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Formulation and Evaluation of a Functional Beverage from Carrots Juice, Aloe Vera Gel, and Cardamom Extract

Abdul Qahar Faiz[1], Rahmat Gul Hassanzai[2], Mohammad Nasim Ayobi

Kabul University, Horticulture Department, Agriculture Faculty, Kabul, Afghanistan
faez.qahar924@gmail.com (corresponding author)

ABSTRACT

The increasing demand for healthy beverages has encouraged the development of products containing natural ingredients with nutritional and functional benefits. This study aimed to develop a functional beverage using carrot juice, aloe vera gel, and cardamom extract and evaluate the effects of different formulations on physicochemical properties, sensory quality, and storage stability. The experiment was conducted in 2025 at the Laboratory of the Department of Horticulture, Faculty of Agriculture, Kabul University, Afghanistan. We prepared eight beverage formulations according to Codex Alimentarius standards and evaluated them using a factorial completely randomized design with three replications. The beverages were pasteurized, bottled, and stored at room temperature for 90 days. We assessed physicochemical properties, including total soluble solids, pH, titratable acidity, and sugar content, and sensory attributes, including appearance, color, flavor, taste, texture, aroma, and overall acceptability, using standard methods. Formulation influenced beverage quality more than storage duration. During storage, total soluble solids and sugar content increased slightly, while pH decreased gradually and titratable acidity remained relatively stable. Sensory attributes changed only slightly, indicating good product stability. Among the eight formulations, T5 achieved the highest overall quality and consumer acceptability, followed by T7 and T8. The findings show that carrot juice, aloe vera gel, and cardamom extract can produce a stable, acceptable functional beverage. T5 (60% carrot juice + 30% aloe vera gel + 10% cardamom extract) was the most suitable formulation because of its superior physicochemical characteristics, sensory quality, and storage performance.

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INTRODUCTION

Carrot (*Daucus carota* L.) is a widely cultivated root vegetable belonging to the Apiaceae family and is grown extensively in both temperate and tropical regions. Its popularity largely stems from its high nutritional value and associated health benefits (Galal & Morsy, 2023;

Thirukkumar et al., 2019). Carrots provide an excellent source of dietary fiber, minerals, β-carotene, and natural antioxidants, all of which contribute to disease prevention and good health (Dayang Norulfairuz et al., 2021; Dorothy et al., 2020). As consumer interest in nutritious, minimally processed foods continues to grow, carrot juice has become an attractive ingredient for developing functional beverages because of its pleasant flavor and rich nutritional composition (Burang & Singh, 2018; Cherian & Lekshmi, 2021).

Aloe vera (*Aloe barbadensis* Miller) is another plant widely valued for its nutritional and medicinal properties. The gel contains a range of bioactive compounds, including polysaccharides, vitamins, enzymes, and phenolic compounds, associated with antioxidant, antimicrobial, anti-inflammatory, and digestive health benefits (Cherian & Lekshmi, 2021; V. Kumari, 2010; Swarnalatha, 2021). These functional properties have encouraged its incorporation into beverage formulations to enhance nutritional quality, improve consumer appeal, and contribute to product stability during storage (Khatri, 2024; Priyanka Gajanan, 2020).

Cardamom (*Elettaria cardamomum*), an aromatic spice in the Zingiberaceae family, is widely used in culinary and traditional medicinal practices. It contains essential oils and bioactive constituents, including cineole, terpenoids, and flavonoids, which possess antioxidant, antimicrobial, and digestive-supporting properties (Galal & Morsy, 2023; Heam, 2022; Winarsi et al., 2020). Besides its health-promoting effects, cardamom is valued in beverage production for enhancing aroma, flavor, and overall sensory quality (Abdullah et al., 2023; Khatri, 2024).

The global demand for functional beverages has increased considerably as consumers become more aware of the relationship between diet, health, and disease prevention (Dayang Norulfairuz et al., 2021; Dorothy et al., 2020). Beverages fortified with plant extracts and herbal ingredients are increasingly recognized as effective carriers of bioactive compounds that can support normal physiological functions and promote overall well-being (Moselhy et al., 2024; Thirukkumar et al., 2019). Previous studies have also demonstrated that combining fruit juices with herbs and spices can improve nutritional composition, antioxidant capacity, sensory characteristics, and storage stability (Burang & Singh, 2018; V. Kumari, 2010; Swarnalatha, 2021).

Several researchers have successfully developed functional beverages by blending Aloe vera with different fruit juices and herbal ingredients. Fruit sources such as mango, orange, apricot, and cashew apple have been shown to improve antioxidant activity, extend shelf life, and enhance consumer acceptance when combined with Aloe vera gel (Burang & Singh, 2018; Cherian & Lekshmi, 2021; Rakesh Gehlot et al., 2023). Likewise, spices including cardamom and clove have been incorporated into functional foods and beverages to improve flavor while increasing their bioactive and therapeutic potential (Galal & Morsy, 2023; Heam, 2022; Winarsi et al., 2020).

Evidence also suggests that incorporating natural plant-based ingredients can increase the levels of phenolic compounds, flavonoids, vitamin C, and antioxidant activity, thereby improving the nutritional quality of functional beverages (Abdullah et al., 2023; Moselhy et al., 2024). In addition, blending fruit juices with herbal ingredients has been reported to improve sensory characteristics while helping preserve nutrient quality during storage (Khatri, 2024; Swarnalatha, 2021). Despite these advances, limited information exists on beverages combining carrot juice, Aloe vera gel, and cardamom extract in a single formulation under controlled experimental conditions. Carrot juice contributes natural sweetness, β-carotene, and antioxidant compounds; Aloe vera provides functional and therapeutic components; and cardamom enhances flavor, aroma, and bioactive properties. Integrating these ingredients may result in a nutritious beverage with desirable sensory characteristics and improved functional value (Dorothy et al., 2020; Thirukkumar et al., 2019).

To address this research gap, the present study was undertaken with the following objectives:

- To develop functional beverage formulations using carrot juice, Aloe vera gel, and cardamom extract in different proportions.
- To evaluate the physicochemical characteristics of the formulated beverages during storage.
- To assess the sensory quality and consumer acceptability of the different beverage formulations.
- To determine the storage stability of the beverages over a 90-day storage period.
- To identify the formulation that provides the best balance of physicochemical quality, sensory attributes, and storage performance.

METHODS AND MATERIALS

Research Design

The study was conducted in 2025 at the Laboratory of the Department of Horticulture, Faculty of Agriculture, Kabul University, Afghanistan. We used an experimental research design to develop and evaluate a functional beverage made from carrot juice, *Aloe vera* gel, and cardamom extract. The experiment followed a factorial completely randomized design (FCRD) with three replications to examine the effects of beverage formulation and storage duration on physicochemical characteristics and sensory quality. We prepared and evaluated eight formulations with different proportions of carrot juice, Aloe vera gel, and cardamom extract over a 90-day storage period.

Sampling Strategy

A purposive sampling approach was used to select fresh and high-quality raw materials suitable for beverage production. Fresh carrots were purchased from a local market, while

mature *Aloe vera* leaves were collected from the Kabul University research farm. Cardamom seeds were obtained from a local supplier and manually separated from their pods before extraction. The ingredients were selected based on freshness, maturity, and the absence of visible physical damage or spoilage to ensure consistency throughout the experiment. Eight beverage formulations were developed according to the Codex Alimentarius Standard for Fruit Juices and Nectars (CXS 247–2005). The formulations included both single-ingredient and blended treatments with varying proportions of carrot juice, *Aloe vera* gel, and cardamom extract.

Data Collection Method

Carrots were washed thoroughly, peeled, cut into small pieces, and processed using a mechanical juice extractor. Fresh *Aloe vera* gel was carefully removed from the leaves, while cardamom extract was prepared separately using standard extraction procedures. The extracted ingredients were blended, homogenized, and filtered through muslin cloth to obtain a uniform beverage mixture.

A sugar syrup with a total soluble solids concentration of 15 °Brix was prepared and incorporated into each formulation. Titratable acidity was adjusted to 0.3% using citric acid, and sodium benzoate (120 ppm) was added as a preservative. The beverages were filled into sterilized 200 mL glass bottles, sealed, pasteurized in near-boiling water for 25 minutes, cooled, and stored at room temperature for 90 days.

Samples were collected at predetermined storage intervals (0, 30, 60, and 90 days) for physicochemical and sensory evaluation. During each sampling period, we determined chemical parameters, including pH, total soluble solids (TSS), titratable acidity, reducing sugar, non-reducing sugar, and total sugar. We also monitored visible spoilage throughout the storage period.

Data Collection Instruments

Physicochemical measurements were conducted using standard laboratory equipment and analytical procedures. Total soluble solids were determined with a hand refractometer, pH was measured using a calibrated digital pH meter, and standard titration methods determined titratable acidity. Sugar fractions were analyzed following established laboratory protocols.

Sensory evaluation was carried out by a trained panel consisting of ten members. A nine-point hedonic scale, ranging from 1 ("dislike extremely") to 9 ("like extremely"), was used to assess appearance, color, aroma, flavor, taste, texture, and overall acceptability. All sensory evaluations were conducted under controlled laboratory conditions to minimize external influences on panelists' responses.

Data Analysis

The experiment used a factorial completely randomized design (FCRD) with three replications. Data were analyzed using STAR statistical software. Analysis of variance (ANOVA) was performed to determine the effects of formulation, storage period, and their interaction on the measured physicochemical and sensory parameters. Whenever significant differences were detected, treatment means were compared using the Least Significant Difference (LSD) test at the 5% level of significance ($p \leq 0.05$).

FINDINGS

The total soluble solids (TSS) content of the beverages increased gradually during the 90-day storage period, although the magnitude of the increase varied among the different formulations. This indicates that both beverage composition and storage duration influenced changes in soluble solids over time. The increase was generally more pronounced in some formulations than in others, suggesting differences in the stability of the ingredient combinations.

Among the treatments, T6 (70% carrot juice, 20% Aloe vera gel, and 10% cardamom extract) showed one of the greatest increases in TSS, rising from 15.00 °Brix at the beginning of storage to 17.00 °Brix after 90 days. A comparable trend was observed in T1 (100% carrot juice), where TSS increased from 15.00 to 17.16 °Brix. Similarly, T7 and T2 reached final values of 16.90 and 16.66 °Brix, respectively. T3 and T4 showed moderate increases, reaching 16.86 and 16.63 °Brix by the end of the storage period. In contrast, T5 and T8 showed the smallest changes, with both treatments reaching a final TSS of 16.00 °Brix, indicating greater stability during storage. Statistical analysis showed that storage period, treatment, and their interaction significantly affected TSS ($p \leq 0.01$) (Table 1).

Table 1. *Changes in total soluble solids (TSS) of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)			
	initial	30	60	90
T1(Carrots Juice)	$15.00^{a}{}_{D}$	$15.80^{bc}C$	$16.60^{a}{}_{b}B$	17.16^{a} A
T2(Aleo Vera gel)	$15.00^{a}D$	$16.00^{b}C$	16.93^{a} A	16.66^{b} B
T3(Cardamom extract)	$15.00^{a}D$	$16.00^{b}C$	$16.30^{b}{}_{c}B$	$16.86^{a}{}_{b}A$
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	$15.00^{a}C$	$16.00^{b}B$	$16.06^{c}{}_{d}B$	16.63^{b} A
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	$15.00^{a}C$	$15.30^{d}B$	15.83^{d} A	16.00^{c} A
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	$15.00^{a}C$	$16.50^{a}B$	16.90^{a} A	17.00^{ab} A
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	$15.00^{a}D$	$16.00^{b}C$	$16.26^{b}{}_{c}B$	$16.90^{a}{}_{b}A$
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	$15.00^{a}C$	$15.53^{cd}B$	$16.00^{c}{}_{d}A$	16.00^{c} A
	Storage period (A)	Treatment (B)	Interaction (A×B)	

F-test	**	**	**
LSD0.01	0.32	0.44	
CV (%)	0.92		

*CV: Coefficient of Variation, LSD: Least Significant Difference, **: P≤0.01, According to LSD, 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.*

Table 2 presents the changes in titratable acidity of the beverage formulations during the 90-day storage period. Across all treatments, titratable acidity remained constant at 0.30%, with no measurable variation from the beginning to the end of storage. This consistency indicates that neither the formulation nor the storage period noticeably affected the acidity of the beverages.

The stable acidity observed throughout the study suggests the beverage formulations maintained their chemical balance during storage. It also indicates that the processing procedures, including pasteurization and the use of sodium benzoate as a preservative, effectively preserved acid content and prevented changes that could affect product quality.

The analysis of variance showed that storage period, treatment, and their interaction had no significant effect ($p > 0.05$) on titratable acidity. Although the coefficient of variation was 21.19%, all recorded values remained identical throughout the experiment, confirming that the observed variability had no practical influence on the results (Table 2).

Table 2. *Changes in titratable acidity of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	**Storage period (Days)**			
	initial	**30**	**60**	**90**
T1(Carrots Juice)	0.30	0.30	0.30	0.30
T2(Aleo Vera gel)	0.30	0.30	0.30	0.30
T3(Cardamom extract)	0.30	0.30	0.30	0.30
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	0.30	0.30	0.30	0.30
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	0.30	0.30	0.30	0.30
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	0.30	0.30	0.30	0.30
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	0.30	0.30	0.30	0.30
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	0.30	0.30	0.30	0.30
	Storage period (A)	Treatment (B)	Interaction (A×B)	
F-test	NS	NS	NS	
LSD0.01	.	.	.	
CV (%)	21.19			

CV: *Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant*

Table 3 summarizes the changes in pH of the carrot–Aloe vera–cardamom beverage formulations over the 90-day storage period. The results showed that pH differed significantly among the formulations and changed throughout storage. Statistical analysis

revealed that treatment, storage duration, and their interaction had a highly significant effect on pH ($p \leq 0.01$), indicating that both ingredient composition and storage time influenced the beverages' acidity.

The pH values did not follow a uniform pattern during storage. Instead, each formulation showed its own trend, with some declining gradually and others fluctuating temporarily before stabilizing. The greatest decrease was observed in T2 (100% Aloe vera gel), where the pH dropped from 4.23 at the beginning of storage to 2.94 after 60 days before increasing slightly to 3.50 at the end of the storage period. This response suggests that the Aloe vera-based formulation was more sensitive to storage conditions than the other treatments.

By comparison, the blended formulations, particularly T5, T6, T7, and T8, maintained relatively stable pH values throughout the experiment. Although minor fluctuations were recorded, these treatments experienced less variation than the single-ingredient formulations. This indicates that combining carrot juice, Aloe vera gel, and cardamom extract contributed to a more stable pH during storage (Table 3).

Table 3. *Changes in pH content of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)			
	initial	30	60	90
T1(Carrots Juice)	5.16^{a}A	4.30^{bc}B	4.17^{ab} B	5.06^{a} A
T2(Aleo Vera gel)	4.23^{c}A	4.10^{c}A	2.94^{d} C	3.50^{d} B
T3(Cardamom extract)	4.60^{abc}A	4.53^{abc}A	3.50^{cd} B	3.84^{cd} B
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	4.70^{abc}AB	4.90^{a}A	3.76^{bc} C	4.44^{b} B
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	4.70^{abc}A	4.76^{ab}A	4.01^{ab} ^{c}B	4.26^{bc} B
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	4.36^{bc}B	5.06^{a}A	4.36^{a} B	4.30^{bc} B
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	4.86^{ab}A	5.10^{a}A	4.34^{ab} B	4.35^{bc} B
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	4.96^{a}A	5.00^{a}A	4.16^{ab} B	4.38^{bc} B
	Storage period (A)	Treatment (B)	Interaction (A×B)	
F-test	**	**	**	
LSD0.01	0.41	0.58		
CV (%)	4.4			

*CV: Coefficient of Variation, LSD: Least Significant Difference, **: P≤0.01, According to LSD, 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.*

Table 4 presents the changes in reducing sugar content of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. Statistical analysis showed that treatment, storage duration, and their interaction significantly affected sugar reduction ($p \leq 0.01$). The results indicate that the different beverage formulations responded differently during storage, leading to noticeable variation in reducing sugar levels over time.

During the first 30 days of storage, reducing sugar content increased in most formulations. For example, T1 increased from 10.49 to 11.92, T2 from 11.83 to 13.65, and T3 from 8.58 to 12.30. Similar increases were observed in the blended formulations, including T4, which rose from 8.33 to 13.31, and T8, which increased from 6.25 to 11.63. These early increases may reflect the hydrolysis of complex carbohydrates into simpler reducing sugars during storage.

As storage progressed, the pattern of change differed among the treatments. At 60 days, some formulations remained at relatively high reducing sugar levels, while others declined slightly. T2 remained high at 13.31, whereas T7 increased further to 12.52. In contrast, the reducing sugar content of T5 declined from 11.74 at 30 days to 10.35 at 60 days. By the end of the 90-day storage period, several formulations, including T1 and T2, showed lower reducing sugar values of 8.79 and 9.93, respectively. However, T5 and T4 retained comparatively higher concentrations, reaching 12.50 and 12.40, respectively.

Among all the treatments, T2 recorded the highest reducing sugar content (13.65) after 30 days of storage, whereas T6 had the lowest initial value (5.51). Overall, the blended formulations, particularly T4, T5, and T6, exhibited more gradual changes in reducing sugar content than the single-ingredient treatments, indicating a more stable response during storage (Table 4).

Table 4. *Changes in reducing sugars of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)			
	initial	30	60	90
T1(Carrots Juice)	10.49^{aB}	11.92^{abA}	$11.34b^{cAB}$	8.79^{cC}
T2(Aleo Vera gel)	11.83^{aB}	13.65^{aA}	13.31^{aA}	9.93^{bcC}
T3(Cardamom extract)	8.58^{bB}	12.30^{abA}	11.74^{abcA}	9.35^{bcB}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	8.33^{bC}	13.31^{abA}	11.65^{abcB}	12.40^{aAB}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	6.92^{bcC}	11.74^{bA}	10.35^{cB}	12.50^{aA}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	5.51^{cC}	9.05^{cB}	10.99^{bcA}	11.11^{abA}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	5.55^{cD}	7.79^{cC}	12.52^{abA}	10.21^{bcB}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	6.25^{cC}	11.63^{bAB}	$12.01a^{bc}A$	10.50^{bcB}
	Storage period (A)	Treatment (B)	Interaction (A×B)	
F-test	**	**	**	
LSD0.01	1.28	1.79		
CV (%)	5.7			

CV: Coefficient of Variation, LSD: Least Significant Difference, **: P≤0.01. According to LSD, 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.

Table 5 presents the changes in total sugar content of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. Total sugar content varied only slightly among the different formulations throughout storage. Statistical analysis showed that storage duration had a highly significant effect on total sugar content ($p \leq 0.01$), whereas treatment and the treatment × storage interaction were not significant. These findings indicate that storage time, rather than differences in beverage formulation, primarily influenced changes in total sugar.

Although some fluctuations were observed during storage, the overall changes in total sugar were relatively small. In T1, the total sugar content increased from 15.02 at the beginning of storage to 15.97 after 30 days, declined slightly to 14.94 at 60 days, and then increased to 16.48 by the end of the storage period. A similar trend was observed in T2, where total sugar gradually increased from 15.15 initially to 16.89 after 90 days. T3 also showed a modest increase, rising from 15.07 to 16.07 during storage.

The blended formulations exhibited comparable patterns. In T6, the total sugar content decreased to 13.10 after 30 days before increasing steadily to 16.29 at 90 days. Likewise, T7 followed a similar trend and recorded the highest final total sugar value (16.96) among all treatments. In contrast, T4 showed only minor variation throughout storage and ended with a slightly lower value of 15.40 at the end of the experiment (Table 5).

Table 5. *Changes in total sugar of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)			
	initial	30	60	90
T1(Carrots Juice)	15.02	15.97	14.94	16.48
T2(Aleo Vera gel)	15.15	15.97	16.31	16.89
T3(Cardamom extract)	15.07	15.81	15.81	16.07
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	15.07	16.14	15.69	15.40
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	14.92	15.32	14.04	15.62
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	15.07	13.10	15.98	16.29
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	14.48	12.71	15.81	16.96
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	14.02	14.94	15.97	16.22
Storage Period Mean	14.84^{b}	15.00^{b}	15.57^{ab}	
	Storage period (A)	Treatment (B)	Interaction (A×B)	
F-test	**	NS	NS	
LSD0.01	0.88			
CV (%)	7.48			

CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01. According to LSD, 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.

Table 6 shows the changes in non-reducing sugar content of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. Analysis of variance showed that treatment, storage duration, and their interaction significantly influenced non-reducing sugar content ($p \leq 0.01$). These findings indicate that both beverage formulation and storage duration contributed to the observed changes in non-reducing sugar levels.

The pattern of change differed among formulations, with non-reducing sugar content fluctuating throughout storage rather than following a consistent increasing or decreasing trend. In T1, non-reducing sugar content declined from 4.29 at the start of storage to 3.42 after 60 days, then increased markedly to 7.30 at the end of the experiment. A comparable trend was observed in T2, where the value decreased from 3.14 initially to 2.85 at 60 days and subsequently increased to 6.60 after 90 days. These results suggest that sugar composition changed continuously during storage.

Differences among the formulations were also evident. T6 recorded the highest initial non-reducing sugar content (9.08), whereas T2 had the lowest initial value (3.14). The blended formulations displayed more variable responses during storage. For example, T4 declined gradually from 6.40 at the initial stage to 2.84 after 90 days. In contrast, T7 fluctuated throughout storage but retained a relatively high final value of 6.41, indicating a different pattern of sugar transformation than the other formulations (Table 6).

Table 6. *Changes in non-reducing sugar of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)			
	initial	30	60	90
T1(Carrots Juice)	4.29^{bc}B	3.84^{a}B	3.42^{a} B	7.30^{a}A
T2(Aleo Vera gel)	3.14^{c}B	2.20^{a}B	2.85^{a} B	6.60^{a}A
T3(Cardamom extract)	6.16^{ab}A	3.33^{a}B	3.86^{a} B	6.38^{a}A
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	6.40^{ab}A	2.68^{a}B	3.83^{a} B	2.84^{b}B
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.59^{a}A	3.40^{a}B	3.51^{a} B	2.96^{b}B
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	9.08^{a}A	3.84^{a}B	4.74^{a} B	4.92^{ab} B
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	8.48^{a}A	4.68^{a}BC	3.12^{a} C	6.41^{a}A B
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	7.38^{a}A	3.14^{a}C	3.76^{a} BC	5.43^{ab}A B
	Storage period (A)	Treatment (B)	Interaction (A×B)	
F-test	**	**	**	
LSD0.01	2.16	3.01		
CV (%)	21.04			

*CV: Coefficient of Variation, LSD: Least Significant Difference, **: P≤0.01, According to LSD, 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.*

Table 7 presents the appearance scores of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. Statistical analysis showed that beverage formulation had a highly significant effect on appearance ($p \leq 0.01$). In contrast, storage duration and the interaction between treatment and storage period did not significantly influence this sensory attribute. These findings indicate that differences in ingredient composition had a greater impact on the visual quality of the beverages than the length of storage.

Although appearance changed slightly over time, the overall pattern remained relatively stable across the storage period. In T1, the appearance score increased from 7.12 at the beginning of storage to 7.75 after 30 days and remained unchanged until the end of the experiment. In contrast, T2 declined slightly from 7.62 initially to 7.00 after 60 days before improving to 7.50 at 90 days, indicating only minor variation in visual acceptability during storage.

Differences among the formulations were more evident than changes over time. T7 achieved the highest mean appearance score (7.69), improving from 6.62 at the start of storage to 8.25 after 90 days. T5 and T8 also received relatively high appearance ratings, with mean scores of 7.59 and 7.66, respectively. Conversely, T4 recorded the lowest mean score (6.72), suggesting comparatively lower visual appeal than the other formulations (Table 7).

Table 7. *Changes in appearance of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)				
	initial	30	60	90	Treatments mean
T1(Carrots Juice)	7.12	7.75	7.75	7.75	7.59^{ab}
T2(Aleo Vera gel)	7.62	7.12	7.00	7.50	7.31^{abc}
T3(Cardamom extract)	7.00	6.75	6.62	7.12	6.88^{bc}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	7.12	6.62	6.62	6.50	6.72^{c}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.37	7.87	7.75	7.37	7.59^{ab}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	7.50	7.12	6.87	7.37	7.22^{abc}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	6.62	8.00	7.87	8.25	7.69^{a}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	7.25	7.75	7.87	7.75	7.66^{ab}
	Storage period (A)	Treatment (B)	Interaction (A×B)		
F-test	NS	**	NS		
LSD0.01	.	0.79			
CV (%)	12.1				

*CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01, According to LSD, 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.*

Table 8 presents the color scores of the carrot–Aloe vera–cardamom beverage formulations throughout the 90-day storage period. Statistical analysis indicated that beverage formulation had a highly significant effect on color ($p \leq 0.01$). In contrast, storage duration and the interaction between treatment and storage period did not significantly influence this sensory attribute. These findings suggest that ingredient composition contributed more to color variation than storage duration.

Although slight color changes were observed during storage, the overall pattern remained relatively stable. In T1, the color score increased from 7.50 at the beginning of the study to 7.87 after 30 days, then remained almost unchanged at 7.75 at both 60 and 90 days. In contrast, T2 showed a gradual decline in color score from 7.62 initially to 7.00 at 60 days, followed by a slight improvement to 7.12 at the end of the storage period. These results indicate that color change differed among formulations but was generally small.

Among the treatments, T7 achieved the highest mean color score (7.91), improving from 7.25 at the start of storage to 8.25 after 90 days. T8 also maintained high color acceptability throughout the study, with a mean score of 7.84 and a gradual improvement during storage. In comparison, T3 recorded the lowest mean score (6.75), indicating relatively lower color acceptability than the other formulations (Table 8).

Table 8. *Changes in color of carrots juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)				
	initial	30	60	90	Treatments mean
T1(Carrots Juice)	7.50	7.87	7.75	7.75	7.72^{ab}
T2(Aleo Vera gel)	7.62	7.12	7.00	7.12	7.22^{abc}
T3(Cardamom extract)	6.87	6.50	6.37	7.25	6.75^{c}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	7.25	6.62	6.62	7.12	6.91^{bc}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.75	7.75	8.12	7.00	7.66^{ab}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	7.37	7.25	7.00	7.50	7.28^{abc}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	7.25	8.12	8.00	8.25	7.91^{a}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	7.62	7.75	7.87	8.12	7.84^{a}
	Storage period (A)	Treatment (B)	Interaction (A×B)		
F-test	NS	**	NS		
LSD0.01	.	0.82			
CV (%)	12.43				

*CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01. According to LSD, 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.*

Table 9 presents the flavor scores of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. Statistical analysis showed that beverage formulation significantly affected flavor ($p \leq 0.01$), whereas storage duration and the treatment-storage interaction had no significant effect. These findings indicate that differences in ingredient composition contributed more to flavor variation than storage length.

Flavor scores remained relatively stable in most formulations throughout storage, although some variation was observed. In T1, the flavor score changed only slightly, increasing from 7.62 at the beginning of storage to 7.87 after 90 days, indicating good flavor stability. In contrast, T2 declined noticeably from 7.50 initially to 6.00 after 30 days, then gradually improved to 6.87 at the end of storage. A similar pattern was observed in T3, where the score decreased to 5.62 after 60 days before recovering to 7.50 by day 90.

Among the evaluated formulations, T7 achieved the highest mean flavor score (7.75), maintaining values close to 8.00 throughout the storage period. T5 and T8 also performed well, with mean scores of 7.66 and 7.56, respectively, indicating good flavor retention during storage. In comparison, T4 recorded the lowest mean score (6.62), suggesting comparatively lower flavor acceptability than the other formulations (Table 9).

Table 9. *Changes in flavor of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)				
	initial	30	60	90	Treatments mean
T1(Carrots Juice)	7.62	7.50	7.50	7.87	7.62^{ab}
T2(Aleo Vera gel)	7.50	6.00	6.37	6.87	6.69^{ab}
T3(Cardamom extract)	7.62	6.00	5.62	7.50	6.69^{ab}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	7.25	6.50	6.37	6.37	6.62^{b}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.87	7.87	8.00	6.87	7.66^{ab}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	7.25	7.50	7.12	7.50	7.34^{ab}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	7.00	8.00	8.00	8.00	7.75^{a}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	7.12	7.50	7.62	8.00	7.56^{ab}
	Storage period (A)	Treatment (B)	Interaction (A×B)		
F-test	NS	**	NS		
LSD0.01	.	1.12			
CV (%)	17.36				

CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01, According to LSD, 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.

Table 10 presents the taste scores of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. Analysis of variance showed that beverage formulation significantly affected taste ($p \leq 0.01$), whereas storage duration and the treatment-storage interaction had no significant influence. These findings suggest that differences in ingredient composition contributed more to taste variation than storage duration.

Taste scores remained relatively stable in several formulations, although some changes were observed during storage. In T1, the taste score increased slightly from 7.37 at the beginning of storage to 7.87 after 90 days, indicating good sensory stability. In contrast, T2 declined from 7.37 initially to 6.00 at both 30 and 60 days before improving slightly to 6.75 at the end of the storage period. T3 showed a more pronounced reduction, with the score decreasing to 5.62 after 30 days and then gradually recovering to 6.87 by day 90.

Among the evaluated formulations, T5 achieved the highest mean taste score (7.81). Its score increased from 7.75 at the start of storage to 8.37 after 60 days, then declined to 6.87 at the end of the experiment. T7 and T8 also maintained consistently high taste ratings, with mean scores of 7.72 and 7.59, respectively, indicating good sensory acceptability throughout storage. In comparison, T3 recorded the lowest mean taste score (6.38), reflecting comparatively lower consumer acceptance (Table 10).

Table 10. Changes in taste of carrot juice, aloe vera gel, and cardamom extract nectar during storage

Treatment	Storage period (Days)				
	initial	30	60	90	Treatments mean
T1(Carrots Juice)	7.37	7.50	7.37	7.87	7.53^{abc}
T2(Aleo Vera gel)	7.37	6.00	6.00	6.75	6.53^{bc}
T3(Cardamom extract)	7.00	5.62	6.00	6.87	6.38^{c}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	7.25	6.50	6.75	6.75	6.81^{abc}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.75	8.25	8.37	6.87	7.81^{a}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	7.37	7.25	6.87	7.37	7.22^{abc}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	7.37	7.75	7.75	8.00	7.72^{ab}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	7.37	7.62	7.75	7.62	7.59^{ab}
	Storage period (A)	Treatment (B)	Interaction (A×B)		
F-test	NS	**	NS		
LSD0.01	.	1.19			
CV (%)	18.63				

CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01, According to LSD, 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.

Table 11 presents the odor scores of the carrot–Aloe vera–cardamom beverage formulations throughout the 90-day storage period. Statistical analysis showed that beverage formulation significantly affected odor ($p \leq 0.01$), whereas storage duration and the treatment-storage interaction had no significant influence. These findings indicate that ingredient composition played a greater role in determining aroma quality than storage duration.

Although odor scores varied during storage, the changes were generally small and differed among formulations. In T1, the odor score improved steadily from 6.75 at the beginning of storage to 8.12 after 90 days, reflecting enhanced aroma acceptability over time. In contrast, T2 declined from 7.12 initially to 6.12 at both 30 and 60 days before recovering slightly to 6.87 at the end of the storage period. A similar trend was observed in T3, where the score decreased to 6.00 after 30 days and subsequently increased to 7.12 by the 90th day.

Among the tested formulations, T7 achieved the highest mean odor score (7.97), increasing consistently from 7.62 at the start of the experiment to 8.25 after 90 days. T5 and T8 also maintained favorable aroma characteristics, with mean scores of 7.81 and 7.72, respectively. In contrast, T2 and T3 recorded the lowest mean scores (6.56), indicating comparatively lower aroma acceptability than the other formulations (Table 11).

Table 11. *Changes in odor of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)				
	initial	30	60	90	Treatments mean
T1(Carrots Juice)	6.75	7.62	7.62	8.12	7.53^{abc}
T2(Aleo Vera gel)	7.12	6.12	6.12	6.87	6.56^{c}
T3(Cardamom extract)	7.00	6.00	6.12	7.12	6.56^{c}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	7.50	6.62	6.25	7.00	6.84^{bc}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.50	8.12	8.12	7.50	7.81^{ab}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	7.62	7.50	7.25	7.25	7.41^{abc}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	7.62	8.00	8.00	8.25	7.97^{a}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	7.50	7.62	7.75	8.00	7.72^{ab}
	Storage period (A)	Treatment (B)	Interaction (A×B)		
F-test	NS	**	NS		
LSD0.01	.	1.08			
CV (%)	16.58				

CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01. According to LSD, 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.

Table 12 presents the texture scores of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. The statistical analysis revealed that beverage formulation had a highly significant effect on texture ($p \leq 0.01$). In contrast, storage duration and the interaction between treatment and storage period did not significantly influence this sensory attribute. These findings suggest that ingredient proportions played a greater role in determining texture than storage duration.

Texture scores remained relatively stable throughout storage, although slight variations were observed among the formulations. In T1, the texture score increased from 6.87 at the beginning of storage to 8.25 after 90 days, indicating improved texture acceptability over time. In contrast, T2 declined gradually from 7.75 initially to 7.00 at the end of storage. T3 exhibited only minor fluctuations, with scores ranging between 7.00 and 7.25 after an initial decrease, suggesting that its texture remained fairly consistent during storage.

Among the tested formulations, T5 achieved the highest mean texture score (7.91). Its score increased from 7.62 at the start of storage to 8.25 after 30 days, then declined slightly during the remaining storage period. T7 and T8 also maintained favorable texture characteristics, with mean scores of 7.75 and 7.72, respectively. In comparison, T4 recorded the lowest mean score (7.06), indicating comparatively lower texture acceptability than the other formulations (Table 12).

Table 12. *Changes in texture of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)				
	initial	30	60	90	Treatments mean
T1(Carrots Juice)	6.87	7.75	7.75	8.25	7.66^{ab}
T2(Aleo Vera gel)	7.75	7.25	7.00	7.00	7.25^{ab}
T3(Cardamom extract)	7.62	7.00	7.12	7.25	7.25^{ab}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	6.75	7.00	7.00	7.50	7.06^{b}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.62	8.25	8.00	7.75	7.91^{a}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	6.87	7.50	7.50	7.37	7.31^{ab}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	7.37	7.62	7.50	8.50	7.75^{ab}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	8.00	7.37	7.50	8.00	7.72^{ab}
	Storage period (A)	Treatment (B)	Interaction (A×B)		
F-test	NS	**	NS		
LSD0.01	.	0.78			
CV (%)	11.68				

CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01, According to LSD, 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.

Table 13 presents the overall acceptability scores of the carrot–Aloe vera–cardamom beverage formulations during the 90-day storage period. Statistical analysis indicated that beverage formulation significantly influenced overall acceptability ($p \leq 0.01$), whereas storage duration and the interaction between treatment and storage period had no significant effect. These findings suggest that ingredient composition was the primary factor affecting consumer acceptance of the beverages.

Although acceptability scores varied during storage, overall trends remained relatively stable across formulations. T1 showed a slight improvement in consumer acceptance, with the score increasing from 7.25 at the beginning of storage to 7.62 after 90 days. In contrast, T2 declined from 7.75 initially to 6.00 after 60 days before recovering to 7.50 at the end of the storage period. A similar trend was observed in T3, where the score decreased to 5.62 at 60 days but increased to 7.37 by the end of storage, indicating partial recovery in sensory acceptance.

Among all the formulations, T5 achieved the highest mean overall acceptability score (8.00). Its acceptability increased from 7.62 at the beginning of storage to 8.37 at 30 and 60 days, then returned to 7.62 after 90 days. T7 and T8 also received favorable ratings, with mean scores of 7.78 and 7.59, respectively, demonstrating consistently good consumer acceptance throughout the storage period. In comparison, T3 recorded the lowest mean score (6.66), reflecting comparatively lower overall sensory acceptance than the other treatments (Table 13).

Table 13. *Changes in overall acceptance of carrot juice, aloe vera gel, and cardamom extract nectar during storage*

Treatment	Storage period (Days)				
	initial	30	60	90	Treatments mean
T1(Carrots Juice)	7.25	7.37	7.37	7.62	7.41^{abc}
T2(Aleo Vera gel)	7.75	6.12	6.00	7.50	6.84^{bc}
T3(Cardamom extract)	7.62	6.00	5.62	7.37	6.66^{c}
T4(33.3% Carrots Juice + 33.3% Aleo Vera gel + 33.3% Cardamom extract)	7.37	6.87	6.75	7.25	7.06^{abc}
T5(60% Carrots Juice + 30% Aleo Vera gel + 10% Cardamom extract)	7.62	8.37	8.37	7.62	8.00^{a}
T6(70% Carrots Juice + 20% Aleo Vera gel + 10% Cardamom extract)	7.25	7.62	7.50	7.75	7.53^{abc}
T7(80% Carrots Juice + 15% Aleo Vera gel + 5% Cardamom extract)	7.25	7.87	7.87	8.12	7.78^{ab}
T8(90% Carrots Juice + 5% Aleo Vera gel + 5% Cardamom extract)	7.25	7.50	7.62	8.00	7.59^{abc}
	Storage period (A)	Treatment (B)	Interaction (A×B)		
F-test	NS	**	NS		
LSD0.01	.	1			
CV (%)	15.32				

*CV: Coefficient of Variation, LSD: Least Significant Difference, NS: Non-significant, **: P≤0.01, According to LSD, 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.*

DISCUSSION

The findings show that both beverage formulation and storage duration influenced the physicochemical and sensory characteristics of the carrot juice–Aloe vera gel–cardamom beverage. However, the magnitude of these effects differed among the evaluated parameters. Formulation, storage period, or their interaction significantly affected most physicochemical and sensory attributes. In contrast, titratable acidity and total sugar remained relatively stable throughout storage. These results suggest that although storage caused gradual changes in beverage quality, formulation played a more important role in overall product stability and consumer acceptability.

The total soluble solids (TSS) of all beverage formulations increased gradually during storage, although the extent of this increase varied among treatments. The highest TSS value (17.16 °Brix) was recorded in T1 after 90 days, whereas T5 and T8 showed the lowest final values (16.00 °Brix). The greater increase observed in T1 may be attributed to a higher rate of carbohydrate hydrolysis, resulting in the formation of soluble sugars during storage. In contrast, the blended formulations showed smaller changes in TSS, suggesting that combining carrot juice, Aloe vera gel, and cardamom extract improved beverage stability. Similar increases in TSS during storage have been reported in fruit-based beverages and have been associated with the conversion of complex carbohydrates into soluble compounds (Aware & Sanjay, 2018; S. Kumari et al., 2025; Sharma et al., 2026). Comparable observations have also been reported by (V. Kumari (2010), Moselhy et al. (2024), and Swarnalatha (2021), who noted that gradual increases in soluble solids can influence the sweetness and overall quality of stored beverages.

Titratable acidity remained unchanged at 0.30% throughout the 90-day storage period, regardless of formulation. This finding indicates that the beverages maintained a stable acid balance during storage and that no substantial acid degradation occurred. The stability of titratable acidity may be attributed to effective processing conditions, including pasteurization and preservative application, that maintain the beverage's chemical integrity. Similar findings have been reported in other fruit-based beverages stored under appropriate conditions (Ahmed & Bendantunguka, 2020). Tahmouzi et al. (2023) also suggested that stabilizing agents such as guar gum and pectin primarily improve physical stability without substantially altering acidity.

Both formulation and storage duration significantly affected beverage pH. Most formulations showed a gradual decline in pH during storage, indicating a slight increase in acidity over time. The greatest reduction occurred in the Aloe vera-based formulation (T2), whereas the blended formulations exhibited comparatively smaller changes. These results

suggest that combining carrot juice, Aloe vera gel, and cardamom extract enhanced the beverage's buffering capacity and reduced pH fluctuations during storage. Similar behavior has been reported for mixed fruit and plant-based beverages, where interactions among ingredients contribute to greater pH stability and improved storage performance (Das et al., 2025; Dongre, 2023; Tahmouzi et al., 2023).

Reducing sugar content was influenced by both formulation and storage period. Most formulations increased during the early stages of storage, particularly within the first 30 to 60 days, which may be explained by the hydrolysis of complex carbohydrates into simpler reducing sugars (Ahmed & Bendantunguka, 2020; Varshney & Mishra, 2022). T2 showed the highest reducing sugar content after 30 days, suggesting hydrolysis occurred more rapidly in this formulation. As storage continued, reducing sugar levels declined in several treatments, possibly because sugars were involved in browning reactions or other degradation processes. In contrast, T5 showed a more gradual increase throughout storage, indicating a slower, more sustained release of reducing sugars. These findings show that ingredient composition strongly influenced sugar transformations during storage, consistent with previous studies (Anand & Awasti, 2020; Nickhil et al., 2025).

Unlike reducing sugars, total sugar content was affected mainly by storage duration and showed no significant differences among formulations. Only small fluctuations were observed throughout the storage period, with a slight increase during the first 60 days followed by relatively stable values. This pattern may reflect the slow conversion of complex carbohydrates into simpler sugars over time (Varshney & Mishra, 2022). Because treatment effects were not significant, total sugar appeared to be less sensitive to formulation than individual sugar fractions. Previous studies of stored fruit beverages reported similar patterns, with gradual changes in total sugar during storage and no major differences among formulations (Ahmed & Bendantunguka, 2020; Dongre, 2023).

Formulation, storage period, and their interaction also significantly affected non-reducing sugar content. Values varied considerably among treatments and changed over time, indicating that sugar composition remained dynamic during the experimental period. Some formulations showed a decline in non-reducing sugars, while others increased, suggesting continuous conversion between sugar fractions. These changes likely reflect hydrolysis and other biochemical processes during storage, with the extent of change depending on each formulation's composition (Ahmed & Bendantunguka, 2020; Varshney & Mishra, 2022). Similar observations have been reported by (Anand and Awasti (2020) and Nickhil et al. (2025), who found that both storage conditions and ingredient composition strongly influence the transformation of sugar fractions in fruit beverages.

Sensory evaluation showed that beverage formulation significantly influenced appearance, whereas storage duration had little effect. The blended formulations maintained attractive visual characteristics throughout storage, with T7 receiving the highest appearance

score and T4 the lowest. The relatively stable appearance observed across storage suggests that the beverages retained their physical integrity without noticeable sedimentation or color separation. Differences among formulations may be related to the stability of suspended particles, pigment retention, and the interactions among the ingredients, which contributed to the visual appeal of the beverages (Hassanzadeh et al., 2023; Moselhy et al., 2024).

Color was likewise affected primarily by formulation rather than storage duration. Although minor changes occurred during storage, most formulations remained relatively stable in color. T7 and T8 received the highest color scores, whereas T3 received the lowest sensory rating. The better color retention observed in the blended formulations may be attributed to the protective effects of natural antioxidants present in carrot juice, Aloe vera gel, and cardamom extract, which may have reduced pigment degradation during storage. Similar findings have been reported in studies of functional beverages containing plant-derived ingredients, where antioxidant compounds contributed to improved color stability and consumer acceptance (Galal & Morsy, 2023; Hassanzadeh et al., 2023; Moselhy et al., 2024).

Beverage formulation significantly influenced flavor, while storage duration did not. Among the evaluated treatments, T7 achieved the highest flavor score, whereas T4 received the lowest. The relatively consistent flavor scores throughout the storage period indicate that the beverages retained their characteristic flavor profiles over time. The improved flavor of the blended formulations may be associated with the complementary effects of carrot juice, Aloe vera gel, and cardamom extract, particularly the aromatic compounds contributed by cardamom, which enhanced overall flavor perception. These observations align with previous reports showing that spice extracts and plant bioactive compounds positively contribute to flavor quality in functional beverages (Bautista-Hernández et al., 2025; Das et al., 2025; Galal & Morsy, 2023; Hassanzadeh et al., 2023).

Taste followed a similar pattern, with formulation exerting a significant influence, whereas storage duration had only a limited effect. T5 produced the highest taste score, while T3 showed the lowest level of acceptability. The relatively stable taste ratings throughout storage indicate that the balance among sweetness, acidity, and aroma was largely maintained over 90 days. The superior taste of the blended formulations likely resulted from a more balanced combination of ingredients, which improved flavor harmony and overall palatability. Comparable findings have been reported by (Bautista-Hernández et al. (2025), Galal and Morsy (2023), Hassanzadeh et al. (2023) and Moselhy et al. (2024), who observed enhanced sensory quality in beverages prepared with complementary plant-based ingredients.

Odor quality was also affected mainly by formulation rather than storage duration. T7 consistently achieved the highest odor score, while T2 and T3 received comparatively lower ratings. The relatively stable aroma throughout storage suggests that the volatile

compounds responsible for the characteristic fragrance of the beverages were largely retained during the storage period. Cardamom extract may have contributed to this stability because its essential oils provide a distinctive aroma and antioxidant properties that help preserve volatile compounds (Das et al., 2025; Galal & Morsy, 2023; Hassanzadeh et al., 2023).

Texture remained largely stable during storage and was influenced primarily by beverage formulation. T5 recorded the highest texture score, whereas T4 showed comparatively lower acceptability. The favorable texture observed in the blended formulations may be attributed to the combined effects of natural polysaccharides from Aloe vera gel and soluble components from carrot juice, which likely improved consistency and reduced structural changes during storage. Similar findings have been reported in beverages containing hydrocolloids and plant-derived stabilizing compounds, which help maintain texture and improve product stability over time (Ahmed & Bendantunguka, 2020; Das et al., 2025; Tahmouzi et al., 2023).

Overall acceptability reflected the combined influence of all sensory attributes and was affected mainly by beverage formulation. T5 achieved the highest overall acceptability score, followed closely by T7 and T8, indicating that these formulations provided the most favorable balance of appearance, color, flavor, taste, aroma, and texture. In contrast, T2 and T3 received comparatively lower ratings, suggesting that single-ingredient formulations were less preferred than blended beverages. The consistently high acceptability of T5, T7, and T8 throughout storage indicates that these formulations successfully maintained their sensory quality over time. These findings agree with previous studies showing that carefully balanced combinations of fruit juices, herbal extracts, and spices improve consumer acceptance and enhance the overall quality of functional beverages (Anand & Awasti, 2020; Nickhil et al., 2025; Paparella et al., 2024).

CONCLUSION

The results show that beverage formulation influenced physicochemical and sensory quality more than storage duration. Among the eight formulations, T5 consistently achieved the best overall performance, while T7 and T8 also exhibited favorable quality characteristics and good storage stability throughout the 90-day study.

T5 showed the most desirable balance of taste, texture, appearance, and overall acceptability, together with stable physicochemical properties. Although pH and sugar content changed slightly during storage, the beverages generally maintained acceptable quality, indicating that the selected formulations remained stable under the experimental conditions.

This study was limited by its 90-day storage period, controlled laboratory conditions, the absence of microbiological evaluation, and a relatively small sensory panel. Future research should investigate longer storage periods, different packaging systems, microbiological quality, and consumer acceptance using a larger and more diverse panel.

Overall, the findings suggest that beverages formulated with carrot juice, Aloe vera gel, and cardamom extract have strong potential as functional beverages. Among the tested formulations, T5 emerged as the most promising candidate for further product development and potential commercial application, with T7 and T8 also demonstrating favorable performance.

Author Contributions

- Rahmat Gul Hasanzai: Conceptualization, Methodology, Supervision.
- Abdul Qahar Faiz: Investigation, Data Curation, Formal Analysis, and Writing Original Draft.
- Mohammad Khalid Rashidi: Writing, Review & Editing the manuscript.
- All authors: Reviewed, revised, and approved the final manuscript.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Data Availability Statement

The data supporting the findings of this study are available within the article. Further information may be obtained from the corresponding author upon reasonable request.

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