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Dr. Sakthivel B
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Dharshini RB
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Jayashree R
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Kalaimani S
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Preethika S
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Sarumathi A
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Sivaranjani K
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Vimala P
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Correspondence
Dr. Sakthivel B
Assistant Professor, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Tiruvalluar, Tamil Nadu, India

Studies on various sweeteners and drying methods for candy produced from aonla (*Emblica officinalis Gaertn.*) cv. BSR-1

Sakthivel B, Dharshini RB, Jayashree R, Kalaimani S, Preethika S, Sarumathi A, Sivaranjani K and Vimala P

Abstract
An experiment entitled "Studies on various sweeteners and drying methods for candy produced from aonla (*Emblica officinalis Gaertn.*) cv. BSR-1" was carried out during year 2024-2025 at biochemistry laboratory, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Thiruvallur district. The experiment was carried out in a Factorial Completely Randomized Design (CRD) using two components. Factor A; sugar solution at the steeping period for an aonla recipe *viz.*, R_1 (50sugar solution @ steeping time 4 day), R_2 (60 sugar solution @ steeping time 3 day), R_3 (70 sugar solution @ steeping time 2 day), R_4 (80 sugar solution @ steeping time 1 day), and factor B; drying methods of aonla candy *viz.*, D_1 (Shade drying), D_2 (Sun drying), D_3 (Oven drying), D_4 (Microwave drying). The study included sixteen treatment variations and three replications. Physical attributes were noted when the fruit was fresh. The chemical analyses of the dried aonla candy occurred after 30 days. From the findings, it was observed that there was a progressive increase in TSS, protein, and total sugar of aonla candy regardless of the sugar solution, steeping period, and drying methods utilized in the experiment. However, the moisture, titratable acidity, ascorbic acid, and reducing sugar of aonla candy were found to decrease with the progression of the storage time. As a result, the produced aonla candies have the potential to be one of the most valuable food products in the future. They might have a healthy commercial market and be able to attract clients of all ages.

Keywords: Aonla, candy, acorbic acid, sugar solution, drying methods

Introduction
Aonla, or Indian gooseberry (*Emblica officinalis Gaertn., syn.Phyllanthus emblica*), is a member of the Euphorbiaceae family. The king of arid fruits, also known as Indian aonla. Aonla is one of the oldest Indian fruits and is considered a "wonder fruit for health" because of its unique quality. Aonla is native to tropical Southeast Asia, primarily in central and southern India. In India, forests have traditionally supplied aonla fruit for medical purposes, with each year's harvest estimated to reach around 50,000 tons. Increased demand from industry, particularly for ayurvedic formulations, and recognition of nutraceutical and therapeutic benefits for home consumption have led to the cultivation of aonla fruit. It is high in vitamin C, and its ascorbic acid level is second only to Barbados cherries (*Malpighia glabra* L.). Other parts are well preserved, as derived from aonla fruit (Pareek and Kaushik, 2012) [19]. In addition to vitamin C, it contains calcium, protein, iron, carbohydrates, tannic acids, sugars, and phosphorus. Aonla is mostly composed of tannins, amino acids, alkaloids, phenolic compounds, and carbohydrates. Consumers dislike this fruit in its natural form due to its extreme acidity and astringency. Thus, it is typically consumed in processed forms such as jam, jelly, RTS, nectar, squash, candy, pickles, murabba, herbal jam, canned fruit, ice cream, toffees, preserves, laddu, sauce, pan masala, supari, capsules, mukhwas, and so forth (Singh and Singh, 2014) [26].

Aonla fruit is also more valued for its antiscorbutic, diuretic, laxative, antidiarrheal, anti-jaundice, anti-inflammatory, and alternative antibiotic properties and is used in the ayurvedic and unani medicinal systems. The traditional Indian system of medicine utilizes their medicinal properties to cure diabetes, chronic dysentery, and bronchitis. The ripened fruits are widely used for the preparation of Ayurvedic medicines, i.e., *charanprash*, *Triphala*, *Ashokarishta*, and *Triphalamasin* reported by Datta and Paramesh (2010) [4].

In India, the major states that produce aonla, such as Rajasthan, Gujarat, Uttar Pradesh, Bihar, Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu are used for consumption. According to estimates, aonla is grown on around 50,000 ha in India, with a production of 1.75 lakh tonnes (Annon 2025) [2]. Aonla fruits are extremely perishable in nature; their shelf life in open conditions after harvest is only 5-6 days. So far, it is impossible to store and carry over vast distances. As a result, it necessitates rapid marketing and implementation. Therefore, aonla is ready for harvesting between mid-November and the first week of January. The produce lasts for a short time on the market. Because it is a perishable item, it requires prompt disposal. The farmers are required to sell their produce at a lower price when there is an abundance of crops harvested during the peak harvesting season. Aonla's post-harvest losses range from 30 to 40% given their perishable characteristics and overstock at harvesting, which affects the market value of the fruit.The reason for this is the limited availability and high perishability of aonla fruits mentioned by Singh *et al.*, (1993) [23]. Processing varieties of Banarasi, BSR-1, Krishna, Chakaiya, Kanchana, Hathijhool, Pink-tinged, Bansi Red, and NA-7 can result in value-added products that are the most effective economic equipment to promote aonla fruit production. Furthermore, aonla fruit has an acidic and bitter taste, thus it is used after processing. Several kinds have been produced in our country, including Kanchan, Krishna Gujarat Aonla-1, Banarasi, and NA-7. (Balaji *et al.*, 2014) [3].

As a result, there has been a focus on producing various value-added products from aonla. Candy is a sweet food made by soaking fruits with sugar syrup, draining off the excess syrup, and drying the product to make it shelf-stable. Aonla candy has been produced, which delivers a pleasant flavor while still delivering all of the health benefits. It is a dried-up version of Aonla that tastes delicious. Many people find it difficult to stop using it once they've started. Aonla candy is often manufactured from sugar, glucose and salt.The most common sweetener used in candy making is white sugar. This sugar comprises sucrose (99.7%). Aonla sweets are becoming increasingly popular due to their high acceptance, low volume, increased nutritional value, and longer shelf life. These have the added benefit being some of less thirst-provoking and ready for consumption food. (Vikram *et al.*, 2014) [31]. Dried products conserve energy, money, and space during packaging, storage, and transportation (Nayak *et al.* 2012) [16]. Aonla candy has a shelf life of around 9 months. They would appeal to customers since the substance appears more convenient for humans to consume. It has a wide range of nutrients and is nutritionally superior to other foods. Preparation involves soaking treated fruit in a strong sugar solution or syrup. It is virtually unknown in the global market and would like to be popularized over the years. Given the health benefits, there is a need to make fruits more suitable for value-added products. Candy, one of Aonla's unique goods, is in high demand both domestically and internationally. To strengthen the market, aonla candy's storage capacity and exceptional quality are essential. As a result, attempting to convert aonla into various value-added items such as aonla candies can aid in reducing distressed sales of aonla fruits, which are commonly recognized on the market when harvest occurs. Thus, the current study attempted to evaluate the impact of sugar concentration on the physico-chemical parameters of aonla candy. Thus, considering the potentials of the processed aonla product, the research project is entitled "Studies on various sweeteners and drying methods for candy produced from aonla (*Emblica officinalis Gaertn*.) cv. BSR-1".

Materials and Methods

An investigation was carried out in the biochemistry laboratory, Department of Horticulture, Jaya Agricultural College, Vyasapuram, Thiruvallur district, during 2024-2025. The experiment laid out CRD with a factorial concept of two factors, *viz*., Factor A: different recipe, and Factor B: different drying, and their four treatment combinations. The freshly harvested aonla fruits were well-matured, healthy, and uniform in size. The BSR-1 variety was procured from the local market. The selection of fresh fruit was properly rinsed with pure tap water to wash away any dirt or dust particles that had stuck to the fruit's pericarp. Healthy and high-quality matured fruits were chosen for candy production, and the fruit was boiled in water until soft. To conduct experiments, the seeds have been removed, and each segment was separated. The product was made by soaking the segments in successively varying amounts of sugar syrup until equilibrium was established at 50, 60, 70, and 80° Brix, as reported by Tandon *et al.*, (2003) [28]. First, a 50°Brix sugar syrup was made, and processing segments were added to it. After 24 hours of soaking, the segments were removed, the syrup drained, and their concentrations were adjusted to 50, 60, 70, and 80 Brix by adding sugar in the appropriate quantities. The appropriate amounts of sugar were added later to obtain the required concentrations for different Brix strengths of syrup at 50, 60, 70, and 80. The fruit segments were kept in 50, 60, 70, and 80° Brix syrup solution of sugar based on the treatment for four distinct steeping durations, *viz*., 4, 3, 2, and 1 days, respectively, until the segments and the sugar syrup concentration achieved equilibrium. Finally, the segments soaked in each treatment were drained of syrup and promptly rinsed with tap water to remove the adhering sugar solution and dried in different drying methods, such as shade, sun, oven, and microwave, till the moisture content was noticed to be up to 12%. After drying, the candy's observations were recorded at 30 days until the candy remained acceptable and recorded maximum consumer acceptability. A change in nutritional composition in terms of moisture, TSS, protein, acidity, ash content, fiber content, ascorbic acid, reducing sugar, and total sugar of aonla candy was determined as per the method mentioned by Ranganna, (2000) [21]. Each experiment was carried out in triplicate. The data was statistically analyzed using the method stated by Panse and Sukhatme (1967) [18]. Performed a C.R.D. factorial experiment. Table 1 shows the physical attributes of fresh aonla fruits. Fresh aonla fruits that are fully matured and disease-free have a medium to large size and a cone-shaped apex. Skin is smooth, apricot-golden in hue, with a pink flush. The fruit weight, girth, length, specific gravity, and juice content were recorded, respectively.

Results and Discussions

Effect of physical characteristics of fresh aonla fruits

The data on the physical characteristics of fresh aonla fruits was reported in Table 1. Fresh aonla fruits were fully matured, disease-free, and had medium to large conical apexes. The skin is smooth and apricot-golden with a pink

flush. The maximum recorded were diameter, length, average weight, specific gravity, seed weight, pulp weight and juice content, 12.44 cm, 3.58 cm, 29.79 g, 2.46 g, 1.83 g, 25.39 g, 10.10 ml respectively. The fruit displayed a light greenish-yellow color, which was reflected in the appearance of the final prepared candy. The fruit had an initial weight of 15.58g, while the pulp accounted for 90% of the total fruit weight. The information presented in Table 1 aligns closely with the findings reported by Shivani *et al.*, (2023) [24].

Table 1: Physical characteristics of fresh aonla fruits

Fresh Fruit Sample No	Diameter (cm)	Length (cm)	Weight (g)	Specific Gravity (g)	Seed Weight (g)	Pulp Weight (g)	Juice Content (ml)
1	10.98	3.11	26.39	2.12	1.74	23.67	9.00
2	11.30	3.18	27.08	2.40	1.57	24.21	8.33
3	12.44	3.58	29.79	2.46	1.83	25.39	10.10
4	12.16	3.49	29.14	2.28	1.43	26.89	9.66
S.Ed	0.12	0.03	0.29	0.02	0.01	0.24	0.08
CD(0.05)	0.25	0.07	0.61	0.05	0.03	0.51	0.18

Effect of different recipe and drying methods

Among the different recipes, the significant maximum of TSS (51.54 Brix), acidity (3.43%), and total sugars (79.81%) were found in R_3 (70% sugar solution at steeping time 2 days), whereas the significant minimum TSS, acidity, and total sugars were found in R_1 (50% sugar solution at steeping time 4 days). While significantly maximum protein (3.48%), ascorbic acid (341.22 mg/100 g), and reducing sugar (38.24%) were found in R_3 (70% sugar solution at steeping time 2 days), significantly lower acidity, ascorbic acid, and reducing sugar were found in R_1 (50% sugar solution at steeping time 4 days). In the case of drying methods, at the 30th day, the significant maximum of TSS (46.460 Brix), acidity (2.09%), and total sugar (69.29%) were found in D_2 (sun drying) and D_3 (oven drying). While the maximum protein, ascorbic acid, and reducing sugar (2.92%, 249.01 mg/100 g, and 28.61%) were found in D_2 (sun drying), respectively, the lowest of TSS, acidity, protein, ascorbic acid, reducing sugar and total sugar were found in D_1 (shade drying) in aonla candy (Table 2). When compared to oven drying, sun drying results in a greater loss of moisture; this could be because sun drying takes longer. However, in comparison with sun drying, oven drying resulted in a higher rate of moisture loss. Fruit that was sun-dried took 36.30 to 40 hours to obtain a moisture content of 4-6%, whereas fruit that was oven-dried took roughly 28.50 to 32 hours to reach a moisture content of 4-8%. These results are consistent with the findings of Nayak *et al.*, (2012) [16]. Who in their right mind observed that oven drying increases moisture loss as compared to sun drying. Sun drying takes a longer drying period. (Pareek and Kaushik, 2012) [19]. Osmotic initial treatment has been found to be an efficient way to greatly reduce the duration of processing as administered prior to freezer drying.(Valentina and Ian, 2017) [30]. The preliminary treatment effectively minimizes water, reducing the total water reduction stress through the method of drying (Alam *et al.*, 2018) [1]. After storage, candy may lose vitamin C due to oxidation or the irreversible conversion of antioxidants into dehydro vitamin C oxidants (ascoribimase). A reduction in ascorbic acid could also be caused by oxidation to dihydroxy-ascorbic acid through its storage period and due to the high temperatures at tray drying. The reduction in ascorbic acid over the time of storage period was also observed by Navitha and Mishra, (2018) [15] in Ber, Mahato *et al.*, (2020) [13] in Mango, Kumar and Pathak (2020) [12] in Aonla and Dinde *et al.*, (2021) [6] in karonda.

Interaction effect of recipe and drying methods

The data analysis presented in Table 3 showed a considerable the interaction effect of influence of recipe and drying methods of TSS and the sugar solution of dried aonla segments. The highest of TSS were found in R_3D_2 (54.55°B), which is at par with the R_3D_3 and R_3D_1. The oven-dried aonla segments had higher TSS levels compared to the sun-dried segments, which could be attributed to the restricted loss of moisture along with the elevated moisture level of the crop during sun drying. A comparable result of higher TSS content in the oven-dried aonla product compared to sun-dried has already been described by Deepika *et al.*, (2016) [5] and Katke *et al.*, (2018) [10].

Results clearly show the combined effect of recipe and drying methods on acidity at the 30th day of storage was found to be maximum in R_3D_2 (3.73%), which was found to be on par with R_3D_3 and R_3D_1, whereas lower acidity (0.24%) was found in R_2D_4 (Table 3). They showed that the acidity of the sun-dried products previously treated with 2% salt was higher than that of the alternate product. The increase in acidity in sun-dried samples could be ascribed to the gradual breakdown of carbohydrates to acid. Pretreatment with salt has a considerable effect on acidity. This could be assigned to the phenomenon of 'the more the salt concentration, the less the acidity' caused by acid leaching throughout osmotic pressure. The results are consistent with Katke *et al.*, (2019). Nilam *et al.*, (2021) [17] which recognized highest acidity within sun-dried fruit, followed by oven-dried fruit.

The data in Table 3 show that the recipe and drying methods have a substantial effect on the amount of ascorbic acid present in the dried aonla products. The maximum of ascorbic acid (371.53 mg/100 g) was found in R_3D_2. Ascorbic acid is important in human nutrition, so aonla fruits are used by people everywhere not only as an eating fruit but also in processed form as candy. The selected aonla variety contributes significantly to the nutritional enrichment of the final processed product, namely aonla candies. This might be due to conversion. The high conservation of ascorbic acid in sun-dried products could be attributed to the quicker drying process and shorter exposure time of segments to oxidation. The results are consistent with the findings of Shailendra *et al.*, (2017) [23] and Katke *et al.*, (2018) [11] It revealed that oven-dried fruit contained considerably more ascorbic acid compared to sun-dried fruit.

Table 3 presents the findings on the interaction between the recipe and drying methods on the proteins of aonla candy. The maximum protein content was found in treatment R_3D_2 (3.64%) at 30 days of storage period. Aonla candy's protein content increased considerably with the storage period extended. These findings are consistent given the results generated by Mondal *et al.* (2017), [14] Rajesh Kumar and Sanjay Pathak (2020) [20].

The evidence on interactions and their factors of recipe and drying methods on reducing sugars of aonla candy was showed in Table 3. The maximum reducing sugars are found in treatment combination R_3D_2 (41.97%), whereas the minimum reducing sugars were found in treatment combinations R_2D_4 (13.80%) on each processing day and after the ending of 30 days' storage. The increase in reduce sugars with the advent of storage could be ascribed to the higher degree of sugar inversion. These findings agree with the results provided by Navitha and Mishra, (2018) [15] in Ber, Harsha *et al.*, (2022) [8] in Aonla, Shivani *et al.*, (2023) [24] in aonla, Sonia Minhas *et al.*, (2024) [27] in anola.

The total sugars as influenced by recipe and drying methods of aonla candy are showed in Table 4. The total sugar content of Aonla candy improved considerably, the maximum total sugars were recorded in treatment combination R_3D_2 (81.70%) at 30 days of storage period. After storage of aonla candy, total sugar content increased, which could be explained by polysaccharide hydrolysis, which results in the transformation of soluble substances such as sugars. The total sugar content of these products has been determined by their total soluble solids. The rise in total sugars after storage could have been related to enhanced sugar inversion. These findings are consistent with the results disclosed by Mahato *et al.*, (2020) [14] in Mango. Nilam *et al.*, (2021) [17] in Papaya Harsha *et al.*, (2022) [8] in aonla, Shivani *et al.*, (2023) [24] in aonla and Rushikesh *et al.*, (2025) [22] in aonla

Table 2: Effect of recipe and drying methods on quality parameters of aonla candy at 30th days

T. No.	Treatment Details	TSS (°brix)	Acidity (%)	Ascorbic Acid (mg/100g)	Protein (%)	Total Sugar (%)	Reducing Sugar (%)
A. Recipe							
R_1	50% Sugar Solution + Steeping time 4 days	42.23	1.63	191.63	2.5	60.63	22.81
R_2	60% Sugar Solution + Steeping time 3 days	37.07	0.51	117.95	2.34	54.88	16.39
R_3	70% Sugar Solution+ Steeping time 2 days	51.54	3.43	341.21	3.48	79.81	38.24
R_4	80% Sugar Solution+ Steeping time 1 days	46.7	1.9	260.79	2.91	70.74	26.46
S.Ed		0.24	0.01	1.25	0.02	0.35	0.14
C.D@5%		0.50	0.02	2.53	0.03	0.71	0.29
B. Drying method							
D_1	Shade Drying	43.76	1.78	214.69	2.76	65.29	24.72
D_2	Sun Drying	46.46	2.09	249.01	2.92	69.29	28.61
D_3	Oven Drying	44.65	1.92	232.57	2.82	66.99	26.62
D_4	Microwave Drying	42.66	1.69	225.92	2.72	64.24	23.99
S.Ed		0.52	0.02	2.65	0.03	0.75	0.31
C.D@5%		1.05	0.05	5.37	0.07	1.51	0.62
Interaction		NS	NS	SIG	NS	SIG	SIG

Table 3: Interaction effects of recipe and drying methods on quality parameters of aonla candy at 30th days

Treatment (RxD)	TSS(°brix)	Acidity (%)	Ascorbic Acid (mg/100g)	Protein (%)	Total Sugar (%)	Reducing Sugar (%)
R_1D_1	42.15	1.63	184.49	2.53	58.29	22.06
R_1D_2	44.22	1.75	233.86	2.56	66.39	24.82
R_1D_3	42.06	1.65	197.04	2.48	61.04	23.18
R_1D_4	40.51	1.51	151.39	2.45	56.82	21.29
R_2D_1	37.40	0.38	109.46	2.43	54.89	15.41
R_2D_2	39.25	0.88	146.87	2.36	56.76	19.60
R_2D_3	37.09	0.55	109.17	2.28	54.38	16.76
R_2D_4	34.54	0.24	106.32	2.32	53.50	13.80
R_3D_1	50.30	3.32	324.06	3.38	78.82	36.24
R_3D_2	54.55	3.73	371.53	3.64	81.70	41.97
R_3D_3	51.72	3.53	349.96	3.52	80.41	39.51
R_3D_4	49.58	3.16	319.31	3.41	78.35	35.27
R_4D_1	45.19	1.81	243.80	2.71	69.19	25.20
R_4D_2	47.82	2.02	278.79	3.14	73.35	28.08
R_4D_3	47.76	1.94	274.14	3.07	72.14	27.04
R_4D_4	46.03	1.84	246.43	2.72	68.31	25.62
S.Ed	1.33	0.03	3.74	0.05	1.06	0.43
C.D (0.5%)	1.49	0.07	7.59	0.09	2.14	0.88
CV (%)	2.28	2.45	2.26	2.27	2.19	2.30

Effect on organoleptic qualities

In the current investigation, all samples greatly improved the organoleptic acceptability of the dried candies. According to the data in Figure 1, the highest mean color score (8.65), texture (8.87) and taste (8.48), was found in S_4 which is at par with the S_3. This could be due to a faster drying time in the hot air oven dryer and less exposure of the segments to hot air. The sun-dried product demonstrated worse organoleptic acceptability compared the others. The finding is consistent with the results found of Gaurav *et al.*, (2017) [7] and Harsha *et al.*, (2022) [8] which stated along with sun dried are superior to the other drying methods.

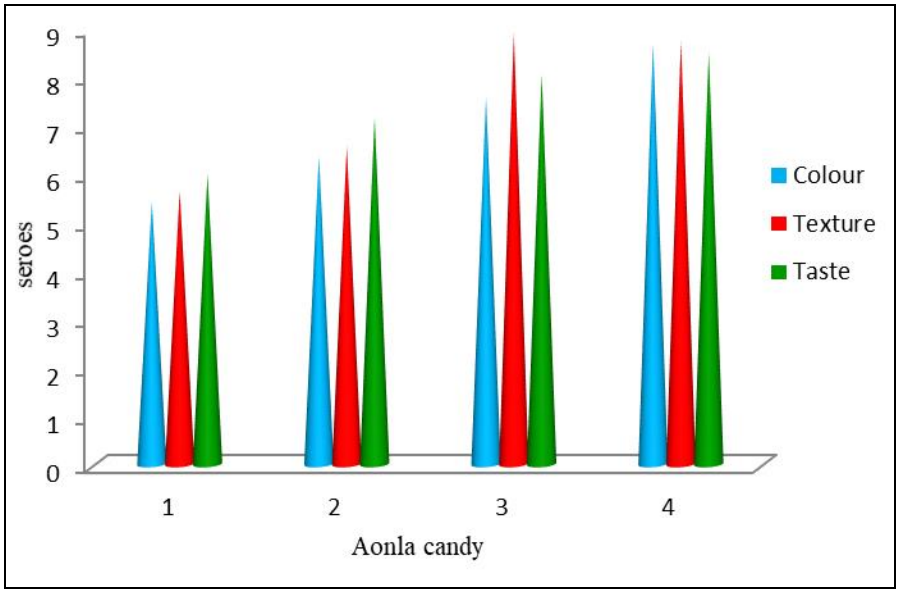

Fig 1: Organoleptic qualities of prepared aonla candy

Conclusion

This finding highlights the importance of both ingredient ratios and processing techniques in maximizing the nutritional and sensory qualities of aonla candy. Future studies could explore variations in sugar concentration or alternative drying methods to further enhance these desirable attributes. As a result, the R_3D_2 (70% sugar solution steeped for 2 days and sun-dried) got the best for the overall quality parameters of aonla candy. However, the several drying processes decrease the spread and proliferation of germs in the product during storage. Finally, this approach is ideal for adding value to fruits such as aonla candy, with the goal of generating more income. Therefore, this study has laid the foundation for further research that will incorporate other remedies intended to enhance the taste and texture of aonla candy after storage periods.

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