

Development of Basil-Flavored Apple Nectar

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ABSTRACT

Many people enjoy drinking apple nectar because it tastes good and is considered quite healthy; however, maintaining its quality during extended storage remains a major commercial challenge. In recent years, using natural plant extracts as alternatives to synthetic preservatives has received increasing attention. However, systematic studies evaluating the specific formulation, chemical stability, and shelf-life of apple nectar blended with basil leaf extract are limited in the existing literature. This study aimed to evaluate the effects of basil leaf extract on the physicochemical properties, sensory quality, and storage stability of apple nectar. The experiment was conducted in 2025 at Kabul University using a Factorial Completely Randomized Design (F-CRD) with eight treatments (1–7% basil extract) and three replications over 90 days. The study found that the amount of basil used and the length of storage both had a significant impact on all measured variables; specifically, while TSS, acidity, and both total and reducing sugars rose, the pH levels, non-reducing sugars, and sensory ratings declined as time passed. Formulations containing 1–3% basil extract maintained the highest quality, stability, and overall acceptability. In conclusion, incorporating 1–3% basil extract provides a viable, natural alternative to synthetic additives, which successfully optimizes both the nutritional value and marketability of functional apple nectar during storage.

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INTRODUCTION

Globally, the apple (*Malus domestica* Borkh.) is among the most extensively produced temperate fruits, contributing significantly to agricultural economies, global markets, and human nutrition. (Patocka et al., 2020). The geographical origins of this crop are widely traced back to China and the Central Asian region, where it has been cultivated for thousands of years before spreading to Europe and other regions (Brite, 2021). Apple fruit is highly valued for its pleasant taste, nutritional quality, long shelf life, and wide consumer acceptance across different populations. In addition, apples are among the most important temperate

fruits due to their desirable sensory and postharvest characteristics. (Musacchi & Serra, 2018).

Nutritionally, apples are rich in carbohydrates, dietary fiber, vitamin C, potassium, and contain small amounts of proteins and organic acids, which contribute to their health benefits. (Gawliński et al., 2020). It is also rich in phytochemicals, such as flavonoids, phenolic acids, and polyphenols, which are responsible for its strong antioxidant activity (Amarowicz & Biedrzycka, 2008). Consuming these bioactive substances is widely connected with preventing chronic conditions, particularly heart disease, diabetes, obesity, and certain forms of cancer. (Hyson, 2011). Due to these functional properties, apple has become an important raw material in the food industry for production of juices, purees, and functional beverages (Arya et al., 2023).

Fruit nectar quality is greatly influenced by its chemical composition, particularly titratable acidity, which plays an important role in determining the taste, stability, and shelf life of the product. During storage, acidity levels may change due to various biochemical reactions, such as hydrolysis, fermentation, and interactions among organic acids within the beverage matrix. Previous studies have reported that storage duration significantly affects acidity in fruit-based beverages, leading to changes in overall quality and consumer acceptability (Stanikzai et al., 2026). Fruit-based beverages, especially fruit nectars, are widely consumed because of their nutritional value, pleasant taste, and refreshing properties. Recently, interest has increased in improving their quality and storage stability through the use of natural plant extracts. Herbal additives can enhance sensory qualities and influence physicochemical properties during storage (Otmankhil et al., 2025). Globally, apple production is dominated by countries such as China, the United States, Poland, India, and Turkey, making it one of the most important commercial fruit crops. (Muder et al., 2022). Afghanistan's horticultural sector has experienced steady growth, with overall fruit production reaching an all-time high of approximately 3.91 million tons in 2024, marking a 1.09% increase from 2023 (FAOSTAT, 2024). Apple cultivation remains a critical cornerstone of this sector; national apple production expanded to 334,000 tons in 2024, representing a 3.04% annual growth (FAOSTAT, 2024). Historically, Wardak province has stood out as the leading apple-producing region, maintaining the largest share in cultivated area and yield despite minor localized fluctuations and shifting production trends in newer contexts like the Qades District (Orfany et al., 2026; Wardak et al., 2024). While the bulk of Afghan fresh fruit exports continues to target regional markets such as Pakistan and India, the global export share remains comparatively small. Concurrently, local agro-processing is expanding to enhance value-added utilization, focusing on the standardization of blended fruit beverages such as pomegranate and apple nectars to reduce post-harvest losses. (Muslim et al., 2026)

Widely recognized as Reyhan, basil (*Ocimum basilicum* L.) is a prominent essential oil-bearing therapeutic plant within the Lamiaceae family, extensively produced throughout tropical and subtropical environments (Mamita Kalita & Devi, 2023). It is well known for its essential oils that contain compounds such as linalool, eugenol, methyl chavicol, and cineole

which are responsible for its aroma and biological activity (Iliev et al., 2024). Basil leaves are a potent source of polyphenols and flavonoids, showcasing exceptional antioxidant, antibacterial, and anti-inflammatory qualities (Backiam et al., 2023). Traditionally, basil has been used in herbal medicine for treating digestive disorders, infections, inflammation, and respiratory problems (Shahrajabian et al., 2020). Because of its bioactive potential, basil has gained increasing attention in the development of functional foods, nutraceuticals, and natural food preservatives (Sharifi-Rad et al., 2023).

Fruit nectar is a non-fermented beverage prepared by mixing fruit pulp or juice with water, sugar, and sometimes stabilizers or preservatives to improve stability and sensory quality (Nicolson & Thornburg, 2007). Nectar products are widely consumed due to their balanced taste, nutritional value, and affordability compared to fresh juices (Matsuura et al., 2004). In recent years, the incorporation of herbal extracts into fruit beverages has increased significantly due to their functional and health-promoting properties (Park et al., 2017). Such plant-based additives improve antioxidant activity, antimicrobial potential, flavor complexity, and overall nutritional quality of beverages (Tarko et al., 2015).

In developing countries, postharvest losses of fruits remain a serious problem due to poor storage, transportation, and lack of processing facilities (Kitinoja & Kader, 2015). A large portion of fruit production is wasted during peak harvesting seasons, which reduces farmers' income and market value (Hodges et al., 2011). Therefore, value addition through processing fruits into products such as nectar, juice, and concentrates is an effective strategy to reduce losses and increase profitability.

The combination of apple with basil in nectar formulation is considered a novel approach to enhance both sensory attributes and functional properties of beverages (Kiran, 2018). Such combinations may improve antioxidant activity, flavor diversity, and consumer acceptability in functional beverage development (Skąpska et al., 2020a).

Global apple production faces significant post-harvest losses, driving the food industry to explore value-added processing into functional beverages like nectars (Anbesse Girma et al., 2022). However, standard apple nectar often lacks distinct sensory appeal and specialized functional properties (Dyab & Abo Taleb, 2024). Incorporating aromatic herbs, such as basil (*Ocimum basilicum*), presents a viable strategy to enhance both the antioxidant profile and consumer acceptance of fruit beverages (Gotal Skoko et al., 2026).

While the individual health benefits of apple and basil are well-documented, systematic research evaluating the formulation, physicochemical interactions, and sensory stability of a combined basil-flavored apple nectar remains highly limited (Maleš et al., 2023). Specifically, how basil extract affects the quality and shelf-life of apple nectar during extended storage has not been clearly established in existing literature (Gil et al., 2023).

Therefore, the present study aims to;

- Develop a novel basil-flavored apple nectar and comprehensively evaluate its physicochemical properties, sensory characteristics, and storage stability over a defined storage period.

To achieve these objectives, this study addresses the following key questions:

1. What is the definitive blending proportion of basil extract to apple nectar that optimizes organoleptic characteristics and yields peak consumer acceptability?
2. In what manner do key physicochemical indices, specifically total soluble solids (TSS), pH, and bioactive antioxidant capacity, fluctuate when the fortified beverage is exposed to varying storage temperatures?
3. To what extent does prolonged storage duration compromise or influence the microbiological safety parameters and longitudinal sensory profile of the developed formulation?

METHODS AND MATERIALS

The materials and methods used in this study were carefully selected and systematically followed to ensure accurate and reproducible results. This section details the experimental location, raw material collection, preparation processes for both apple juice and basil extract, and the final standardization of the nectar formulation.

Research Site

The study was commenced on October 29, 2025. and was conducted at the Laboratory of the Horticulture Department, Faculty of Agriculture, Kabul University, Kabul, Afghanistan.

Raw Materials Collection

The raw materials used in this research included fresh apple fruits (*Malus domestica* 'Red Delicious' variety), fresh basil leaves (*Ocimum basilicum*), sugar, citric acid, sodium benzoate, water, and 250 mL glass bottles. All materials were procured from the local market in Kabul.

Apple Juice Preparation

To prepare the beverage base, mature apple fruits underwent a rigorous washing process with distilled water before being portioned into uniform slices using a stainless-steel blade. The internal fibrous cores and seeds were meticulously excised by hand. Subsequently, the portioned flesh was subjected to a mechanical fruit press to yield fresh apple juice. To eliminate residual particulate matter and guarantee a standardized homogeneity, the raw juice was expressed through a fine muslin filter cloth.

Basil Leaf Extract Preparation

Similarly, dust and extraneous contaminants were removed from fresh basil leaves by washing them carefully with pure water. The clean leaves were processed in a mechanical

laboratory mixer until a fine paste was formed. This mixture was then filtered using a clean muslin filter to separate the solid pulp from the liquid basil leaf juice, which was subsequently collected and preserved in a pre-sterilized container.

Nectar Formulation and Standardization

For nectar formulation, the extracted apple juice and basil leaf extract were blended in eight different proportions, as presented in Table 1. The formulation of the nectar was strictly carried out according to standard guidelines for fruit nectar preparation (Codex Standard CXS 247-2005).

Table 1. Recipe for nectar (according to codex standards - CXS 247-2005)

Treatment	Pulp (%)	TSS (°B)	Acidity (%)
T ₁	(Pure Apple Juice)	14	0.3
T ₂	(Apple juice + 1 % basil extract)	14	0.3
T ₃	(Apple juice + 2 % basil extract)	14	0.3
T ₄	(Apple juice + 3 % basil extract)	14	0.3
T ₅	(Apple juice + 4 % basil extract)	14	0.3
T ₆	(Apple juice + 5 % basil extract)	14	0.3
T ₇	(Apple Juice + 6 % basil extract)	14	0.3
T ₈	(Apple Juice + 7 % basil extract)	14	0.3

According to Table 1, eight treatments of basil-flavored apple nectar were prepared using predetermined proportions of apple pulp and basil leaf extract. The pure apple juice contents for all treatments were 50%, and initial TSS and titratable acidity were adjusted to 14°Brix and 0.3%, respectively. Sugar syrup was prepared by dissolving sugar in warm water to adjust TSS, while citric acid was added to achieve the desired acidity. Sodium benzoate (120 ppm) was dissolved in a small volume of warm water and used as a preservative.

The final nectar was hot-filled into 250 mL glass bottles, sealed with metal caps using a capping machine. The bottles were then stored at room temperature.

The nectar was analyzed monthly for pH, TSS, reducing sugars, non-reducing sugars, total sugars, and acidity during storage. To avoid errors due to suspended solids, the nectar was well shaken before taking samples for measuring the parameters. TSS was measured with a hand refractometer, and pH was measured with a digital pH meter under constant-temperature conditions.

Reducing sugar content was determined by blending 25 mL of nectar with 100 mL distilled water, neutralizing with 1 N NaOH, and treating with lead acetate and potassium oxalate. The solution was brought to 250 mL, filtered, and titrated with 10 mL of Fehling's solution to calculate the reducing sugar percentage.

Non-reducing sugars were calculated as:

Non-reducing sugars (%) = Total sugars (%) – Reducing sugars (%)

Total sugars were measured by hydrolyzing 100 mL of filtrate with 10 g citric acid overnight, neutralizing with NaOH, and titrating with Fehling's solution after bringing the volume to 250 mL. Acidity was determined by titration against 0.1 N NaOH using phenolphthalein as an indicator and expressed as % citric acid.

During storage, the nectar was checked visually for mold growth every month. A panel of 10 trained individuals conducted sensory evaluation. They assessed appearance, color, flavor, aroma, texture, and overall acceptance using a 9-point Hedonic scale (9 = like extremely, 1 = dislike extremely).

The economic evaluation was performed to determine the best treatment. Net income was calculated as:

Net Income = Total Income – Total Cost

The benefit-cost ratio was calculated using:

Benefit-Cost Ratio = Total Income / Total Cost

The experiment was conducted using a Factorial Completely Randomized Design (CRD) with three replicates. Data were analyzed using STAR software, and differences among treatments were compared using Least Significant Difference (LSD) at the 5% significance level.

FINDINGS

This section presents the experimental findings regarding the quality attributes of the formulated basil-flavored apple nectar. The collected data evaluate the progressive changes in chemical, sensory, and microbiological parameters across different treatment blends during the defined storage period.

Chemical Parameters

The chemical evaluation of the blended nectar focused primarily on key quality markers that dictate shelf-life and taste profile stability, including total soluble solids, acidity, and pH stability.

Total Soluble Solids (TSS)

The total soluble solids (TSS) of basil-flavored apple nectar were significantly influenced by the type of treatment, storage duration, and their interaction ($p \leq 0.01$). According to Table 2, TSS values at the baseline (day 0) were uniform across all treatments, measuring exactly 14.00 °Brix.

During the storage period, the TSS content exhibited divergent trends depending on the specific formulation. For instance, treatment T₂ (apple juice + 1% basil extract) showed a notable increase in TSS at 30 days (16.93 °Brix). Conversely, T₃ (2% basil) slightly decreased to 13.66 °Brix at 60 days and remained relatively stable at 90 days (13.73 °Brix). Treatments

with higher basil concentrations, such as T₅ (4% basil) and T₈ (7% basil), exhibited higher TSS values at 60 days (15.83 °Brix and 16.00 °Brix, respectively) compared to the alternative blends.

Overall, a progressive increase in TSS was observed in the majority of treatments during storage. This upward trend is likely attributed to the acid-catalyzed hydrolysis and subsequent breakdown of complex polysaccharides into simpler soluble sugars. However, minor fluctuations were evident, contingent upon the specific treatment combinations and compound interactions.

Table 2. *Effect of Different Treatments on the Total Soluble Solids Content of Basil-Flavored Apple Nectar*

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	14.00 ^a _B	16.00 ^{ab} _A	13.66 ^b _{BC}	13.23 ^c _C
T ₂	14.00 ^a _B	16.93 ^a _A	14.00 ^b _B	14.56 ^{ab} _B
T ₃	14.00 ^a _{AB}	14.66 ^c _A	13.66 ^b _B	13.73 ^{bc} _B
T ₄	14.00 ^a _B	15.00 ^{bc} _A	14.33 ^b _{AB}	14.10 ^{abc} _B
T ₅	14.00 ^a _C	16.00 ^{ab} _A	15.83 ^a _A	15.03 ^a _B
T ₆	14.00 ^a _B	14.93 ^{bc} _A	14.33 ^b _{AB}	14.10 ^{abc} _B
T ₇	14.00 ^a _B	14.93 ^{bc} _A	14.33 ^b _{AB}	14.50 ^{ab} _{AB}
T ₈	14.00 ^a _C	15.60 ^{bc} _{AB}	16.00 ^a _A	15.16 ^a _B
Factor	F-test	LSD (_{5%})	CV (%)	
Storage Period (A)	**	0.71	3.01	
Treatment (B)	**	1.12	-	
Interaction (A×B)	**	-	-	

Titrateable Acidity

The titrateable acidity of basil-flavored apple nectar was affected by the treatment type, storage duration, and their interaction. According to Table 3, all treatments started with a similar acidity (0.27%) at day 0.

During storage, acidity levels changed differently depending on the treatment. For example, T₂ (apple juice + 1% basil) and T₅ (apple juice + 4% basil) showed relatively high acidity at 30 days (0.51%), while T₈ (7% basil) reached the highest acidity (0.51%) at 90 days. Treatments with moderate basil levels, such as T₃ (2% basil) and T₄ (3% basil), exhibited increases in acidity at 60 days (0.54% and 0.45%, respectively), followed by slight decreases at 90 days.

Overall, most treatments showed an increase in acidity during the first 60 days of storage, which may be due to hydrolysis of polysaccharides into simpler acids. After 60 days, some treatments showed slight decreases in acidity, possibly related to chemical changes in sugars and acids over time.

Table 3. Effect of Storage Duration on the Acidity Content of Basil-Flavored Apple Nectar

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	0.27 ^a _B	0.42 ^{ab} _A	0.33 ^b AB	0.30 ^b B
T ₂	0.27 ^a _C	0.51 ^a A	0.42 ^{ab} AB	0.33 ^b BC
T ₃	0.27 ^a _C	0.39 ^{ab} B	0.54 ^a A	0.30 ^b BC
T ₄	0.27 ^a _B	0.42 ^{ab} A	0.45 ^{ab} A	0.39 ^{ab} A
T ₅	0.27 ^a _B	0.51 ^a A	0.46 ^{ab} A	0.45 ^{ab} A
T ₆	0.27 ^a _B	0.39 ^{ab} A	0.43 ^{ab} A	0.42 ^{ab} A
T ₇	0.27 ^a _B	0.36 ^{ab} AB	0.45 ^{ab} A	0.36 ^a AB
T ₈	0.27 ^a _B	0.33 ^b B	0.46 ^{ab} A	0.51 ^a A
Factor	F-test	LSD _(5%)	CV (%)	
Storage Period (A)	**	0.1	16.45	
Treatment (B)	**	0.15	-	
A X B	*	-	-	

PH

The pH of basil-flavored apple nectar changed during the storage period, depending on the treatment type and basil concentration. Initially (day 0), the pH of all treatments ranged from 3.00 to 3.50, showing slightly acidic conditions.

During storage, the pH of most treatments decreased at 30 days, likely due to increased acidity and early chemical changes. For example, T₁ (pure apple juice) decreased from 3.00 to 2.76, and T₂ (1% basil) decreased from 3.50 to 3.01. At 60 days, the pH increased in most treatments, indicating partial stabilization. T₇ (6% basil) and T₈ (7% basil) showed the highest pH at 60 days (3.79 and 3.76, respectively). By 90 days, the pH of all treatments remained relatively stable, ranging between 3.13 and 3.35, reflecting the chemical stability of the nectar over time.

Table 4. Effect of Storage Duration on the PH Content of basil-Flavored Apple Nectar

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	3.00 ^b AB	2.76 ^b B	3.22 ^b A	3.18 ^a A
T ₂	3.50 ^a A	3.01 ^{ab} C	3.27 ^b AB	3.17 ^a BC
T ₃	3.30 ^{ab} A	3.06 ^{ab} A	3.31 ^b A	3.15 ^a A
T ₄	3.45 ^a A	3.20 ^{ab} A	3.35 ^b A	3.35 ^a A
T ₅	3.30 ^{ab} AB	3.18 ^a AB	3.42 ^{ab} A	3.13 ^a B
T ₆	3.10 ^{ab} B	3.10 ^{ab} B	3.57 ^{ab} A	3.16 ^a B
T ₇	3.13 ^{ab} B	3.11 ^{ab} B	3.79 ^a A	3.19 ^a B
T ₈	3.36 ^{ab} B	3.21 ^a B	3.76 ^a A	3.20 ^a B
Factor	F-test	LSD _(5%)	CV (%)	
Storage Period (A)	**	0.26	4.96	
Treatment (B)	**	0.41	-	
A X B	**	-	-	

Reducing sugars

The reducing sugar content of basil-flavored apple nectar changed noticeably during storage. Initially (day 0), the reducing sugar content ranged from 5.72% to 5.72% across treatments. Over time, the reducing sugars increased in most treatments. At 30 days, values increased to 6.27–6.70%, and at 60 days, further increases were observed (up to 6.70–6.80%). By 90 days, the reducing sugar content reached its highest levels (10.11%) (Table 5). The effect of basil leaf extract and the interaction were not statistically significant.

This increase in reducing sugars during storage is attributed to the breakdown of complex sugars (polysaccharides) into simpler sugars (mono- and disaccharides) through hydrolysis. This process contributes to improved sweetness and flavor of the nectar over the storage period.

Table 5. Effect of Storage Duration on the Reducing sugars Content of Basil-Flavored Apple Nectar

Storage period (Days)	Reducing sugars
Initial	5.72 ^c
30	6.27 ^b
60	6.70 ^b
90	10.11 ^a
F-test	**
LSD _{0.05}	0.46
CV (%)	11.20

Non-reducing sugars

The non-reducing sugar content of basil-flavored apple nectar changed significantly during the storage period. On day 0, the initial non-reducing sugar content ranged from 2.80% to 7.32% across treatments, depending on the concentration of basil extract. After 30 days of storage, most treatments showed a noticeable decrease in non-reducing sugars (up to 6.60%), followed by a further decrease at 60 and 90 days of storage.

The observed decrease in non-reducing sugars over time may be attributed to hydrolysis during storage, converting non-reducing sugars into reducing sugars. This change plays an important role in influencing the sweetness and overall taste of the nectar.

Table 6. Effect of Storage Duration on the Non-Reducing Sugars Content of Ginger-Flavored Peach Nectar

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁ :	2.80 ^b C	6.25 ^a A	5.18 ^a AB	3.12 ^a BC
T ₂ :	6.67 ^a A	5.12 ^a A	5.99 ^a A	1.47 ^a B
T ₃ :	6.90 ^a A	6.60 ^a A	5.46 ^a A	1.51 ^a B
T ₄ :	7.32 ^a A	6.37 ^a A	5.03 ^a B	2.31 ^a C
T ₅ :	5.59 ^{ab} A	4.43 ^a A	6.32 ^a A	1.16 ^a B
T ₆ :	5.94 ^{ab} A	4.48 ^a A	6.88 ^a A	2.10 ^a B

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₇ :	6.45 ^a A	3.73 ^a B	3.90 ^a B	2.17 ^a B
T ₈ :	6.20 ^{ab} A	4.07 ^a AB	4.99 ^a AB	3.58 ^a B
Factor	F-test	LSD (5%)	CV (%)	
Storage Period (A)	**	2.2	28.76	
Treatment (B)	Ns	-	-	
A X B	*	-	-	

Total sugars

The total sugar content of basil-flavored apple nectar changed during the storage period. At day 0, the total sugars ranged from 10.26% to 12.39% depending on the treatment. During the first 30 days of storage, the sugar content slightly varied among treatments, with some treatments showing a small increase while others decreased. By 60 days, most treatments exhibited an increase in total sugar content, reaching values up to 13.52%. At the end of 90 days, total sugars slightly decreased in some treatments but remained higher than the initial values in several cases, indicating good stability of sweetness during storage.

Statistical analysis revealed that the interaction between treatment and storage period significantly affected total sugar content ($p \leq 0.05$), while the effects of storage period or treatment alone were not significant (NS).

Table 7. Effect of storage duration on the total sugars content of ginger-flavored peach nectar

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	10.26 ^a B	12.17 ^a AB	12.29 ^a A	12.55 ^a A
T ₂	11.61 ^a A	11.53 ^a A	12.90 ^a A	11.09 ^a A
T ₃	12.39 ^a AB	13.04 ^a A	12.47 ^a AB	10.97 ^a B
T ₄	12.20 ^a A	11.93 ^a A	11.49 ^a A	11.77 ^a A
T ₅	11.21 ^a A	10.88 ^a A	12.49 ^a A	11.90 ^a A
T ₆	12.19 ^a AB	10.85 ^a B	13.52 ^a A	13.53 ^a A
T ₇	12.16 ^a B	10.41 ^a B	10.60 ^a B	12.75 ^a A
T ₈	11.63 ^a B	10.71 ^a B	11.57 ^a B	13.73 ^a A
Factor	F-test	LSD (5%)	CV (%)	
Storage Period (A)	Ns	2	10.32	
Treatment (B)	Ns	3.14	-	
A X B	*	-	-	

Nectar Spoilage

The basil-flavored apple nectar was monitored for spoilage throughout the three-month storage period. Observations were made at monthly intervals for any signs of microbial growth, off-odor, turbidity, or visible changes in appearance. Results showed that no spoilage occurred in any of the eight treatments, indicating that the product remained

microbiologically safe and stable during the entire storage period. This stability can be attributed to the use of proper sanitation during preparation, pasteurization, and the addition of sodium benzoate as a preservative.

Sensory Evaluation

The sensory profile of the formulated basil-flavored apple nectar was evaluated to determine consumer acceptability across various organoleptic attributes over the storage period.

Appearance

The appearance of basil-flavored apple nectar varied depending on the treatment and storage period. Initially, the formulations with low content of basil leaf extract received relatively high scores, ranging from 7.14 to 7.71, indicating good visual quality. while for the treatments with higher level of basil leaf extract the appearance was rated below average ranging from 4.85 to 6.57. the appearance improved during first 30 days of storage and then declined in 60 and 90 days of storage period. After 90 days of storage the first four treatments containing 0 – 3 % basil leaf extract maintained its appearance and were rated highly acceptable by the sensory panel. While the last four treatments with 4 – 7 % basil leaf extract were rated below average. Overall, treatments with moderate basil extract levels (T₂ and T₃) maintained better stability, achieving scores of 8.00 at the end of the storage period (Table 8). Statistical analysis revealed that both treatment and storage period had a significant effect on appearance ($p \leq 0.01$), as did their interaction. The results suggest that moderate basil extract addition helps preserve the appearance of apple nectar during storage, while higher levels may negatively affect its visual appeal.

Table 8. Table of means for comparison of treatments in storage periods

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	7.14 ^{aB}	8.85 ^{aA}	8.71 ^{aA}	8.28 ^{aA}
T ₂	7.14 ^{aB}	8.71 ^{aA}	8.28 ^{abA}	8.00 ^{aA}
T ₃	7.71 ^{aA}	8.28 ^{aA}	7.85 ^{abA}	8.00 ^{aA}
T ₄	7.57 ^{aA}	8.00 ^{aA}	7.57 ^{abA}	7.85 ^{aA}
T ₅	6.57 ^{abB}	6.71 ^{bB}	7.57 ^{abA}	6.14 ^{bB}
T ₆	5.85 ^{bcB}	5.85 ^{bcB}	8.42 ^{abA}	5.71 ^{bB}
T ₇	5.00 ^{cC}	5.85 ^{bcB}	7.57 ^{abA}	5.85 ^{bB}
T ₈	4.85 ^{cBC}	4.71 ^{cC}	7.28 ^{bA}	5.57 ^{bB}
Factor	F-test	LSD (_{1%})	CV (%)	
Storage Period (A)	**	0.81	10.82	
Treatment (B)	**	1.26	-	
A X B	**	-	-	

Color

The color of basil-flavored apple nectar varied noticeably depending on the treatment and storage period. During the first 30 days of storage, treatments T₁–T₄ maintained high scores (7.57–8.57), whereas formulations with higher basil extract concentrations (T₆–T₈) showed lower scores (4.71–5.85).

As storage progressed to 60 and 90 days, a decline in color quality was observed in formulations containing higher levels of basil extract (T₅–T₈), where scores decreased to 5.28–6.57 at 90 days. In contrast, treatments with moderate basil extract levels (T₂ and T₃) maintained better color stability throughout storage, achieving scores of 8.00–8.28 at the end of the storage period.

Statistical analysis indicated that both treatment and storage period, as well as their interaction, significantly affected the color of nectar ($p \leq 0.01$). Overall, the moderate basil addition preserves visual appeal during storage.

Table 1. Table of mean for nectar compression of treatments in storage periods

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	6.71 ^{ab} B	8.57 ^a A	8.42 ^a A	7.85 ^{ab} A
T ₂	7.42 ^a B	8.42 ^a A	8.28 ^a AB	8.00 ^a AB
T ₃	7.57 ^a A	8.28 ^a A	8.42 ^a A	8.28 ^a A
T ₄	7.28 ^a A	7.57 ^{ab} B	7.85 ^a A	8.14 ^a A
T ₅	6.85 ^a AB	6.57 ^{bc} B	7.71 ^a A	6.57 ^{bc} B
T ₆	5.42 ^{bc} B	5.85 ^{cd} B	7.71 ^a A	6.00 ^c B
T ₇	4.85 ^c C	5.71 ^{cd} BC	7.42 ^a A	5.85 ^c B
T ₈	4.71 ^c B	4.71 ^d B	7.14 ^a A	5.28 ^c B
Factor	F-test	LSD _(1%)	CV (%)	
Storage Period (A)	**	0.87	11.74	
Treatment (B)	**	1.35	-	
A X B	**	-	-	

Flavor

The flavor of basil-flavored apple nectar was influenced by both the treatment and storage duration. Initially, the first four formulations containing 0–3 % basil leaf extract received high flavor scores (6.85–7.71), indicating good flavor quality across samples.

After 30 days of storage, formulations with moderate basil extract (T₂ and T₃) achieved higher flavor scores (8.00–8.57), whereas treatments with higher basil concentrations (T₆–T₈) showed lower scores (5.00–6.00). At 60 days, T₁–T₄ maintained acceptable flavor quality, and T₃ recorded the highest score (8.28). Treatments with higher basil extract (T₆–T₈) showed gradual improvement at 60 days but still scored lower than moderate treatments. By 90 days, T₃ maintained stable flavor (7.85), indicating that moderate basil levels help preserve

flavor during storage, while higher basil concentrations slightly reduced flavor quality in some treatments.

Statistical analysis indicated that both storage period and treatment, as well as their interaction, significantly affected flavor ($p \leq 0.01$). Overall, formulations with moderate basil levels (1–2%) maintained acceptable flavor throughout the storage period.

Table 10. Table of mean for nectar compression of treatments in storage periods

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	6.85 ^a C	8.28 ^a AB	8.71 ^a A	7.42 ^{abc} BC
T ₂	7.42 ^a A	8.00 ^a A	8.28 ^{ab} A	7.57 ^{abc} CA
T ₃	7.71 ^a A	8.57 ^a A	8.28 ^{ab} A	7.85 ^a A
T ₄	7.71 ^a A	7.42 ^{ab} A	7.71 ^a bcA	7.71 ^{ab} A
T ₅	6.85 ^a A	6.42 ^{bc} A	7.14 ^{bc} A	6.85 ^{abc} A
T ₆	5.42 ^b B	6.00 ^{cd} B	7.00 ^{bc} A	6.28 ^{cd} AB
T ₇	4.57 ^b C	5.85 ^{cd} B	6.85 ^c A	6.42 ^{bcd} AB
T ₈	4.71 ^b B	5.00 ^d B	6.85 ^c A	5.42 ^d AB
Factor	F-test	LSD _(1%)	CV _(%)	
Storage Period (A)	**	0.91	12.42	
Treatment (B)	**	1.42	-	
A X B	**	-	-	

Aroma

The aroma quality of basil-flavored apple nectar was influenced by both treatment and storage duration. The first 5 treatments containing 0–5% basil leaf extract received high aroma scores (7.00–7.57), indicating good aroma across the samples.

During storage, nectar samples with low to moderate basil extract levels (T₂–T₄, 1–3%) maintained high, stable aroma scores (7.42–8.57). In contrast, treatments with higher basil concentrations (T₅–T₈, 4–7%) showed noticeable reductions in odor scores at 30, 60, and 90 days, indicating a decline in aroma quality over time.

At 30 days, T₂ and T₃ recorded the highest odor scores (8.57–8.42), while T₆–T₈ showed the lowest (4.85–5.85). At 60 days, T₃ maintained the highest odor (8.28), whereas T₇ and T₈ remained lower but improved slightly. By 90 days, the low-to-moderate basil treatments (T₂–T₄) still had acceptable odor scores (7.42–7.57), while the high-level treatments (T₆–T₈) scored lower (6.00–6.42).

Statistical analysis confirmed that both storage period and treatment, and their interaction, significantly affected odor quality ($p \leq 0.01$). Overall, using low to moderate basil extract (1–3%) is preferable for preserving apple nectar aroma during storage.

Table 11. Table of mean for nectar compression of treatments in storage periods

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	7.42 ^a BC	8.57 ^a A	8.14 ^a AB	7.14 ^{ab} C
T ₂	7.57 ^a B	8.57 ^a A	8.14 ^a AB	7.42 ^{ab} B
T ₃	7.57 ^a AB	8.42 ^a A	8.28 ^a AB	7.42 ^{ab} B
T ₄	7.28 ^a A	8.00 ^a A	7.71 ^a A	7.57 ^a A
T ₅	7.00 ^{ab} A	6.00 ^a B	7.71 ^a A	6.85 ^{ab} AB
T ₆	5.57 ^{bc} B	5.85 ^b B	6.85 ^a A	6.00 ^b AB
T ₇	4.71 ^c B	5.42 ^b B	7.28 ^a A	6.42 ^{ab} A
T ₈	4.71 ^c B	4.85 ^b B	6.85 ^{ab} A	6.14 ^{ab} A
Factor	F-test	LSD _(1%)	CV (%)	
Storage Period (A)	**	0.93	12.66	
Treatment (B)	**	1.44	-	
A X B	**	-	-	

Texture

The texture quality of basil-flavored apple nectar was evaluated at different levels of basil extract (1–7%) and storage durations. The first 4 treatments received acceptable texture scores (7.42–7.85), indicating consistent texture across samples (Table 12).

During storage, nectar samples with low to moderate basil levels (T₂–T₄, 1–3%) maintained good and stable texture throughout the 90-day storage period. In contrast, higher basil concentrations (T₅–T₈, 4–7%) resulted in a noticeable decline in texture quality at 30, 60, and 90 days.

At 30 days, T₁–T₄ showed the highest texture scores (7.42–8.28), while T₆–T₈ had lower scores (4.57–5.85). At 60 days, T₁–T₃ maintained the highest texture (8.57), whereas the high-level treatments (T₅–T₈) improved slightly but remained lower than those of the moderate treatments. By 90 days, T₂ and T₃ maintained acceptable texture (7.71–7.85), while T₇ and T₈ had the lowest scores (5.57–6.42).

Statistical analysis confirmed that both storage period and treatment, and their interaction, significantly affected texture quality ($p \leq 0.01$). Overall, moderate basil extract levels (1–3%) are preferable for maintaining good nectar texture during storage.

Table 12. Table of mean for nectar compression of treatments in storage periods

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	7.85 ^a AB	8.28 ^a AB	8.57 ^a A	7.57 ^{ab} B
T ₂	7.71 ^{ab} A	8.14 ^a A	8.57 ^a A	7.85 ^a A
T ₃	7.42 ^{ab} B	8.28 ^a AB	8.57 ^a A	7.71 ^{ab} AB
T ₄	7.71 ^{ab} A	7.42 ^{ab} A	7.57 ^{ab} A	7.85 ^a A
T ₅	6.42 ^{bc} B	6.28 ^{bc} B	7.57 ^{ab} A	7.14 ^{abc} AB
T ₆	5.71 ^c B	5.85 ^{cd} B	7.28 ^{ab} A	6.00 ^{cd} B

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₇	4.28 ^d C	5.42 ^{cd} B	7.28 ^{ab} A	6.42 ^{bcd} A
T ₈	4.00 ^d C	4.57 ^d C	7.14 ^b A	5.57 ^d B
Factor	<u>F-test</u>	<u>LSD</u> (1%)	<u>CV</u> (%)	
Storage Period (A)	**	0.90	12.3	
Treatment (B)	**	1.41	-	
A X B	**	-	-	

Overall Acceptance

The overall acceptance of basil-flavored apple nectar was evaluated based on different levels of basil extract (1–7%) and storage periods (0, 30, 60, and 90 days). The results showed that nectar samples with low to moderate basil levels (T₂–T₄, 1–3%) maintained high, stable, and consumer-acceptable quality throughout the 90-day storage period. In contrast, higher basil concentrations (T₅–T₈, 4–7%) led to a noticeable decline in overall acceptance, particularly at 30 and 60 days, suggesting that high basil levels may negatively affect the taste and overall quality of apple nectar.

At 30 days, T₂ and T₃ maintained the highest scores (8.42), while higher basil levels (T₆–T₈) recorded the lowest scores (4.71–5.85). At 60 days, moderate basil levels (T₂–T₄) continued to show high acceptance (7.85–8.57), whereas T₇ and T₈ remained lower (7.00–7.57). By 90 days, T₂ and T₃ retained high acceptability (8.00–8.28), whereas higher basil levels (T₆–T₈) scored lower (6.00–6.28).

Statistical analysis revealed significant effects of storage period, treatment, and their interaction on overall acceptance ($p \leq 0.01$), confirming that moderate basil levels (1–3%) are preferable for maintaining consumer-acceptable quality throughout storage.

Table 13. Table of mean values for nectar compression of treatments in storage periods

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T ₁	7.14 ^{ab} C	8.71 ^a A	8.14 ^{abc} AB	7.57 ^{ab} BC
T ₂	7.71 ^{ab} B	8.42 ^a AB	8.57 ^a A	8.28 ^a AB
T ₃	7.85 ^a A	8.42 ^a A	8.28 ^{ab} A	8.00 ^{ab} A
T ₄	7.71 ^{ab} A	7.85 ^a A	7.85 ^{abc} A	7.85 ^{ab} A
T ₅	6.57 ^{bc} B	6.14 ^b B	7.85 ^{abc} A	6.85 ^{bc} B
T ₆	5.42 ^{cd} C	5.85 ^{bc} BC	7.57 ^{abc} A	6.28 ^c B
T ₇	4.57 ^d C	5.14 ^{bc} C	7.28 ^{bc} A	6.28 ^c B
T ₈	4.42 ^d C	4.71 ^c C	7.00 ^c A	6.00 ^c B
Factor	<u>F-test</u>	<u>LSD</u> (1%)	<u>CV</u> (%)	
Storage Period (A)	**	0.81	10.88	
Treatment (B)	**	1.26	-	
A X B	**	-	-	

** $P \leq 0.01$; LSD: Least Significant Difference; CV: Coefficient of Variation; According to LSD at the 0.05 level, means within the same column, followed by the same small letter, and means within the same row, followed by the same capital letter, are not significantly different for treatment and storage period, respectively.

DISCUSSION

The observed changes in TSS during storage may be attributed to the hydrolysis of complex carbohydrates and pectic substances into simpler sugars such as glucose and fructose. These biochemical transformations contribute to variations in soluble solids content during storage. In addition, enzymatic and non-enzymatic reactions occurring in fruit-based beverages during storage may lead to both increases and decreases in TSS, depending on the product's composition and storage conditions. Such variations are commonly associated with sugar conversion, the degradation of organic compounds, and interactions among the various constituents of nectar. Similar findings have been reported in studies on fruit juices and nectars, where TSS values showed significant changes during storage due to biochemical and physicochemical transformations (Akhtar et al., 2010; Singh, 2017).

Formation of organic acids occurs due to biochemical reactions and breakdown of complex compounds in fruit nectar. Hydrolysis of pectic substances and other constituents also contributes to changes in acidity during storage. A slight decrease in acidity at later stages may be due to interaction and gradual degradation of organic acids during prolonged storage. Similar trends of an initial increase followed by a decrease or stabilization in acidity during storage have been reported in fruit juice products due to biochemical and physicochemical changes (Gülüm et al., 2026; Habibi et al., 2024).

The decrease in pH during the early storage period may be attributed to the formation of organic acids and to biochemical reactions in the nectar, which increase acidity. These changes are common in fruit-based beverages during storage, as documented in recent investigations evaluating the chemical kinetics of pasteurized fruit matrices (Chin et al., 2025; Gülüm et al., 2026) at the initial stages of storage. The subsequent increase in pH observed at later stages may be due to the degradation or interaction of organic acids with sugars and other components, thereby partially stabilizing the system. Enzymatic and non-enzymatic reactions during storage can significantly alter the beverage's acid–base balance. Similar trends have been reported in fruit juices and nectar products, where pH initially decreases and later stabilizes or slightly increases during storage due to ongoing biochemical transformations (Islam et al., 2015; Kausar et al., 2012).

The increase in reducing sugars during storage may be attributed to the hydrolysis of complex carbohydrates, such as polysaccharides, into simpler sugars, such as glucose and fructose. These biochemical transformations occur due to enzymatic and non-enzymatic reactions during storage. The sharp increase observed at later stages of storage may also be associated with the conversion of non-reducing sugars into reducing sugars, contributing to increased sweetness and changes in flavor of the nectar. Similar findings have been reported

in fruit juices and nectar products, where reducing sugars increase significantly during storage due to hydrolysis and sugar conversion processes (Asikin et al., 2014; Bhatt et al., 2020; Kausar et al., 2012).

The decrease in non-reducing sugars during storage may be attributed to the hydrolysis of disaccharides, such as sucrose, into simpler reducing sugars, such as glucose and fructose. This conversion process is common in fruit-based beverages and contributes to changes in sweetness and flavor during storage. The initial increase observed in some treatments may be due to compositional variation and interactions among sugars. At the same time, the subsequent decline reflects the ongoing breakdown of non-reducing sugars. These findings are consistent with previous studies on fruit juices, in which non-reducing sugars decrease during storage due to their conversion into reducing sugars through hydrolytic reactions (Bhardwaj, 2013; Hussain et al., 2008).

Changes in total sugar content during storage may be attributed to the hydrolysis of non-reducing sugars, such as sucrose, into reducing sugars, such as glucose and fructose. This conversion helps maintain or slightly increase the total sugar content of the nectar. In addition, enzymatic and non-enzymatic reactions during storage may influence the transformation and redistribution of sugars within the nectar matrix, leading to fluctuations in total sugar levels. The relative stability of total sugars observed in this study indicates that the nectar's sweetness was largely preserved during storage, an important quality attribute for consumer acceptance. Similar findings have been reported in fruit-based beverages, where total sugars show slight increases or remain stable during storage due to sugar interconversion and biochemical reactions (Deka et al., 2005; Iqbal et al., 2016).

No signs of spoilage were observed in the basil-flavored apple nectar throughout the storage period. This stability may be attributed to the use of sodium benzoate as a preservative, which effectively inhibited microbial growth and helped maintain the quality of the nectar during storage.

The decline in appearance scores during storage may be attributed to physical and chemical changes in the nectar, such as particle sedimentation, cloud loss, and non-enzymatic reactions that affect visual clarity and uniformity. These changes are more pronounced in treatments with higher levels of plant extract, which may contribute to turbidity and instability in the beverage system. On the other hand, treatments with moderate basil concentrations showed better stability, possibly due to a balanced composition that maintained uniform dispersion and reduced visual deterioration over time. Similar trends have been reported in fruit-based beverages, where sensory attributes such as appearance decline gradually during storage due to physicochemical changes and instability in the juice matrix (Ahsan et al., 2024; S. K. Singh & Sharma, 2017).

The decline in color quality during storage may be attributed to pigment degradation, oxidation reactions, and non-enzymatic browning processes occurring in the nectar. These reactions can lead to loss of natural color and reduced visual appeal, especially in

formulations containing higher levels of plant extracts. Additionally, higher concentrations of basil extract may accelerate color changes by increasing interactions between phenolic compounds and oxidation processes, resulting in darker or less stable color during storage. In contrast, moderate levels of basil extract help maintain color stability by preserving pigment balance and slowing the rate of degradation reactions. Similar observations have been reported in fruit-based beverages, where color deterioration occurs during storage due to oxidation and degradation of pigments, particularly in treatments with higher concentrations of added plant materials(Kausar et al., 2012; Maskan, 2001).

The variation in flavor during storage may be attributed to chemical and biochemical changes occurring in the nectar, including oxidation, degradation of volatile compounds, and interactions between sugars, acids, and plant extracts. These changes can directly affect the beverage's flavor and aroma profile. Higher concentrations of basil extract may lead to stronger or slightly bitter flavors, which can reduce consumer acceptability over time. In contrast, moderate levels of basil extract help maintain a balanced flavor by enhancing aroma without overpowering the natural apple juice flavor. Moreover, changes in sugar composition during storage, particularly the conversion of complex sugars into simpler sugars, may also influence the perceived sweetness and overall flavor of the nectar. Similar findings have been reported in fruit-based beverages, where flavor quality tends to decline during storage due to the loss of volatile compounds and chemical interactions, especially in formulations containing higher levels of plant extracts(Kausar et al., 2012; Sakhale & Pawar, 2012).

The changes in aroma during storage may be attributed to the loss of volatile aromatic compounds, oxidation reactions, and interactions between organic acids and sugars. These processes can reduce the intensity and quality of aroma over time. Higher concentrations of basil extract may lead to stronger and sometimes undesirable aroma, which can negatively affect consumer acceptance. In contrast, moderate levels of basil extract help maintain a balanced and pleasant aroma by enhancing natural flavor compounds without causing sensory overload. Furthermore, storage conditions can accelerate the degradation of aroma-active compounds, leading to gradual declines in odor quality, especially in formulations with higher plant extract concentrations. Similar trends have been reported in fruit beverages, where odor quality decreases during storage due to the loss of volatile compounds and chemical changes in the beverage matrix(Kausar et al., 2012; Sakhale & Pawar, 2012).

The changes in texture during storage may be attributed to physicochemical and structural changes in the nectar, including pectin degradation, sedimentation, and interactions between soluble solids and plant extracts, which directly influence viscosity and mouthfeel. Higher concentrations of basil extract may negatively affect texture stability by increasing suspended particles and fiber content, which can promote sediment formation and reduce uniformity during storage. In contrast, moderate levels of basil extract help maintain a balanced and stable consistency throughout the storage period.

Additionally, enzymatic and non-enzymatic reactions during storage can lead to breakdown of structural components, resulting in gradual changes in texture quality over time.

Similar findings have been reported in recent studies on fruit beverages, where texture changes during storage were associated with pectin degradation and colloidal instability, particularly in formulations containing plant extracts (Nadeem et al., 2017; Sharma et al., 2020).

Both basil concentration and storage duration significantly influenced the overall acceptance of basil-flavored apple nectar. In the present study, formulations containing low to moderate levels of basil extract (1–3%) consistently maintained higher sensory acceptability throughout the 90-day storage period. This indicates that limited incorporation of basil enhances flavor balance, aroma, and consumer preference in apple nectar. In contrast, higher basil concentrations (4–7%) led to a gradual decline in overall acceptance, particularly during the early and mid-storage periods. This reduction may be attributed to basil's strong herbal flavor, which can overpower the natural apple taste and reduce consumer liking. Similar observations have been reported in studies on herbal-enriched fruit beverages, where excessive levels of plant extracts negatively affected sensory attributes, including taste and overall acceptability. The present findings also demonstrate that storage duration plays a crucial role in modifying sensory perception. A slight improvement in acceptance at later storage stages for some treatments may be associated with flavor integration and stabilization of volatile compounds over time. However, even at extremely high basil levels, scores remained lower, indicating that formulation balance is more critical than storage adaptation. Statistical analysis confirmed that both treatment and storage period, as well as their interaction, had a highly significant effect ($p \leq 0.01$) on overall acceptance, suggesting that sensory quality is strongly dependent on formulation optimization and storage behavior.

These results are in agreement with earlier research on fruit-based functional beverages, which reported that moderate levels of herbal or plant extracts (typically 1–3%) provide optimal sensory acceptance, while higher concentrations reduce consumer preference due to intensified bitterness and aroma imbalance (Esperança et al., 2025; Mendonça et al., 2021; Skąpska et al., 2020b).

CONCLUSION

This study was conducted to develop a novel basil-flavored apple nectar and evaluate the influence of different formulation ratios and storage duration on its quality attributes. The results reveal that low to moderate basil concentrations (1–3%) consistently showed progressive improvements in chemical properties and higher sensory acceptance than higher basil levels. These treatments maintained satisfactory appearance, color, flavor, odor, texture, and overall acceptability throughout the 90-day storage period. Physicochemical analysis revealed gradual changes in TSS, acidity, and sugar fractions during storage, mainly

due to biochemical reactions, including hydrolysis and sugar conversion. Although significant variations occurred during storage in both sensory and physicochemical properties, these trends remained within acceptable commercial limits for fruit beverages at room temperature. Sensory evaluation further confirmed that higher basil concentrations (4–7%) negatively affected consumer acceptability, while moderate levels enhanced product quality and maintained desirable sensory characteristics over time.

Overall, the study concluded that basil extract can be successfully used as a flavoring agent in apple nectar at an optimal level of 1–3%, ensuring acceptable nutritional profiles and sensory quality under normal storage conditions. For future research, it is highly recommended to investigate the thermal kinetics of pasteurization, microbiological safety under different packaging materials, and the degradation rates of specific bioactive compounds during long-term storage.

Authors Contributions

We both contributed significantly to the conceptualization, design, experimental work, data analysis, and drafting of this research article. As the primary author, I carried out the laboratory experiments. I prepared the initial manuscript, while my co-author, Hamid Salari, provided technical supervision, statistical guidance, and critical revisions to enhance the scientific quality of our study. We both have read and approved the final version of the manuscript for publication.

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Conflict of Interest Statement

The authors report no conflicts of interest related to this study.

Data Availability Statement

All data generated and analyzed during this study are included within this article. Additional raw data related to the physicochemical and sensory evaluations of basil-flavored apple nectar are available from the corresponding author upon reasonable request.

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