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Standardizing Recipe for Mint Flavored Grape Nectar

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ABSTRACT

Grape nectar is widely consumed due to its nutritional value and sensory appeal; however, limited information is available regarding the incorporation of natural herbal extracts to enhance its physicochemical stability and consumer acceptability during storage. Therefore, this study was conducted in the Horticulture Department Laboratory, Faculty of Agriculture, Kabul University, Afghanistan (2024–2025) to evaluate the effect of mint leaf extraction on the physicochemical properties, sensory attributes, and storage stability of grape nectar. The experiment comprised eight treatments prepared from 50% sugar syrup and 50% natural ingredients, consisting of 93–100% grape pulp combined with 1–7% mint leaf extract. Each treatment was replicated three times and arranged in a split-plot CRD design. The main parameters assessed included biological characteristics, chemical properties, sensory quality, and economic feasibility. Results indicate significant changes in nectar quality during three months of storage. TSS, acidity, reducing sugar, and total sugar values increased, while non-reducing sugar, pH, and sensory scores gradually decreased over time. Among all treatments, T4 (98% grape juice + 3% mint leaf extract) exhibited the least change in chemical properties, suggesting better storage stability, while T3 (98% grape juice + 2% mint leaf extract) achieved superior sensory acceptance. The findings indicate that T3 is the most suitable for producing high-quality mint-flavored grape nectar. It achieved superior sensory quality and consumer preference, along with a benefit–cost ratio of 1:1.57 AFN, emphasizing its potential for large-scale commercial production.

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INTRODUCTION

The grapevine (*Vitis vinifera*), a member of the Vitaceae family and the genus *Vitis*, has played a central role in human civilization since ancient times. Archaeological findings confirm its use as early as the Bronze Age, with grape seed remnants discovered in the bays of south-central Europe. Domestication likely occurred approximately 11,000 years ago in regions of Western Asia and the Caucasus (Atif & Samadi, 2025; Dong et al., 2023; Reynolds, 2017; Shirzad & Samadi, 2018). Historical records further demonstrate cultivation during Egypt's Fourth Dynasty around 2440 BCE, and references to vineyards appear in biblical texts(Shirzad

& Samadi, 2018). Most botanists agree that domestication originated in the Middle East, especially the region between the Black and Caspian Seas, encompassing the Caucasus, northern Iraq, Azerbaijan, Turkestan, and possibly extending into present-day Afghanistan (Creasy & Creasy, 2018; Reisch et al., 2012; Shirzad & Samadi, 2018).

The genus *Vitis* consists of two subgenera: *Euvitis* (true grapes) and *Muscadinia*, comprising 60–69 species globally. Of these, *V. vinifera* represents about 90% of cultivated grapevines, while the United States commercially grows *V. rotundifolia* and *V. munsoniana* from *Muscadinia*. Grapevines thrive in temperate regions between latitudes 30° and 50°, with optimal growth temperatures ranging from 15°C to 30°C hemispheres (Creasy & Creasy, 2018; Reisch et al., 2012; Shirzad & Samadi, 2018). Economically, the grape industry is highly significant, with the global market valued at USD 70 billion in 2020 and projected to reach USD 85 billion by 2025, a CAGR of 4.5%. In that year, production reached 77 million metric tons, led by China with nearly 40% of global output, followed by the United States (6.5 million metric tons) and Italy (6 million metric tons) (Team, 2025).

Nutritionally, grapes are rich in water (80.54 g/100 g), moderate in energy (69 Kcal), and a good source of carbohydrates (18.10 g), including glucose (7.20 g) and fructose (8.13 g). They are low in protein (0.72 g) and fat (0.16 g) but provide dietary fiber (0.90 g), potassium (191 mg), and small amounts of calcium, iron, magnesium, and phosphorus. Vitamins include vitamin C (3.2 mg) and B-complex, though vitamins B12 and D are absent (Agulheiro-Santos et al., 2021; Elejalde et al., 2021). Bioactive compounds, especially polyphenols such as resveratrol, catechins, and proanthocyanidins, provide broad therapeutic benefits. These include anticancer activity through apoptosis induction, estrogen modulation, and inhibition of proliferation and metastasis (Agulheiro-Santos et al., 2021; Liu et al., 2018; Wang, 2025). Cardiovascular health is supported by improved endothelial function, reduced blood pressure, and antioxidant protection, explaining the "French Paradox." Neurological benefits include enhanced memory, protection against neurodegeneration, and reduced amyloid-β aggregation in Alzheimer's disease. Grapes also promote eye health, renal function, glycemic regulation, wound healing, and photoprotection, while their phytochemicals exhibit antiviral and anti-inflammatory effects, notably inhibiting SARS-CoV-2 replication (Wang, 2025; Zhou et al., 2022).

In beverages, grape juice offers a natural carbohydrate source for sports drinks, with anthocyanins providing antioxidant capacity and natural coloration. Salts in isotonic drinks influence anthocyanin stability and antioxidant activity (Bendaali et al., 2024). Concentrated and reconstituted grape juices retain sugars, organic acids, minerals, and phenolic compounds that define their sensory qualities (Bendaali et al., 2022; Dutra et al., 2021). Regular consumption enhances cardiovascular, hepatic, and neurological health through antioxidant, anticancer, antibacterial, antidiabetic, and anti-inflammatory actions (Bendaali et al., 2022; Wu et al., 2021).

Mentha L. is a perennial herb propagating via slender rhizomes, with broad ovate leaves and dense whorled flowers, mostly protandrous though self-pollination occurs (Saqib et al., 2022). Cultivated for its aromatic essential oils, commercial production focuses on M. arvensis, M. spicata, and M. ×piperita, with India, the U.S., China, and Brazil as major producers; India alone provides 80% of global menthol mint (Tzanetakis et al., 2010). Medicinally, mint exhibits cholagogue, spasmolytic, antiseptic, antibacterial, antidiabetic, anticancer, antiallergic, and analgesic effects (Balan et al., 2024; Brown et al., 2019; Dung, 2020; Hussain et al., 2021; Hutsol et al., 2023; Saqib et al., 2022; Tang et al., 2024). Its oils are widely used in foods, pharmaceuticals, cosmetics, and aromatherapy, ranking as the third most popular global flavor with menthol's cooling effect (Arshad et al., 2023; Dung, 2020; Hutsol et al., 2023; Prakash & Srivastava, 2020; Saqib et al., 2022). Nutritionally, mint is rich in carbohydrates, fiber, moderate protein, and essential minerals including iron, manganese, copper, and zinc (Tang et al., 2024).

The grape and mint postharvest sector faces major losses due to low prices, poor market access, and costly processing (Elik et al., 2019; Gouda & Duarte-Sierra, 2024; Singh et al., 2021). Standardized blended nectar with high nutritional and sensory quality can reduce losses, ensure affordability, enhance consumer trust, and generate sustainable employment while supporting farmers' economic resilience(Saima et al., 2014). However, despite the growing interest in functional beverages, limited studies have systematically evaluated the combined effects of grape and mint on the physicochemical stability, sensory attributes, and economic feasibility of nectar formulations, particularly under local production conditions. This gap highlights the need for targeted research to optimize formulation and storage strategies for high-quality grape-mint nectar.

The main objective of this research is to minimize postharvest losses through value addition and to develop a standardized, high-quality grape nectar flavored with mint. Specifically, the study aims to investigate the extent to which the incorporation of mint flavor affects the nutritional composition, influences the physicochemical properties, and impacts the sensory attributes and overall consumer acceptability of grape nectar.

- To what extent does the incorporation of mint flavor affect the nutritional composition of grape nectar?
- How does the addition of mint flavor influence the physicochemical properties of grape nectar?
- What effect does the incorporation of mint flavor have on the sensory attributes and overall consumer acceptability of grape nectar?

METHODS AND MATERIALS

For clarity and better organization, the Materials and Methods section was structured into distinct subheadings, allowing readers to easily follow and comprehend each methodological procedure of the study.

Study Area

This study, was conducted in the Horticulture Department Laboratory, Faculty of Agriculture, Kabul University, Afghanistan, during 2024–2025 to evaluate the effect of mint flavor on the physicochemical properties, sensory attributes, and storage stability of grape nectar.

Raw Materials and Juice Preparation

The raw materials included fresh grapes of the Kishmishi variety, fresh mint, sugar, citric acid, and sodium benzoate. All materials were provided from the local market. To extract the juice from grapes, the berries were first separated from the clusters. All damaged or spoiled fruits were then carefully removed. The healthy grapes were thoroughly washed with clean water. Juice was subsequently extracted from the grapes using a mechanical pressing machine. Similarly, for mint, fresh leaves were separated from the stems, washed with water, and the juice was extracted using a juicer. The blended juice intended for nectar formulation was prepared by combining grape and mint juices in eight different proportions, as outlined in Table 1.

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

Treatment	Juice (%)	TSS (°B)	Acidity (%)
T1	50 (100 % grape juice)	15	0.4
T2	50 (99 % grape juice with 1 % mint juice)	15	0.4
T3	50 (98 % grape juice with 2 % mint juice)	15	0.4
T4	50 (97 % grape juice with 3 % mint juice)	15	0.4
T5	50 (96 % grape juice with 4 % mint juice)	15	0.4
T6	50 (95 % grape juice with 5 % mint juice)	15	0.4
T7	50 (94 % grape juice with 6 % mint juice)	15	0.4
T8	50 (93 % grape juice with 7 % mint juice)	15	0.4

According to Table 1, treatments were prepared using predetermined percentages of grape and mint juice blends. The formulation consisted of 50% syrup powder and 50% pure apple juice, in which 1–7% mint leaf extract was incorporated into the apple juice portion. The TSS of each blend were then measured and adjusted to 15°Brix by adding a sugar syrup prepared by dissolving sugar in warm water. The acidity level was also analyzed and adjusted to the desired level (0.4%) using citric acid. Sodium benzoate (120 ppm), dissolved in a small volume of warm water, was added as a preservative. The final product was filled into 250 mL bottles and sealed with metal caps using a capping machine. The sealed bottles were pasteurized by immersing them in near-boiling water for 25 minutes and then stored at room temperature.

Determination of Physical Parameters

Five grape bunches were selected randomly and tested for three physical parameters such as berry size, berry weight and juice recovery percentage. The values were averaged to record the observations. The fruit size of grapes was determined by measuring their diameter using a caliper and expressed in centimeters. The fruits were weighed using an electronic balance, and the values were recorded in kilograms. For this purpose, the juice extracted from a specific quantity of grapes and mint was recorded, and juice recovery was calculated using the following formula:

Juice Recovery $_{(\%)}$ = [Volume of Fruit Juice $_{(mL)}$ / Total Fruit Weight $_{(g)}$] ×100

Determination of Chemical Parameters

The mint flavored grape nectar was analyzed for pH, total soluble solids, reducing sugars, non-reducing sugars, total sugars and acidity at monthly interval up to three months during storage at ambient temperature. A Hand Refractometer was used to measure the TSS of nectar. TSS data for all samples were recorded, and the values were expressed in °Brix. A digital pH meter was used to measure the pH of nectar. The temperature was kept constant while taking observations for all the samples.

To determine the reducing sugar content, 25 mL of the product was blended with 100 mL of distilled water and neutralized with 1 N NaOH using phenolphthalein as an indicator. Subsequently, 2 mL of 45% lead acetate was added, followed by 2 mL of 22% potassium oxalate. The volume was then made up to 250 mL, and the solution was filtered. The filtrate was titrated against 10 mL of Fehling's solution. The titer value obtained was used to calculate the percentage of reducing sugars (Ranganna, 1986).

The content of non-reducing sugars was calculated using the following formula:

Non-reducing sugars $_{(\%)}$ = Total sugars $_{(\%)}$ – Reducing sugars $_{(\%)}$.

To determine the total sugars, 25 mL of the filtrate was hydrolyzed by mixing with 10 g of citric acid and kept overnight. It was then neutralized with sodium hydroxide using phenolphthalein as an indicator. The volume was made up to 250 mL, and the filtrate was titrated against 10 mL of Fehling's mixture. The titer value obtained was used to calculate the percentage of total sugars (Ranganna, 1986).

To determine the titratable acidity, the nectar sample was diluted and titrated against a standard 0.1 N sodium hydroxide solution using phenolphthalein as an indicator. The results were expressed as percent citric acid (Ranganna, 1986).

Determination of Biological Parameters

The prepared nectar was observed visually for mold growth at monthly intervals throughout the storage period.

Sensory Evaluation

Sensory evaluation was performed by a sensory panel comprising 10 individuals with basic knowledge and training in the organoleptic assessment of nectar. The sensory attributes evaluated included appearance, aroma, flavor, color, mouthfeel, and overall acceptability. Juice from all treatments was assessed using a 9-point Hedonic scale, where: 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely.

Economic Analysis

The cost economics of the product was analyzed for the best treatment. Net income was calculated using the following formula:

Net Income = Total Income – Total Cost

Since the benefit-cost ratio is an effective indicator of the commercial feasibility of product preparation, it was also calculated using the formula:

Benefit-Cost Ratio = Total Income / Total Cost

Statistical Analysis

The study was designed in Split Plot CRD with three replicates. The generated data was analyzed by using Statistical Tool for Agricultural Research (STAR) software and treatments are compared using Least Significant Difference (LSD) at a five percent level of significance.

FINDINGS

In this section, the findings are presented under specific subheadings, including physical, chemical, biological, and sensory attributes, along with an economic analysis. The results are tabulated in a clear and comprehensible format and are systematically explained.

Physical Parameters of Fruits

The Kishmishi cv. of grape used in this study had an average berry diameter of 9.4 mm, a bunch weight of 240 g, TSS of 21 °Brix, acidity of 0.4%, pH of 3.5, and juice recovery of 62%. In mint leaves, the juice recovery was 3%, TSS was 4.5%, acidity was 0.2%, and pH was 4.1.

Chemical Parameters

For the chemical parameters, TSS, reducing sugars, non-reducing sugars, total sugars, pH, and titratable acidity were tabulated in a clear and comprehensible manner, allowing easy interpretation of the results.

TSS

The mean TSS of grape nectar flavored with mint were significantly influenced by storage duration, different combinations of grape juice and mint, and their interaction. Over a three-month storage period, the effects of various juice–mint combinations on TSS are summarized in Table 2. A significant interaction between juice formulation and storage duration was observed ($p \leq 0.01$).

Table 2. *Effect of mint leaves extract and storage duration on TSS of grape nectar (° Brix)*

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T_1	15^{a}	16.81^{a}	17.72^{a}	18.75^{a}
T_2	15^{a}	16.68^{ab}	17.58^{ab}	18.60^{ab}
T_3	15^{a}	16.54^{bc}	17.44^{bc}	18.44^{bc}
T_4	15^{a}	16.43^{cd}	17.32^{cd}	18.33^{cd}

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T_5	15 ^{a}	16.29 ^{de}	17.16 ^{de}	18.16 ^{de}
T_6	15 ^{a}	16.18 ^{e}	17.05 ^{e}	18.04 ^{e}
T_7	15 ^{a}	16.12 ^{e}	16.99 ^{e}	17.98 ^{e}
T_8	15 ^{a}	16.09 ^{e}	16.95 ^{e}	17.93 ^{e}
Factor	F-test	LSD $_{(0.01)}$		CV $_{(\%)}$
Storage Period (A)	**	-		0.96
Blend Ratio (B)	**	-		0.63
A x B	**	0.25		-

CV: Coefficient of Variation; LSD: Least Significant Difference; A x B**:** Interaction between factors; **: P ≤ 0.01 (highly significant); Within each column, means followed by different lowercase letters (a, b, c, ...) indicate significant differences according to the LSD test.

The greatest increase in TSS occurred in T1, while the smallest change was recorded in T8, indicating that both the type of juice blend and the storage period substantially affected the TSS of the blended nectar Table 2.

pH

Storage duration and different grape–mint combinations significantly affected the pH of grape nectar (p ≤ 0.01), while no significant interaction was observed. The highest pH was recorded at the initial stage (3.85) and the lowest after 90 days of storage (3.55).

Table 3. *Effect of mint leaves extract and storage duration on pH of grape nectar*

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	3.7	3.59	3.5	3.42	3.55 ^{c}
T_2	3.8	3.69	3.6	3.51	3.65 ^{bc}
T_3	3.8	3.69	3.6	3.51	3.65 ^{bc}
T_4	3.73	3.62	3.53	3.45	3.58 ^{c}
T_5	3.93	3.82	3.72	3.63	3.78 ^{b}
T_6	3.9	3.78	3.69	3.6	3.74 ^{b}
T_7	3.8	3.69	3.6	3.51	3.65 ^{bc}
T_8	4.1	3.98	3.88	3.79	3.94 ^{a}
Storage period Means	3.85 ^{A}	3.73 ^{B}	3.64 ^{C}	3.55 ^{D}	
Factor	F-test		LSD $_{(0.01)}$		CV $_{(\%)}$
Storage Period (A)	**		0.08		2.36
Blend Ratio (B)	**		0.15		3.89
A x B	Ns		-		-

Ns: Not Significant. Within each row, means followed by different uppercase letters (A, B, C, ...) indicate significant differences according to the LSD test.

Among the treatments, T8 exhibited the highest pH (3.94), whereas T1 showed the lowest (3.55) Table 3.

Reducing Sugar

Storage duration and different grape–mint combinations significantly affected the reducing sugar content of grape nectar ($p \leq 0.01$), while no significant interaction between treatments and storage period was observed.

Table 4. *Effect of mint leaves extract and storage duration on reducing sugar of grape nectar (%)*

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	7.23	8.20	9.25	10.08	8.69 ^{bc}
T_2	7.29	8.25	9.31	10.16	8.75 ^{b}
T_3	7.56	8.56	9.66	10.54	9.08 ^{a}
T_4	7.59	8.59	9.70	10.58	9.11 ^{a}
T_5	7.35	8.33	9.40	10.25	8.83 ^{b}
T_6	7.10	8.04	9.07	9.90	8.53 ^{c}
T_7	6.95	7.87	8.88	9.68	8.34 ^{d}
T_8	6.74	7.64	8.62	9.40	8.10 ^{e}
Storage period Means	7.23 ^{D}	8.19 ^{C}	9.24 ^{B}	10.07 ^{A}	
Factor	F-test		LSD $_{(0.01)}$		CV $_{(\%)}$
Storage Period (A)	**		0.18		2.15
Blend Ratio (B)	**		0.17		1.88
A x B	Ns		-		-

Over the three-month storage period, reducing sugar increased from 7.23 at the initial stage to 10.07 after storage. Among the treatments, T4 exhibited the highest reducing sugar content (9.11), whereas T8 showed the lowest (8.10) Tables 4.

Non-Reducing Sugar

Storage duration and different grape–mint combinations significantly affected the non-reducing sugar content of grape nectar ($p \leq 0.01$), while no significant interaction between treatments and storage period was observed. During the three-month storage period, the highest non-reducing sugar content was recorded at the initial stage, and the lowest at the final stage.

Table 5. *Effect of mint leaves extract and storage duration on non-reducing sugar of grape nectar (%)*

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	6.13	5.97	5.78	5.65	5.88 ^{a}
T_2	5.92	5.76	5.58	5.45	5.68 ^{a}
T_3	5.51	5.36	5.19	5.07	5.28 ^{b}
T_4	5.23	5.09	4.93	4.82	5.02 ^{c}

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_5	5.37	5.22	5.06	4.95	5.15 ^{bc}
T_6	5.37	5.22	5.06	4.94	5.15 ^{bc}
T_7	5.40	5.26	5.09	4.97	5.18 ^{bc}
T_8	5.57	5.42	5.25	5.13	5.34 ^{b}
Storage period Means	5.56 ^{A}	5.41 ^{B}	5.24 ^{C}	5.12 ^{C}	
Factor	F-test		LSD $_{(0.01)}$	CV $_{(\%)}$	
Storage Period (A)	**		0.13	2.53	
Blend Ratio (B)	**		0.23	3.98	
A x B	Ns		-	-	

Among the treatments, T1 exhibited the highest non-reducing sugar content (5.88), whereas T4 showed the lowest (5.02) Table 5.

Total Sugar

Neither storage duration nor the different grape–mint combinations had a significant effect on the total sugar content of grape nectar ($p \leq 0.01$); however, a significant interaction between treatments and storage period was observed.

Table 6. *Effect of mint leaves extract and storage duration on total sugar of grape nectar (%)*

Treatment		Storage Period			
		Initial	30 Days	60 Days	90 Days
T_1		13.37 ^{a}	13.39 ^{ab}	14.19 ^{ab}	15.53 ^{ab}
T_2		13.20 ^{ab}	13.42 ^{ab}	14.22 ^{ab}	15.54 ^{ab}
T_3		13.07 ^{ab}	13.70 ^{a}	14.42 ^{ab}	15.65 ^{ab}
T_4		12.82 ^{bc}	12.92 ^{bc}	13.61 ^{cd}	14.77 ^{c}
T_5		12.72 ^{bcd}	13.82 ^{a}	14.63 ^{a}	15.97 ^{a}
T_6		12.46 ^{cd}	13.17 ^{b}	13.97 ^{bc}	15.28 ^{b}
T_7		12.35 ^{cd}	12.61 ^{c}	13.35 ^{d}	14.56 ^{c}
T_8		12.31 ^{d}	12.60 ^{c}	13.37 ^{d}	14.63 ^{c}
Factor	F-test	LSD $_{(0.01)}$		CV $_{(\%)}$	
Storage Period (A)	Ns	-		1.20	
Blend Ratio (B)	Ns	-		1.67	
A x B	**	0.5		-	

Analysis of this interaction indicated that the greatest changes over the storage period occurred in T5, whereas the smallest changes were observed in T4, highlighting the differential stability of the juice formulations during storage Table 6.

Titratable Acidity

Storage duration and different grape–mint combinations significantly affected the titratable acidity of grape nectar ($p \leq 0.01$), while no significant interaction between treatments and storage period was observed.

Table 7. *Effect of mint leaves extract and storage duration on titratable acidity of grape nectar (%)*

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	0.40	0.56	0.57	0.59	0.529^{a}
T_2	0.40	0.58	0.60	0.61	0.547^{a}
T_3	0.40	0.50	0.51	0.52	0.481^{b}
T_4	0.40	0.49	0.50	0.51	0.476^{b}
T_5	0.40	0.49	0.50	0.51	0.475^{b}
T_6	0.40	0.55	0.57	0.58	0.524^{a}
T_7	0.40	0.56	0.57	0.58	0.527^{a}
T_8	0.40	0.55	0.57	0.58	0.524^{a}
Storage period Means	0.400^{B}	0.535^{A}	0.548^{A}	0.560^{A}	
Factor	F-test		$LSD_{(0.01)}$		$CV_{(\%)}$
Storage Period (A)	**		0.05		10.48
Blend Ratio (B)	**		0.04		7.13
A x B	Ns		-		-

During the storage period, the highest treatable acidity was recorded at the initial stage (0.4), whereas the lowest was observed at the final stage (0.56). Among the treatments, T2 exhibited the highest titratable acidity (0.547), while T5 showed the lowest (0.475) Table7.

Biological Parameters

Among the biological parameters, the most significant issue occasionally detected in nectar is the presence of fermented or spoiled juice.

Nectar Spoilage

During the three-month storage period, no signs of juice spoilage were observed or recorded in any of the eleven different combinations of grape and mint juice in the blended nectar.

Sensory Evaluation

In the sensory evaluation section, the parameters of appearance, color, flavor, aroma, mouthfeel, and overall acceptability were systematically presented in distinct tables for clarity.

Appearance

Storage duration and different grape–mint combinations significantly affected the appearance of grape nectar ($p \leq 0.05$), while no significant interaction between treatments and storage period was observed.

Table 8. *Effect of mint leaves extract and storage duration on appearance of grape nectar*

Treatment	**Storage Period**				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	6.14	5.71	5.14	4.43	5.36 ^{d}
T_2	6.43	6.00	5.43	4.43	5.57 ^{cd}
T_3	7.86	7.43	6.86	6.00	7.04 ^{a}
T_4	5.86	5.43	4.86	4.00	5.04 ^{d}
T_5	7.29	6.86	6.29	5.43	6.46 ^{ab}
T_6	7.00	6.57	6.00	5.14	6.18 ^{bc}
T_7	6.57	6.14	5.57	4.71	5.75 ^{bcd}
T_8	6.29	5.86	5.29	4.43	5.46 ^{cd}
Storage period Means	6.68 ^{a}	6.25 ^{a}	5.68 ^{ab}	4.82 ^{b}	
Factor	F-test		LSD $_{(0.05)}$		CV $_{(\%)}$
Storage Period (A)	*		1.31		57.54
Blend Ratio (B)	*		0.78		25.52
A x B	Ns		-		-

Over the 90-day storage period, the highest appearance score was recorded at the initial stage (6.68), and the lowest after storage (4.82). Among the treatments, T3 exhibited the highest appearance score (7.04), whereas T4 showed the lowest (5.04) Tables 8.

Color

Storage duration and different grape–mint combinations significantly affected the color of grape nectar ($p \leq 0.05$), while no significant interaction between treatments and storage period was observed.

Table 9. *Effect of mint leaves extract and storage duration on color of grape nectar*

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	7.57	7.14	6.57	5.71	6.75 ^{a}
T_2	7.43	7.00	6.43	5.43	6.57 ^{a}
T_3	7.14	6.71	6.14	5.14	6.29 ^{a}
T_4	6.71	6.29	5.71	4.86	5.89 ^{a}
T_5	5.43	5.00	4.43	3.86	4.68 ^{b}
T_6	5.71	5.29	4.71	3.86	4.89 ^{b}
T_7	5.00	4.57	4.00	3.14	4.18 ^{b}
T_8	4.86	4.43	3.86	3.00	4.04 ^{b}
Storage period Means	6.23 ^{a}	5.80 ^{a}	5.23 ^{ab}	4.38 ^{b}	
Factor	F-test		LSD $_{(0.05)}$		CV $_{(\%)}$
Storage Period (A)	*		1.11		52.84
Blend Ratio (B)	*		0.97		34.02
A x B	Ns		-		-

Over the 90-day storage period, the highest color scores were recorded at the initial stage, whereas the lowest were observed after storage. Among the treatments, T1 exhibited the highest color score (6.75), while T8 showed the lowest (4.04) Tables 9.

Flavor

Storage duration and different grape–mint combinations significantly affected the flavor of grape nectar ($p \leq 0.05$), while no significant interaction between treatments and storage period was observed.

Table 10. *Effect of mint leaves extract and storage duration on flavor of grape nectar*

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	6.71	6.29	5.71	4.86	5.89 ^{ab}
T_2	6.71	6.29	5.71	4.71	5.86 ^{ab}
T_3	7.29	6.86	6.29	5.43	6.46 ^{a}
T_4	6.71	6.29	5.71	4.71	5.86 ^{ab}
T_5	6.14	5.71	5.14	4.29	5.32 ^{b}
T_6	6.14	5.71	5.14	4.29	5.32 ^{b}
T_7	5.14	4.71	4.14	3.29	4.32 ^{c}
T_8	7.14	6.71	6.14	5.14	6.29 ^{a}
Storage period Means	6.50 ^{a}	6.07 ^{a}	5.50 ^{ab}	4.59 ^{b}	
Factor	F-test		LSD $_{(0.05)}$		CV $_{(\%)}$
Storage Period (A)	*		1.23		56.01
Blend Ratio (B)	*		0.84		28.37
A x B	Ns		-		-

Over the three-month storage period, the highest flavor scores were recorded at the initial stage (6.50), whereas the lowest were observed after 90 days of storage (4.59). Among the treatments, T3 exhibited the highest flavor score (6.46), while T7 showed the lowest (4.32) Table 10.

Aroma

Storage duration significantly affected the aroma of grape nectar flavoured with mint ($p \leq 0.05$), whereas the different grape–mint juice combinations showed no significant effect, and no significant interaction between treatments and storage period was observed.

Table 11. *Effect of mint leaves extract and storage duration on aroma of grape nectar*

Treatment	Storage Period			
	Initial	30 Days	60 Days	90 Days
T_1	7.00	6.57	6.00	5.14
T_2	7.29	6.86	6.29	5.57
T_3	7.43	7.00	6.43	5.57
T_4	7.57	7.14	6.57	5.71
T_5	7.71	7.29	6.71	5.57
T_6	7.86	7.43	6.86	5.86
T_7	8.00	7.57	7.00	6.14
T_8	8.14	7.71	7.14	6.29
Storage period Means	7.62^{a}	7.20^{a}	6.62^{ab}	5.73^{b}
Factor	F-test	LSD $_{(0.05)}$		CV $_{(\%)}$
Storage Period (A)	*	1.19		45.07
Blend Ratio (B)	Ns	-		23.74
A x B	Ns	-		-

Over the 90-day storage period, the highest aroma score was recorded at the initial stage (7.62), while the lowest was observed after 90 days of storage (5.73) Tables 11.

Mouth Feel

Different grape–mint juice combinations significantly affected the mouthfeel of grape nectar ($p \leq 0.05$), whereas storage duration showed no significant effect, and no significant interaction between treatments and storage period was observed.

Table 12. *Effect of mint leaves extract and storage duration on mouth feel of grape nectar*

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	6.86	6.43	5.86	5.00	6.04^{abc}
T_2	7.00	6.57	6.00	5.00	6.14^{ab}
T_3	7.57	7.14	6.57	5.57	6.71^{a}
T_4	6.86	6.43	5.86	5.00	6.04^{abc}
T_5	6.29	5.86	5.29	4.43	5.46^{bc}
T_6	6.14	5.71	5.14	4.29	5.32^{bc}
T_7	6.14	5.71	5.14	4.29	5.32^{bc}
T_8	6.00	5.57	5.00	4.29	5.21^{c}
Factor	F-test		LSD $_{(0.05)}$		CV $_{(\%)}$
Storage Period (A)	Ns		-		63.75
Blend Ratio (B)	*		0.90		29.55
A x B	Ns		-		-

Among the treatments, T3 exhibited the highest mouthfeel score (6.71), while T8 showed the lowest (5.21) Table 12.

Overall Acceptance

Storage duration and different grape–mint combinations significantly affected the overall acceptability of grape nectar ($p \leq 0.05$), while no significant interaction between treatments and storage period was observed.

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

Treatment	Storage Period				
	Initial	30 Days	60 Days	90 Days	Treatments Means
T_1	7.29	6.86	6.29	5.43	6.46 ^{ab}
T_2	7.86	7.43	6.86	5.86	7.00 ^{ab}
T_3	8.00	7.57	7.00	6.14	7.18 ^{a}
T_4	7.29	6.86	6.29	5.29	6.43 ^{ab}
T_5	7.14	6.71	6.14	5.29	6.32 ^{ab}
T_6	7.00	6.57	6.00	5.14	6.18 ^{b}
T_7	6.00	5.57	5.00	4.14	5.18 ^{c}
T_8	5.71	5.29	4.71	3.86	4.89 ^{c}
Storage period Means	7.04 ^{a}	6.61 ^{a}	6.04 ^{ab}	5.14 ^{b}	
Factor	F-test		LSD $_{(0.05)}$		CV $_{(\%)}$
Storage Period (A)	*		1.1		45.80
Blend Ratio (B)	*		0.86		26.27
A x B	Ns		-		-

Over the 90-day storage period, the highest overall acceptability score was recorded at the initial stage (7.04), whereas the lowest was observed after storage (5.14). Among the treatments, T3 exhibited the highest overall acceptability (7.18), while T8 showed the lowest (4.89) Tables 13.

Economic Evaluation of Nectar

Table 34 presents the economic analysis and cost assessment for the best treatment in this study. Based on the sensory characteristics, T_3 (98% Grape juice + 2% Mint juice) was identified as the optimal treatment.

Table 14. *Cost accounting for T_3 (98 % Grape juice + 2 % Mint Juice)*

No	Materials	Amounts	Cost per Unit (AFN)	Grand Total Cost
1	Mint (g)	250.000	0.015	3.750
2	Grape Bunch (g)	565.000	0.028	16.6
3	Sugar (g)	35.000	0.055	1.920
4	Sodium benzoate (ppm)	0.090	0.040	0.004
5	Water(mL)	340.000	0.001	0.450
6	Citric Acid (g)	1.500	0.100	0.015
7	Bottles and corks	3.000	10.000	30.000
8	Labors	1.000	2.000	2.000
9	Other Expense	1.000	3.000	3.000
Cost per Bottle			19.24 AFN	
Total Cost			57.73 AFN	

AFN-Afghani.

The economic analysis and cost assessment were carried out for a total nectar volume of 750 mL, packaged in three 250 mL bottles, taking into account the physical parameters of the fruit as determined in the study.

DISCUSION

The increase in TSS of the nectar could be attributed to the hydrolysis of starch into simple sugars during storage. Similar trends have been reported by Priyanka et al. (2015), Singh et al. (2023), and Kumari et al. (2025), who observed a gradual increase in TSS during the storage of blended fruit beverages. Furthermore, reducing the proportion of grape juice (21 °Brix) while increasing mint juice (4.5 °Brix) led to reduce the overall TSS of nectar. This trend is consistent with the findings of Priyanka et al. (2015) and Hameed et al. (2021), who reported that increasing the proportion of low-TSS juices decreased the total soluble solids of blended drinks. In addition, decreasing the amount of juice with a higher TSS contributes to a reduction in the overall TSS of the final beverage.

An increase in reducing and total sugars was observed with prolonged storage, whereas non-reducing sugars declined, likely due to the hydrolysis of polysaccharides and the conversion of non-reducing sugars into reducing sugars. Comparable trends have been documented by Priyanka et al. (2015), Singh et al. (2023), Kumari et al. (2025), and Murali et al. (2023), although the magnitude of change differed among studies. Moreover, increasing the proportion of mint juice led to a reduction in reducing, non-reducing, and total sugar contents, which can be attributed to the lower intrinsic sugar content of mint relative to grape. These observations underscore the critical role of juice composition and storage duration in shaping the sugar profile of blended nectar beverages.

The pH of grape nectar decreased during storage due to the formation of organic acids from ascorbic acid and sugar conversion, while increasing the proportion of mint juice raised pH owing to its higher intrinsic pH. Concurrently, titratable acidity increased with storage, reflecting sugar-to-acid conversion and ascorbic acid transformation. These trends, consistent with Priyanka et al. (2015), Singh et al. (2023), Kumari et al. (2025), and Hameed et al. (2021), highlight the combined effects of storage-induced biochemical changes and juice composition on the acidity and pH of blended nectars.

No juice spoilage was observed during storage, as sodium benzoate was used as a preservative. Prolonged storage led to declines in all sensory attributes of grape–mint nectar, including appearance, color, flavor, aroma, mouthfeel, and overall acceptability, primarily due to biochemical changes such as sugar–acid interconversions, ascorbic acid degradation, enzymatic browning, and volatile compound loss. Increasing the proportion of mint juice generally reduced sensory scores, likely due to suspended particles, insoluble compounds, or alterations in flavor balance. Across all attributes, T3 consistently showed the highest scores, indicating optimal sensory quality. These findings are in agreement with Priyanka et al. (2015), Singh et al. (2023), and Kumari et al. (2025), although the extent of change varied among studies. In contrast, Poornima et al. (2018) reported the highest flavor and acceptability scores at an 8% mint juice concentration in blended grape–celery–mint nectar, highlighting the influence of juice composition on sensory outcomes.

The production cost per 250 mL bottle of grape–mint nectar was 19.24 AFN, and when sold at a wholesale price of 30 AFN, a profit of 1.57 AFN is generated per 1 AFN invested, resulting in a benefit-cost ratio of 1:1.57 AFN.

CONCLUSION

This study was conducted to evaluate the effects of mint flavor and storage duration on the physicochemical and sensory properties of grape nectar. Storage duration significantly influenced the chemical composition of the nectar, resulting in increases in TSS, total sugar, reducing sugar, and titratable acidity, while pH, non-reducing sugar, and sensory attributes declined, reflecting biochemical transformations during storage. Among the treatments, T4 (97% grape juice + 3% mint juice) showed the least changes in chemical properties, whereas T3 (98% grape juice + 2% mint juice) was identified as the most favorable in terms of sensory quality, including appearance, aroma, flavor, mouthfeel, and overall acceptability. Economic analysis indicated that producing a 250 mL bottle of grape–mint nectar costs 19.24 AFN and can be sold at a wholesale price of 30 AFN, yielding a benefit–cost ratio of 1:1.57 AFN. Considering both sensory quality and profitability, commercial production is recommended to focus on T3, and further optimization of juice formulations, storage conditions, and production scale could enhance both product quality and economic returns, highlighting the potential for sustainable commercialization of grape–mint nectar.

AUTHORS CONTRIBUTIONS

Hamid Salari initiated the research idea, supervised the research process, and monitored the data analysis and manuscript writing process. Mohammadullah Amin analyzed and interpreted the data and wrote the manuscript. Mohammad Hamid Stanikzai, practically conducted the research and collected the data. All authors equally contributed to structuring the paper and editing the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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