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RESEARCH ARTICLE

Advancements in Aonla Preservation: Impact of Sweeteners on Quality and Shelf Life of Osmodehydrated Aonla Slices

Rashmi Thakur[1*], Anil Kumar Verma[1], Vikas Kumar Sharma[2], Lakesh Rahi[2]

Abstract

Aonla is a sub-tropical deciduous fruit crop native to India, known for its high nutritional value. It is the second most abundant source of vitamin C and is also renowned for its medicinal properties. The fruit has an acidic and astringent flavor, making it highly suitable for processing into various products. Aonla slice, characterized by its soft, sweet, and tangy flavor, offers numerous health benefits. However, these slices can be made even more innovative by substituting sugar with different types of sweeteners. The goal of this study was to investigate how different osmotic treatments affected the osmotic dehydration process of aonla slices. Fresh aonla fruits of the Krishna variety were harvested at physiological maturity and subjected to different osmotic treatments. The fruits were soaked in sugar solution (T1), honey solution (T2), and apple juice concentrate solution (T3) to complete the osmotic dehydration process. Aonla slices prepared with the sugar solution were used as the control group. The osmotic treatments were carried out for 4 hours at 50°C, which resulted in increased weight loss, water loss, and solid gain in the aonla slices. After preparation, the aonla slices were packed in aluminum-laminated pouches and stored at room temperature (20–25°C) and 90–95% relative humidity for 0, 30, 60, and 90 days. During storage, the slices were evaluated for their physiological attributes, biochemical characteristics, and enzymatic activities. An increase in total soluble solids and titratable acidity was observed, while ascorbic acid content and antioxidant activity were found to decline over the storage period of time.

Keywords: Aonla slice. Apple juice concentrate. Honey. Osmotic dehydration

INTRODUCTION

Aonla (*Phyllanthus emblica* L.) or Indian gooseberry belongs to the family of Phyllanthaceae and is regarded as a wonder fruit for health because of its medicinal and therapeutic qualities. The seeds of the aonla fruit are enclosed in six perpendicular furrows that are yellowish-green in color (Parveen and Khatkar 2015). Aonla fruits are in huge demand in the local and large-scale food sectors for the production of a variety of health-based preserved foods that are popular in marketplaces (Deepika and Panja 2017; Pathak *et al.*, 2009). Aonla is India's most significant dryland fruit crop, accounting for 1.41% of total fruit crop area with an annual yield of 1077 thousand tonnes from 93 thousand hectares of land. Aonla ranks first in terms of area, accounting for 1.14% of total fruit crop output (NHB 2019).

Aonla fruits are available for harvest in north India between the months of November and December. The highest ascorbic acid is found in ripe fruits, while immature fruits are bitter and low in ascorbic acid. The aonla fruits mature to a distinct hue. The fruits are often light green at first, but as they develop, they turn dull greenish-yellow or even brick red occasionally. Iron, calcium, phosphorus, magnesium, amino acids and phytochemicals (such as corilagin, phyllemblin, and rutin) are plentiful in aonla fruits (Murthy and Joshi 2007). Aonla is the second most abundant source of natural vitamin C after the Barbados cherry. The fruits also contain leucoanthocyanin, which is a kind of polyphenol that slows the oxidation of vitamin C. Ascorbic acid does not oxidize fast during heat processing because aonla fruit contains tannins. Aonla fruit must be treated especially during glut seasons to extend its shelf life

[1]Department of Food Science and Technology, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh-173230, India.

[2]Department of Fruit Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh-173230, India.

***Corresponding Author:** Rashmi Thakur, Department of Food Science and Technology, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh-173230, India., E-Mail: rashmithakur1197@gmail.com

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and to increase value addition (Prajapathi *et al.,* 2011). Most individuals avoid eating fresh aonla fruits because they are acidic and astringent in flavour. It has tremendous promise in processed forms to compensate for its astringent flavour. Among different types of processed products, sliced is the most popular one. Fruit slice is impregnated with sugar before being drained and dried. Given the detrimental effects of sugar consumption, there is a lot of interest in figuring out how to substitute sugar with various artificial sweeteners. Furthermore, the food industry is seeing an increase in health-conscious customers drawn in by labelling claims such as sugar-free, reduced-calorie, no-calorie, and so on. Now-a-days people are looking for natural dietary components as a result of the increasing popularity of low-calorie or artificial sweeteners. The goal of this study was to prepare aonla slices with a distinctive flavor by using natural sweeteners such as honey and apple juice concentrate as a replacement for sugar.

Materials And Methods

During the year 2020-2021, the Aonla fruits cv. Krishna were harvested randomly at the physiological mature stage from the Regional Horticultural Research and Training Station and the fruits were transported to the laboratory. The raw material was properly cleansed with clean water. The fruits were blanched for 10 minutes at 70 to 100°C in the boiling water before being used (Geetha *et al.,* 2006). The seeds were removed and the segments were carefully separated. The fruit segments were soaked for 4 hours in three distinct hypertonic osmotic solutions, namely sugar solution, honey solution, and apple juice concentrate solution, all of which had a TSS of 70°B and were kept at 50°C in a hot water bath in the proportion of 1:3 (fruit: syrup). After completion of osmosis, the solution was then drained and the segments were washed under water to remove the sugar solution before drying in a dehydrator at 55 ± 2°C until the weight was constant. The slices were packaged in aluminium laminated pouches (AP) and kept at room temperature (20–25°C) for storage studies.

Determination of the effect of different osmotic treatments on the mass transfer of aonla slices

Different intervals were used to evaluate the parameters of the osmotic dehydration process, such as water loss (WL), solid gain (SG), weight reduction (WR) and equilibrium of TSS between slices and solution, which define the process.

Determination of physico-chemical characteristics of aonla slices

Moisture content

The moisture content of the dried aonla slices was determined by drying pre-weighed samples in a hot air oven at 105 ± 5°C until a constant weight was achieved. After drying, the samples were allowed to cool to room temperature in a desiccator. Moisture content was then calculated and reported on a fresh weight basis, following the method described by Ranganna (2014).

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

Titratable acidity

Titratable acidity was measured by titrating a known volume of the sample aliquot with 0.1 N NaOH using 0.1% phenolphthalein as an indicator, until a persistent pink endpoint was reached. The acidity was calculated and expressed as a percentage of citric acid, following the procedure outlined by Ranganna (2014) and calculated as

$$Titratable\ acidity\ (\%) = \frac{Titre\ value \times Normality\ of\ alkali \times Volume\ made\ up \times Eq.Wt.of\ predominant\ acid}{Weight\ of\ sample \times Volume\ of\ aliquot\ taken \times 1000} \times 100$$

Ascorbic acid

Ascorbic acid content in the aonla slices was estimated using a titrimetric procedure involving 2,6-dichlorophenol-indophenol dye. A measured amount of the sample was diluted to 100 mL with 3% metaphosphoric acid, and an aliquot of this extract was titrated with the standardized dye solution until a faint pink colour persisted for at least 15 seconds. The dye was standardized separately by titrating it against a known ascorbic acid solution (0.1 mg L-ascorbic acid per mL of 3% HPO_3), and the dye factor was determined using the following equation

$$Dye\ factor = \frac{0.5}{Titre\ value}$$

The calculation given below was used to determine the ascorbic acid content of aonla slices, which was then expressed as mg/100 g of the sample (Ranganna 2014).

$$Ascorbic\ acid\ (mg/100g) = \frac{Titre\ Value \times Dye\ factor \times Volume\ made\ up}{Aliquot\ of\ extract\ taken \times Weight\ of\ sample} \times 100$$

Antioxidant activity

The free radical scavenging activity of aonla slices was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay. For analysis, 0.1 mL of the methanolic sample extract was mixed with 3.9 mL of DPPH solution (6×10^{-5} mol/L), while methanol served as the blank. After allowing the reaction mixture to stand for 30 minutes, the absorbance was recorded at 515 nm. The antioxidant activity was then calculated using the equation described by Brand-Williams *et al.* (1995).

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

Where,

Ab (B) = Absorbance of blank

Ab (S) = Absorbance of sample

Total soluble proteins

Total soluble protein content was determined using the Lowry method. In this procedure, proteins first react with copper ions under alkaline conditions, after which the aromatic amino acids present in the mixture reduce the Folin–Ciocalteu reagent. This reaction produces a blue-coloured complex, the intensity of which is directly proportional to the protein concentration and can be quantified colorimetrically. The absorbance of the final reaction mixture was measured at 660 nm, and protein content was calculated using a standard curve prepared with bovine serum albumin (BSA), following the method described by Waterborg (2009).

Regression Y = 2.394x

X= Y/2.394

$$X\,(\%) = \frac{Y}{2.394} \times \frac{Total\ volume}{Aliquot\ taken} \times \frac{100}{Weight\ of\ sample} \times Dilution\ factor$$

The chemical characteristics of the various aonla slice samples were statistically evaluated using a Completely Randomized Design (CRD) as outlined by Cochran and Cox (1987). All measurements were performed in triplicate.

Results And Discussion

Mass transfer

It comprises weight reduction, water loss, and solid gain, all of which rose with the immersion duration of fruit slices (1:3; fruit:syrup) in 70°B solution at 50°C temperature maintained in a hot water bath, as shown in Figure 1. Temperature increased water and solids diffusivity, resulting in higher water loss and solids gain (Figure 2). The rise in solution concentration resulted in an increase in solids gain but at

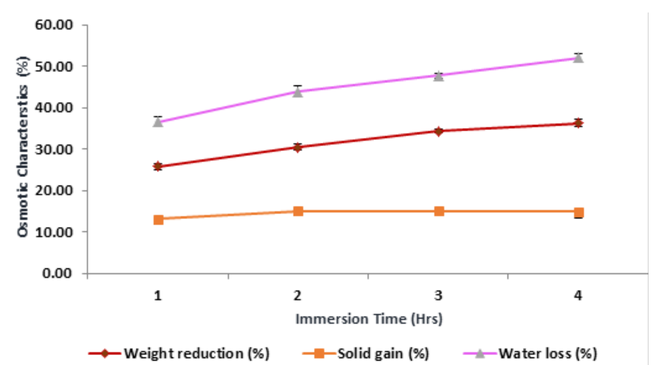
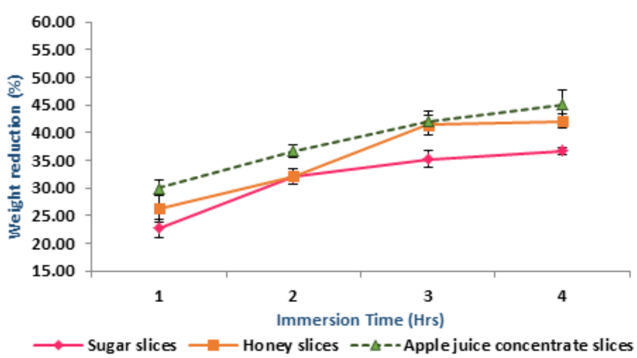
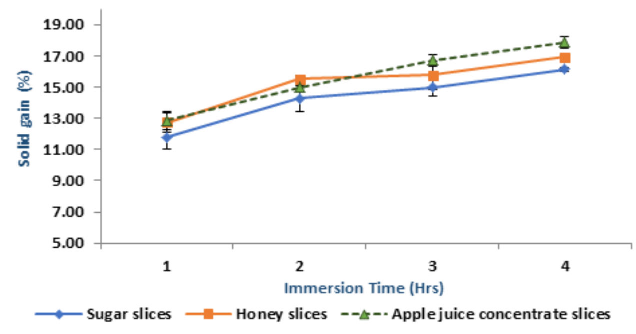


Figure 1: Effect of immersion time (hrs) on osmotic characteristics (%), i.e., weight reduction, solid gain and water loss of aonla slices





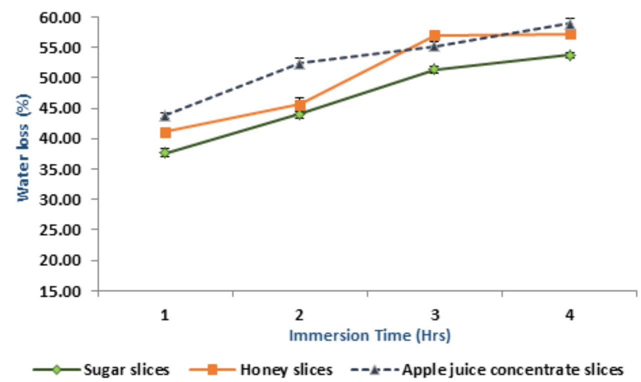


Figure 2: Effect of immersion time on weight reduction (%), solid gain (%) and water loss (%) during different treatments

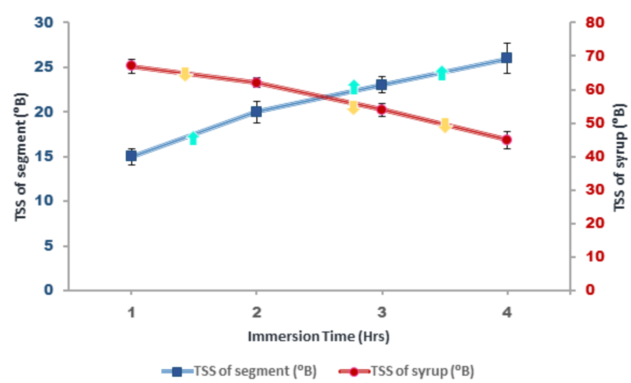


Figure 3: Effect of immersion time on TSS of segment (°B) and TSS of syrup (°B)

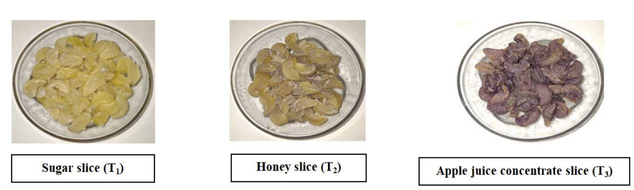


Figure 4: Osmodehydrated aonla slices prepared using different sweeteners

Table 1: Effect of different osmotic treatments on total soluble solids, moisture content, titratable acidity, ascorbic acid, antioxidant activity and total soluble proteins of aonla slices stored at room temperature (20–25^{0}C) and 90–95% relative humidity.

Treatment (T)	*Storage period (days) (S)*					*CD0.05*		
	0	*30*	*60*	*90*	*Mean (S)*			
Total soluble solids (°B)								
Sugar slice (T1)	74.14	74.39	74.66	74.93	74.53	S	=	0.10
Honey slice (T2)	75.00	75.21	75.42	75.55	75.30	T	=	0.12
Apple juice concentrate slice (T3)	72.97	73.37	74.15	73.67	73.54	S×T	=	0.23
Mean (T)	74.04	74.32	74.74	74.72				
Moisture content (%)								
Sugar slice (T1)	16.57	16.49	16.15	16.11	16.33	S	=	0.01
Honey slice (T2)	15.52	15.45	15.19	15.12	15.32	T	=	0.01
Apple juice concentrate slice (T3)	16.80	16.64	16.49	16.35	16.57	S×T	=	0.03
Mean (T)	16.30	16.19	15.94	15.86				
Titratable acidity (%)								
Sugar slice (T1)	0.50	0.55	0.61	0.64	0.58	S	=	0.01
Honey slice (T2)	0.53	0.59	0.63	0.65	0.60	T	=	0.01
Apple juice concentrate slice (T3)	0.58	0.65	0.72	0.76	0.68	S×T	=	0.02
Mean (T)	0.54	0.60	0.65	0.68				
Ascorbic acid (mg/100g)								
Sugar slice (T1)	160.75	155.85	151.68	149.74	154.51	S	=	0.37
Honey slice (T2)	160.94	156.36	153.88	150.54	155.43	T	=	0.46
Apple juice concentrate slice (T3)	202.14	197.88	194.70	190.94	196.42	S×T	=	0.91
Mean (T)	174.61	170.03	166.75	163.74				
Antioxidant activity (%)								
Sugar slice (T1)	78.84	78.31	77.81	77.51	78.12	S	=	0.01
Honey slice (T2)	79.64	79.60	79.37	79.15	79.44	T	=	0.02
Apple juice concentrate slice (T3)	80.06	79.78	79.74	79.68	79.82	S×T	=	0.03
Mean (T)	79.51	79.23	78.97	78.78				
Total soluble proteins (%)								
Sugar slice (T1)	13.16	13.01	12.97	12.73	12.97	S	=	0.02
Honey slice (T2)	13.82	13.46	13.11	13.01	13.35	T	=	0.02
Apple juice concentrate slice (T3)	15.17	15.09	14.52	14.49	14.82	S×T	=	0.05
Mean (T)	14.05	13.85	13.53	13.41				

Where,
S = Storage period
T = Treatments
S×T = Interaction between storage period and treatments
NS = Non-significant

specific temperatures, when the solution viscosity increased, it impeded water loss. The initial fruit: syrup ratio had minimal effect on the process (Campos *et al.,* 2012).

During osmotic dehydration, water migrates from the food material into the surrounding solution due to the osmotic pressure gradient, while solutes from the solution simultaneously diffuse into the food. The extent of water removal is influenced by several factors, including the concentration of the osmotic medium, treatment duration, temperature, solution-to-sample ratio, and level of agitation. In addition, food characteristics such as internal structure, particle size and shape, available surface area for mass transfer, and system pressure also affect the dehydration rate (Herman-Lara *et al.,* 2013; Silva *et al.,* 2012).

Osmotic dehydration in sugar solution can be used to partially dehydrate aonla slices. Depending on the sugar solution concentration (50–70 ^{0}Brix) and temperature (40–60^{0}C), they can lose 15.65 to 62.28% water and gain 3.69 to 18.14% sugar in 4 hours of osmosis (Jadhav *et al.* 2016). TSS of aonla segments and TSS of the solution during osmotic dehydration were modelled at various immersion intervals.

It is clear from Figure 1 that there was a progressive increase in weight reduction, solid gain and water loss during the immersion time of 4 hours. The water loss rate was quite faster at the beginning of osmosis, but it steadily decreased as the immersion time increased. Similar observations have been reported by Lenart and Flink (1984) and Alam and Singh (2008). With the progressive increase in water loss, the weight reduction increased accordingly. The solid gain simultaneously increased with an increase in the immersion time, when the sugar solution temperature was 50^{0}C. Our results are in consonance with the reports of Jain *et al.* (2011) in papaya cubes and Jadhav *et al.* (2016) in aonla slices. Further, it is also clear from Figure 3 that the decrease in the TSS of the solution is inversely proportional to the TSS of segments with an increase in the immersion time.

Effect of different sweeteners on mass transfer of aonla slices

Mass transfer or osmosis was carried out to prepare aonla slices using different sweeteners. The mass transfer properties of aonla slices were varied due to the osmotic variables used in the preparation process.

The water loss, weight reduction and solid gain were maximum in the aonla slices prepared along with apple juice concentrate, followed by honey and sugar. Mass transfer goes on increasing throughout the process.

Effect of quality characteristics on aonla slices:

The aonla fruit slices prepared with sugar solution (T_1), honey solution (T_2) and apple juice concentrate solution (T_3) presented in figure 4 were evaluated for different quality characteristics after packing in aluminium laminated pouches stored at ambient temperature (20–25^{0}C) up to 90 days at periodic intervals of 0, 30, 60 and 90 days. Changes in various physico-chemical properties of the products during the entire period of storage are described as under

Total soluble solids

The total soluble solids of aonla slices showed a gradually increasing trend during storage at ambient temperature (20–25^{0}C). The hydrolysis of polysaccharides and oligosaccharides into monosaccharides (reducing sugars) and moisture evaporation during storage could be the cause of this. An increase in TSS content after storage was also found in sapota slice (Divya *et al.,* 2014), flavoured aonla slice (Nayak *et al.,* 2012) and aonla slice enriched with natural oils/extracts (Kumar and Pathak, 2020).

Moisture content

Amid the treatments, apple juice concentrate slices had the highest moisture content produced with aonla cv. Krishna. The evaporation of moisture from the product may account for the reduction in moisture content in aonla slices as storage time increases. The decrease in moisture with storage of aonla slices was also noticed by Mehta *et al.* (2005) in gal gal peel slice and Kumar and Pathak (2020) in aonla slice enriched with natural oils/extract.

Titratable acidity

A gradual increase has been seen in titratable acidity among different aonla slices (Table 1). The rise in titratable acidity during the storage period might be attributed to pectic acid; hence, the breakdown of pectic compounds into soluble solids could have contributed to the increase in acidity of aonla products. A similar pattern has been observed in aonla products by Kumar and Pathak (2020) and Vikram *et al.* (2014) in honey-coated aonla slices.

Ascorbic acid

The ascorbic acid content of food items diminishes as the storage period increases. This reduction might be because of temperature, light, and oxygen, which are responsible for oxidation in packing materials, resulting in the production of dehydro-ascorbic acid. Our findings are in consonance with those of Nayak *et al.* (2012); Pawar *et al.* (2013) in aonla slice, Mishra *et al.* (2013) in bael slice and Vikram *et al.* (2014) in honey-coated aonla slice.

Antioxidant activity

The mean antioxidant activity showed a declining trend, as shown in Table 1. The interaction between aonla slices and storage period was discovered to be significant. A decrease in antioxidant activity might result from the breakdown of total phenolic compounds and vitamin C during storage. Our results were in accordance with the findings of Mir *et al.* (2015) in quince slice, Muzzaffar *et al.* (2016) in pumpkin slice and Bishnoi *et al.* (2018) in aonla ladoo.

Total soluble proteins

After preparation of aonla slices, the apple juice concentrate aonla slice was found to have more content of total soluble proteins (15.17%), followed by the honey aonla slice (13.82 %), than the standard sugar slice (13.16%). The total soluble proteins decrease with the increase in the storage period because of the denaturation of proteins or Maillard reaction.

Conclusion

The findings of this study demonstrate that aonla fruits can be effectively utilized to produce high-quality osmodehydrated slices with a distinctive flavor. The evaluation of different natural sweeteners confirmed their suitability for developing candied aonla products. Among the tested treatments, aonla slices prepared using apple juice concentrate and honey, followed by packaging in aluminium-laminated pouches, exhibited superior stability in physicochemical attributes during storage. Overall, apple juice concentrate proved to be a promising alternative to refined sugar for preparing value-added aonla slices, offering both functional and sensory advantages. The study demonstrates the potential for developing healthier, value-added aonla products, thereby supporting the wider utilization of this nutrient-rich indigenous fruit.

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Author's Contribution

RT conducted the experiments and drafted the article. AKV, VKS, and RT designed the experiments. RT, AKV, VKS, and LR executed the laboratory experiments and collected the data. RT, AKV, VKS, and LR carried out data analysis and interpretation. The manuscript was prepared by RT and AKV.

Declaration

The authors declare that this research article is their original work and affirm that no portion of it has been previously published elsewhere. We accept full responsibility if the manuscript is found to be invalid in the future based on established standards. All relevant references have been cited to the best of our knowledge. Furthermore, the authors declare that there are no competing interests, and all listed authors have read and approved the final manuscript.

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