colour, which persists for 10 seconds. The readings were recorded and calculated using the formula

Calculation

$$\text{Ascorbic acid (mg /100g)} = \frac{\text{Titre value} \times \text{Dye Factor} \times \text{Vol. made up} \times 100}{\text{Vol. taken for titration} \times \text{Wt. of sample}}$$

4. Sugars

Sugars present in the osmotically dehydrated *aonla* samples were estimated following the method outlined by Lane and Eynon (Ranganna ,1991).

Reducing sugar

Preparation of sample

Ten grams of sample were taken and grinded in the pestle and mortar. Grinded sample was taken in 250 ml volumetric flask. To this 5 ml of lead acetate solution was added, shaked and allowed to stand for 10 minutes. Excess of lead was precipitated using 6 ml of potassium oxalate solution. Volume was made up to 250 ml by adding water and filtered. The solution was filtered through Whatman No. 4 filter paper and the filtrate was used for analysis.

Procedure

Ten ml of Fehling's solution [Fehling's No.A (5 ml) + Fehling's No.B (5 ml)] with 25 to 50 ml of distilled water was taken in a conical flask, heated to boil and titrated against the filtrate sample using methylene blue as an indicator. The end point of titration was brick red colour.

Calculation

$$\text{Reducing Sugar (\%)} = \frac{\text{Factor} \times \text{Dilution} \times 100}{\text{Titre value} \times \text{Wt. or volume of sample}}$$

Total sugars

Preparation of sample

50 ml of the filtrate (prepared for reducing sugar estimation) was hydrolyzed with 5 ml of concentrated HCL at room temperature for 24 hours. The hydrolyzed sample was neutralized with 40 per cent NaOH and the volume was made up to 100 ml with distilled water. Since all the sugars present in the sample were now converted to reducing sugars.

Procedure

Ten ml of Fehling's solution [Fehling's No. A (5 ml) + Fehling's No. B (5 ml)] with 25 to 50 ml of distilled water was taken in a conical flask, heated to boil and titrated against the sample using methylene blue as an indicator. The end point of titration was brick red colour. Total sugars were estimated and the values were expressed as percentage on weight basis.

Calculation

$$\text{Total sugars (\%)} = \frac{\text{Factor} \times \text{Vol. made up} \times \text{Dilution} \times 1000}{\text{Titre value} \times \text{weight of the sample}}$$

$$\text{Sucrose } (\%) = (\text{\% of total sugars - \% of reducing sugars}) \times 0.95$$

$$\text{Total sugars } (\%) = \text{\% of reducing sugars + \% of Sucrose}$$

Non-reducing sugars

The non-reducing sugar contents of the *aonla* segments were determined by the method of difference as: $\text{Non-reducing sugars} = \text{Total sugars - Reducing sugars}$

5. Non-enzymatic browning

Ten gram of sample was mixed with 100 ml of 80 per cent alcohol and kept for two hours. The absorbance of the filtrate at 440 nm was recorded in spectrophotometer using 80 per cent alcohol as blank. The value of non-enzymatic browning was expressed as optical density (OD at 440nm) (Srivastava and Sanjeevkumar 1998).

6. Total antioxidant activity (FRAP method)

Standards were prepared by taking 0 (blank), 0.2, 0.4, 0.6, 0.8 and 1.0 ml of the working standards and volume made to 1 ml by adding distilled water and 0.2ml of the standards were taken in test tubes to and to that 1.8 ml working FRAP reagent was added and incubated for 30 minutes at room temperature. The absorbance was read using UV/VIS spectrophotometer (Model: SP-3000 plus) at 593 nm against blank. The standard graph was plotted by taking the concentration of the standards on X -axis and absorbance on the Y-axis.

Procedure: 0.5 gram of sample was taken and extracted with 99:1 per cent methanol: HCl and 0.2 ml of the extract was taken in test tube and to that 1.8 ml working FRAP reagent was added and incubated for 30 minutes at ambient condition. The absorbance was read using UV/VIS spectrophotometer (Model: SP-3000 plus) at 593 nm against blank. Total antioxidant activity was calculated using standard graph (AOAC, 1990).

3.11.3 Sensory evaluation of the product

Organoleptic quality evaluation of osmotically dehydrated *aonla* segments was done for dried product at initial as well as stored samples at 2 months and 4 month intervals analyzed during storage. The various sensory features of the dehydrated samples was done by a panel of semi-skilled judges (10) by adopting a hedonic rating system having 100 points and score for quality parameters was 30 for colour and texture and 40 for flavour. The score card used for sensory evaluation is furnished (Sumitha *et al.,* 2013) .The organoleptic quality score card for fruits and vegetable products are given in Table 3.2.

3.12 Statistical analysis and interpretation of the data

The experimental data from 18 treatments, 3 replications pertaining to physico-chemical and sensory quality of osmotically dehydrated spiced aonla segments. Analysis of variance (ANOVA) was conducted to determine whether significant difference existed between different packages and temperatures on physico-chemical composition and sensory qualities of osmotically dehydrated spiced *aonla* segments. Further to know the effect of treatments and different methods of storage on samples during storage, individual means were calculated. Data has been suitably presented in form of tables and graphs (Fisher and Yates, 1963).

Table 3.2: Organoleptic quality score card for osmotically dehydrated spiced aonla product

Name of the product		Date of judging and time			
Sample Code	Sample / Treatment	Score			
		Colour (30)	Texture (30)	Flavour (40)	Total (100)
1					
2					
3					
4					
5					

Note: Please give the scores as per the details below.

No.	Scoring for color and consistency/ Texture	Scoring for Flavour
1	25-30 Very good	30-40 Very good
2	20-24 Good	20-29 Good
3	10-19 Average	10-19 Average
4	00-09 Poor	00-09 Poor

Name & Designation of the evaluator **Signature**

IV. EXPERIMENTAL RESULTS

The results of present investigation on 'Development of protocol for spiced dehydrated aonla (*Phyllanthus emblica* L.) segments' conducted at the Division of Post Harvest Technology, ICAR-Indian Institute of Horticultural Research (IIHR), Hessarghatta, Bengaluru are presented in this chapter.

4.1 Physical parameters of fresh *aonla* fruits

The observation of physical parameters of aonla such as Average weight of fruit (g), Pulp weight (%), Seed weight (%) are presented in the Table 1.

The average weight of fruit (g), Pulp weight (%) and Seed weight (%) of aonla variety Krishna was 37.27 gm, 94.41 % and 5.35 % respectively.

4.2 Chemical composition of *aonla* fruits

The chemical parameters of *aonla* fruits such as moisture content, TSS, ascorbic acid, titratable acidity, reducing sugars, non-reducing sugars, and total sugars are presented in Table 1.

The average moisture content in the fruits was 88.50 per cent, TSS 7.5 $^{\circ}$Brix, titratable acidity 2.35 per cent (as citric acid), ascorbic acid 395.2 (mg/100 g of edible portion), reducing sugars 3.25 per cent, nonreducing sugars 1.96 per cent and total sugars of 5.21 per cent, respectively (Table 1).

4.3 Effect of pre-treatments on per cent weight reduction (WR) by aonla segments after osmosis

Data pertaining to per cent weight reduction (WR) in osmosed aonla segments immediately after osmosis is given in Table 2.

Significant differences were recorded for per cent weight reduction in osmosed aonla segments as influenced by various osmotic treatments.

Table 1: Physico-chemical parameters of aonla fruit used in study

Sl. No.	Physical parameters	Values
1.	Average weight of fruit (g)	37.27
2.	Pulp weight (%)	94.41
3.	Seed weight (%)	5.35
Chemical parameters		
4.	Moisture content (%)	88.5
5.	Titrable acidity (%)	2.35
6.	Ascorbic acid (mg/100 g)	395.2
7.	TSS $^{\circ}$B	7.5
8.	Total sugar (%)	5.21
9.	Reducing sugar (%)	3.25
10.	Non-reducing sugar (%)	1.96

As a result of solid gain, maximum weight reduction (21.60 to 30.37 %) was also recorded in osmotically dehydrated samples, while values were negative (-4.45 to 4.52 %) in combined processed samples (T_6 to T_8).

4.4 Effect of pre-treatments on per cent solid gain (SG) in osmosed aonla segments

Data given in Table 2 and Figure 1 clearly indicates that there was a significant difference in per cent solid gain (SG) in aonla segments as influenced by various osmotic treatments.

Significantly higher solid gain (16.68 to 18.85 %) was recorded in blanched and frozen samples (T_6 to T_8) treated for 4 hrs as compared to blanched samples subjected to osmotic treatments for 24 hrs (T_1 to T_4) in which SG values ranged from 11.93 to 12.43 %.

In general combined processed samples showed maximum solid gain than simple osmotically dehydrated samples.

4.5 Effect of osmotic pre-treatments on per cent water loss (WL) by aonla segments after osmosis

Data pertaining to water loss (WL) clearly indicates that there was a significant difference in per cent water loss (%) in aonla segments as influenced by various osmotic treatments is given in Table 2.

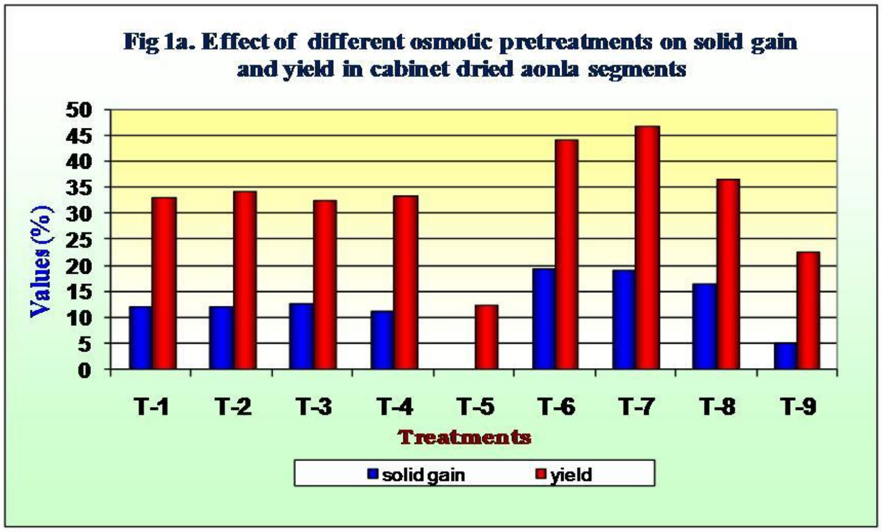
Maximum water loss of 42.57 per cent was found with Treatment T-2 (aonla segments with spices level-2 with OD in 60^o Brix sugar syrup for 24 hrs) which was at par with treatment T_1 and T_3. Water loss values were higher (33.85 to 42.57 %) in blanched segments (T_1 to T_3) as compared to blanched and frozen segments (T_6 - T_8) in which water loss values (15.97 to 21.18) were lower than solid gain and impact was negative.

Table 2: Effect of pre-treatments on water loss, solid gain and weight reduction in osmosed aonla segments used for cabinet and solar drying

Treatments		Water Loss (%)			Solid Gain (%)			Weight reduction (%)		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	42.46	41.09	41.77	12.36	11.50	11.93	29.07	30.10	29.59
OD 60 °B 24h + Spice Level-1	T_2	42.74	42.39	42.57	12.27	12.02	12.15	30.27	30.47	30.37
OD 60 °B 24h + Spice Level-2	T_3	38.53	36.93	37.73	12.89	11.24	12.07	25.74	25.64	25.69
OD 60 °B 24h + Spice Level-3	T_4	32.61	35.08	33.85	11.38	13.48	12.43	21.97	21.23	21.60
Control(CP-Blanched & frozen)	T_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPOD 60 °B 4h + Spice Level-1	T_6	16.61	15.32	15.97	19.41	17.80	18.61	-2.16	-2.80	-2.48
CPOD 60 °B 4h + Spice Level-2	T_7	17.09	16.23	16.66	19.10	18.60	18.85	-2.74	-2.01	-2.38
CPOD 60 °B 4h + Spice Level-3	T_8	21.04	21.33	21.18	16.54	16.81	16.68	4.53	4.50	4.52
Control (3% salt dip 24h)	T_9	1.75	2.68	2.21	5.29	6.21	5.75	-3.53	-3.54	-3.54
Mean		23.65	23.45		12.14	11.96		11.46	11.51	

	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	8.83	1.29	10.01
Factor B (drying)	NS	NS	NS
Interaction A x B	NS	2.23	NS

OD- Osmo dried, CP- Combined process, NS- Non significant.



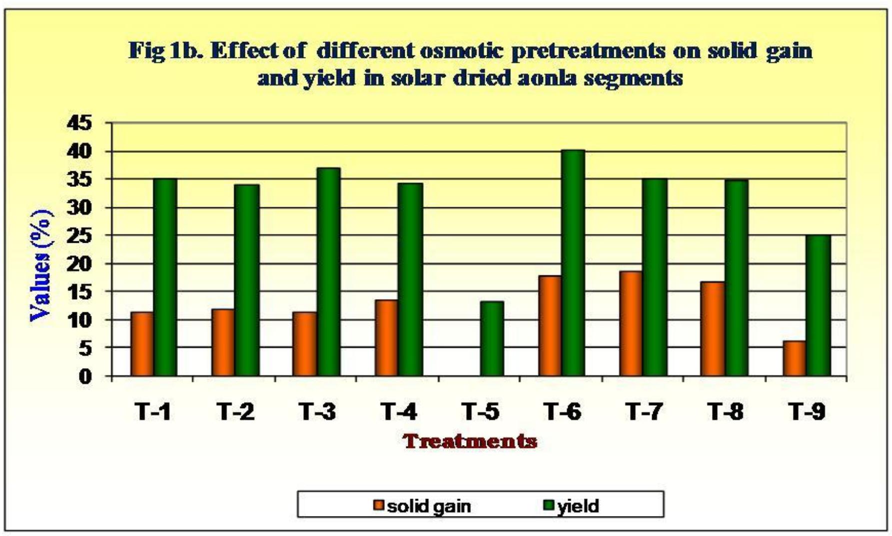


Fig 1. Effect of different osmotic pretreatments on solid gain and yield in cabinet dried (a) and solar dried (b) *aonla* segments

Osmo-dried (OD) 60° Brix 24h	T-1	CPOD 60° B 4h + Spice Level-1	T-6
OD 60° B 24h + Spice Level-1	T-2	CPOD 60° B 4h + Spice Level-2	T-7
OD 60° B 24h + Spice Level-2	T-3	CPOD 60° B 4h + Spice Level-3	T-8
OD 60° B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

Osmotic pretreatment of aonla segments with spices level-2 with OD in 60 °Brix sugar syrup for 24 hrs (T_2) shown maximum water loss of 42.49 per cent followed by T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) whereas water loss was not observed in (CP) T_5 (Control: Aonla segments with combined processing (blanching + freezing + drying).

4.6 Effect of osmotic pre-treatments on the yield of osmotically dehydrated aonla segments

Data pertaining to dried yield of aonla segments as affected by various osmotic pre-treatments is given in Table 3. There was a statistically significant difference among the treatments and drying methods with respect to final yield of osmo-air dried aonla segments.

Osmotic pretreatments significantly increased the yield in blanched aonla segments (T_1 to T_4) as well as combined processed samples (T6 to T_8) as compared to control samples (T5 and T_9).

Maximum product yield 47.10 per cent was recorded in aonla segments with spices level-2(CP) with OD in 60 °Brix sugar syrup for 4 hrs) followed by T_6 (aonla segments with spices level-1 (CP) with OD in 60 °Brix sugar syrup for 4 hrs) with an yield of 44.48 per cent in cabinet dried samples. Combined processed samples showed higher product yield as compared to osmotically dehydrated samples (T_1 to $T_{4)}$ in which mean value ranged from 33.90 to 34.82 %).Lowest yield was recorded in control samples T_5 (12.56 %) made by cabinet drying.

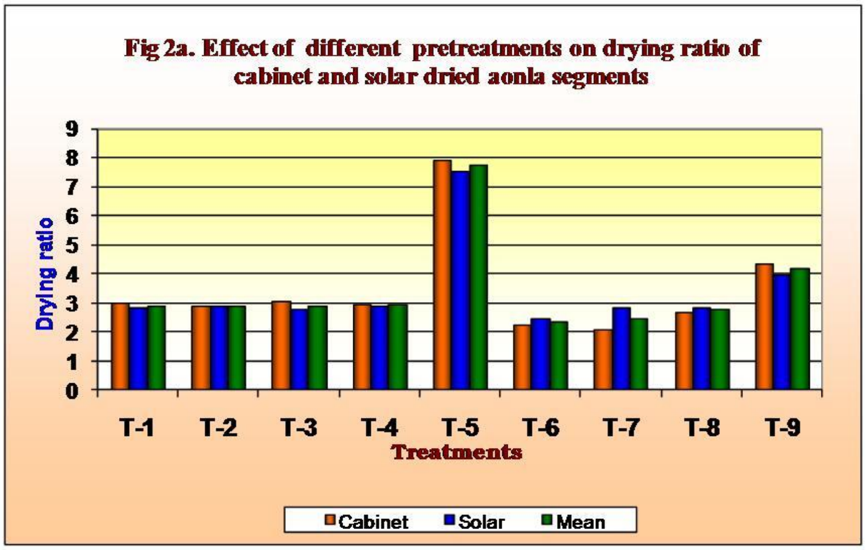
4.7 Effect of different osmotic pre-treatments on drying ratio of dehydrated aonla segments

Data given in Table 3 and Figure 2a indicates that different pre-treatments significantly affected the drying ratio of dehydrated aonla segments. Different pre-treatments significantly affected the drying ratio of dehydrated aonla segments. Maximum drying ratio 7.77:1 was observed in case of control (T_5). The drying ratio was minimum 2.12: 1 in aonla segments with spices level-2(CP) with OD in 60 °Brix sugar syrup for 4 hrs (T_7) in cabinet dried samples. In general the drying ratio was lower combined processed samples.

Table 3: Effect of pre-treatments on yield, drying ratio and rehydration ratio in dehydrated spiced aonla segments dried under cabinet and solar drier

Treatments		Yield (%)			Drying ratio			Rehydration ratio		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	33.25	35.04	34.14	3.01	2.85	2.93	2.07	1.71	1.89
OD 60 °B 24h + Spice Level-1	T_2	34.53	34.02	34.27	2.90	2.94	2.92	2.19	1.78	1.99
OD 60 °B 24h + Spice Level-2	T_3	32.68	36.96	34.82	3.06	2.79	2.92	2.10	2.26	2.18
OD 60 °B 24h + Spice Level-3	T_4	33.42	34.37	33.90	2.99	2.91	2.95	2.17	2.46	2.31
Control(CP-Blanched & frozen)	T_5	12.56	13.20	12.88	7.96	7.58	7.77	2.35	2.99	2.67
CPOD 60 °B 4h + Spice Level-1	T_6	44.48	40.15	42.31	2.25	2.49	2.37	2.01	2.60	2.30
CPOD 60 °B 4h + Spice Level-2	T_7	47.10	35.13	41.12	2.12	2.85	2.49	1.68	2.58	2.13
CPOD 60 °B 4h + Spice Level-3	T_8	36.84	34.84	35.84	2.72	2.87	2.80	1.76	2.61	2.18
Control (3% salt dip 24h)	T_9	22.80	25.03	23.91	4.39	4.00	4.19	2.03	3.01	2.52
Mean		33.07	32.08		3.49	3.48		2.04	2.44	
		CD at 5%			**CD at 5%**			**CD at 5%**		
Factor A (treatments)		2.30			0.22			0.13		
Factor B (drying)		1.33			NS			0.07		
Interaction A x B		NS			0.37			0.22		

OD- Osmo dried, CP- Combined process, NS- Non significant.



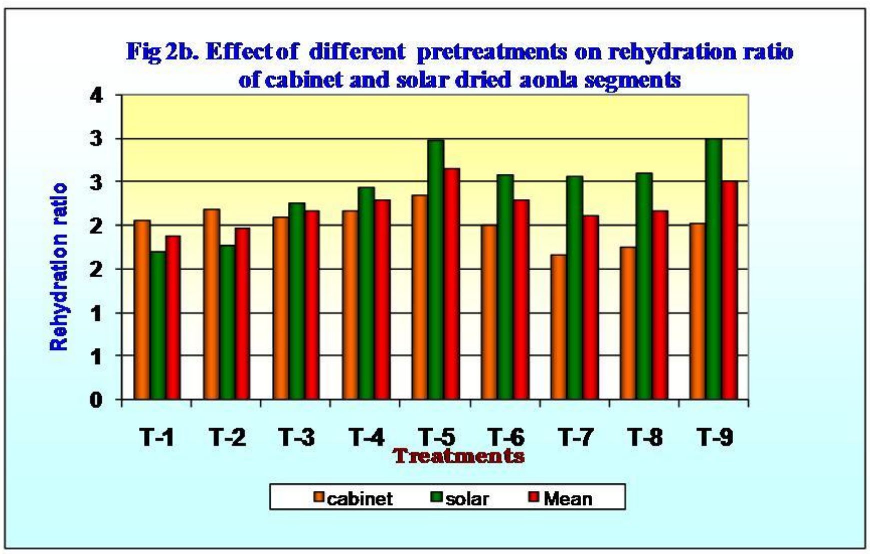


Fig 2. Effect of different osmotic pretreatments on drying ratio (a) and rehydration (b) in cabinet dried and solar dried *aonla* segments

Osmo-dried (OD) 60^0 Brix 24h	T-1	CPOD 60^0 B 4h + Spice Level-1	T-6
OD 60^0 B 24h + Spice Level-1	T-2	CPOD 60^0 B 4h + Spice Level-2	T-7
OD 60^0 B 24h + Spice Level-2	T-3	CPOD 60^0 B 4h + Spice Level-3	T-8
OD 60^0 B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

4.8 Effect of different osmotic pre-treatments on rehydration ratio of dehydrated aonla segments

Data given in Table 3 and Figure 2b indicates that different pre-treatments, drying methods and interaction significantly affected the drying ratio of dehydrated aonla segments. An improvement in the rehydration ratio of solar dried samples is observed compared to cabinet dried samples. Highest rehydration ratio was observed in (CP) T_5 (Control: Aonla segments with combined processing (blanching + freezing + drying) with a value of 2.35:1 and 2.99:1 in case of cabinet and solar dried samples respectively.

4.9 Effect of different pretreatments and drying methods on moisture content of dehydrated spiced aonla segments

Data pertaining to moisture content of osmotically dehydrated aonla segments at different stages of storage is presented in Table 4.

4.9.1 Effect on moisture content at initial stage

Data presented in (Table 4) about moisture content at initial stage of storage indicates that there was no significant difference in drying and interaction in moisture content as influenced by osmotic treatments. In the treated segments moisture content ranged from 11.01 (T_2) to 13.83 (T_8) percent in cabinet dried samples and 11.26 (T_2) to 13.58 (T_8) percent in solar dried samples. The control samples shows significantly high moisture content of 14.77 (T_9) and 15.02 (T_5) per cent in cabinet and solar dried samples respectively.

4.9.2 Effect on moisture content after two months of storage.

Significant differences were observed (Table 4) among the treatments. There is no significant difference between drying and interaction in moisture content after two months of storage. In the treated segments moisture content ranged from 10.31 (T_2) to 12.73 (T_7) percent in cabinet dried samples and 10.27 (T_2) to 12.37 (T_8) percent in solar dried samples.

A close persual of data indicates that there was slight decrease in moisture content in dehydrated samples during subsequent storage period (Table 4).

4.9.3 Effect on moisture content after four months of storage.

Data presented in Table 4 about moisture content after four months of storage indicates that there was no significant difference in drying and interaction in moisture content as influenced by osmotic treatments. Significant difference has been observed among the treatments.

It was observed that after four month of storage, lowest moisture content (9.78 per cent) reported in T_3 (osmotically dehydrated aonla segments with spice level-2 in 60 °Brix for 24 hrs) in cabinet dried samples and 9.55 percent (T_2- osmotically dehydrated aonla segments with spice level-1 in 60 °Brix for 24 hrs) in solar dried samples. A lower moisture content of 9.36 and 9.55 percent was observed in control T_5 sample and 9.39 and 9.44 percent in T_9 of both cabinet and solar respectively.

Data shown in Table 4 and indicates that moisture content in osmotically dehydrated aonla segments slightly decreased after four months of storage at room temperature and blanched frozen samples (T_6 to T_8)shows higher moisture than unfrozen osmotically dehydrated samples (T_1 to T_4) in both cabinet and solar dried samples. Not much variation was observed in moisture content in osmotically dehydrated aonla segments and moisture content slightly decreased after four months of storage at room temperature. Average moisture content values in cabinet dried and solar dried samples were 13.17 and 13.21 respectively.

Table 4: Effect of different pre- treatments and drying methods on moisture content in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Moisture content (%)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	13.00	12.70	12.85	11.86	12.00	11.93	10.99	11.05	11.02
OD 60 °B 24h + Spice Level-1	T_2	11.01	11.26	11.14	10.31	10.27	10.29	9.97	9.55	9.76
OD 60 °B 24h + Spice Level-2	T_3	11.76	12.00	11.88	10.56	11.01	10.79	9.78	10.12	9.95
OD 60 °B 24h + Spice Level-3	T_4	13.34	13.54	13.44	11.57	12.01	11.79	11.00	11.47	11.24
Control (CP-Blanched & frozen)	T_5	14.74	15.02	14.88	10.34	11.37	10.86	9.36	9.55	9.46
CPOD 60 °B 4h + Spice Level-1	T_6	12.85	12.65	12.75	11.37	11.28	11.33	10.21	10.35	10.28
CPOD 60 °B 4h + Spice Level-2	T_7	13.21	13.43	13.32	12.73	12.29	12.51	12.00	11.59	11.80
CPOD 60 °B 4h + Spice Level-3	T_8	13.83	13.58	13.71	12.22	12.37	12.30	11.49	11.07	11.28
Control (3% salt dip 24h)	T_9	14.77	14.73	14.75	10.67	11.01	10.84	9.39	9.44	9.42
Mean		13.17	13.21		11.29	11.51		10.47	10.47	

	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	0.68	0.52	0.47
Factor B (drying)	NS	NS	NS
Interaction A x B	NS	NS	NS

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage

4.10 Effect of different pretreatments and drying methods on total solids content of dehydrated spiced aonla segments

Data regarding total solids content in osmotically dehydrated aonla segments is presented in Table 5.

4.10.1 Effect on total solids at initial stage

Significant differences were observed (Table 5) among the treatments. There is no significant difference between drying and interaction in total solid content at initial stage of storage.

Among the treated samples highest total solid content was 88.99 (T_2) per cent and lowest of 86.17 (T_8) per cent in cabinet dried samples and total solids ranges from 86.42 (T_8) to 88.74 (T_2) in solar dried samples. The control samples has significantly lower total solid content of 85.26 and 84.98 percent in T_5 of both cabinet and solar dried samples respectively. And also the untreated T_9 samples has 85.23 and 85.27 percent total solids in cabinet and solar dried samples respectively.

4.10.2 Effect on total solids after 2 months of storage

Significant differences were observed (Table 5) among the treatments. There is non significant difference between drying and interaction in total solid content after two months of storage.

In the treated samples total solids ranged from 87.27 (T_7) to 89.69 (T_2) in cabinet dried samples whereas in solar dried samples it ranged from 86.41 (T_4) to 88.69 (T_2) percent. Untreated T_5 showed a higher total solid content of 91.58 percent in solar dried samples.

A close persual of data indicates that there was slight increase in the total solids content in dehydrated samples during subsequent storage period (Table 5).

Table 5: Effect of different pre- treatments and drying methods on total solids content in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Total solids (%)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	87.00	87.30	87.15	88.14	88.00	87.52	89.01	90.73	88.11
OD 60 °B 24h + Spice Level-1	T_2	88.99	88.74	88.87	89.69	88.69	89.00	90.03	87.42	88.93
OD 60 °B 24h + Spice Level-2	T_3	88.24	88.00	88.12	89.44	87.42	88.24	90.22	88.58	88.53
OD 60 °B 24h + Spice Level-3	T_4	86.66	86.46	86.56	88.43	86.41	86.90	89.00	85.98	87.05
Control(CP-Blanched & frozen)	T_5	85.26	84.98	85.12	89.66	91.58	87.32	90.64	92.32	88.36
CPOD 60 °B 4h + Spice Level-1	T_6	87.15	87.35	87.25	88.63	87.84	87.64	89.79	88.96	88.08
CPOD 60 °B 4h + Spice Level-2	T_7	86.79	86.57	86.68	87.27	87.71	87.00	88.00	88.49	87.31
CPOD 60 °B 4h + Spice Level-3	T_8	86.17	86.42	86.30	87.78	87.63	86.86	88.51	91.09	87.59
Control (3% salt dip 24h)	T_9	85.23	85.27	85.25	89.33	88.99	86.81	90.61	94.24	88.22
Mean		86.83	86.79		88.71	88.25		89.53	89.76	
		CD at 5%			**CD at 5%**			**CD at 5%**		
Factor A (treatments)		0.68			0.52			0.47		
Factor B (drying)		NS			NS			NS		
Interaction A x B		NS			NS			NS		

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage

4.10.3 Effect on total solids after 4 months of storage

In the treated samples total solids ranged from 88 (T_7) to 89.79 (T_6) percent in cabinet dried samples and 85.98 (T_4) to 91.09 (T_8) percent in solar dried samples. Overall the untreated T_9 of solar dried sample showed a highest total solid content of 94.24 percent.

Further, it was observed that there was slight increase in total solids content in the samples during the subsequent storage periods.

4.11 Effect of different pretreatments and drying methods on titratable acidity content of dehydrated spiced aonla segments

Data pertaining to titrable acidity in osmotically dehydrated spiced aonla segments at different stage of storage in given in Table 6 and Figure 3a and 3b.

4.11.1 Effect on titratable acidity at initial stage

Data given in Table 6 about titrable acidity in osmotically dehydrated spiced aonla segments indicates that there was significant variation among the treatments.

Among the treated samples highest (1.93 %) acidity was observed in T_6 (Combine processing with spice level -1 with OD at 60° Brix for 4hrs) of solar dried samples whereas lowest (0.88 %) acidity in T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) in the cabinet dried samples. Untreated frozen samples T_5 showed a highest acidity of 7.94 % and 6.71 % in cabinet and solar dried samples respectively.

Combined processed samples (T_6 to T_8) showed a highest acidity content than simple osmotically dehydrated samples (T_1 to T_4) in both cabinet and solar dried samples.

4.11.2 Effect on titatable acidity after 2 months of storage

It is evident from the data (Table 6) that titrable acidity in osmotically dehydrated *aonla* segments had significant variation among the treatments after 2 months of storage.

Table 6: Effect of different pre- treatments and drying methods on titratable acidity in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Titratable acidity (%)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	0.88	0.96	0.92	0.95	1.12	1.04	1.21	1.28	1.25
OD 60 °B 24h + Spice Level-1	T_2	1.10	1.12	1.11	1.39	1.41	1.40	1.71	1.76	1.74
OD 60 °B 24h + Spice Level-2	T_3	1.40	1.50	1.45	1.64	1.73	1.69	1.91	2.05	1.98
OD 60 °B 24h + Spice Level-3	T_4	1.71	1.20	1.46	1.86	1.46	1.66	2.22	2.13	2.18
Control(CP-Blanched & frozen)	T_5	7.94	6.71	7.33	8.11	7.57	7.84	8.18	7.68	7.93
CPOD 60 °B 4h + Spice Level-1	T_6	1.58	1.93	1.76	2.52	2.50	2.51	2.88	2.89	2.89
CPOD 60 °B 4h + Spice Level-2	T_7	1.53	1.81	1.67	2.38	2.43	2.41	2.91	2.87	2.89
CPOD 60 °B 4h + Spice Level-3	T_8	1.78	1.75	1.77	2.47	2.62	2.55	2.99	2.93	2.96
Control (3% salt dip 24h)	T_9	5.32	5.31	5.32	5.62	5.68	5.65	6.12	6.10	6.11
Mean		2.58	2.48		2.99	2.95		3.35	3.3	
		CD at 5%			**CD at 5%**			**CD at 5%**		
Factor A (treatments)		0.61			0.83			0.94		
Factor B (drying)		NS			NS			NS		
Interaction A x B		NS			NS			NS		

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage

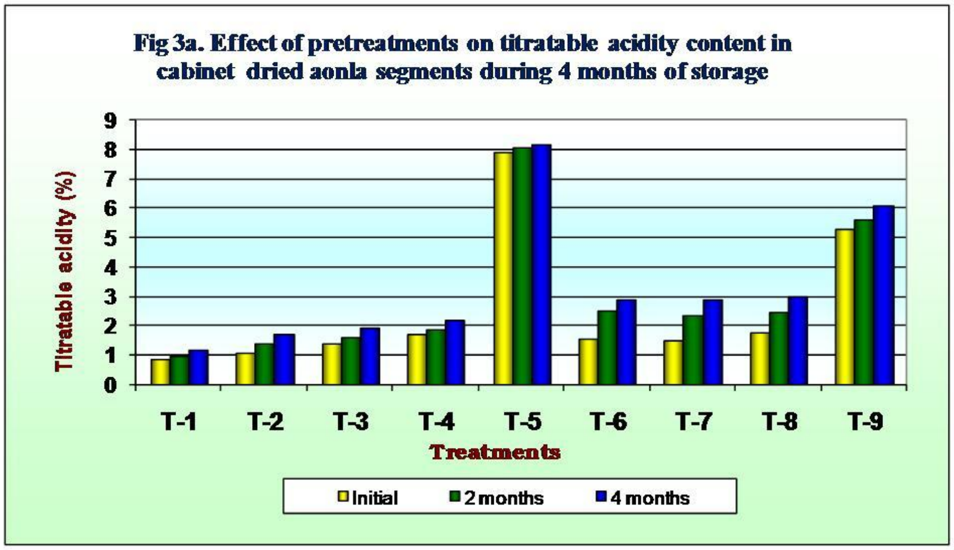


Fig 3a. Effect of pretreatments on titratable acidity content in cabinet dried aonla segments during 4 months of storage

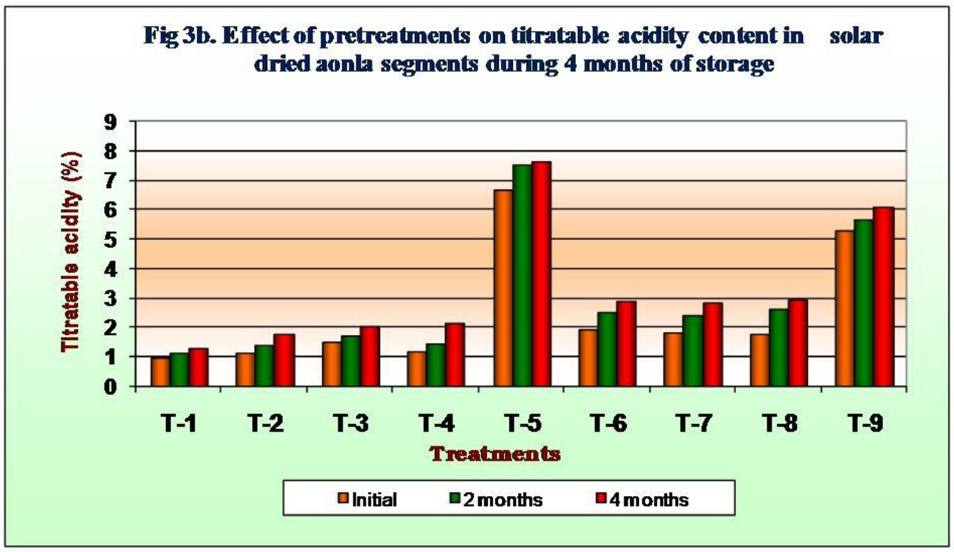


Fig 3b. Effect of pretreatments on titratable acidity content in solar dried aonla segments during 4 months of storage

Fig 3. Effect of different pretreatments on titratable acidity content in cabinet dried (a)

Osmo-dried (OD) 60^0 Brix 24h	T-1	CPOD 60^0 B 4h + Spice Level-1	T-6
OD 60^0 B 24h + Spice Level-1	T-2	CPOD 60^0 B 4h + Spice Level-2	T-7
OD 60^0 B 24h + Spice Level-2	T-3	CPOD 60^0 B 4h + Spice Level-3	T-8
OD 60^0 B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

Among the treated samples acidity varied from 0.95 % (T_1) to 2.52 % (T_6) in cabinet dried samples whereas from 1.12 % (T_1) to 2.62 % (T_8) in solar dried samples. Untreated frozen sample (T_5) dried under cabinet drier showed a highest acidity of 8.11 %.

A close persual of data indicates that there was slight increase in the titrable acidity content in dehydrated samples during subsequent storage period (Table 6).

4.11.3 Effect on titatable acidity after 4 months of storage

Data (Table 6) with respect to titrable acidity after four months of storage clearly indicates that there was significant difference among the treatments.

Among the treated samples titrable acidity ranged from 1.21 % (T_1) to 2.99 % (T_8) in cabinet dried samples and 1.28 % (T_1) to 2.93 % (T_8) in solar dried samples.

Maximum acidity content was recorded in control sample T_5 7.94 % (cabinet dried) & 6.71 % (solar dried). However osmotic treatment resulted in significant reduction in acidity content in dehydrated aonla segments. During the subsequent storage period there was slight increase in the titratable acidity content in dehydrated samples (Table 6). The combined processed samples(T_6 to T_8) showed a highest acidity content than simple osmotically dehydrated samples (T_1 to T_4) in both cabinet and solar dried samples in all three stages of storage.

4.12 Effect of different pretreatments and drying methods on ascorbic acid content of dehydrated spiced aonla segments

Data pertaining to ascorbic acid content (mg/100 g) in osmotically dehydrated *aonla* segments at different stage of storage is given in Table 7 and Figure 4a and 4b.

4.12.1 Effect on ascorbic acid at initial stage

Data given about ascorbic acid content in osmotically dehydrated spiced *aonla* segments clearly indicates that there was no significant variation among the drying and interaction .Significant difference was observed between treatments.

However in general treated sample dried using cabinet drier has higher content of 146.10 mg/100 (T_4) than that of solar dried samples of 124.92 mg/ 100 g (T_4) which was significantly different from rest of the samples. Ascorbic acid content (mg/100 g) ranged from 104.04 to 146.10 mg/100 g in cabinet dried samples while it was in the range of 95.08 to 124.92 mg/100 g in solar dried samples. Untreated frozen samples (T_5) dried under cabinet drier showed higher ascorbic acid content of 205.63 mg/100 g.

A gradual increase in ascorbic acid content (114.24 mg/100 gm to 146.10 mg/100 gm) is found from T_2 to T_4 with increase in spice content. Similar trend has been observed in case of combined process samples from T_6 to T_8 where ascorbic acid ranges from 108.02 mg/100 gm to 127.34 mg/100 gm. Among the treated samples combined processed samples with various spice levels showed higher ascorbic acid content than simple osmotically dehydrated samples with varied spice levels.

4.12.2 Effect on ascorbic acid after 2 months of storage.

Data given in Table 7 clearly indicates that various treatments and drying methods significantly affected the ascorbic acid content in osmotically dehydrated *aonla* samples after two months of storage.

Among the treated samples ascorbic acid content ranged from 93.11 mg/100 g (T_1) to 132.00 mg/100 g (T_4) in cabinet dried samples whereas from 72.67 mg/100 g (T_1) to 111.56 mg/100 g (T_8) in solar dried samples. Untreated frozen cabinet dried sample (T5) showed a higher ascorbic acid content of 177.89 mg/100 g.

Further values given in Fig 4a and 4b indicate that in general the ascorbic acid content decreased during storage in osmotically dehydrated spiced aonla segments.

4.12.3 Effect on ascorbic acid after 4 months of storage

Data regarding the ascorbic acid content in osmotically dehydrated spiced *aonla* segments after four months of storage is given in Table 7.

There was significant difference between treatment and interation. Among the treated samples ascorbic acid varied from 80.64 mg/100 g (T_1) to 105.28 mg/100 g (T_4) in cabinet dried samples whereas 65.71 mg/100 g (T_6) to 94.58 mg/100 gm in solar dried samples. Untreated frozen (T_5) showed higher ascorbic acid content of 155.58 mg/100 g dried under cabinet drier.

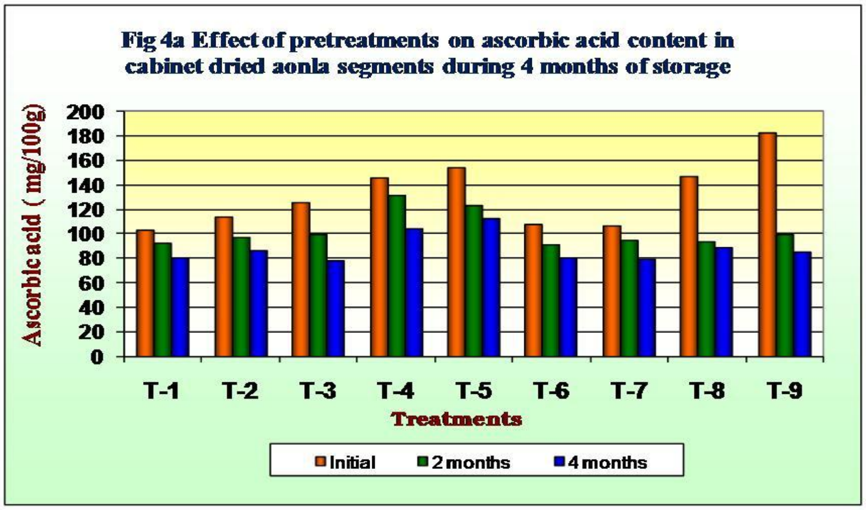
A close persual of data indicates that there was decrease in the ascorbic acid content in dehydrated samples during subsequent storage period (Table 7). A gradual increase in ascorbic acid content is found from T_2 to T_4 with increase in spice content. Similar trend has been observed in case of combined process samples from T_6 to T_8. Among the treated samples combined processed samples with various spice levels showed higher ascorbic acid content than simple osmotically dehydrated samples with varied spice levels.

Table 7: Effect of different pre- treatments and drying methods on ascorbic acid content in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Ascorbic acid (mg/100gm)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	104.04	95.08	99.56	93.11	72.67	92.89	80.64	68.11	74.38
OD 60 °B 24h + Spice Level-1	T_2	114.24	101.03	107.63	106.42	93.78	104.62	86.86	81.64	84.25
OD 60 °B 24h + Spice Level-2	T_3	126.68	118.65	122.67	117.30	89.78	115.02	96.53	83.88	90.20
OD 60 °B 24h + Spice Level-3	T_4	146.10	124.92	135.51	132.00	103.82	128.47	105.28	94.58	99.93
Control(CP-Blanched & frozen)	T_5	205.63	154.31	179.97	177.89	145.38	172.64	155.58	110.76	133.17
CPOD 60 °B 4h + Spice Level-1	T_6	108.02	98.98	103.50	91.56	80.44	96.50	81.39	65.71	73.55
CPOD 60 °B 4h + Spice Level-2	T_7	115.19	108.26	111.72	95.78	92.00	104.59	88.81	83.08	85.95
CPOD 60 °B 4h + Spice Level-3	T_8	127.34	119.31	123.33	115.78	111.56	119.46	98.19	88.02	93.10
Control (3% salt dip 24h)	T_9	97.37	93.92	95.64	88.37	82.22	91.50	74.23	64.71	69.47
Mean		127.18	112.72		113.13	96.85		96.39	82.28	

	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	18.37	7.71	7.16
Factor B (drying)	NS	4.45	NS
Interaction A x B	NS	NS	12.39

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage



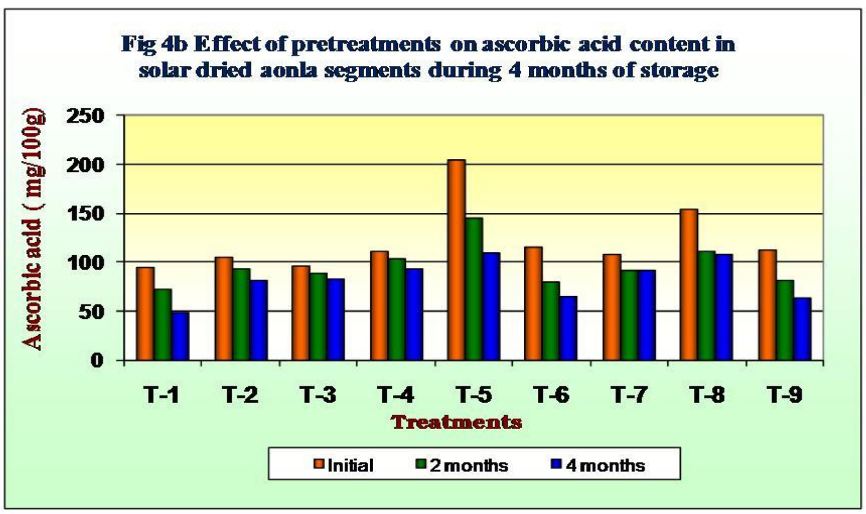


Fig 4. Effect of different pretreatments on ascorbic acid content in cabinet dried (a) and solar dried (b) *aonla* segments during 4 months of storage

Osmo-dried (OD) 60^0 Brix 24h	T-1	CPOD 60^0 B 4h + Spice Level-1	T-6
OD 60^0 B 24h + Spice Level-1	T-2	CPOD 60^0 B 4h + Spice Level-2	T-7
OD 60^0 B 24h + Spice Level-2	T-3	CPOD 60^0 B 4h + Spice Level-3	T-8
OD 60^0 B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

4.13 Effect of different pretreatments and drying methods on total antioxidant content of dehydrated spiced aonla segments

Data pertaining to ascorbic acid content (mg/100 g) in osmotically dehydrated *aonla* segments at different stage of storage is given in Table 8 and Figure 5a and 5b

4.13.1 Effect on total antioxidant content at initial stage

Different treatments and drying methods significantly affected the total antioxidant content in osmotically dehydrated spiced aonla segments at initial stage of storage as given in Table 8.

Among the treated samples highest total antioxidant content (2423 mg/100 g) was observed in T_4 (aonla segments treated with spices level-3 with OD in 60 °Brix sugar syrup for 24 hrs) in cabinet dried samples and lowest (1734 mg/100 g) in T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) in cabinet dried samples. Total antioxidant content ranges from 1890 mg/100 g (T_1) to 2423 mg/100 g (T_4) in cabinet dried samples whereas from 1734 mg/100 g (T_1) to 2248 mg/100 gm (T_8) in solar dried samples. Untreated frozen samples (T_5) under solar drier showed maximum total antioxidant of 2814 mg/100 g.

A gradual increase in antioxidant content (2227 mg/100 g to 2423 mg/100 g) is found from T_2 to T_4 with increase in spice content. Similar trend has been observed in case of combined process samples from T_6 to T_8 where ascorbic acid ranges from 2189 mg/100 gm to 2258 mg/100 g.

4.13.2 Effect on total antioxidant content after 2 months of storage

Different treatments, drying methods and interaction significantly affected the total antioxidant content in osmotically dehydrated spiced aonla segments after two months of storage as given in Table 8.

Among the treated samples highest antioxidant content was observed in T_4 (2170 mg/100 g) in cabinet dried sample and lowest (1689 mg/100 g) in T_1 in solar dried samples. Total antioxidant content ranges from 1746 mg/100 g (T_1) to 2170 mg/100 gm (T_4) in cabinet dried samples whereas it ranges from 1689 mg/100 g (T_1) to 2102 mg/100 g (T_4) in solar dried samples. A gradual increase in antioxidant content was found from T_2 to T_4 with increase in spice content. Similar trend has been observed in case of combined process samples from T_6 to T_8.

4.13.3 Effect on total antioxidant content after 4 months of storage.

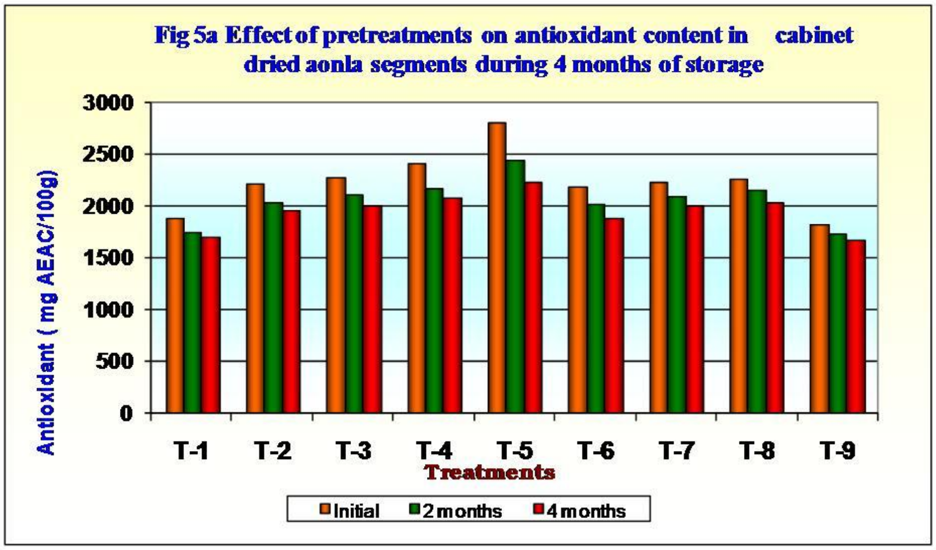
Different treatments and drying methods significantly affected the total antioxidant content in osmotically dehydrated spiced aonla segments after four months of storage as given in Table 8

Among the treated samples highest antioxidant content was observed in 2080 mg/100 gm in T_4 (Aonla segments with spices level-3 with OD in 60 °Brix sugar syrup for 24 hrs) in cabinet dried samples and lowest in T_1 of solar dried samples with 1600 mg/100 g.

Table 8: Effect of different pre- treatments and drying methods on total antioxidant content in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		**Total antioxidant (mg AEAC/100 g))**								
		INITIAL			**2 MAS**			**4 MAS**		
		Cabinet	**Solar**	**Mean**	**Cabinet**	**Solar**	**Mean**	**Cabinet**	**Solar**	**Mean**
Osmo-dried (OD) 60 °Brix 24h	T_1	1890	1734	1812	1746	1689	1718	1700	1600	1650
OD 60 °B 24h + Spice Level-1	T_2	2227	2008	2118	2036	1926	1981	1961	1858	1910
OD 60 °B 24h + Spice Level-2	T_3	2274	2104	2189	2114	1987	2050	2004	1877	1941
OD 60 °B 24h + Spice Level-3	T_4	2423	2144	2283	2170	2102	2136	2080	1989	2034
Control(CP-Blanched & frozen)	T_5	2814	2419	2616	2442	2193	2318	2241	2145	2193
CPOD 60 °B 4h + Spice Level-1	T_6	2189	2148	2168	2029	2029	2029	1888	1833	1860
CPOD 60 °B 4h + Spice Level-2	T_7	2228	2184	2206	2094	2065	2080	2005	1876	1941
CPOD 60 °B 4h + Spice Level-3	T_8	2258	2248	2253	2153	2085	2119	2036	1945	1991
Control (3% salt dip 24h)	T_9	1832	1644	1738	1734	1590	1662	1674	1500	1587
Mean		2237	2070		2058	1963		1954	1847	
		CD at 5%			**CD at 5%**			**CD at 5%**		
Factor A (treatments)		78			71			61		
Factor B (drying)		45			41			35		
Interaction A x B		NS			124			NS		

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage



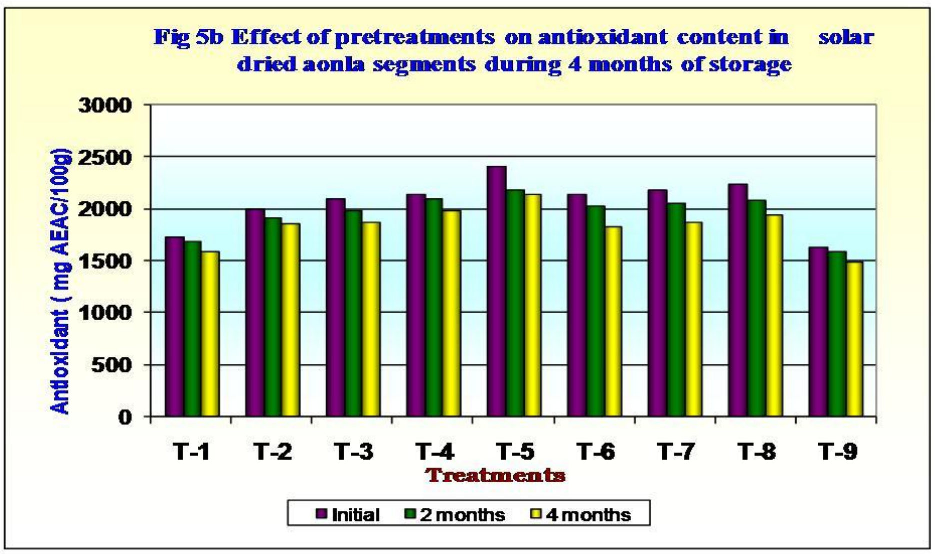


Fig 5. Effect of different pretreatments on antioxidant content in cabinet dried (a) and solar dried (b) *aonla* segments during 4 months of storage

Osmo-dried (OD) 60° Brix 24h	T-1	CPOD 60° B 4h + Spice Level-1	T-6
OD 60° B 24h + Spice Level-1	T-2	CPOD 60° B 4h + Spice Level-2	T-7
OD 60° B 24h + Spice Level-2	T-3	CPOD 60° B 4h + Spice Level-3	T-8
OD 60° B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

A close persual of data indicates that a gradual increase in antioxidant content was found from T_2 to T_4 with increase in spice content. Similar trend has been observed in case of combined process samples from T_6 to T_8. During subsequent storage periods total antioxidant content decreased.

4.14 Effect of different pretreatments and drying methods on reducing sugar content of dehydrated spiced aonla segments

4.14.1 Effect on reducing sugar at initial stage

Different treatments, drying methods and interaction significantly affected the reducing sugar content in osmotically dehydrated spiced aonla segments as given in Table 9 and Figure 6a and 6b.

Among the treated samples highest sugar content observed is 17.83 percent in T_2 of cabinet dried samples and lowest of 15.30 (T_7) percent in solar dried samples. Among the treated samples reducing sugar content ranged from 14.32 percent (T_7) to 17.83 percent (T_2) in cabinet dried samples and 15.30 (T_7) to 18.12 (T_3) percent in solar dried samples. Untreated samples (T_9) showed lower reducing sugar content of 3.08 percent and 3.11 percent in cabinet and solar drier respectively.

4.14.2 Effect on reducing sugar after 2 months of storage.

Different treatments, drying and interaction significantly affected the reducing sugar content in osmotically dehydrated spiced aonla segments after 2 months storage is given in Table 9.

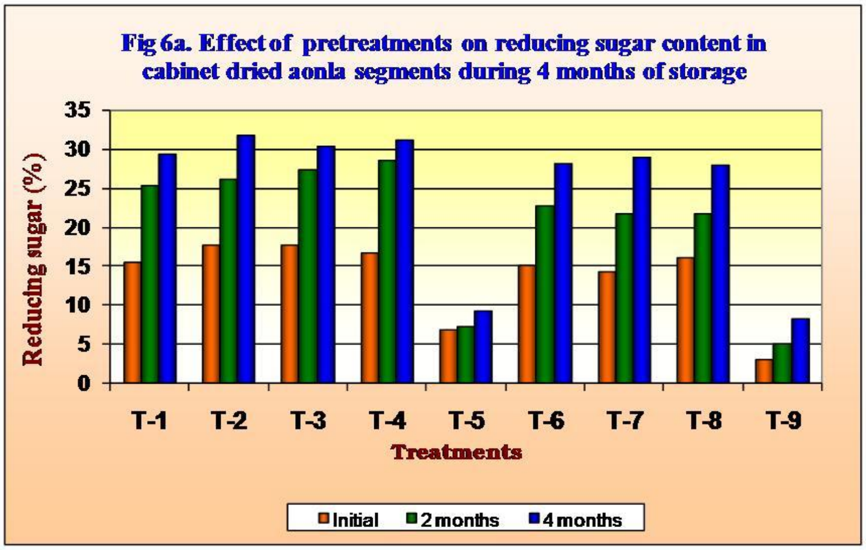
Among the treated samples reducing sugar content ranged from 21.69 (T_8) percent to 28.64 (T_4) percent in cabinet dried samples whereas 23.05 (T_8) percent to 27.31 (T_4) percent in solar dried samples. Untreated T9 samples of both cabinet and solar dried samples showed lower reducing sugar content of 5.12 percent and 5.23 percent respectively. Highest sugar content (28.64 percent) was observed in T_4 of cabinet drier.

Table 9: Effect of different pre- treatments and drying methods on reducing sugar content in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Reducing sugar (%)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	15.57	15.79	15.68	25.46	26.34	25.90	29.37	30.53	29.95
OD 60 °B 24h + Spice Level-1	T_2	17.83	18.00	17.92	26.24	25.65	25.95	31.91	32.01	31.96
OD 60 °B 24h + Spice Level-2	T_3	17.66	18.12	17.89	27.31	26.97	27.14	30.34	31.53	30.94
OD 60 °B 24h + Spice Level-3	T_4	16.78	16.55	16.67	28.64	27.31	27.98	31.17	32.62	31.90
Control(CP-Blanched & frozen)	T_5	6.83	6.51	6.67	7.32	8.71	8.02	9.21	11.12	10.17
CPOD 60 °B 4h + Spice Level-1	T_6	15.13	15.76	15.45	22.85	23.13	22.99	28.22	29.68	28.95
CPOD 60 °B 4h + Spice Level-2	T_7	14.32	15.30	14.81	21.72	24.03	22.88	29.04	29.99	29.52
CPOD 60 °B 4h + Spice Level-3	T_8	16.22	17.23	16.73	21.69	23.05	22.37	27.96	26.51	27.24
Control (3% salt dip 24h)	T_9	3.08	3.11	3.10	5.12	5.23	5.18	8.38	8.67	8.53
Mean		13.71	14.04		20.71	21.16		25.07	25.85	

	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	1.67	1.41	1.60
Factor B (drying)	0.96	0.81	0.93
Interaction A x B	2.89	2.44	2.78

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage



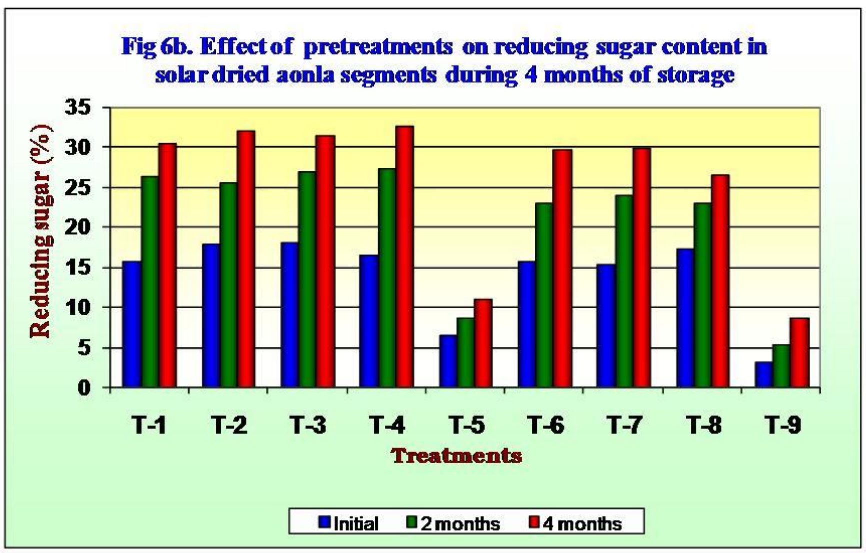


Fig 6. Effect of different pretreatments on reducing sugar content in cabinet dried (a) and solar dried (b) *aonla* segments during 4 months of storage

Osmo-dried (OD) 60° Brix 24h	T-1	CPOD 60° B 4h + Spice Level-1	T-6
OD 60° B 24h + Spice Level-1	T-2	CPOD 60° B 4h + Spice Level-2	T-7
OD 60° B 24h + Spice Level-2	T-3	CPOD 60° B 4h + Spice Level-3	T-8
OD 60° B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

A close persual of data indicates that there was slight increase in the reducing sugar content dehydrated samples during subsequent storage period (Table 9).

4.14.3 Effect on reducing sugar after 4 months of storage

Different treatments, drying and interaction significantly affected the reducing sugar content in osmotically dehydrated spiced aonla segments after 4 months storage is given in Table 9.

Highest reducing sugar content observed is 32.62 (T_4) percent in solar dried sample where aonla segments were treated with spices level-3 with OD in 60 °Brix sugar syrup for 24 hrs. Among the treated samples reducing sugar content ranged from 27.96 (T_8) percent to 31.91 (T_2) percent in cabinet dried samples and 26.51 (T_8) percent to 32.62 (T_4) percent in solar dried samples.

During subsequent storage period, reducing sugar content increased. In general treated combined processed samples with varying spice levels (T_6 to T_8) of both cabinet and solar drying showed lower reducing sugar content than general osmotically dehydrated aonla segments with varying spice levels (T_2 to T_4).

4.15 Effect of different pretreatments and drying methods on non reducing sugar content of dehydrated spiced aonla segments

4.15.1 Effect on non reducing sugar at initial stage

The data on the effect of treatments, drying and there interaction on the changes in the non-reducing sugar content (%) in osmotically dehydrated *aonla* segments during storage is presented in the Table 10 and Figure 7.

There was significant difference between treatments, drying and interaction on changes of non-reducing sugar content .Among the treated samples highest non-reducing sugar content was found in T_7 (13.29 per cent) of cabinet dried samples and lowest in T_8 (9.25 per cent) of solar dried sample. Reducing sugar content varied from 10.36 (T_1) percent to 13.29 (T_7) percent in cabinet dried samples whereas 9.25 (T_8) to 12.91 (T_4 and T_7) in solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) of both cabinet and solar driers showed low non-reducing sugar content.

4.15.2 Effect on non reducing sugar after 2 months of storage

Different treatments significantly affected the non-reducing sugar content in osmotically dehydrated spiced aonla segments after 2 months storage is given in Table 10.

There was significant difference between treatments, drying and interaction on changes of non-reducing sugar content .Among the treated samples highest non reducing sugar was recorded as 9.13 (T_8) percent in cabinet dried samples and lowest content (3.83 percent) in T_1 of cabinet drier. Non reducing sugar content of cabinet dried samples varied from 3.83 (T_1) percent to 9.13 (T_8) percent whereas 3.91 (T_1) to 7.65 (T6) percent in solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) of both cabinet and solar drier showed a lower non-reducing sugar contents.

A close persual of data indicates that there was a decrease in the non reducing sugar content dehydrated samples during subsequent storage period (Table 9) and Fig 7a and 7b.

4.15.3 Effect on non reducing sugar after 4 months of storage

Different treatments significantly affected the non-reducing sugar content in osmotically dehydrated spiced aonla segments after 2 months storage is given in Table 10.

There was significant difference between treatments, drying and interaction on changes of non-reducing sugar content. Among the treated samples highest non reducing sugar observed is 6.91 (T_8) percent in solar dried samples and lowest found is 1.84 (T_2) percent in cabinet dried sample. Non reducing content of cabinet dried samples ranged from 1.84 (T_2) to 5.94 (T_8) percent in cabinet dried samples whereas 2.35 (T_2) percent to 6.91 (T_8) percent in solar dried samples.

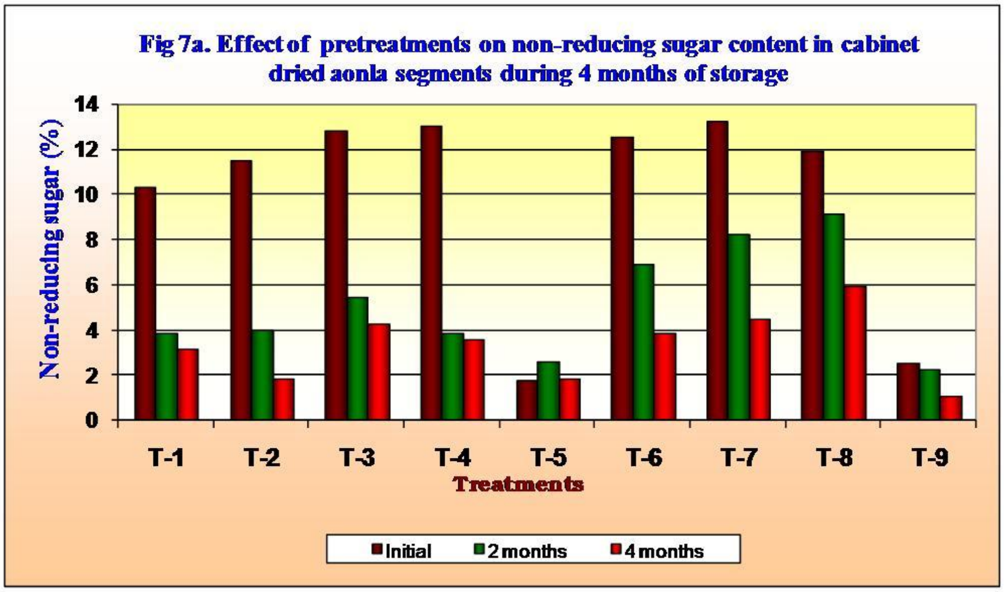
During subsequent storage period the non reducing sugar content of samples decreased (Table 10) and Fig 7a and 7b.

Table 10: Effect of different pre- treatments and drying methods on non- reducing sugar content in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Non-reducing sugar (%)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	10.36	11.11	10.74	3.83	3.91	3.87	3.18	3.08	3.13
OD 60 °B 24h + Spice Level-1	T_2	11.53	11.65	11.59	3.98	6.40	5.19	1.84	2.35	2.10
OD 60 °B 24h + Spice Level-2	T_3	12.82	12.10	12.46	5.47	7.01	6.24	4.31	4.18	4.25
OD 60 °B 24h + Spice Level-3	T_4	13.07	12.91	12.99	3.86	5.77	4.82	3.56	4.24	3.90
Control(CP-Blanched & frozen)	T_5	1.79	3.58	2.69	2.60	3.06	2.83	1.83	1.34	1.59
CPOD 60 °B 4h + Spice Level-1	T_6	12.54	11.50	12.02	6.93	7.65	7.29	3.88	2.65	3.27
CPOD 60 °B 4h + Spice Level-2	T_7	13.29	12.91	13.10	8.26	6.39	7.33	4.46	3.67	4.07
CPOD 60 °B 4h + Spice Level-3	T_8	11.94	9.25	10.60	9.13	6.96	8.05	5.94	6.91	6.43
Control (3% salt dip 24h)	T_9	2.57	2.15	2.36	2.24	1.90	2.07	1.08	0.67	0.88
Mean		9.99	9.68		5.14	5.45		3.34	3.23	

	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	1.66	1.48	1.48
Factor B (drying)	0.96	0.85	0.85
Interaction A x B	2.88	2.56	2.56

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage



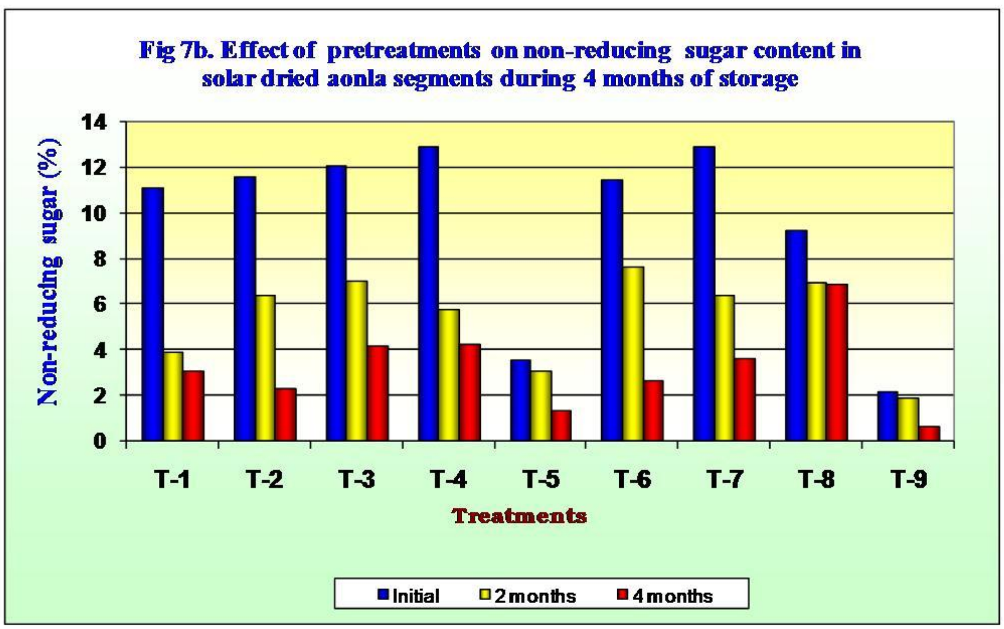


Fig 7. Effect of different pretreatments on non-reducing sugar content in cabinet dried (a) and solar dried (b) *aonla* segments during 4 months of storage

Osmo-dried (OD) 60^{0} Brix 24h	T-1	CPOD 60^{0} B 4h + Spice Level-1	T-6
OD 60^{0} B 24h + Spice Level-1	T-2	CPOD 60^{0} B 4h + Spice Level-2	T-7
OD 60^{0} B 24h + Spice Level-2	T-3	CPOD 60^{0} B 4h + Spice Level-3	T-8
OD 60^{0} B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

4.16 Effect of different pretreatments and drying methods on total sugar content of dehydrated spiced aonla segments

Different treatments significantly affected the total sugar content in osmotically dehydrated spiced aonla segments is given in Table 11 and Figure 8.

4.16.1 Effect on total sugar at initial stage

Different treatments significantly affected the total sugar content in osmotically dehydrated spiced aonla segments at initial stage of storage is given in Table 11.

There was significant difference between treatments, drying and interaction on changes of total sugar content. Among the treated samples highest total sugars was observed is 30.48 (T_3) percent in cabinet drier and lowest is 25.93 (T_1) percent in cabinet drier. In contrast, untreated frozen samples (T_5) showed a lower content of 8.62 percent and 10.09 percent in cabinet and solar dried samples respectively. Total sugar content ranged from 25.93 (T_1) percent to 30.48 (T_3) percent in cabinet dried samples whereas from 26.48 (T_8) percent to 30.22 (T_3) percent in solar dried samples. Least total sugar content of 5.65 percent and 5.46 percent was observed in 3 % salt dipped samples (T_9) in cabinet and solar dried samples respectively.

4.16.2 Effect on total sugar after 2 months of storage

Different treatments significantly affected the total sugar content in osmotically dehydrated spiced aonla segments after two months of storage is given in Table 11.

There was significant difference between treatments and interaction on changes of total sugar content. Among the treated samples highest total sugar was observed in T_3 (33.98 percent) in solar drier and lowest in T_1 (29.29 percent) in cabinet drier. In contrast, untreated frozen samples (T_5) showed less total sugar content compared to treated one. Least total sugar content was observed in T_9 (3 % salt dip) in both cabinet and solar dried samples.

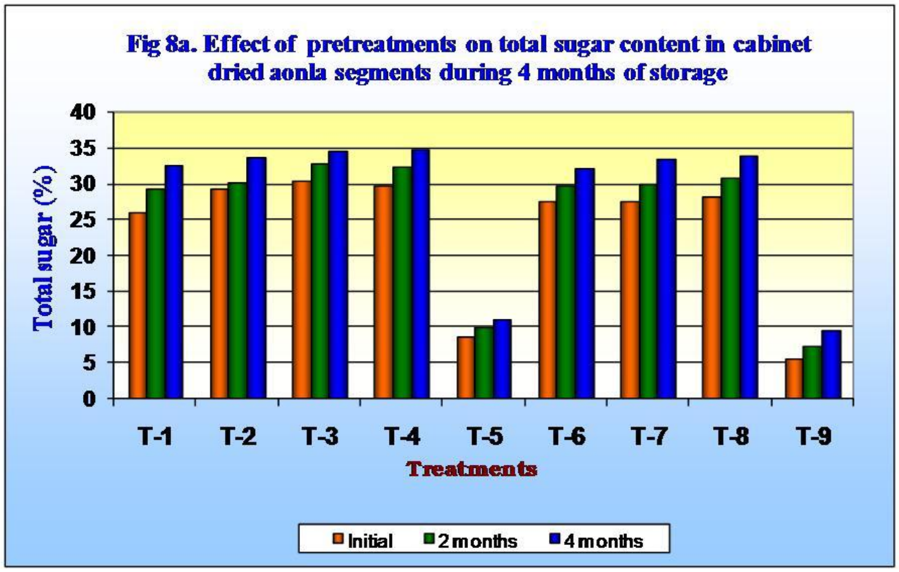
In the subsequent period of storage total sugar content increased in both solar and cabinet drier. (Table 11 and Figure 8a and 8b).

Table 11: Effect of different pre- treatments and drying methods on total sugar content in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Total sugar (%)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	25.93	26.9	26.42	29.29	30.25	29.77	32.55	33.61	33.08
OD 60 °B 24h + Spice Level-1	T_2	29.36	29.65	29.51	30.22	32.05	31.14	33.75	34.36	34.06
OD 60 °B 24h + Spice Level-2	T_3	30.48	30.22	30.35	32.78	33.98	33.38	34.65	35.71	35.18
OD 60 °B 24h + Spice Level-3	T_4	29.85	29.46	29.66	32.5	33.08	32.79	34.73	36.86	35.80
Control(CP-Blanched & frozen)	T_5	8.62	10.09	9.36	9.92	11.77	10.85	11.04	12.46	11.75
CPOD 60 °B 4h + Spice Level-1	T_6	27.67	27.26	27.47	29.78	30.78	30.28	32.1	32.33	32.22
CPOD 60 °B 4h + Spice Level-2	T_7	27.61	28.21	27.91	29.98	30.42	30.20	33.5	33.66	33.58
CPOD 60 °B 4h + Spice Level-3	T_8	28.16	26.48	27.32	30.82	30.01	30.42	33.9	33.42	33.66
Control (3% salt dip 24h)	T_9	5.65	5.26	5.46	7.36	7.13	7.25	9.46	9.34	9.40
Mean		23.70	23.73		25.85	26.61		28.41	29.08	

	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	1.66	1.57	1.45
Factor B (drying)	0.96	NS	NS
Interaction A x B	2.88	2.73	2.51

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage



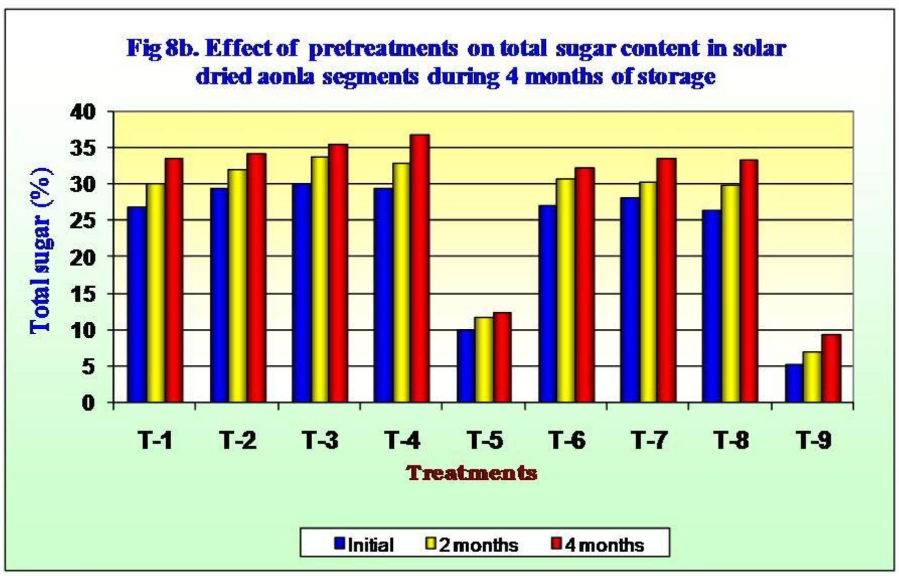


Fig 8. Effect of different pretreatments on total sugar content in cabinet dried (a) and solar dried (b) *aonla* segments during 4 months of storage

Osmo-dried (OD) 60° Brix 24h	T-1	CPOD 60° B 4h + Spice Level-1	T-6
OD 60° B 24h + Spice Level-1	T-2	CPOD 60° B 4h + Spice Level-2	T-7
OD 60° B 24h + Spice Level-2	T-3	CPOD 60° B 4h + Spice Level-3	T-8
OD 60° B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

4.16.3 Effect on total sugar after 4 months of storage

Different treatments significantly affected the total sugar content in osmotically dehydrated spiced aonla segments after four months of storage is given in Table 11.

There was significant difference between treatments and interaction on changes of total sugar content. Among the treated samples, highest total sugar content was observed in T_4 (36.86 per cent) in solar dried sample and lowest in T_6 (32.1 per cent) in cabinet drier. Total sugar content varied from 32.1 (T_6) per cent to 34.73(T_4) per cent in cabinet dried sample whereas 32.33 (T_6) per cent to 36.86(T_4) in solar dried samples. In contrast, untreated frozen samples (T_5) showed less total sugar content compared to treated one. Least total sugar content was observed in T_9 (3 % salt dip) in both cabinet and solar dried samples.

In the subsequent period of storage total sugar content increased in both solar and cabinet drier. (Fig 8a and 8b)

4.17 Effect of different pretreatments and drying methods on non-enzymatic browning of dehydrated spiced aonla segments

Data pertaining to non-enzymatic browning optical density values of osmotically dehydrated spiced aonla segments is given in Table 12.

4.17.1 Effect on non-enzymatic browning at initial stage

Different treatments significantly affected the non-enzymatic browning in osmotically dehydrated spiced aonla segments at initial stage of storage is given in Table 13.

There was significant difference between treatments, drying methods and interaction on changes of total sugar content. Among the treated samples highest non-enzymatic browning (NEB OD at 440 nm) is found in T_8 (0.196) in solar dried samples and lowest in T_1 (0.057) in cabinet dried samples. Non-enzymatic browning values ranged from 0.057 (T_1) to 0.096 (T_8) in cabinet dried samples and 0.067 (T_1) to 0.196 (T_8) in solar dried samples. Untreated frozen samples (T_5) of both cabinet and solar drier showed highest non-enzymatic browning comparing other samples. Solar dried samples showed higher non-enzymatic browning than cabinet dried samples.

4.17.2 Effect on non-enzymatic browning after 2 months of storage

Significant differences (Table 12) were observed for non-enzymatic browning as influenced by different treatments at two months after storage. There was significant difference between treatments, drying and interaction on changes of total sugar content. Among treated samples highest non-enzymatic browning was observed in T_4 (0.258) in solar dried samples and lowest in T_1 (0.067) in cabinet dried samples.

Non-enzymatic browning ranged from 0.067 (T1) to 0.104 (T8) in cabinet dried samples whereas, 0.084 (T_1) to 0.258 (T_4) solar dried samples. Untreated frozen samples (T_5) of both cabinet and solar drier showed highest non-enzymatic browning comparing other samples. Solar dried samples showed higher non-enzymatic browning than cabinet dried samples.

Table 12: Effect of different pre- treatments and drying methods on non-enzymatic browning in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Non-enzymatic browning (OD 440 nm)								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	0.057	0.067	0.062	0.067	0.084	0.076	0.126	0.16	0.143
OD 60 °B 24h + Spice Level-1	T_2	0.065	0.135	0.1	0.075	0.207	0.141	0.151	0.242	0.197
OD 60 °B 24h + Spice Level-2	T_3	0.061	0.146	0.104	0.07	0.22	0.145	0.17	0.248	0.209
OD 60 °B 24h + Spice Level-3	T_4	0.085	0.168	0.127	0.096	0.258	0.177	0.186	0.263	0.225
Control(CP-Blanched & frozen)	T_5	0.33	0.494	0.412	0.76	0.878	0.819	0.975	1.242	1.109
CPOD 60 °B 4h + Spice Level-1	T_6	0.05	0.116	0.083	0.067	0.135	0.101	0.094	0.248	0.171
CPOD 60 °B 4h + Spice Level-2	T_7	0.066	0.185	0.126	0.081	0.205	0.143	0.119	0.314	0.217
CPOD 60 °B 4h + Spice Level-3	T_8	0.096	0.196	0.146	0.104	0.244	0.174	0.216	0.436	0.326
Control (3% salt dip 24h)	T_9	0.102	0.373	0.238	0.151	0.945	0.548	0.45	1.382	0.916
Mean		0.101	0.209		0.163	0.353		0.276	0.504	
		CD at 5%			**CD at 5%**			**CD at 5%**		
Factor A (treatments)		0.015			0.125			0.052		
Factor B (drying)		0.009			0.072			0.030		
Interaction A x B		0.026			0.216			0.091		

OD- Osmo dried, CP- Combined process, MAS- Months after storage

4.17.3 Effect on non-enzymatic browning after 4 months of storage

Significant differences (Table 12) were observed for non-enzymatic browning as influenced by different treatments, drying and interaction at four months after storage. Among the treated samples non-enzymatic browning ranged from 0.094 (T_6) to 0.216 (T_8) in cabinet dried samples whereas 0.16 (T_1) to 0.436 (T_8) in solar dried samples. Untreated frozen samples (T_5) and 3 % salt dipped samples (T_9) of both cabinet and solar drier showed highest non-enzymatic browning comparing other samples.

Solar dried samples showed higher non-enzymatic browning than cabinet dried samples. A close persual of data indicates that there was an increase in the non-enzymatic browning content of dehydrated samples during subsequent storage period (Table 12)

4.18 Effect of different pretreatments and drying methods on water activity of dehydrated spiced aonla segments

Data pertaining to water activity values of osmotically dehydrated spiced aonla segments is given in Table 13.

4.18.1 Effect on water activity at initial stage

There is no significant difference between treatments, drying and interaction at initial stage. Among treated samples highest water activity was observed in T_1 (0.660) of cabinet dried sample and lowest in T_3 (0.538) in cabinet dried samples. Water activity ranged from 0.538 (T_3) to 0.660 (T_1) in cabinet dried sample whereas 0.570 (T_2) to 0.605 (T_1) in solar dried samples.

4.18.2 Effect on water activity after 2 months of storage

There is significant difference between treatments and drying methods during two months of storage. Among treated samples highest water activity was found in 0.582 (T_1) in cabinet dried samples and lowest in 0.514 (T_3) in solar dried samples. Water activity ranged from 0.514 (T_3) to 0.554 (T_7) in cabinet dried samples whereas it ranges from 0.537 (T_6) to 0.582 (T_1) in solar dried samples.

A close persual of data indicates that there was a decrease in the water activity of dehydrated samples during subsequent storage period.

4.18.3 Effect on water activity after 4 months of storage

There is significant difference between treatments and drying during two months of storage. Among treated samples highest water activity was found in 0.516 (T_7) in cabinet dried samples and lowest in 0.458 (T_3) in solar dried samples. Water activity ranged from 0.482 (T_8) to 0.516 (T_7) in cabinet dried samples whereas it ranges from 0.458 (T_4) to 0.492 (T_1) in solar dried samples.

A close persual of data indicates that there was a decrease in the water activity of dehydrated samples during subsequent storage period.

Table 13: Effect of different pre- treatments and drying methods on water activity in dehydrated spiced aonla segments at initial and after 2 & 4 months of storage at room temperature

Treatments		Water activity								
		INITIAL			2 MAS			4 MAS		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 $^{\circ}$Brix 24h	T_1	0.660	0.605	0.633	0.551	0.582	0.567	0.510	0.492	0.501
OD 60 $^{\circ}$B 24h + Spice Level-1	T_2	0.559	0.570	0.565	0.539	0.565	0.552	0.495	0.491	0.493
OD 60 $^{\circ}$B 24h + Spice Level-2	T_3	0.538	0.585	0.562	0.514	0.540	0.527	0.484	0.462	0.473
OD 60 $^{\circ}$B 24h + Spice Level-3	T_4	0.578	0.587	0.583	0.519	0.549	0.534	0.483	0.458	0.471
Control(CP-Blanched & frozen)	T_5	0.687	0.668	0.678	0.537	0.539	0.538	0.501	0.499	0.500
CPOD 60 $^{\circ}$B 4h + Spice Level-1	T_6	0.564	0.583	0.574	0.520	0.537	0.529	0.485	0.472	0.479
CPOD 60 $^{\circ}$B 4h + Spice Level-2	T_7	0.566	0.586	0.576	0.554	0.561	0.558	0.516	0.485	0.501
CPOD 60 $^{\circ}$B 4h + Spice Level-3	T_8	0.597	0.592	0.595	0.553	0.557	0.555	0.482	0.467	0.475
Control (3% salt dip 24h)	T_9	0.654	0.648	0.651	0.472	0.508	0.490	0.434	0.407	0.421
Mean		0.600	0.603		0.529	0.549		0.488	0.470	
		CD at 5%			**CD at 5%**			**CD at 5%**		
Factor A (treatments)		NS			0.016			0.014		
Factor B (drying)		NS			0.009			0.008		
Interaction A x B		NS			NS			NS		

OD- Osmo dried, CP- Combined process, NS- Non significant, MAS- Months after storage

OSMO-AIR DRIED SPICED AONLA AT INITIAL STAGE OF STORAGE

PLATE -4

4.19 Effect of different pretreatments and drying methods on sensory quality of dehydrated spiced aonla segments at initial

Osmotically dehydrated carrot slices were evaluated for their sensory qualities. Sensory scores obtained for colour, texture, flavour as well as overall acceptability is given in Table14, 15 and 16. It would be appropriate to mention at the beginning that the obtained overall acceptability scores in the range of 80-100 is very good; 60-79 is good, 30-59 average and 0-29 poor.

4.19.1 Effect of pre-treatments and drying on colour at initial

Data given in Table 14 and Figure 9 indicates that sensory score for colour was significantly superior in osmotically dehydrated spiced aonla segments as compared to control.

There was significant difference among treatments. Sensory score of colour for treated aonla segments ranged from 15.64 to 30.00. Sensory score ranges from 22.00 (T_8) to 30.00 (T_1) in case of cabinet dried samples and 15.64 (T_4) to 27.00 (T_1) in case of solar dried samples. Cabinet dried samples showed higher sensory score than the respective solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score than other treated samples in both cabinet and solar dried samples.

Osmotically dehydrated samples in 60 $^{\circ}$Brix sugar syrup for 24 hrs with varying spice levels (T_1 to T_4) shown higher sensory score of colour than combined processed samples (T_6 to T_8) with varying spice levels in both cabinet and solar dried samples. Among T_1 to T_4 samples, T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 $^{\circ}$Brix sugar syrup) scored higher sensory score of 30.00 and 27.00 in cabinet and solar dried samples whereas among T_6 to T_8 samples, T_6 (Aonla segments with spices level-1 (CP) with OD in 60 $^{\circ}$Brix sugar syrup for 4 hrs) scored higher sensory score of 26.00 and 21.71 in cabinet and solar dried samples.

OSMO-AIR DRIED SPICED AONLA AT INITIAL STAGE OF STORAGE

PLATE -5

Table 14: Effect of different pre - treatments and drying methods on sensory quality of dehydrated spiced aonla segments at initial stage of storage

Treatments		COLOUR (30)			TEXTURE (30)			FLAVOUR (40)			TOTAL (100)		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	30.00	27.00	28.50	26.00	26.80	26.40	32.00	34.29	33.14	88.00	88.09	88.04
OD 60 °B 24h + Spice Level-1	T_2	26.00	24.00	25.00	26.00	26.40	26.20	31.00	32.86	31.93	83.00	83.26	83.13
OD 60 °B 24h + Spice Level-2	T_3	23.00	22.00	22.50	24.67	26.10	25.38	26.58	32.86	29.72	74.25	80.96	77.60
OD 60 °B 24h + Spice Level-3	T_4	24.00	15.64	19.82	22.83	22.00	22.42	27.50	26.00	26.75	74.33	63.64	68.99
Control(CP-Blanched & frozen)	T_5	16.00	9.00	12.50	14.46	9.00	11.73	18.00	12.00	15.00	48.46	30.00	39.23
CPOD 60 °B 4h + Spice Level-1	T_6	26.00	21.71	23.86	30.00	26.60	28.30	39.00	31.57	35.29	95.00	79.89	87.44
CPOD 60 °B 4h + Spice Level-2	T_7	24.00	19.43	21.71	24.00	23.60	23.80	36.00	25.80	30.90	84.00	68.83	76.41
CPOD 60 °B 4h + Spice Level-3	T_8	22.00	20.20	21.10	22.00	24.60	23.30	27.00	16.86	21.93	71.00	61.66	66.33
Control (3% salt dip 24h)	T_9	15.00	9.00	12.00	15.33	9.23	12.28	22.31	5.40	13.86	52.64	23.63	38.14
Mean		22.89	18.66		22.81	21.59		28.82	24.18		74.52	64.44	

	CD at 5%	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	3.19	2.56	3.67	4.30
Factor B (drying)	NS	NS	NS	NS
Interaction A x B	NS	NS	NS	7.45

OD- Osmo dried, CP- Combined process, NS- Non significant.

OSMO-AIR DRIED SPICED AONLA AT INITIAL STAGE OF STORAGE

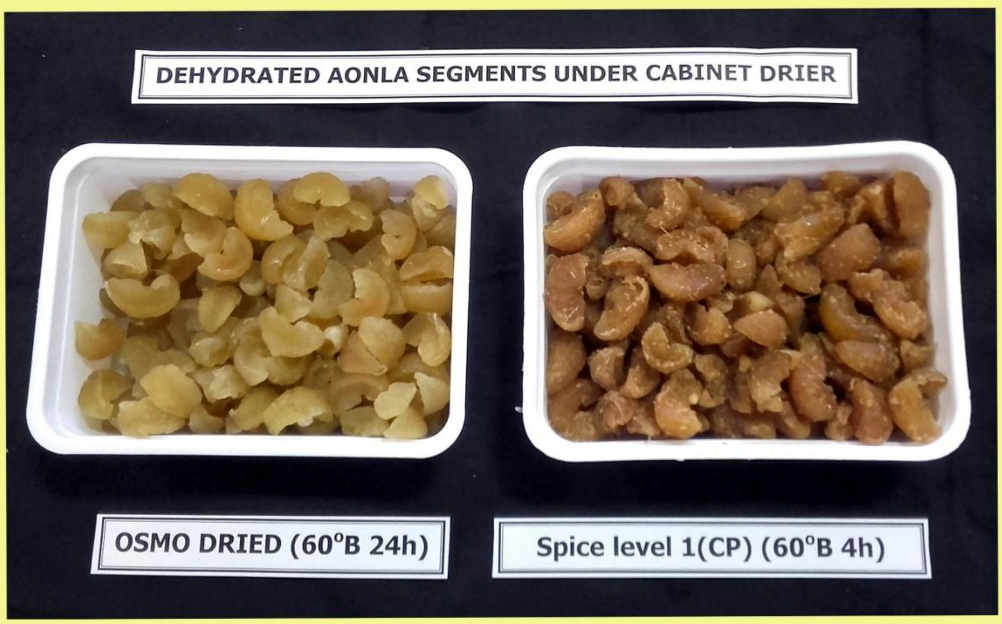


PLATE -6

4.19.2 Effect of pre-treatments and drying on texture at initial

Data given in Table 14 and Figure 9 indicates that sensory score for texture was significantly superior in osmotically dehydrated spiced aonla segments as compared to control.

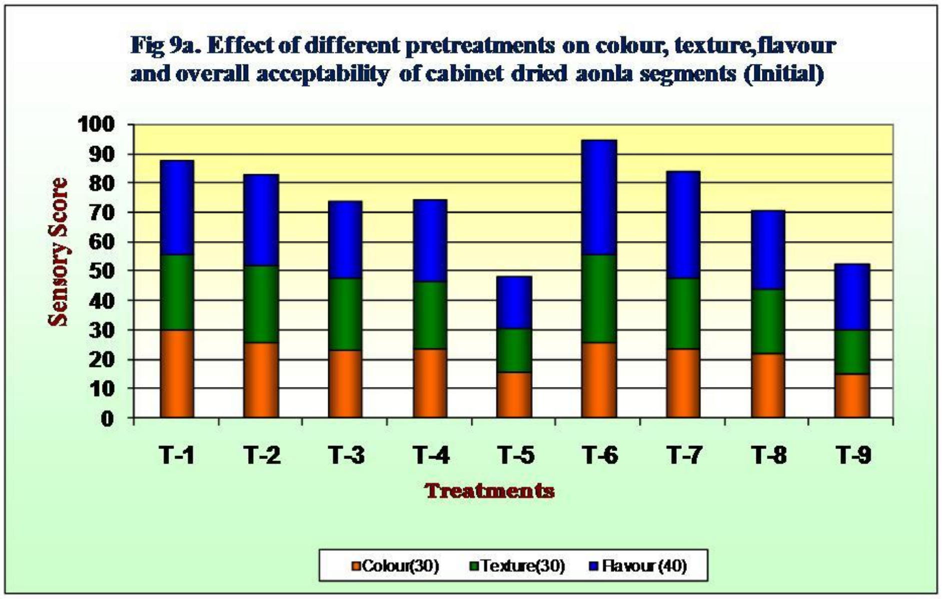
There was significant difference among treatments. Sensory score for texture for treated aonla segments ranged from 22.00 to 30.00. Sensory score for texture ranged from 22.00 (T_8) to 30.00 (T_6) in cabinet dried samples and 22.00 (T_4) to 26.80 (T_1) in case of solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for texture than other treated samples in both cabinet and solar dried samples. In general, cabinet dried samples showed higher sensory score than the respective solar dried samples.

T_1 sample (Osmotically dehydrated sample in 60 $^{\circ}$Brix sugar syrup for 24 hrs shown higher sensory score of texture among T_1 to T_4 samples in both cabinet and solar dried samples. and T_6 sample (Aonla segments with spices level-1(CP) with OD in 60^0 Brix sugar syrup for 4 hrs shown higher sensory score for texture among combined processed samples from T_6 to T_8 in both cabinet and solar dried samples.

4.19.3 Effect of pre-treatments and drying on flavour at initial

Data given in Table 14 and Figure 9 indicates that sensory score for texture was significantly superior in osmotically dehydrated spiced aonla segments as compared to control.

There was significant difference among treatments. Sensory score for flavor for treated aonla segments ranged from 25.80 to 39.00. Sensory score for flavour ranged from 26.58 (T_3) to 39.00(T_6) in cabinet dried samples and 25.80 (T_7) to 34.29 (T_1) in case of solar dried samples. In contrast, untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for flavour than other treated samples in both cabinet and solar dried samples. Among the osmotically dehydrated samples with varying spice levels T_1 showed maximum sensory score of 32.00 and 34.29 in cabinet and solar dried samples respectively whereas among combined processed samples with varying spice levels, T_6 scored maximum sensory score of 39.00 and 31.57 in cabinet and solar dried samples respectively.



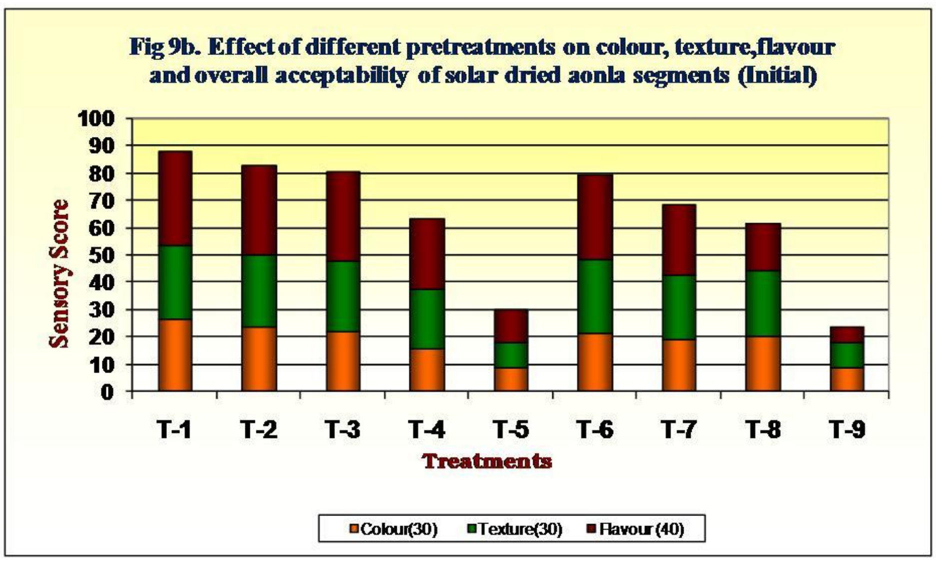


Fig 9 . Effect of different pretreatments on colour, texture, flavour and overall acceptability of cabinet dried (a) solar dried (b) *aonla* segments (Initial)

Osmo-dried (OD) 60^{0} Brix 24h	T-1	CPOD 60^{0} B 4h + Spice Level-1	T-6
OD 60^{0} B 24h + Spice Level-1	T-2	CPOD 60^{0} B 4h + Spice Level-2	T-7
OD 60^{0} B 24h + Spice Level-2	T-3	CPOD 60^{0} B 4h + Spice Level-3	T-8
OD 60^{0} B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

4.19.4 Effect of pre-treatments and drying on overall acceptability at initial

There was a significant difference between treatment and interaction. The total sensory score for treated aonla segments ranges from 61.66 (T_8) in solar dried samples to 95.00 (T_6) of cabinet dried samples. Total sensory score of treated samples ranges from 71.00 (T_8) to 95.00 (T_6) in cabinet dried samples whereas from 61.66 (T_8) to 88.09 (T_1) in solar dried samples. Highest total sensory score was obtained for T6 (Aonla segments with spices level-1(CP) with OD in 60 °Brix sugar syrup for 4 hrs) with a score of 95.00.Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for total than other treated samples in both cabinet and solar dried samples.

4.20 Effect of different pretreatments and drying methods on sensory quality of dehydrated spiced aonla segments after 2 months of storage

4.20.1 Effect of pre-treatments and drying on colour after 2 months

There was significant difference between treatments. Sensory score of colour for treated aonla segments ranged from 20.00 to 26.83.Sensory score ranges from 22.00 (T_8) to 26.83 (T_1) in case of cabinet dried samples and 14.56 (T_4) to 25.10 (T_1) in case of solar dried samples. Cabinet dried samples showed higher sensory score than the respective solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score than other treated samples in both cabinet and solar dried samples.

T_1 showed maximum colour score among osmotically dehydrated samples in 60 °Brix sugar syrup for 24 hrs with varying spice levels (T_1 to T_4) of 26.83 and 25.10 in both cabinet and solar drier respectively. T_6 showed maximum colour score among combined processed samples (T_6 to T_8) with varying spice levels of 24.50 and 20.00 in both cabinet and solar dried samples.

4.20.2 Effect of pre-treatments and drying on texture after 2 months

There was significant difference between treatments and drying. Sensory score for texture for treated aonla segments ranged from 20.00 to 26.00 .Sensory score for texture ranged from 22.00 (T_4) to 25.17 (T_7) in cabinet dried samples and 20.00 (T_8) to 26.00 (T_1) in case of solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for texture than other treated samples in both cabinet and solar dried samples. Highest score for texture was observed in T_7 (Aonla segments with spices level-2 (CP) with OD in 60 °Brix sugar syrup for 4 hrs) with a score of 25.17 among cabinet dried samples and T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) with a score of 26.00 in solar dried samples.

4.20.3 Effect of pre-treatments and drying on flavour after 2 months

There was significant difference between treatments. Sensory score for flavor for treated aonla segments ranged from 18.00 to 32.00. Sensory score for flavour ranged from 26.67 (T_8) to 31.33 (T_1) in cabinet dried samples and 18.00 (T_8) to 32.00 (T_1) in case of solar dried samples. In contrast, untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for flavour than other treated samples in both cabinet and solar dried samples.Among the combined processed samples T_6 (Aonla segments with spices level-1(CP) with OD in 60 °Brix sugar syrup for 4 hrs) scored high with 30.33 and 25.40 in cabinet and solar dried samples whereas among the osmotically dehydrated samples T_1 showed maximum score of 31.33 and 32.00 in case of cabinet and solar drier.

4.20.4 Effect of pre-treatments and drying on overall acceptability after 2 months

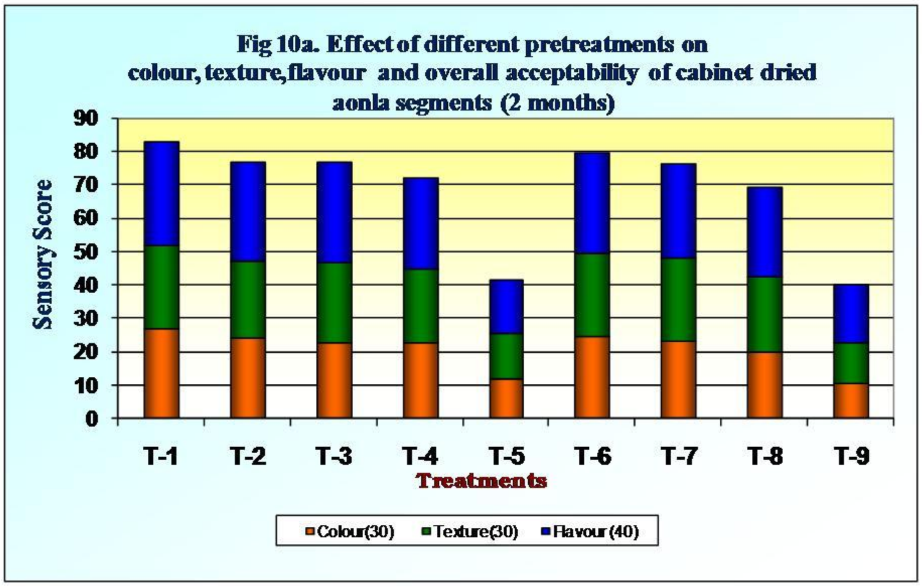
There was significant difference between treatments, drying and interaction. The total sensory score ranges from 54.00 to 83.17 in treated samples. Total scores varies from 69.33 (T_8) to 83.17 (T_1) in

Table 15: Effect of different pre - treatments and drying methods on sensory quality of dehydrated spiced aonla segments after two months of storage

Treatments		COLOUR (30)			TEXTURE (30)			FLAVOUR (40)			TOTAL (100)		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	26.83	25.10	25.97	25.00	26.00	25.50	31.33	32.00	31.67	83.17	83.10	83.13
OD 60 °B 24h + Spice Level-1	T_2	24.25	22.20	23.23	22.83	24.00	23.42	29.67	30.80	30.23	76.75	77.00	76.88
OD 60 °B 24h + Spice Level-2	T_3	22.67	20.60	21.64	24.00	24.40	24.20	30.33	30.40	30.37	77.00	75.40	76.20
OD 60 °B 24h + Spice Level-3	T_4	22.83	14.56	18.70	22.00	21.00	21.50	27.33	22.60	24.97	72.17	58.16	65.16
Control(CP-Blanched & frozen)	T_5	12.00	5.80	8.90	13.50	8.40	10.95	15.83	5.86	10.85	41.33	21.66	31.50
CPOD 60 °B 4h + Spice Level-1	T_6	24.50	20.00	22.25	24.83	24.71	24.77	30.33	25.40	27.87	79.67	70.11	74.89
CPOD 60 °B 4h + Spice Level-2	T_7	23.00	19.00	21.00	25.17	20.43	22.80	28.17	25.00	26.58	76.33	64.43	70.38
CPOD 60 °B 4h + Spice Level-3	T_8	20.00	16.00	18.00	22.67	20.00	21.33	26.67	18.00	22.33	69.33	54.00	61.67
Control (3% salt dip 24h)	T_9	10.33	6.71	8.52	12.50	8.40	10.45	17.33	6.57	11.95	40.16	21.69	30.92
Mean		20.71	16.66		21.39	19.70		26.33	21.85		68.44	58.39	

	CD at 5%	CD at 5%	CD at 5%	CD at 5%
Factor A (treatments)	2.53	2.18	3.00	3.15
Factor B (drying)	NS	1.26	NS	1.82
Interaction A x B	NS	NS	NS	5.45

OD- Osmo dried, CP- Combined process, NS- Non significant.



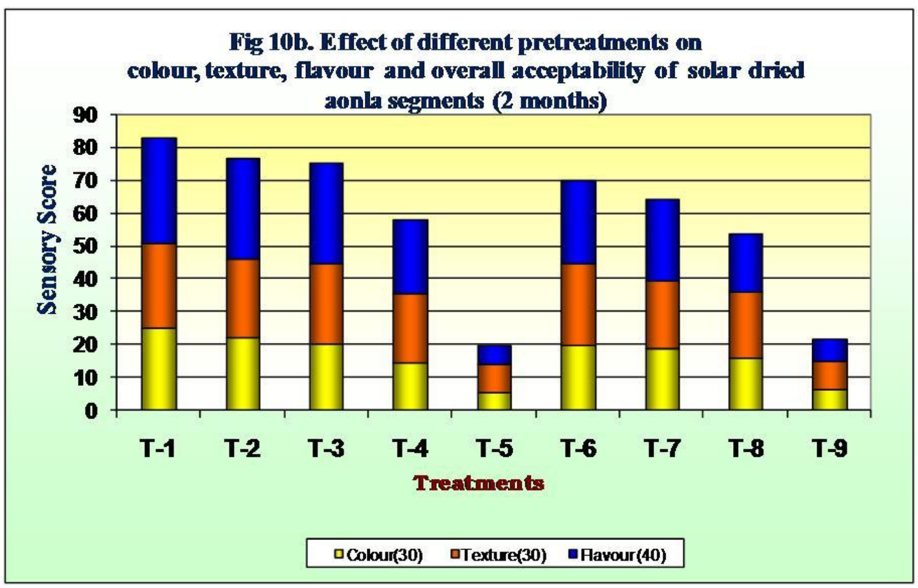


Fig 10 . Effect of different pretreatments on colour, texture, flavour and overall acceptability of cabinet dried (a) solar dried (b) *aonla* segments (2 months)

Osmo-dried (OD) 60^{0} Brix 24h	T-1	CPOD 60^{0} B 4h + Spice Level-1	T-6
OD 60^{0} B 24h + Spice Level-1	T-2	CPOD 60^{0} B 4h + Spice Level-2	T-7
OD 60^{0} B 24h + Spice Level-2	T-3	CPOD 60^{0} B 4h + Spice Level-3	T-8
OD 60^{0} B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

cabinet dried samples and 54.00 (T_8) to 83.10 (T_1) in solar dried samples. Highest sensory score is obtained in T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) among osmotically dehydrated samples with varying spice levels with a score of 83.17 and 83.10 in cabinet and solar dried samples respectively. In case of combined processed samples with varying spice levels, T_6 (Aonla segments with spices level-1 (CP) with OD in 60 °Brix sugar syrup for 4 hrs) shown maximum score.

4.21 Effect of different pretreatments and drying methods on sensory quality of dehydrated spiced aonla segments after 4 months

4.21.1 Effect of pre-treatments and drying on colour after 4 months

There was significant difference between treatments. Sensory score of colour for treated aonla segments ranges from 14.43 to 26.12. Sensory score ranges from 19.08 (T_8) to 26.12 (T_1) in case of cabinet dried samples and 14.43 (T_8) to 24.43 (T_1) in case of solar dried samples. Cabinet dried samples showed higher sensory score than the respective solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score than other treated samples in both cabinet and solar dried sample.T_1 sample (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) showed superiority in colour among all other treatments in both cabinet and solar dried samples.

4.21.2 Effect of pre-treatments and drying on texture after 4 months

There is significant difference between treatments. Sensory score for texture for treated aonla segments ranged from 18.29 to 24.43. Sensory score for texture ranged from 21.33 (T_4) to 24.25 (T_7) in cabinet dried samples and 18.29 (T_4) to 24.43 (T_1) in case of solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for texture than other treated samples in both cabinet and solar dried samples. Highest score for texture was observed in T_7 (aonla segments with spices level-2 (CP) with OD in 60 °Brix sugar syrup for 4 hrs) with a score of 24.25 among cabinet dried samples and T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) with a score of 24.43 in solar dried samples.

OSMO-AIR DRIED SPICED AONLA AFTER 4 MONTHS OF STORAGE

PLATE -7

4.21.3 Effect of pre-treatments and drying on flavour after 4 months

There is significant difference between treatments. Sensory score for flavor for treated aonla segments ranged from 20.00 to 32.00. Sensory score for flavour ranged from 20.00 (T_3) to 32.00 (T_6) in cabinet dried samples and 20.00 (T_7) to 30.00 (T_1) in case of solar dried samples. In contrast, untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for flavour than other treated samples in both cabinet and solar dried samples. Among the combined processed samples T_6 (Aonla segments with spices level-1(CP) with OD in 60 °Brix sugar syrup for 4 hrs) scored high with 32.00 and 22.00 in cabinet and solar dried samples whereas among the osmotically dehydrated samples T_1 showed maximum score of 30.21 and 30.00 in case of cabinet and solar dried samples.

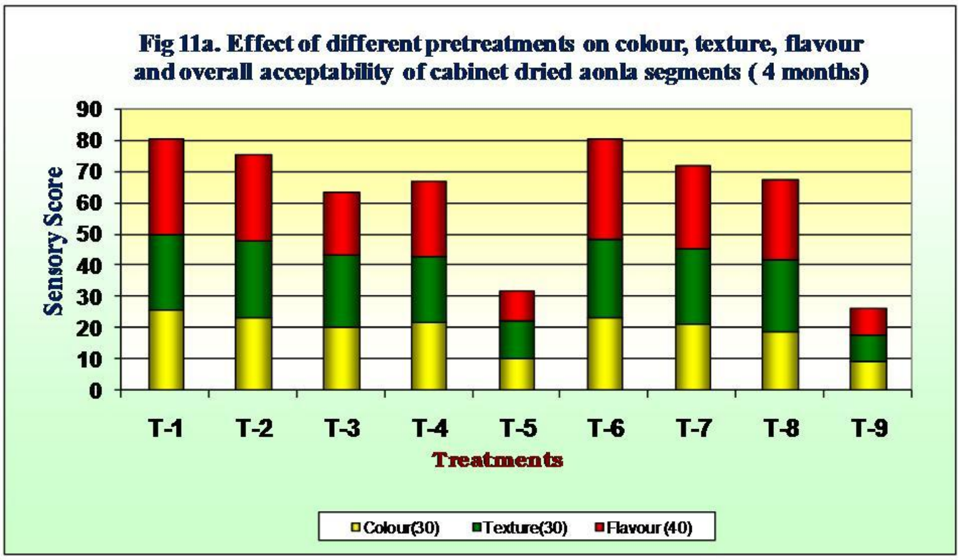
4.21.4 Effect of pre-treatments and drying on overall acceptability after 4 months

There is significant difference between treatments, drying and interaction. The total sensory score for treated aonla segments ranges from 51.14 to 80.56. Total sensory score of treated samples ranges from 63.56 (T_3) to 80.56 (T_1) in cabinet dried samples whereas from 51.14 (T_4) to 78.86 (T_1) in solar dried samples. Highest total sensory score was obtained for T_1 followed by T_6 in cabinet dried samples whereas T_1 in solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for total than other treated samples in both cabinet and solar dried samples.

Table 16: Effect of different pre - treatments and drying methods on sensory quality of dehydrated spiced aonla segments after four months of storage

Treatments		COLOUR (30)			TEXTURE (30)			FLAVOUR (40)			TOTAL (100)		
		Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean	Cabinet	Solar	Mean
Osmo-dried (OD) 60 °Brix 24h	T_1	26.12	24.43	25.27	24.23	24.43	24.33	30.21	30.00	30.11	80.56	78.86	79.71
OD 60 °B 24h + Spice Level-1	T_2	23.67	21.86	22.76	24.20	23.00	23.60	28.00	24.00	26.00	75.87	68.86	72.36
OD 60 °B 24h + Spice Level-2	T_3	20.31	19.22	19.77	23.25	24.14	23.70	20.00	25.00	22.50	63.56	66.53	65.05
OD 60 °B 24h + Spice Level-3	T_4	21.83	12.00	16.92	21.33	18.29	19.81	24.00	20.86	22.43	67.17	51.14	59.15
Control(CP-Blanched & frozen)	T_5	10.33	4.00	7.17	12.12	5.57	8.85	9.50	8.00	8.75	31.95	17.57	24.76
CPOD 60 °B 4h + Spice Level-1	T_6	23.52	18.80	21.16	25.02	22.00	23.51	32.00	22.00	27.00	80.54	62.80	71.67
CPOD 60 °B 4h + Spice Level-2	T_7	21.58	15.00	18.29	24.25	19.00	21.63	26.50	20.00	23.25	72.33	54.00	63.17
CPOD 60 °B 4h + Spice Level-3	T_8	19.08	14.43	16.76	23.13	19.71	21.42	25.25	21.00	23.13	67.46	55.14	61.30
Control (3% salt dip 24h)	T_9	9.23	4.60	6.92	8.52	4.57	6.55	8.67	9.00	8.83	26.42	18.17	22.29
Mean		19.52	14.93		20.67	17.86		22.68	19.98		62.87	52.56	
		CD at 5%			**CD at 5%**			**CD at 5%**			**CD at 5%**		
Factor A (treatments)		2.30			1.97			2.66			3.89		
Factor B (drying)		NS			NS			NS			2.25		
Interaction A x B		NS			NS			NS			6.74		

OD- Osmo dried, CP- Combined process, NS- Non significant.



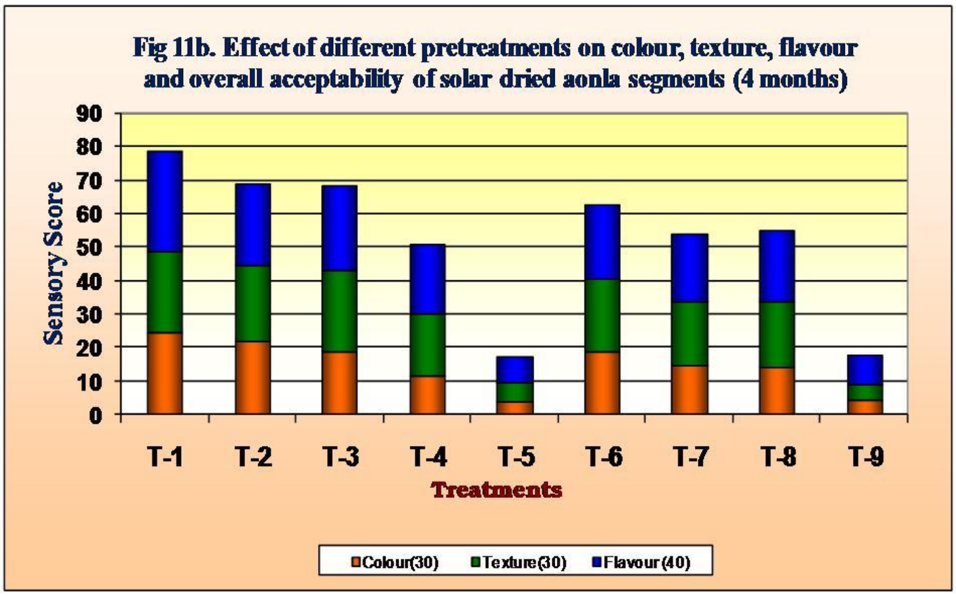
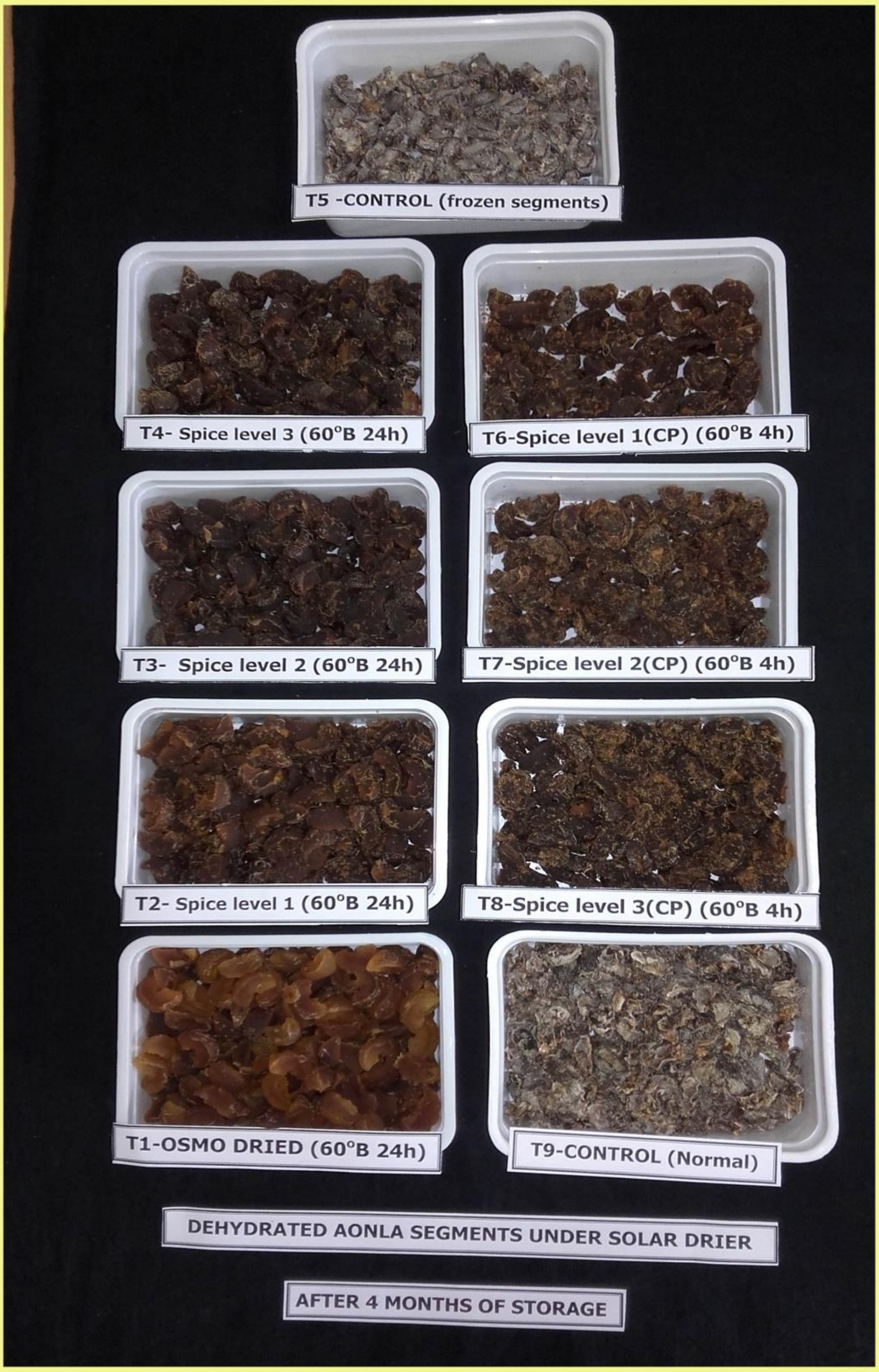


Fig 11 . Effect of different pretreatments on colour, texture, flavour and overall acceptability of cabinet dried (a) solar dried (b) *aonla* segments (4months)

Osmo-dried (OD) 60^0 Brix 24h	T-1	CPOD 60^0 B 4h + Spice Level-1	T-6
OD 60^0 B 24h + Spice Level-1	T-2	CPOD 60^0 B 4h + Spice Level-2	T-7
OD 60^0 B 24h + Spice Level-2	T-3	CPOD 60^0 B 4h + Spice Level-3	T-8
OD 60^0 B 24h + Spice Level-3	T-4	Control (3% salt dip 24h)	T-9
Control(CP-Blanched & frozen)	T-5		

OSMO-AIR DRIED SPICED AONLA AFTER 4 MONTHS OF STORAGE



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V. DISCUSSION

The present investigation was focused on the “Development of protocol for spiced dehydrated *aonla* (*Phyllanthus emblica* L.) segments” with systematic approach to understand the response of different treatments and drying methods on a diversified product development and its quality during different storage period.

The osmotically dehydrated spiced *aonla* segments were subjected to chemical analysis at an interval of two months of storage and evaluated for their overall acceptability by subjecting to periodic sensory evaluation. The results obtained are discussed in this chapter.

With brief introduction on the importance of osmotic dehydration technology the findings are discussed in the chapter in the light of available reports.

5.1 Physical parameters of fresh *aonla* fruits.

The average weight of fruit (g), pulp content (%) and seed content (%) of *aonla* variety Krishna was 37.27 gm, 94.41 % and 5.35 % respectively. The average moisture content in the fruits was 88.50 per cent, TSS 7.5 $^{\circ}$Brix, titratable acidity 2.35 per cent (as citric acid), ascorbic acid 395.25 (mg/100 g of edible portion), reducing sugars 3.25 per cent, non-reducing sugars 1.96 per cent and total sugars of 5.21 per cent, respectively. These results are in conformity with observations made by other workers in aonla (Thripathi *et al.,* 1988; Pragathi *et al*., 2003; Singh *et al*., 2012).

5.2 Effect of pre-treatments on water loss, solid gain and weight reduction in osmosed aonla segments used for cabinet and solar drying

Significant differences were recorded for per cent water loss (WL), solid gain (SG) and weight reduction (WR) in osmosed *aonla* segments as influenced by various osmotic treatments. Maximum water loss of 42.57 per cent was found with Treatment T_2 (aonla segments with spices level-2 with OD in 60 $^{\circ}$Brix sugar syrup for 24 hrs) which was at par with treatment T_1 and T_3.Water loss values were higher (33.85 to 42.57 %) in blanched segments (T_1 to T_3) as compared to blanched and frozen segments (T_6 - T_8) in which water loss values (15.97 to 21.18) were lower than solid gain and impact was negative.

Significantly higher solid gain (16.68 to 18.85 %) was recorded in blanched and frozen samples (T_6 to T_8) treated for 4 hrs as compared to blanched samples subjected to osmotic treatments for 24 hrs (T_1 to T_4) in which SG values ranged from 11.93 to 12.43 %. Combined processed samples showed maximum solid gain than simple osmotically dehydrated samples. As a result maximum weight reduction (21.60 to 30.37 %) was also recorded in osmotically dehydrated samples, while values were negative (-4.45 to 4.52 %) in combined processed samples (T_6 to T_8).

In fact, mass transfer of the solute is dependent on the effective diffusion coefficient that can be affected by the radius of the molecules. Osmotic dehydration is a dewatering and impregnation soaking process that the water diffuses from dilute solution to concentrated solution due to osmotic pressure. Hence the aonla segments subjected to osmotic dehydration responded to above line of fact. Variation in the mass reduction, solid gain and water loss was in confirmation with the results of Lerici *et al*. (1985) in osmosed apples; Panagiotou *et al*. (1999) in apples, banana and kiwifruits ; Garrote *et al*. (1992) in pear, apples cubes and strawberry halves ; Preethi and Tiroutchelvame (2013) in aonla. Further freezing of sample might have resulted in microcrystal formation disrupting the cellular structure and allowing solute entry in the segments more freely which ultimately resulted in a negative water loss value. The results are also in conformity with Kumar *et al*. (2012) and Lombard *et al.* (2007) in pineapple.

5.3 Effect of pre-treatments on yield, drying ratio and rehydration ratio in dehydrated spiced aonla segments dried under cabinet and solar drier

Osmotic pretreatments significantly increased the yield in blanched aonla segments (T_1 to T_4) as well as combined processed samples (T_6 to T_8) as compared to control samples (T_5 and T_9). Maximum product yield 47.10 per cent was recorded in aonla segments with spices level-2 (CP) with OD in 60 °Brix sugar syrup for 4 hrs) followed by T_6 (aonla segments with spices level-1 (CP) with OD in 60 °Brix sugar syrup for 4 hrs) with an yield of 44.48 per cent in cabinet dried samples. Combined processed samples showed higher product yield as compared to osmotically dehydrated samples (T_1 to T_4) in which mean value ranged from 33.90 to 34.82 %). Lowest yield was recorded in control samples T_5 (12.56 %) made by cabinet drying. These results are in conformity with (Gheybi *et al*., 2013) in honeydew papaya; Oladejo *et al*. (2013) in mango: Devaraju (2001) in ber.

Different pre-treatments significantly affected the drying ratio of dehydrated aonla segments. Maximum drying ratio 7.77:1 was observed in case of control (T_5). The drying ratio was minimum 2.12: 1 in aonla segments with spices level-2 (CP) with OD in 60° Brix sugar syrup for 4 hrs (T_7) in cabinet dried samples. In general the drying ratio was lower combined processed samples. Higher rehydration ratio was found in solar dried samples as compared to cabinet dried samples. This results are in conformity with (Gheybi *et al*., 2013) in honeydew papaya; Oladejo *et al*. (2013) in mango: Devaraju (2001) in ber.

5.4 Changes in moisture content

Not much variation was observed in moisture content in osmotically dehydrated aonla segments and moisture content slightly decreased after four months of storage at room temperature. Average moisture content values in cabinet dried and solar dried samples were 13.17 and 13.21 respectively. Average moisture content of osmotically dehydrated spiced aonla segments was 13.17 and 13.21 per cent at initial in cabinet and solar drier respectively which decreased to 11.29 and 11.51 percent after two months of storage and 10.47 percent in both drier after four months of storage. There was slight decrease in moisture content in dehydrated samples during subsequent storage period. The reduction in moisture content may be due to the reduced water activity and due to evaporation of moisture from the samples during storage**.** Rani and Bhatia (1986) and Singh *et al*. (2012) also reported a decline in moisture content of intermediate moisture bagughosa and intermediate moisture baby corn, respectively during storage. Panwar *et al.* (2013) also reported the same result in aonla.

5.5 Changes in total solids

The average total solid content was 86.83 and 86.79 per cent at initial in cabinet and solar dried aonla segments which increased to 88.71 and 88.25 percent in two months and 89.53 and 89.76 percent in four months of storage. It was observed that there was slight increase in total solids content in the samples during the subsequent storage periods. This may be due to the concentration of solids due to reduction in the moisture content during subsequent storage periods. Similar findings were found by Abrol *et al*. (2014) in mango, banana and papaya fruits dried at 60 ± 2 °C for 6 h under solar tunnel drier. Teotia *et al.* (1968) also reported values of total soluble solids between 9.0 - 15.0 per cent in aonla fruits.

5.6 Changes in titrable acidity

Significant variations were observed with respect to titratable acidity content in dehydrated aonla segments. Maximum acidity content was recorded in control sample T_5 7.94 % (cabinet dried) & 6.71 % (solar dried). However osmotic treatment resulted in significant reduction in acidity content in dehydrated aonla segments. Not much variation was observed in acidity content during storage. Combined processed samples (T_6 to T_8) showed a highest acidity content than simple osmotically dehydrated samples (T_1 to T_4) in both cabinet and solar dried samples. Data indicates that there was slight increase in the titrable acidity content in dehydrated samples during subsequent storage period. The main reason of the variation in acidity in osmotically dehydrated sample was the varying solid uptake, resultant variation in yield and drying ratio of the products. The limitation in conversion of carbohydrates and proteins into other fractions and also, oxygen free microenvironment might have prevented the oxidation reduction reaction which reduces the acidity content. Similar findings were recorded by Abrol *et al*. (2014) in dehydration of mango, banana and papaya.

5.7 Changes in ascorbic acid

Significant variations were observed with respect to ascorbic acid content in dehydrated aonla segments. Ascorbic acid content reduces considerably after osmotic dehydration of *aonla* segments and also during storage period. Treated sample dried using cabinet drier has higher content of 146.10 mg/100 g than that of solar dried samples of 124.92 mg/ 100 g. Ascorbic acid content was higher in cabinet dried samples as compared to solar dried samples and mean value ranged from 95.64 to 179.97 mg/ 100 g. Untreated frozen sample dried under cabinet drier retained higher ascorbic acid content of 205.63 mg/100 g. A gradual increase in ascorbic acid content was observed in treated aonla segments with correspond to increase in spice levels. Among the treated samples combined processed samples with various spice levels showed higher ascorbic acid content than simple osmotically dehydrated samples with varied spice levels. Osmotically dehydrated *aonla* segments showed maximum ascorbic acid content at initial when compared to two and four months after storage.

Thermal degradation during processing and subsequent oxidation and light reaction may be the other possible causes of reduction in ascorbic acid content. Spiced aonla segments retained more ascorbic acid, and it might be due to antioxidants in the spices, which protected ascorbic acid from oxidation and it is supported Ginger juice mixing increases ascorbic acid retention (Prajapati *et al*., 2011). Untreated aonla samples dried in solar tunnel dryer showed maximum ascorbic acid content (Priyanka, 2015). Ascorbic acid content significantly declined in all the four cultivars during 135 days storage of aonla supari (Singh *et al*., 2012). Heat sensitive vitamin -C decreased used solar tunnel drying (Abrol *et al*., 2014). Ade-Omowaye *et al*. (2003) in air dried bell pepper; Abrol *et al*. (2014) in mango, banana and papaya.

Gupta (2014) has also reported about the effect of blanching and drying on vitamin C content of aonla shreds. They found that the initial vitamin C content of aonla shreds was 360 mg/100 g. After blanching, the vitamin C content was 260 ± 10.5 mg/100 g and content in dried samples ranged from 110.32 to 122.42 mg/100 g. Hence findings of lower ascorbic acid content in dehydrated spiced samples in comparison of fresh fruit content is in conformity of these observations. Similar observations about ascorbic acid in intermediate moisture aonla segments has been reported by (Panwar *et al*., 2013) who found that there was a significantly decreased in ascorbic acid from fresh content (427 to 185 mg/100 g) during six months storage period.

5.8 Changes in total antioxidant content

Among the treated samples highest total antioxidant content (2423 mg/100 g) was observed in T_4 (aonla segments treated with spices level-3 with OD in 60 °Brix sugar syrup for 24 hrs) in cabinet dried samples and lowest (1734 mg/100 g) in T_1 (Osmotically dehydrated (OD) aonla segments using standard process with 60 °Brix sugar syrup) in cabinet dried samples. Total antioxidant content ranges from 1890 mg/100 g (T_1) to 2423 mg/100 g (T_4) in cabinet dried samples whereas from 1734 mg/100 g (T_1) to 2248mg/100 gm (T_8) in solar dried samples. Untreated frozen samples (T_5) under solar drier showed maximum total antioxidant of 2814 mg/100 g. A gradual increase in antioxidant content was found from T_2 to T_4 with increase in spice content. The subsequent increase in the antioxidant activity is due to the increase in the spice content. Cabinet dried samples had higher retention of total antioxidants than solar dried samples. Similar trend has been observed in case of combined process samples from T_6 to T_8. These results are in conformity with reports of Abrol *et al*. (2014); Gudapaty *et al*. (2010) ; Priyanka (2015) ; Nain *et al*. (2009) ; Mongi *et al*. (2015).

5.9 Changes in sugar contents

Sugar content in the osmotically dehydrated spiced aonla segments treatments showed significant variations with respect to reducing sugars, non-reducing sugars and total sugar contents. There was slight increase in the reducing sugar and total sugar content whereas non-reducing sugar decreased in dehydrated samples during subsequent storage period.

Among the treated samples reducing sugar content ranged from 21.69 (T_8) per cent to 28.64 (T_4) per cent in cabinet dried samples whereas 23.05 (T_8) per cent to 27.31 (T_4) per cent in solar dried samples. Untreated T_9 samples of both cabinet and solar dried samples showed lower reducing sugar content of 5.12 percent and 5.23 percent respectively. Highest sugar content (28.64 percent) was observed in T_4 of cabinet drier. Data indicates that there was slight increase in the reducing sugar content dehydrated samples during subsequent storage period.

Among the treated samples highest non-reducing sugar content was found in T_7 (13.29 per cent) of cabinet dried samples and lowest in T_8 (9.25 per cent) of solar dried sample. Reducing sugar content varied from 10.36 (T_1) percent to 13.29 (T_7) percent in cabinet dried samples whereas 9.25 (T_8) to 12.91(T_4 and T_7) in solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) of both cabinet and solar driers showed low non-reducing sugar content. Data indicates that there was a decrease in the non-reducing sugar content dehydrated samples during subsequent storage period.

There was significant difference between treatments, drying and interaction on changes of total sugar content. Among the treated samples highest total sugars was observed was 30.48 (T_3) percent in cabinet drier and lowest was 25.93 (T_1) percent in cabinet drier. In contrast, untreated frozen samples (T_5) showed a lower content of 8.62 percent and 10.09 percent in cabinet and solar dried samples respectively. Total sugar content ranged from 25.93 (T_1) percent to 30.48 (T_3) percent in cabinet dried samples whereas from 26.48 (T_8) percent to 30.22 (T_3) percent in solar dried samples. Least total sugar content of 5.65 percent and 5.46 percent was observed in 3 % salt dipped samples (T_9) in cabinet and solar dried samples respectively.

In the subsequent period of storage total sugar content increased in both solar and cabinet drier. This results were in conformity with the findings of Sumitha *et al.,* 2003, Thippanna, 2005; Anitha, 2007; Tiwari, 2005.

5.10 Changes in the non-enzymatic browning

There was significant difference between treatments, drying and interaction on changes of total sugar content .Among the treated samples highest non-enzymatic browning (NEB OD at 440 nm) is found in T_8 (0.196) in solar dried samples and lowest in T_1 (0.057) in cabinet dried samples. Non-enzymatic browning values ranged from 0.057 (T_1) to 0.096 (T_8) in cabinet dried samples and 0.067 (T_1) to 0.196 (T_8) in solar dried samples. Untreated frozen samples (T_5) of both cabinet and solar drier showed highest non-enzymatic browning comparing other samples. Solar dried samples showed higher non-enzymatic browning than cabinet dried samples. Data indicates that there was an increase in the non-enzymatic browning content of dehydrated samples during subsequent storage period.

As the preservatives were added to the osmotic medium and control was treated with potassium meta-bi sulphate it helped to maintain the NEB in slices at very low level. However, there was slight increase in the non-enzymatic browning during storage which was slight increase in the non-enzymatic browning during storage which was may be due to loss of sulphur dioxide. These findings are in conformity with the observations of other workers (Sharma *et al*., acids, oxygen and sugars have also been reported to be responsible for causing NEB in stored food as reported 2004. Further several factors such as temperature, moisture, carbonyl compounds, organic by Thippanna (2005), Anitha (2007), Kumar *et al*., (2008) and Sumitha (2010). Non enzymatic browning might be also due to condensation of tannins into brown pigments. The spiced IMF aonla segments were found to have more NEB than sweet IMF aonla segments, and it might be due to additional browning contributed by spices (Panwar *et al.,* 2013). Singh *et al.* (2010) also reported that browning increased gradually in Intermediate moisture baby corn with increase in storage period of 60 days.

5.11 Changes in the water activity

Data indicates that there was a decrease in the water activity of dehydrated samples during subsequent storage period. The spiced aonla candy showed lower aw as compared to sweet aonla candy and it was because of presence of sodium chloride in spice mixture. The ability of salt to decrease water activity is thought to be due to ability of sodium and chloride ions to associate with water molecules (Fennema, 1996; Potter and Hotchkiss, 1995). Increased the water loss and thus, lowered the water activity in the samples (Panwar *et al*., 2013).

5.12 Effect of different pretreatments and drying methods on sensory quality

5.12.1 Effect on colour

Osmotically dehydrated samples in 60 $^{\circ}$Brix sugar syrup for 24 hrs with varying spice levels (T_1 to T_4) shown higher sensory score of colour than combined processed samples (T_6 to T_8) with varying spice levels in both cabinet and solar dried samples. Cabinet dried samples showed higher sensory score than the respective solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score than other treated samples in both cabinet and solar dried samples. A significant decrease in mean score of colour in simple osmotically dehydrated and spiced aonla segments was recorded during four months storage period. This could be due to occurrence of non-enzymatic browning in aonla segments during storage. The spiced aonla segments had slightly lower mean score for colour than simple osmotically dehydrated samples aonla candy. The spices added their colour to aonla segments and made the product darker as compared to simple osmotically dehydrated samples (Panwar *et al.,* 2013).

Similar results were reported by Thippanna (2005) in banana,Anitha (2007) in guava and Sumitha (2010) in aonla. Dermesonlouoglou *et al*., 2008 showed that dehydrofrozen samples exhibited significantly improved stability, with the rates of colour change being reduced. Results are also in conformity with Raj *et al*., 2015 in apricots.

5.12.2 Effect on texture

There was significant difference among treatments. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score for texture than other treated samples in both cabinet and solar dried samples. In general, cabinet dried samples showed higher sensory score than the respective solar dried samples. T_1 sample (Osmotically dehydrated sample in 60 $^{\circ}$Brix sugar syrup for 24 hrs shown higher sensory score of texture among T_1 to T_4 samples in both cabinet and solar dried samples and T_6 sample (Aonla segments with spices level-1 (CP) with OD in 60 $^{\circ}$Brix sugar syrup for 4 hrs) shown higher sensory score for texture among combined processed samples from T_6 to T_8 in both cabinet and solar dried samples. Highest score for texture was observed in T_7 (Aonla segments with spices level-2(CP) with OD in 60 °Brix sugar syrup for 4 hrs) in the two months and four months of storage. The textural improvement of T_6 and T_7 which are combined processed (blanched and frozen) were superior. This might be due to the formation of ice crystals inside the tissue during freezing. Ade-Omowaye *et al*., 2003 also reported showed that freezing resulted in total pore area.

Falade *et al*., 2007 also reported that compositional-structural profiles that are developed with gas-liquid exchanges in the tissue during osmotic process have a significant impact on physical (optical), textural and chemical properties (e.g., flavour profile) of the final product, which is in part influenced by the differences in the number of cells that are altered and unaltered during the treatment.

5.12.3 Effect on flavour

Among the combined processed samples T_6 (Aonla segments with spices level-1(CP) with OD in 60 °Brix sugar syrup for 4 hrs) scored high in cabinet and solar dried samples whereas among the osmotically dehydrated samples T_1 showed maximum score. The spice level-1 which was incorporated in T_6 given it an acceptable flavour which was a combination of 10 ml/ lit of ginger extract + Black pepper 1 % + Cumin 5 % + Salt 2 %. This results were in conformity with Prajapati *et al*., 2011 were common salt, black salt and ginger juice were mixed for enhancing sensory quality of the product and a report on effect of dried ginger powder, fennel powder, cumin powder and fresh ginger extract addition on supari from *aonla* by Abraham *et al.* (2010) in the overall acceptability of product. The result is in conformity with Falade *et al*., 2007 where he reported that gas-liquid exchanges in the tissue during osmotic process have a significant impact on flavour profile of the final product. Same result was presented by Germer *et al*. (2010) in peaches.

5.12.4 Effect on overall acceptability

Overall highest total sensory score was obtained for T_6 (Aonla segments with spices level-1 (CP) with OD in 60 °Brix sugar syrup for 4 hrs) and T_1 among the osmotically dehydrated samples. T_6 treatment showed superiority because of improvement in its microstructure by freezing which enhanced its texture and also the use of spice level -1 which contain 10 ml/ lit of ginger extract + Black pepper 1 % + Cumin 5 % + Salt 2 % which given a mild flavour of these spices along with aonla flavour. These results were in conformity with Abraham *et al.* (2010), and Prajapati *et al*., 2011.The infusion of spices into the intercellular spaces of tissues given better organoleptic characteristics to the product. This was in conformation with Nayak *et al*. (2012); George *et al*., 2016; Chwastek (2014).

Treatment T6 showed superiority because of improvement in its microstructure by freezing which enhanced its texture and also the use of spice level -1 which contain 10ml/lit of ginger extract + Black pepper 1 % + Cumin 5 % + Salt 2 % which given a mild flavour of these spices along with aonla flavour. This result is in conformity with Falade *et al*., 2007 who reported that compositional-structural profiles that are developed with gas-liquid exchanges in the tissue during osmotic process have a significant impact on physical (optical), textural and chemical properties (e.g. flavour profile) of the final product, which is in part influenced by the differences in the number of cells that are altered and unaltered during the treatment.

VI. SUMMARY

Infusion of spices through osmotic dehydration process was found effective in improving the quality and dehydrated yield of aonla slices to a greater extent. The result of the "Development of protocol for spiced dehydrated *aonla* (*Phyllanthus emblica* L.) segments" has been summarized in this chapter.

6.1 Aonla characteristics:

- *Aonla* variety Krishna used in this study having average fruit weight 37.27 g, Pulp content 94.41 per cent and seed content of 5.35 per cent.
- In fresh *aonla* fruits, moisture content was 88.50 per cent, total solids 11.50 per cent, TSS 7.5 ^{o}Brix, titratable acidity (as citric acid) 2.35 per cent, ascorbic acid 395.2 (mg/100 g of edible portion), reducing sugars 3.25 per cent, non-reducing sugars 1.96 per cent and total sugars of 5.21 per cent.

6.2 Water Loss, Solid Gain and Weight Reduction:

- Significant differences were recorded for per cent water loss (WL), solid gain (SG) and weight reduction (WR) in osmosed *aonla* segments as influenced by various osmotic treatments.
- Maximum water loss of 42.57 per cent was found with Treatment T_2 (aonla segments with spices level-2 with OD in 60 $^{\circ}$Brix sugar syrup for 24 hrs) which was at par with treatment T_1 and T_3.
- Water loss values were higher (33.85 to 42.57 %) in blanched segments (T_1 to T_3) as compared to blanched and frozen segments (T_6 to T_8) in which water loss values (15.97 to 21.18) were lower than solid gain and impact was negative.
- Significantly higher solid gain (16.68 to 18.85 %) was recorded in blanched and frozen samples (T_6 to T_8) treated for 4 hrs as compared to blanched samples subjected to osmotic treatments for 24 hrs. (T_1 to T_4) in which SG values ranged from 11.93 to 12.43 %.
- Combined processed samples showed maximum solid gain than simple osmotically dehydrated samples. As a result maximum weight reduction (21.60 to 30.37 %) was also recorded in osmotically dehydrated samples, while values were negative (-4.45 to 4.52 %) in combined processed samples (T_6 to T_8).

6.3 Yield, drying ratio and rehydration ratio

- Osmotic pretreatments significantly increased the yield in blanched aonla segments (T_1 to T_4) as well as combined processed samples (T_6 to T_8) as compared to control samples (T_5 and T_9).
- Maximum product yield 47.10 per cent was recorded in aonla segments with spices level-2(CP) with OD in 60 $^{\circ}$Brix sugar syrup for 4 hrs) followed by T_6 (aonla segments with spices level-1 (CP) with OD in 60 $^{\circ}$Brix sugar syrup for 4 hrs) with an yield of 44.48 per cent in cabinet dried samples.
- Combined processed samples showed higher product yield as compared to osmotically dehydrated samples (T_1 to T_4) in which mean value ranged from 33.90 to 34.82 %)
- Lowest yield was recorded in control samples T_5 (12.56 %) made by cabinet drying.
- Different pre-treatments significantly affected the drying ratio of dehydrated aonla segments. Maximum drying ratio 7.77:1 was observed in case of control (T_5). The drying ratio was minimum 2.12: 1 in aonla segments with spices level-2(CP) with OD in 60 $^{\circ}$Brix sugar syrup for 4 hrs (T_7) in cabinet dried samples. In general the drying ratio was lower combined processed samples.

- Higher rehydration ratio was found in solar dried samples as compared to cabinet dried samples.

6.4 Quality of the product

- Not much variation was observed in moisture content in osmotically dehydrated aonla segments and moisture content slightly decreased after four months of storage at room temperature. Average moisture content values in cabinet dried and solar dried samples were 13.17 and 13.21 respectively.
- Significant variations were observed with respect to titratable acidity content in dehydrated aonla segments. Maximum acidity content was recorded in control sample T_5 7.94 % (cabinet dried) & 6.71 % (solar dried). However osmotic treatment resulted in significant reduction in acidity content in dehydrated aonla segments. Not much variation was observed in acidity content during storage.
- Significant variations were observed with respect to ascorbic acid content in dehydrated aonla segments. Ascorbic acid content was higher in cabinet dried samples as compared to solar dried samples and mean value ranged from 95.64 to 179.97 mg/ 100 g. A reduction in ascorbic acid content was observed during storage.
- A gradual increase in antioxidant content was found from T_2 to T_4 with increase in spice content. Similar trend has been observed in case of combined process samples from T_6 to T_8. During subsequent storage periods total antioxidant content decreased.
- There was slight increase in the reducing sugar and total sugar content whereas non-reducing sugar decreased in dehydrated samples during subsequent storage period.
- There was an increase in the non-enzymatic browning content of dehydrated samples during subsequent storage period and solar dried samples showed greater NEB than cabinet dried samples.
- Water activity ranged from 0.514 (T_3) to 0.554 (T_7) in cabinet dried samples whereas it ranges from 0.537 (T_6) to 0.582 (T_1) in solar dried samples. There was a decrease in the water activity of dehydrated samples during subsequent storage period.

6.5 Sensory quality attributes

- Osmotically dehydrated samples made using 60 °Brix sugar syrup for 24 hrs with varying spice levels (T_1 to T_4) shown higher sensory score for colour than combined processed samples (T_6 to T_8) with varying spice levels in both cabinet and solar dried samples.
- Cabinet dried samples showed higher sensory score than the respective solar dried samples. Untreated frozen samples (T_5) and salt dipped samples (T_9) showed lower sensory score than other treated samples made using both method of drying.
- Sensory score for texture was higher in treatment T_6 and T_7 which indicate that combined processed (blanched and frozen) improved textural property in samples.
- Aonla segments with spices level-1 (CP) with OD in 60 °Brix sugar syrup for 4 hrs (Treatment T_6) scored high score for flavour in cabinet and solar dried samples whereas among the osmotically dehydrated samples T_1 showed maximum score.
- The spice level-1 which was incorporated in T_6 given it an acceptable flavour which was a combination of 10 ml/ lit of ginger extract + Black pepper 1 % + cumin 5 % + Salt 2 %.
- Among the spiced samples overall highest total sensory score was obtained in case of treatment T_6 in which spiced aonla segments were made with spices level-1(CP) with OD in 60 °Brix sugar syrup for 4 hrs.
- Treatment T_6 showed superiority because of improvement in its microstructure by freezing which enhanced its texture and also the use of spice level -1 which contain 10 ml/ lit of ginger extract + Black pepper 1 % + Cumin 5 % + Salt 2 % which given a mild flavour of these spices along with aonla flavour.

6.6 Future line of work:

- Industrial application of work.
- Effectiveness of different drying methods for osmotically dehydrated aonla segments has to be explored.
- Popularization of solar drying as an alternative to utilize the renewable source of energy in rural areas.
- Evaluation of different aonla varieties for osmotic dehydration and product development.
- Diversification of product formulation to develop novel tastes.
- To scale up the process, use of infusion technology to incorporate bioactive constituents through osmotic dehydration.
- Microbiological studies of the osmotically dehydrated products.

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