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Nutritional enhancement and storage stability of strawberry aloe vera blended gummies

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ABSTRACT

Strawberry (Fragaria × ananassa), a nutrient-dense fruit rich in antioxidants, phenolics, and vitamin C, was combined with Aloe vera (Aloe barbadensis Miller), renowned for its bioactive compounds and medicinal properties, to develop functional gummies with enhanced nutritional value. The objective of this research was to evaluate the effect of blending strawberry and Aloe vera pulp on the nutritional composition, bioactive compounds, and antioxidant activity of gummies during storage. Six formulations with varying strawberry-to-Aloe vera ratios (100:0 to 0:100) were prepared and analyzed for mineral content, phenolics, anthocyanins, ascorbic acid, and antioxidant capacity over a 90-day storage period. One of the major challenges encountered was maintaining the stability of heat- and light-sensitive bioactive compounds, particularly ascorbic acid and anthocyanins, during processing and storage. Additionally, achieving a balanced texture and flavor profile between the acidic strawberry and the bitter Aloe vera pulp required careful formulation adjustments. Results revealed that increasing Aloe vera concentration improved calcium and antioxidant levels, while higher strawberry proportions enhanced ascorbic acid and anthocyanin content. The optimal formulation (40% strawberry, 60% Aloe vera) retained superior nutritional properties, including calcium (37.60 mg/100 g), phosphorus (14.17 mg/100 g), ascorbic acid (27.07 mg/100 g), total phenols (53.39 mg GAE/100 g), and antioxidant activity (38.99%) after storage. This study contributes to the development of shelf-stable, value-added functional gummies that effectively integrate fruit and herbal components, offering a sustainable approach to post-harvest fruit utilization and promoting consumer health through naturally enriched confectionery products.

Keywords: *Strawberry, aloe vera, gummies, mineral composition, bioactive compounds nutritional quality, post-harvest utilization.*

Introduction

Strawberry (*Fragaria × ananassa*), a temperate fruit belonging to the Rosaceae family, is globally recognized for its distinctive aroma, flavor, and high nutritional value. With approximately 98% edible portion, strawberries are consumed fresh as well as in a variety of processed products. They are particularly rich in essential micronutrients such as vitamins C and E, along with phenolic compounds. Remarkably, the vitamin C content in strawberries exceeds that of oranges. In addition to their high anthocyanin content, strawberries possess tonic, depurative, diuretic, remineralizing, and astringent properties [1]. Ripe fruits typically comprise about 90% water and 10% total soluble solids. Per 100 g of fresh fruit, strawberries contain approximately 64.0 mg of ascorbic acid, 0.61 g of protein, 0.37 g of fat, 7.02 g of carbohydrates, 2.3 g of dietary fiber, 14.0 mg of calcium, 166 mg of potassium, 27 IU of vitamin A, 0.03 g of thiamine, 0.07 g of riboflavin, and 0.06 mg of niacin [2]. They are also abundant in phytochemicals and phenolics, which contribute significantly to their antioxidant potential [3], positioning strawberries among the most antioxidant-rich fruits [4]. The principal phenolic constituents include anthocyanins, hydrolyzable tannins (ellagitannins), flavonols (quercetin, kaempferol, myricetin), flavan-3-ols (catechins and epicatechins), pelargonidin-3-glycoside, β-carotene, and melatonin [5].

Aloe vera (*Aloe barbadensis Miller*), a perennial succulent of the Liliaceae family, is adapted to arid climates through its thick, fleshy leaves capable of storing substantial water reserves, enabling survival under limited or erratic rainfall. This plant has a long history of use for medicinal and therapeutic purposes [6]. Aloe vera gel exhibits multiple biological activities, including antiviral, antitumor, antiseptic, antibacterial, anticancer, laxative, and anti-inflammatory effects. It has been reported to aid in the treatment of ailments such as dermatitis, arthritis, and oral health disorders [7]. These properties are largely attributed to polysaccharides present in the inner gel, which also confer antioxidant, anticancer, antidiabetic, antimicrobial, and immunomodulatory functions [8]. As the most commercially significant aloe species, *A. vera* is extensively processed for the food, cosmetic, and pharmaceutical industries, with its gel commonly incorporated into functional foods and health beverages. The inner gel contains up to 99% water along with glucomannans, amino acids, lipids, sterols, and various vitamins. Other bioactive constituents include enzymes, minerals, carbohydrates, lignin, saponins, salicylic acid, and amino acids [9].

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Gummies are soft, chewable confectionery products traditionally formulated using gelatin or pectin-based gels [10]. The concept gained global popularity after the introduction of gummy bears by Hans Riegel's company Haribo in Germany during the 1920s [11]. Gummies can also be prepared using agar-agar, a seaweed-derived gelling agent that imparts structure without altering flavor [12]. The final texture of gummies, ranging from soft to firm, is determined by the type and concentration of gelling agent used. Flavor and color are typically derived from fruit juices or extracts, making them versatile in both formulation and sensory appeal.

Incorporating fruits into gummy formulations aligns with consumer trends favoring healthier confectionery options. Fruit-based gummies not only deliver natural flavor and color, reducing reliance on synthetic additives, but also contribute antioxidants, vitamins, and minerals, thereby enhancing the functional and nutritional profile of the product. This approach supports the development of confectionery items that balance indulgence with health benefits, while simultaneously promoting value addition and utilization of perishable fruits.

Materials and Methods

Preparation of control gummies: For the preparation of control gummies, the gelatin was soaked in 100 ml of water for 5 minutes and then dissolved at 70º ºC for 5 minutes. Further, a sugar solution was prepared using citric acid, gelatin solution, artificial colours, and flavours. The solution was manually stirred for 15 minutes. The optimum cooking temperature was maintained at 110ºC ± 2ºC. The liquid gummy mix was poured into a silicon mould (2 ×1.5 × 1) cm and kept in the refrigerator for 6 hours at 4ºC. The gummy was then unmolded and packed in polypropylene pouches and stored at 4ºC until further analysis.

Preparation of strawberry and aloe vera blended gummies: For the preparation of strawberry and aloe vera blended gummies, the gelatin was soaked in 100 ml of water for 5 minutes and then dissolved at 70º ºC for 5 minutes. Six combinations were used viz. (T_0:containing sugar only;T_1: contains 100% strawberry + 0% aloe vera; T_2: contains 80% strawberry + 20% aloe vera; T_3: contains 60% strawberry + 40% aloe vera; T_4: 40% starwberry + 60% aloe vera; T_5: 20% strawberry + 80% aloe vera; T_6: 0% strawberry + 100% aloe vera). The sugar and gelatin solution was added to the fruit blend and cooked for 15 minutes. The citric acid was added and cooked for 5 more minutes at 110ºC ± 2ºC. The endpoint of cooking was identified using ahand refractometer for measuring the concentration of total soluble solids (TSS), which ranged from 61 to 67 per cent. The final product was molded into a silicone mold and kept in a refrigerator at 4° C for 6 hours. The gummies were then un-molded and packed in polypropylene pouches and stored at 4° C until further analysis.

Minerals and Bioactive compounds in strawberry and aloe vera blended gummies

Phosphorus: Phosphorus content was analyzed using a spectrophotometer (Labtronics LT-2900) following the yellow color method with vanadate-molybdate reagent, as described by [13]. In a 25 mL volumetric flask, 5 mL of the predigested sample was mixed with 5 mL of vanadate-molybdate reagent. The volume was then made up to 25 mL using double-distilled water. After 30 minutes, absorbance was recorded at 420 nm with a UV spectrophotometer. Phosphorus concentration was determined by comparing the absorbance values with a standard curve prepared using known concentrations of potassium dihydrogen phosphate (KH_2PO_4). The results were expressed in milligrams per 100 mL.

Calcium: 1 ml sample extract was titrated with standard EDTA (N/50) solution and ammonium perpurate (Mure oxide) as an indicator in 4 N NaOH solution. The final result is a colour change from orange-red to purple [14].

Bioactive compounds

Ascorbic acid: Vitamin C was estimated following the method described by [15], using 2,6-dichlorophenol indophenol dye. To determine the dye factor, 5 mL of standard ascorbic acid solution and 5 mL of 3% metaphosphoric acid were titrated with 2,6-dichlorophenol indophenol until a light pink color appeared and persisted for 15 seconds. The dye factor was calculated based on the volume of dye consumed. For vitamin C estimation, 10 mL of the sample was diluted to 100 mL with 3% metaphosphoric acid and filtered through filter paper. A 10 mL aliquot of the filtrate was then titrated with the dye solution until a light pink color persisted for 15 seconds.

Total phenols: Total phenolic content was measured using the Folin-Ciocalteu method as described by [16]. One gram of the sample was placed in a screw-capped vial, and 10 mL of distilled water was added. The mixture was heated at 100°C for 5 minutes to ensure adequate extraction, then cooled and filtered using filter paper. To the filtrate, 0.5 mL of Folin-Ciocalteu reagent was added, mixed thoroughly, and left to stand at room temperature for about 7 minutes. Subsequently, 1.5 mL of 20% (w/w) sodium carbonate solution was added, and the mixture was kept in the dark for 2 hours. Absorbance was then recorded at 756 nm using a UV/VIS spectrophotometer and calculated using a standard curve prepared earlier.

Anthocyanins: Anthocyanin content was determined using the method outlined by [15]. For the estimation, 10 g of gummy sample was homogenized with 10 mL of ethanolic HCl solution (prepared by mixing 95% ethanol and 1.5 N HCl in an 85:15 ratio) and transferred into a 100 mL volumetric flask. The volume was adjusted to 50 mL, and the mixture was stored at 4°C in a refrigerator overnight. It was then filtered using Whatman No. 1 filter paper and a glass funnel. The remaining residue and the container were thoroughly rinsed with ethanolic HCl, and all extracts were combined to reach a final volume of 100 mL. The absorbance of the aliquot was measured at 535 nm using a spectrophotometer, and the anthocyanin content was expressed in milligrams per 100 grams.

Antioxidant activity: The free radical scavenging activity was assessed using 1,1-diphenyl-2-picrylhydrazyl (DPPH), following the method by [17]. A reaction mixture was prepared by combining 500 µL of 0.5 M DPPH solution, 2 mL of 80% methanol (aqueous), and 25 µL of the sample's methanolic extract. The mixture was then kept in the dark for about 30 minutes at 20°C. Absorbance was measured at 517 nm using 80% methanol and Tris buffer as the blank. The free radical scavenging activity was determined by comparing the absorbance of the sample solution to that of a control, in which distilled water was used instead of the sample extract.

RESULTS AND DISCUSSIONS

***Mineral composition of strawberry and aloe vera blended gummies**:* Figure 2 shows a notable decline in the phosphorus content of the strawberry and aloe vera blended gummies across different storage intervals. The initial mean phosphorus content decreased from 8.84 mg per 100 g on the initial day of storage to 7.24 mg per 100 g after 90 days of storage. Similar observations have been reported by [18] while developing jam and fruit bars from wood apple, and they reported a loss of phosphorus content in both jam and fruit bars. The possible reason for the decrease in the mineral content is due to the heat sensitivity of such compounds at high temperatures, which causes their destruction. The results of the decrease in phosphorus content are in accordance with the findings of [19] in jamun-mango jam, [20] in dragon fruit jelly, and [21] in guava-pineapple jelly.

Calcium content of strawberry and aloe vera gummies decreased from 29.61 mg per 100 g on day zero of the storage to 28.78 mg per 100 g after 90 days of storage, which can be seen in Figure 3. The highest calcium content recorded was 48.81 mg per 100 g in treatment T_6(0:100:: Strawberry: Aloe vera) on zero day of storage and 47.98 mg per 100 g after 90 days of storage. The mean calcium content decreased from 29.61 mg per 100 g at the beginning of storage to 28.78 mg per 100 g after 90 days of storage. The results of these observations are supported by the findings of [22], [21], and [23], who observed loss of calcium content during storage of coconut jam, guava-pineapple jelly, and strawberry RTS, respectively.

Effect of blending strawberry and aloe vera on Ascorbic acid content of gummies: In the current study, the ascorbic acid concentration of strawberry and aloe vera blended gummies decreased with the addition of aloe vera. The highest ascorbic acid content was recorded in treatment T_1 (100:0::Strawberry:Aloe vera), which was 55.38 mg per 100 g, while the lowest ascorbic acid content was recorded in treatment T_0 (control), which was 2.89 mg per 100 g. The reason for the decrease in the ascorbic acid content was lower amounts of ascorbic acid in aloe vera as compared to the strawberry. Storage period also influenced the ascorbic acid content of blended gummies. There was a significant decrease in the ascorbic acid content of strawberry and aloe vera blended gummies. The ascorbic acid content significantly fell from 29.29 mg per 100 g at the start of storage to 23.99 mg per 100 g at the end of the storage period. The reduced ascorbic acid level of gummies could be attributed to oxidation by trapped oxygen, which leads to the formation of highly volatile and unstable dehydro ascorbic acid, which is further degraded to 2, 3-diketogulonic acid, and finally, the products of the conversion are furfural compounds. Additionally, a reduction in ascorbic acid might be due to the thermal destruction during the processing of gummy through heat treatment, leaching of ascorbic acid into water, and its subsequent oxidation storage [21]. [24] discovered that oxidation owing to temperature and increased enzymatic activity of fructose in vitamin-C catabolism could be responsible for its reduction. The findings of the current analysis reflect those reported by [25] in Karonda jelly and [26] in guava jam.

Effect of blending strawberry and aloe vera on total phenol content of gummies: The total phenolic contents of strawberry and aloe vera gummies decreased with the increase in the concentration of aloe vera. The highest total phenolic content was observed in treatment T_1 (100:0::Strawberry:Aloe vera), whilst the lowest total phenolic content was observed in treatment T_0 (control). Table 2 further illustrates a declining trend in the total phenolic content of the strawberry and aloe vera gummies, suggesting phenol degradation during ambient storage. Initially, the gummies contained 60.20 mg GAE per 100 g of phenolic compounds, which significantly decreased to 52.14 mg GAE per 100 g by the end of the 90-day storage period.Similar findings were reported by [27], who found that high a_w promotes reactant mobility, leading to degradation of phenolic compounds. Also, as reported by [28], gelatin's interaction with phenolic compounds may reduce their bioavailability, making polyphenols less available for hydrolysis and oxidation processes. The findings are also in conformity with the study of [29], who found that strawberry fruits had significantly higher quantities of total phenolics (1693.55 mg GAE per 100 g), followed by strawberry jam after processing (848.86 mg GAE per 100 g), and strawberry jam stored for 60 days 77.285 mg GAE per 100 g.

Effect of blending strawberry and aloe vera on anthocyanin content of gummies: The data pertaining to anthocyanin content of different treatments of strawberry and aloe vera blended gummies recorded during the entire storage of 90 days is presented in Table 3. The data showed that there was a sharp decrease in the anthocyanin content of the gummies as the concentration of aloe vera was increased. The highest anthocyanin content of 103.58 mgper100 g was observed in treatment T_1 (100:0::Strawberry:Aloe vera), whereas the lowest anthocyanin content of 0.00 mg per 100 g was recorded in both treatments T_6 (0:100::Strawberry:Aloe vera) and treatment T_0 (control) due to the absence of strawberry in the treatments. The reason for the decrease in anthocyanin content among the treatments is due to an increase in the concentration of aloe vera and a decrease in the concentration of strawberry.At the start of the storage period, the mean anthocyanin content was 49.13 mg per 100 g, which reduced to 42.01 mg per 100 g after 90 days of storage. Factors such as heating processes, high temperature, pH, acidity, phenolic compounds, enzyme activity, sugars, and light and storage duration also impact the stability of anthocyanin and can be observed in the form of colour change of the product during storage [30]. These findings are consistent with the results reported by [29], who examined the impact of processing and storage on jam, [31] in wild pomegranate aril syrup, and [32] on strawberry jam. Similarly, [33] also observed the adverse effects of storage on bioactive compounds in various jams, noting a reduction in components such as total phenols and anthocyanins across different fruit jams.

Effect of blending strawberry and aloe vera on antioxidant activityof gummies: The antioxidant activity of strawberry and aloe vera blended gummies showed a decreasing trend during the storage period. Treatment T_6 (0:100::Strawberry:Aloe vera) recorded the maximum mean antioxidant activity of 65.41 per cent, whereas minimum mean values of 0.00 per cent were recorded in treatment T_0 (control). Results regarding the mean antioxidant activity in Table 4indicate that the total antioxidant activity was statistically significant and decreased from 34.60 to 29.00 per cent with the advancement of the storage period. The loss of anthocyanin, polyphenols, and ascorbic acid during storage led to a decrease in antioxidant activity. Heat, light, and chemical degradation could cause a decrease in antioxidant levels during storage. [34]

Investigation on the antioxidant activity and quality of blended pear-jamun juice and [23] observations on antioxidant activity of strawberry RTS are in accordance with our findings. [35] and [36] reported similar observations regarding a decrease in antioxidant activity of strawberry jam during storage. The results obtained in this study are also in accordance with the findings of [29], who reported a decrease in antioxidant activity of the strawberry fruit and strawberry jam during storage.

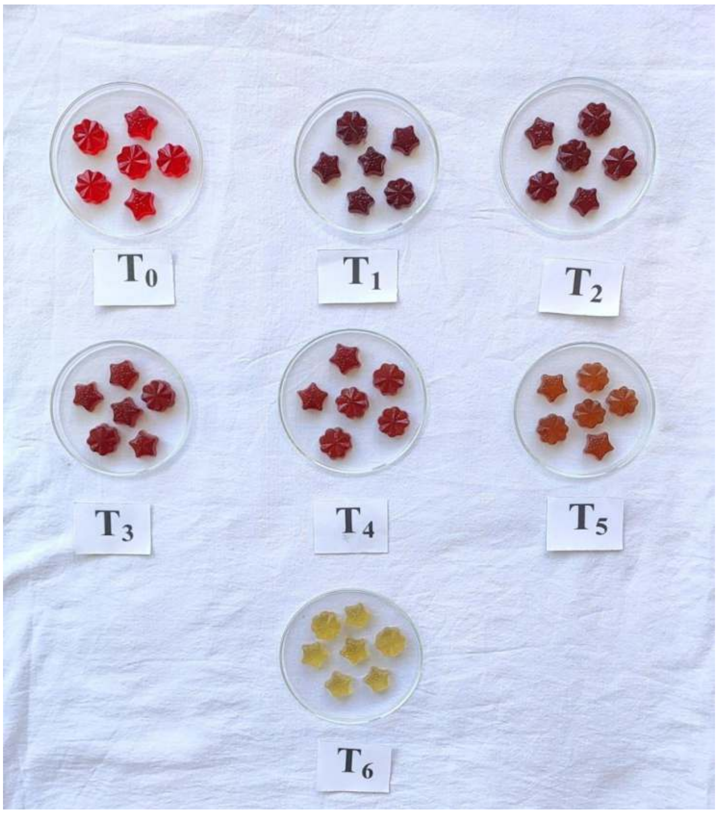

Figure 1: Different treatments of strawberry and aloe vera blended gummies

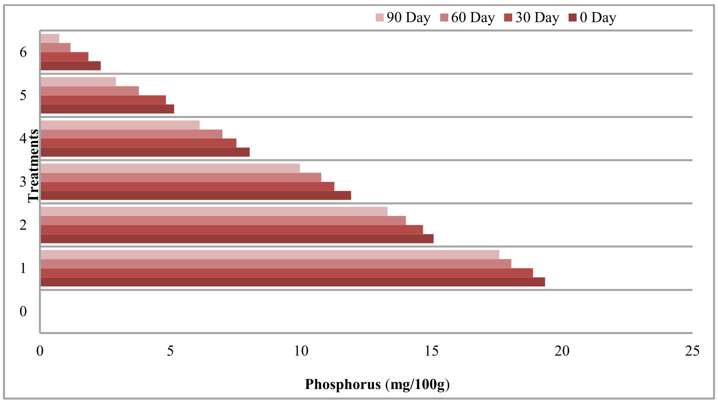

Figure 2: Phosphorus content of strawberry and aloe vera blended gummies

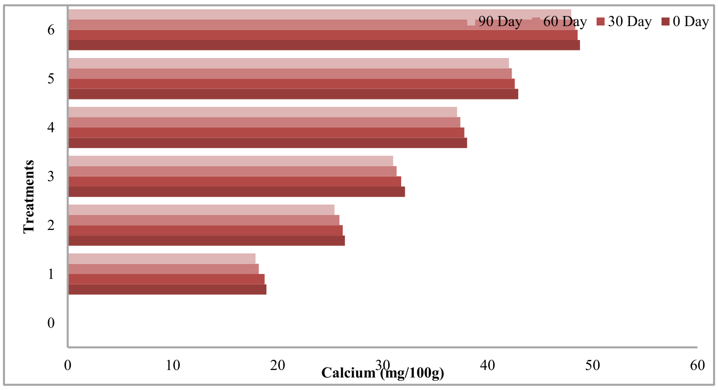

Figure 3: Calcium content of strawberry and aloe vera blended gummies

Table I: Effect of blending and storage on ascorbic acid content (%) of strawberry and aloe vera gummies

Treatment	Storage Period(Days)				
	0	30	60	90	Mean
T_0 (0:0 :: Strawberry : Aloe vera)	2.89	1.42	1.01	0.62	**1.49**
T_1 (100:0 :: Strawberry : Aloe vera)	55.38	53.94	51.29	48.83	**52.36**
T_2 (80:20 :: Strawberry : Aloe vera)	46.94	45.41	43.02	42.66	**44.51**
T_3 (60:40 :: Strawberry : Aloe vera)	37.56	35.18	32.76	30.24	**33.94**
T_4 (40:60 :: Strawberry : Aloe vera)	29.85	28.49	26.13	23.79	**27.07**
T_5 (20:80 :: Strawberry : Aloe vera)	18.63	16.2	14.87	12.31	**15.50**
T_6 (0:100 :: Strawberry : Aloe vera)	10.79	9.31	7.85	6.41	**8.59**
Mean	**28.86**	**27.14**	**25.28**	**23.55**	
CD (p<0.05)	Treatment 0.02 Storage 0.02 Treatment x Storage 0.04				

Table II: Effect of blending and storage on total phenols (mg GAE per 100 g) of strawberry and aloe vera gummies

Treatment	Storage Period(Days)				
	0	30	60	90	Mean
T_0 (0:0 :: Strawberry : Aloe vera)	2.89	1.42	1.01	0.62	**1.49**
T_1 (100:0 :: Strawberry : Aloe vera)	55.38	53.94	51.29	48.83	**52.36**
T_2 (80:20 :: Strawberry : Aloe vera)	46.94	45.41	43.02	42.66	**44.51**
T_3 (60:40 :: Strawberry : Aloe vera)	37.56	35.18	32.76	30.24	**33.94**
T_4 (40:60 :: Strawberry : Aloe vera)	29.85	28.49	26.13	23.79	**27.07**
T_5 (20:80 :: Strawberry : Aloe vera)	18.63	16.2	14.87	12.31	**15.50**
T_6 (0:100 :: Strawberry : Aloe vera)	10.79	9.31	7.85	6.41	**8.59**
Mean	**28.86**	**27.14**	**25.28**	**23.55**	
CD (p<0.05)	Treatment 0.03 Storage 0.03 Treatment x Storage 0.07				

Table III: Effect of blending and storage on anthocyanin content (mg per 100 g)of strawberry and aloe vera gummies

Treatment	Storage Period(Days)				
	0	30	60	90	Mean
T_0 (0:0 :: Strawberry : Aloe vera)	2.89	1.42	1.01	0.62	**1.49**
T_1 (100:0 :: Strawberry : Aloe vera)	55.38	53.94	51.29	48.83	**52.36**
T_2 (80:20 :: Strawberry : Aloe vera)	46.94	45.41	43.02	42.66	**44.51**
T_3 (60:40 :: Strawberry : Aloe vera)	37.56	35.18	32.76	30.24	**33.94**
T_4 (40:60 :: Strawberry : Aloe vera)	29.85	28.49	26.13	23.79	**27.07**
T_5 (20:80 :: Strawberry : Aloe vera)	18.63	16.2	14.87	12.31	**15.50**
T_6 (0:100 :: Strawberry : Aloe vera)	10.79	9.31	7.85	6.41	**8.59**
Mean	**28.86**	**27.14**	**25.28**	**23.55**	
CD (p<0.05)	Treatment 0.24 Storage 0.13 Treatment x Storage 0.08				

Table IV: Effect of blending and storage on antioxidant activity (%)of strawberry and aloe vera gummies

Treatment	Storage Period(Days)				
	0	30	60	90	Mean
T_0 (0:0 :: Strawberry : Aloe vera)	0.00	0.00	0.00	0.00	**0.00**
T_1 (100:0 :: Strawberry : Aloe vera)	16.63	15.08	14.76	13.17	**14.91**
T_2 (80:20 :: Strawberry : Aloe vera)	25.19	23.61	21.78	18.05	**22.16**
T_3 (60:40 :: Strawberry : Aloe vera)	33.40	32.98	30.52	27.68	**31.15**
T_4 (40:60 :: Strawberry : Aloe vera)	42.68	40.36	37.88	35.03	**38.99**
T_5 (20:80 :: Strawberry : Aloe vera)	55.31	53.07	51.17	47.58	**51.78**
T_6 (0:100 :: Strawberry : Aloe vera)	69.02	66.82	64.34	61.46	**65.41**
Mean	**34.60**	**33.13**	**31.49**	**29.00**	
CD (p<0.05)	Treatment 1.14 Storage 0.13 Treatment x Storage 0.07				

CONCLUSION

Thus, based on the scientific data from the current experiment, it was concluded that high-quality healthy gummies can be made using 40 per cent strawberry pulp and 60 per cent aloe vera pulp. The formulated gummies recorded more calcium (37.60 mg/100 g), phosphorus (14.17 mg/100 g), ascorbic acid (27.07 mg/100 g), total phenols (53.39 mg/100 g), and antioxidant activity (38.99%) than T_0 (control). As a result, the proposed technique enables the commercial manufacture of strawberry and aloe vera blended gummies, providing effective usage and higher profits for growers and processors. This innovation addresses consumer demand for nutritious food, lowers post-harvest losses, and provides economic potential.

Future scope of the study

Future research on strawberry–Aloe vera gummies could focus on enhancing their functional profile by incorporating other bioactive-rich ingredients, evaluating clinical health benefits, and exploring natural, low-calorie sweeteners for diabetic-friendly versions. Further work may optimize shelf life through advanced packaging, assess large-scale consumer acceptance, and investigate sustainable processing by utilizing by-products. Such efforts would support the commercialization of nutrient-rich, functional confectionery with broad market appeal.

DECLARATION

The authors declare that there is no conflict of interest.

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