Utilization of aloe vera gel and mango powder in the preparation of instant beverage mix: Physicochemical, phytochemical, and antioxidant analyses

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Abstract

This study aimed to develop an instant beverage mix using aloe vera gel powder and mango powder, evaluating its physicochemical, antioxidant, microbial, and sensory characteristics. The instant beverage mix formulation included six treatments: T0 (100% mango powder) and T1, T2, T3, T4, and T5 containing 5%, 10%, 15%, 20%, and 100% aloe vera gel powder, respectively. Proximate analysis of aloe vera and mango powder showed them to be a good source of ash, fiber, and protein contents. Similarly, proximate and mineral analysis of the beverage mix revealed a significant increase in ash, fiber, sodium (Na), potassium (K), phosphorus (P), and zinc (Zn) content in the formulations having high proportion of aloe vera powder. The results further showed that formulations with increased aloe vera gel powder levels had enhanced antioxidant activity and total phenolic content, indicating improved functionality. Sensory evaluation revealed that treatments containing balanced ratios of aloe vera and mango powder (T2 and T3) were the most acceptable, with superior flavor, appearance, and the overall acceptability. In conclusion, aloe vera- and mango powder-based instant beverage mixes present a potential for functional beverage development, which could provide significant health benefits. The future studies should focus on shelf-life stability and *in vivo* analysis of these formulations.

Keywords: antioxidant capacity; functional beverage; nutritional contents; plant powders; sensory analysis

Introduction

In recent years, the use of natural substances to increase the bioavailability and effectiveness of medications and biologically active molecules has turned more popular (Hussain *et al.*, 2023a, 2023b). Medical plant aloe vera (*Aloe barbadensis* Miller) is increasingly considered as a potential bioenhancer (Kirdeeva *et al.*, 2022). Aloe vera is praised for its medicinal benefits because it contains various bioactive substances having nutritional qualities, including minerals, vitamins, and enzymes. When processed into powder form, these favorable elements are available in a concentrated form (Gorsi *et al.*, 2024; Kothawade *et al.*, 2023; Raza *et al.*, 2024). Several pharmacological properties of aloe vera include antioxidant, protective against digestive disorders, antidiabetic, cardioprotective, skin and bone protective, anticancer, antibacterial, and prebiotic (Djarkasi *et al.*, 2021; Sánchez *et al.*, 2020). Aloe vera is unique among the magical flora discovered in the world's abundant natural flora. Aloe vera has significantly improved our understanding about the wellness of mankind. Additionally, aloe vera is used commercially for producing bioethanol (Iqbal and Ahmed, 2023). Aloe vera contains several bioactive components, such as polyphenols, sterols, and carotenoids, that make it beneficial for treating a variety of ailments (Asif *et al.*, 2023; Sánchez *et al.*, 2020). Therefore, utilization of aloe vera powder in different food formulations may prove helpful in improving functionality and health promoting potential of such formulated food products.

Mango fruit (*Mangifera indica* Linn) is rich in minerals, fiber, macro- and micronutrients, and vitamin C. It also contains a lot of bioactive elements, including carotenoids, especially β-carotene, and polyphenols (Shoukat *et al.*, 2024: Hussain *et al.*, 2024b, 2024c). Consuming mangos improves vascular health because the fruit reduces the expression of adhesion molecules (Castro *et al.*, 2023). A lot of health supplement products are available in the form of drugs and pills, but very few are prepared from mangoes. Furthermore, no product on the market is available that uses mangoes as a source of phytonutrients, such as polyphenols. Although a wide range of supplements and functional food formulations are available on the market containing powders and extracts of medicinal plants, the use of mango is limited in this regard (Bahri *et al.*, 2021; Lebaka *et al.*, 2021). According to recent studies, consumption of foods rich in antioxidants and polyphenols, such as ascorbic acid, β-carotene, quercetin, and kaempferol, is associated with body's resistance to bacterial and viral infections (Djarkasi *et al.*, 2021; Hussain *et al.*, 2023b). Mango is also a good source of such bioactive components. Various research findings suggest that consumption of mangoes has health-promoting effects (Albaayit, 2024; Castro *et al.*, 2023; Lebaka *et al.*, 2021; Pérez-Meza *et al.*, 2024); therefore, utilization of mango powder for preparing instant beverage mix powder could be beneficial for the nourishment of body.

Aloe vera can be combined effectively with other plant materials and juices to create refreshing and health-promoting beverages (Tahosin *et al.*, 2024). One such blend is aloe vera and mango juice, which merges the soothing properties of aloe vera with rich flavor and nutrients of mango. This drink prepared by mixing aloe vera gel and mango pulp or extract offers a unique taste along with various health benefits (Afifah *et al.*, 2022). Studies suggest that mango and aloe vera beverage has the potential to serve as a functional fruit beverage, provided the formulation maintains physiological stability and shelf life without compromising its sensory attributes (Fatima *et al.*, 2023; Siddique *et al.*, 2023; Wibowo *et al.*, 2018). Aloe vera gel, known for its antimicrobial properties, is applied as a coating to extend the shelf life of mangoes, indicating its potential as a preservative ingredient in mango-based beverage formulations (Kundu *et al.*, 2020). Moreover, bioactive compounds in aloe vera enhance the nutritional and antioxidant profile of fruits (Sherani *et al.*, 2021). Additionally, instant mango drink powders have strong consumer appeal and microbiological stability (Badsha *et al.*, 2020), supporting the development of a nutrient-rich aloe vera–mango beverage mix. The increasing demand for nutritious and convenient drinks has driven interest in instant beverage mixes. However, many commercial options rely on synthetic additives that reduce their appeal to health-conscious consumers. Natural ingredients such as aloe vera gel and mango powder offer healthier alternatives that provide essential nutrients and functional benefits. Aloe vera is valued for its therapeutic properties, while mango powder contributes natural sugars, vitamins, and minerals. Despite having health benefits, their combined use in instant beverages is still limited. This study aimed to develop an aloe vera gel–mango powder-based instant beverage mix and evaluate its nutritional, physicochemical, and sensory properties. The goal was to create a shelf-stable health-enhancing product with balanced taste, texture, and functional value.

Materials and Methods

All plant materials used in this study are cultivated and therefore no permission was required for their use. However, national/international guidelines/protocols were followed for their safe use.

Procurement of raw materials

Mangoes, sugar, salt, and glucose powder were bought from the local Multan (Punjab, Pakistan) market for use in this study, while aloe vera leaves were directly collected from the fields of the MNS University of Agriculture, Multan, Pakistan. Mangoes and aloe vera leaves were carefully cleaned before being dried in a hot air oven at the B block laboratory of the MNS University of Agriculture, Multan. The MNS-UAM Central Lab System and the Department of Human Nutrition and Dietetics provided all necessary chemicals and reagents procured from Aladdin Chemicals, Shanghai, China. It was assured that the same trade/brand of chemicals and ingredients were used for product development and analysis to avoid any variation in results.

Proximate analysis of aloe vera powder, mango powder, and beverage powder

Proximate analysis, such as crude protein, crude fat, crude fiber, moisture, and ash, was performed on aloe vera gel and mango powder in accordance with the protocol outlined in the official methods of Association of Official Analytical Chemists (AOAC, 2016).

Moisture analysis

To measure the moisture content of aloe vera gel, mango powder, and beverage powder, samples were prepared in triplicate. The moisture content was analyzed by taking 5-g sample of aloe vera gel and mango powder in a China dish, dried in a hot air oven at 105°C. The dried samples were cooled by placing in a desiccator. The China plates were taken out of the desiccator and weight of samples were measured on weighing balance. The moisture percentage of aloe vera and mango powders was calculated by using the method suggested by AOAC (2016).

Ash determination

The ash percentage of aloe vera gel, mango powder, and beverage powder was calculated by using the method suggested by AOAC (2016). For purpose of charring, measured weights of crucibles were noted. In all, 5 g of pulverized sample was charred by heating in a porcelain dish on a spirit lamp until the temperature reached a point where the sample turned entirely black without emitting smoke. After charring, crucibles were placed in hot air oven to remove remaining moisture. The crucibles were weighed and placed in a muffle furnace, which was heated to 650°C for 5 h. Then the muffle furnace was turned off and left to cool. It took few hours to stabilize it to normal temperature. The crucibles were taken out of the muffle furnace to cool down and placed in a desiccator. Finally, the samples were removed from the desiccator and weight was recorded and calculated by following the method suggested by AOAC (2016). Samples in triplicate were accomplished for the calculation of ash percentage.

Crude fat content

Samples of aloe vera gel, mango powder, and beverage powder were tested for crude fat content using Soxhlet apparatus as described in the AOAC (2016). Pre-weighed samples were placed in a filter paper thimble and weighed again. Then 350 mL of petroleum ether was added to the extraction unit, and the flask was set on the apparatus. The heating system was turned on when the thimble was placed in the thimble jacket. The system was allowed to cool once washing was finished and the heating was stopped. The thimble was removed from the tool and dried in air. The dried thimble was heated in a hot air oven at 70°C for 20–30 min to get rid of any remaining moisture. The dried thimble was taken out of oven and placed in a desiccator for cooling. Finally, the dried thimble was weighed.

Crude fiber content

In order to calculate crude fiber, 3 g each of aloe vera gel, mango powder, and beverage powder were selected and 1.25% H_2SO_4 was used in the digestion process that lasted for 30 min. In a beaker, 0.255-N H_2SO_4 was dissolved in 200-mL of distilled water. A magnetic stirrer was placed in the beaker and heated on a hot plate. The hot plate's temperature and rotating speed were adjusted as per the procedure. The material was filtered through a muslin cloth following H_2SO_4 digestion. To confirm the complete removal of H_2SO_4, the filtrate was meticulously washed thrice with distilled water. Subsequently, the filtrate was placed in a separate digestion flask containing 200 mL of distilled water and NaOH (0.313 N). It took another 30 min for the second digestion. After second digestion, the previous process was used to filter the sample. The filtrate was weighed prior to heating in an oven at 110°C with hot air to maintain a consistent weight. The sample was chilled in a desiccator and weighed to ascertain its final weight. The dried sample was placed in a crucible and fired in a muffle furnace for 5 h at 650°C. Post-heating, the sample was weighed again. The AOAC (2016) procedure was used to collect all samples in triplicate. The crucible was placed in a muffle furnace for 3 h and crude fiber for each sample was calculated.

Crude protein content

The crude protein percentage of aloe vera gel, mango powder, and beverage powder was determined using the Kjeldahl's method as recommended by AOAC (2016). The process involved three steps: digestion, distillation, and titration. For digestion, 2 g of each sample, 2 g of digestion tablets, and 20 mL of concentrated H_2SO_4 (98%) were added in a digestion tube. The mixture was heated until a translucent residue was formed, which took 3–4 h. After cooling, the digested sample was diluted with distilled water to a final volume of 250 mL. During digestion, organic nitrogen was converted to ammonium ions. Following digestion, the diluted sample underwent distillation using a Kjeldahl's distillation unit. Ammonium ions were converted to ammonia with NaOH, and the released ammonia was collected in a 4% boric acid solution containing methyl red indicator, which turning the solution pink. For titration, 10 mL of the boric acid solution was titrated with 0.1-N H_2SO_4 until the solution turned pink from white, indicating the endpoint. The volume of H_2SO_4 used was recorded to calculate the protein content of all samples.

Treatment plan and physicochemical analysis of beverage powder

Beverage mix was produced by utilizing different ratios of aloe vera gel powder and mango powder as per treatment plan shown in Table 1. This beverage mix was then used for analyses.

Determination of pH

Samples of instant beverage mix were homogenized in a homogenizer with 50 mL of distilled water for 1 min at 8,000 rpm. The pH was ascertained by dipping the glass electrode of pH meter into the sample (Siddique *et al.*, 2024).

Total phenolic content

The total phenolic content (TPC) was determined based on the reaction of Folin–Ciocalteu reagent with the test sample. A blue chromophore is produced due to the reduction of phosphotungstic and phosphomolybdic acids in an alkaline media in the presence of phenolic compounds. First, 500 mL of distilled water was added to 125 mL of aqueous extract in a thoroughly clean test tube. Then, 125 mL of Folin–Ciocalteu reagent was added into the above test tube and the contents were allowed to stand for 6 min. Then 1.25 mL of 7% sodium bicarbonate ($NaHCO_3$) was added to the mixture. Following that, 3 mL of distilled water was added to prepare the final volume, and the reaction was allowed to operate for 1–1.5 h. Finally, the absorbance of both standard and sample was measured at 760 nm using an ultraviolet (UV)-visible spectrophotometer (Hussain *et al.*, 2021).

Table 1. Treatments using different proportions of mango powder and aloe vera powder.

Treatments	Mango powder (%)	Aloe vera powder (%)
T0	100	–
T1	95	5
T2	90	10
T3	85	15
T4	80	20
T5	–	100

T0: Treatment with 100% mango powder.
T1: Treatment with 95% mango powder and 5% aloe vera powder.
T2: Treatment with 90% mango powder and 10% aloe vera powder.
T3: Treatment with 85% mango powder and 15% aloe vera powder.
T4: Treatment with 80% mango powder and 20% aloe vera powder.
T5: Treatment with 100% aloe vera powder.

DPPH free-radical scavenging activity analysis

1,1-Diphenyl-2-picrylhydrazyl (DPPH) is essentially an immobile radical of dark red color. An antioxidant's color changes from red to yellow at a wavelength of 515 nm when its free radicals are removed. For this, 4 mg of DPPH was dissolved in methanol to create DPPH reagent. Then, 50 mL of the sample was added to 2 mL of DPPH reagent. The mixture was vigorously shaken and allowed to cool at room temperature in the dark. Finally, the absorbance was determined at a wavelength 515 nm using a UV-visible spectrophotometer (Hussain *et al.*, 2021).

Determination of mineral content

By following the protocols described by Hussain *et al.* (2021), in order to determine minerals, 1 g of sample of each instant beverage mix was placed in a 100-mL beaker. Then, 7 mL of HNO_3 was added to the beaker and the solution was allowed to stay overnight. Then, the solution in the beaker along with 3 mL of $HClO_4$ was placed on a hot plate for digestion at a temperature of 180°C. When roughly 2–3 mL of solution was left, the hot plate was turned off. The beaker was allowed to cool. After cooling, digested sample was diluted with 100 mL of distilled water. Dilution was done in triplicate by adding up to 100-mL distilled water (AOAC, 2016). The prepared dilution was used to determine mineral profile (potassium, sodium, and calcium) by using a flame photometer. An atomic absorption spectrophotometer was used to access heavy metals such as iron and zinc.

Determination of color parameters

For an objective color assessment (L*, a*, and b*), each powder sample was standardized into two 2.54-cm thick steak samples. A colorimeter was used to analyze the colors of beverage samples in accordance with the method described by Hussain *et al.* (2024a). L*, a*, and b* assessment was conducted by placing each sample below the colorimeter's color sensor. Assessment of L* was obtained in the range of 0–100, illustrating the samples lightness and darkness. If a* has positive results, red color is indicated and if a* has negative results, green color appears. Assessment of a* was noted in the positive or negative range of 0–60. In case b* has a positive value, blue color is shown but in case of a negative value, yellow color is presented.

Sensory evaluation

Sensory evaluation of beverage mix samples was conducted at MNS-University of Agriculture, Multan, Pakistan, with the help of teachers and students. This was done to check the acceptability of beverage mix for color, flavor, taste, appearance, and the overall acceptability on a 9-point hedonic scale, as described by Rafique *et al.* (2023). Briefly, an untrained panel of 35 evaluators, irrespective of gender (volunteers from the department where trials were conducted), having an average age of 25–35 years, were involved in sensory evaluation done from December 10, 2023, to January 20, 2024. Informed verbal consent was obtained from all participants and was recorded for evidence.

Statistical analysis

The Statistix 8.1 software was used to evaluate the study data. One-Way ANOVA was the statistical test employed for the analysis of variance. For all cases, the statistical significance was set at $p < 0.05$. The data for every analysis were collected in duplicate and reported as mean + standard deviation (SD). The Latin Square Design test was used for comparison of mean values.

Results and Discussion

Proximate analysis of aloe vera powder

The data presented in Table 2 show that aloe vera powder contains 6.97% moisture, 20.52% crude protein, 0.41% crude fat, 14.93% crude fiber, and 18.32% ash. These findings aligned with the results reported by Das *et al.* (2019), observing 7.65% moisture and 22.23% crude protein in aloe vera powder. Similarly, the crude fiber content was consistent with the results of Hamman (2008), who reported 16.25% crude fiber in aloe vera powder, while the crude fat content (0.41%) also matched Hamman *et al.*'s (2008) reported value of 0.59%. Additionally, the ash content (18.32%) closely matched Hamman *et al.*'s (2008) findings of 19.83%, demonstrating strong agreement between the current study and previous research. Aloe vera powder is considered a good source of protein, fiber, and ash. Thus, its utilization in different food and non-food formulations is proved beneficial because of these nutritional contents (Gorsi *et al.*, 2024). In agreement with the current results, Mali and Swami (2024) provided similar findings for ash, fiber, protein, fat, and moisture contents of aloe vera gel powder at different drying temperatures by using connective drying method. Our findings also aligned with the studies involving aloe vera-fortified bread, where improved nutritional profiles of bread were reported; this confirmed aloe vera's potential as a functional ingredient because of the presence of similar proportions of protein, fiber, and ash (Raza *et al.*, 2024).

Proximate analysis of mango powder

The data presented in Table 3 show that mango powder contains 5.04% moisture, 4.05% crude protein, 1.21% crude fat, 11.30% crude fiber, and 3.80% ash. These results revealed that mango powder could be considered a good source of ash and fiber. These findings aligned with the results reported by Baddi *et al.* (2015), observing a moisture content of 7.84% and ash content of 4.70% in mango powder. Similarly, the crude protein content (4.05%) was consistent with the findings of Vergara-Valencia *et al.* (2007), reporting 6.01% protein contents in mango powder. The crude fiber content (11.30%) closely matched the value of 10.16% reported by Ajila *et al.* (2007). Additionally, the crude fat content (1.21%) also aligned with the results reported by Ajila *et al.* (2007), who discovered fat content as 2.60%, demonstrating agreement between the current study and previous research. This nutritional composition of mango powder was in strong agreement with the findings of Lebaka *et al.* (2021). Mango pulp dried powder is a healthy ingredient of food formulations as this is a rich source of fiber, ash, and proteins (Hussain *et al.*, 2024c). The proximate composition of mango powder is influenced by several factors, particularly the maturity stage and cultivation conditions. Our findings were in accordance with those provided by Albaayit (2024), reporting similar contents of moisture, fat, fiber, ash, and protein. Furthermore, the authors also reported that with the ripening of mangoes, notable changes occur in moisture content, carbohydrate levels, and other proximate components, ultimately affecting nutritional value and sensory properties. Similar to the results of the current study, Nguyen *et al.* (2025) also

Table 2. Proximate analysis (%) of aloe vera powder.

Parameters	Results (%)
Moisture	6.97±0.45
Crude protein	20.52±0.50
Crude fat	0.41±0.20
Crude fiber	14.93±0.50
Ash	18.32±0.71

Table 3. Proximate analysis (%) of mango powder.

Parameters	Results (%)
Moisture	5.04±0.03
Crude protein	4.05±0.04
Crude fat	1.21±0.06
Crude fiber	11.30±0.22
Ash	3.80±0.31

observed that mango powder contains good amounts of ash, fiber and proteins.

Proximate composition of instant beverage mix powder

The results presented in Table 4 highlight the proximate composition of instant beverage mix powder formulated with varying ratios of mango powder and aloe vera powder, demonstrating significant variations in moisture, ash, crude protein, crude fat, and crude fiber contents. It was revealed that treatments with higher proportions of aloe vera powder exhibited higher moisture levels because of the gel-like disposition of aloe vera. The control treatment with 100% mango powder (T0) had a moisture content of 5.63±0.43%, whereas T5 (100% aloe vera powder) showed the highest moisture level at 6.42±0.41%. Mixed treatments showed a nonlinear pattern, with T3 (85% mango powder and 15% aloe vera powder) achieving the lowest moisture content (3.59±0.51%). These findings aligned with the results reported by Barbosa Gámez *et al.* (2017), reporting high moisture in aloe vera gel (97.42%), compared to mango pulp (85%), explaining the observed variations. These findings also matched the results of Mishra and Sangma (2017), who developed aloe vera and mango-based beverage mix. Ash content analysis indicated that increasing content of aloe vera powder significantly increased ash content because of its inherently rich mineral profile. The highest ash content (0.98±0.02%) was observed in treatments T3 and T4, while the control treatments, T0 (100% mango powder) and T5 (100% aloe vera powder), exhibited lower ash levels of 0.47±0.06% and 0.50±0.05%, respectively. These findings corroborated the results of Akhter *et al.* (2010), demonstrating a lower ash content in instant mango drink powder without aloe vera. The inclusion of aloe vera in the current study significantly enhanced the ash content, highlighting its potential to improve the mineral profile of beverage powders.

Crude protein content showed significant variation across treatments. The highest protein content was recorded in T1 (95% mango powder and 5% aloe vera powder) and T2 (90% mango powder and 10% aloe vera powder) at 5.44±0.05% and 5.50±5.50%, respectively. Protein content slightly decreased in treatments with higher proportion of aloe vera, such as T3 (85% mango powder and 15% aloe vera powder) and T4 (80% mango powder and 20% aloe vera powder), at 5.02±0.06% and 4.74±0.40%, respectively. The control treatment T5 (100% aloe vera powder) exhibited the lowest protein content (4.40±4.40%). These results aligned with Akhter *et al.*'s (2010) findings, who reported negligible protein content in pure mango drink powder, indicating that aloe vera enhanced protein levels.

Crude fat content was generally low across all treatments, with T3 (85% mango powder and 15% aloe vera powder) showing the highest value at 0.32±0.02%. Other treatments, such as T0 (100% mango powder), T1 (95% mango powder and 5% aloe vera powder), and T4 (80% mango powder and 20% aloe vera powder), exhibited fat contents ranging from 0.12±0.01% to 0.21±0.1%. Aloe vera's inclusion resulted in slight variations, indicating its limited effect on fat content. These findings aligned with the results of Akhter *et al.* (2010), who also reported low fat content in mango drink powders.

Crude fiber content showed that the control treatments T0 and T5 had the highest fiber levels (14.00±0.46%). Mixed treatments demonstrated reduced fiber content, with T3 (85% mango powder and 15% aloe vera powder)

Table 4. Proximate composition (%) of instant beverage mix powder.

Treatments	Moisture	Ash	Crude protein	Crude fat	Crude fiber
T0	5.6±0.4^{b}	0.5±0.1^{c}	4.5±0.5^{b}	0.2±0.1^{b,c}	14.0±0.5^{a}
T1	5.0±0.5^{b}	0.8±0.1^{b}	5.4±0.1^{a}	0.1±0.0^{d}	11.0±0.3^{b}
T2	4.2±0.1^{c}	0.9±0.0^{b}	5.5±0.1^{a}	0.2±0.0^{b}	10.0±0.2^{c}
T3	3.6±0.5c	1.0±0.0a	5.0±0.1^{ab}	0.3±0.0a	3.9±0.3e
T4	4.1±0.2^{c}	1.0±0.0^{a}	4.7±0.4^{b}	0.1±0.0^{c,d}	7.0±0.1^{d}
T5	6.4±0.4^{a}	0.5±0.1^{c}	4.4±0.1^{b}	0.1±0.0^{d}	14.0±0.5^{a}
Total	4.7±0.3	0.8±0.0	5.0±0.1	0.2±0.0	9.2±0.3

Mean values in a row with the same superscript alphabetical letters are statistically nonsignificant ($p < 0.05$), and values that have different superscript alphabetical letters are statistically significant (One-Way ANOVA).
T0: Treatment with 100% mango powder.
T1: Treatment with 95% mango powder and 5% aloe vera powder.
T2: Treatment with 90% mango powder and 10% aloe vera powder.
T3: Treatment with 85% mango powder and 15% aloe vera powder.
T4: Treatment with 80% mango powder and 20% aloe vera powder.
T5: Treatment with 100% aloe vera powder.

recording the lowest value (3.86±0.26%). Slight increase in fiber content in T4 (80% mango powder and 20% aloe vera powder) to 7.00±0.08% suggests that mango powder contributes significantly to fiber content. These findings differed from that of Anwar *et al.* (2020), who reported lower fiber levels in fresh mango pulp and aloe vera gel. Higher fiber levels in the current study reflected the concentration effect during drying process, consistent with the findings of Akhter *et al.* (2010). These results underscored the impact of processing and formulation on the nutritional composition of beverage powders. Furthermore, another relevant work of Farzana *et al.* (2017) showed similar findings, as a vegetable mix beverage powder was demonstrated as a good source of ash, fiber, and protein contents. Findings of Afifah *et al.* (2022) also matched the present results, as the authors also supported this chemical composition of beverage mix. Mango-based drinks serve as a convenient and palatable means to deliver the nutritional benefits of mangoes, particularly because of their rich carbohydrate and moisture contents while also offering notable amounts of ash, fiber, and protein (Olufemi *et al.*, 2024). Our findings were also supported by the studies that explored the incorporation of aloe vera juice into yoghurt drinks, where similar improvements in the physicochemical attributes of yoghurt were observed (Naz *et al.*, 2025).

Table 5. Physicochemical and antioxidant analysis of beverage.

Treatments	DPPH (%)	TPC (mg GAE/g)	pH
T0	76.7±0.5^{c}	31.3±0.3^{a}	3.5±0.02^{c,d}
T1	75.3±0.1^{d}	19.9±0.2^{e}	3.6±0.01^{c}
T2	73.2±0.3^{e}	17.8±0.04^{f}	3.8±0.01^{b}
T3	78.3±0.2^{a}	26.9±0.2^{b}	3.5±0.01^{d}
T4	76.3±0.5^{c}	21.6±0.1^{d}	3.4±0.02^{e}
T5	77.6±0.5^{b}	24.6±0.2^{c}	4.7±0.03^{a}
Total	76.1±0.3	22.2±0.2	3.8±0.02

Mean values in a row that have the same superscript alphabetical letters are statistically nonsignificant ($p < 0.05$) and values that have different superscript alphabetical letters are statistically significant (One-Way ANOVA).
T0: Treatment with 100% mango powder. GAE: gallic acid equivalent.
T1: Treatment with 95% mango powder and 5% aloe vera powder.
T2: Treatment with 90% mango powder and 10% aloe vera powder.
T3: Treatment with 85% mango powder and 15% aloe vera powder.
T4: Treatment with 80% mango powder and 20% aloe vera powder.
T5: Treatment with 100% aloe vera powder.

Physicochemical and antioxidant analysis of beverage

The data shown in Table 5 indicate that aloe vera enhances the antioxidant activity of the beverage, as measured by DPPH (%) values. The control treatment (T0) with 100% mango powder exhibited a strong antioxidant activity of 76.72±0.49%, while the inclusion of 15% aloe vera powder in T3 resulted in the highest DPPH value of 78.27±0.15%. These findings suggest that a moderate inclusion of aloe vera enhances the beverage's antioxidant properties. However, treatments with lower aloe vera proportions (T1 and T2) showed decreased DPPH values, probably because of a dilution effect. Notably, T4 (20% aloe vera powder) had a DPPH value close to the control, indicating aloe vera's ability to compensate for initial dilution at higher concentrations. These findings aligned with the results provided by Taukoorah and Mahomoodally (2016), highlighting variations in antioxidant activity based on the form of ingredients used. This increased antioxidant activity of beverage mix was also in accordance to the findings of Mishra and Sangma (2017), as their study also witnessed higher vitamin C contents in aloe vera and mango-based beverage mix.

Table 5 also shows that the TPC (mg gallic acid equivalent [GAE]/g) of the beverage decreased with increasing proportions of aloe vera. The control treatment (T0) displayed the highest TPC value of 31.33±0.31%, demonstrating the phenolic richness of mango powder. Among mixed treatments, T3 (15% aloe vera powder) maintained a relatively high TPC of 26.90±0.2%, while lower aloe vera proportions (T1 and T2) showed significantly reduced TPC values. The TPC increased slightly in T4 (20% aloe vera powder) and T5 (100% aloe vera powder), indicating aloe vera's phenolic contribution, although it remained less significant than mango powder. These results aligned with the studies conducted by Taukoorah and Mahomoodally (2016), who reported similar trends based on the ingredient forms, and the study done by Obilana *et al.* (2018), who observed comparable patterns in their research as beverage powder developed from cereal flours was also determined high in antioxidant activity. Vitamins (A, C, E, and B12), enzymes, minerals (zinc, copper, selenium, and calcium), sugars, anthraquinones (aloin and emodin), fatty acids, hormones (auxins and gibberellins), and other substances such as salicylic acid, lignin, and saponins, are just a few of the numerous bioactive substances discovered in aloe vera (Sánchez *et al.*, 2020). The antioxidant potential demonstrated by beverage mixes, including aloe vera powder, is strongly influenced by many of these bioactive substances.

The data in Table 5 reveal significant variations in the beverage's pH values based on ingredient proportions. The control (T0) had a pH of 3.53±0.02, reflecting the acidic nature of mango powder. Aloe vera powder, being less acidic, resulted in higher pH values in treatments T1 (3.56±0.01) and T2 (3.77±0.01). However, higher aloe vera proportions in T3 (3.50±0.01) and T4 (3.44±0.02) resulted in increased acidity, probably because of complex interactions between ingredients. T5 (100% aloe vera powder) had the highest pH of 4.65±0.03, indicating aloe vera's intrinsic alkalinity. These findings are consistent with the results of Mishra and Sangma (2017), who noted ingredient-specific impacts on pH in multi-ingredient beverages.

The current findings are similar to the previous results reported by Afifah *et al.* (2022), as the authors discovered that vitamin C and other organic acids could have contributed to the pH of beverage mix. Our findings were also in accordance with those of Cava and Ladero (2024), who reported that mangoes are rich in polyphenols with strong antioxidant potential that help to reduce lipid and protein oxidation in meat models. Similarly, aloe vera also has a strong potential to contribute to the antioxidant activity of the beverages through bioactive compounds such as saponins, tannins, alkaloids, phenolics, and flavonoids, as confirmed by DPPH assays (Nugrahani *et al.*, 2025; Rakhimzhanova *et al.*, 2024). These results are further supported by the findings of Felicia *et al.* (2024) and Sylvani *et al.* (2025), who demonstrated aloe vera's antioxidant potential in applications such as mayonnaise and edible coatings, respectively.

Color analysis (L*, a*, b*) of the beverage

The data presented in Table 6 show that aloe vera significantly impacts the lightness (L* value) of beverage powders. The control treatment (T0) with 100% mango powder exhibited an L* value of 44.59±0.44, indicating a moderately dark color. As the proportion of aloe vera increased, the L* values showed a clear trend toward lighter colors. For instance, treatments T3 (85% mango powder and 15% aloe vera powder) and T4 (80% mango powder and 20% aloe vera powder) had higher L* values of 51.53±0.38 and 49.64±0.32, respectively. The highest L* value of 59.28±0.37 was observed in T5 (100% aloe vera powder), demonstrating the lightening effect of aloe vera powder. These findings are similar to the results provided by Choi *et al.* (2002), who noted variations in color attributes of the beverage depending on the forms and proportions of ingredients used in beverage formulations. Table 6 further illustrates the influence of aloe vera on the redness (a* value) of beverage powders. The control treatment (T0) with 100% mango powder had an a* value of 5.13±0.03, reflecting a moderate red hue because of mango powder's natural carotenoid content. Treatments with inclusion of higher proportions of aloe vera displayed varying effects, with T3 (85% mango powder and 15% aloe vera powder) showing the highest a* value of 6.07±0.01, indicating enhanced redness. However, the redness decreased significantly in T5 (100% Aloe vera powder), which had the lowest a* value of 3.45±0.02, indicating a shift toward a greener hue. These results aligned with Choi *et al.*'s (2002) findings, who reported that form of ingredients and processing methods could significantly influence color properties. According to Chaudhary *et al.* (2017), variation in carotenoid contents could be the reason for this change in color parameters, as beverage mix was developed using different ratios of mango powder and aloe vera powder. Further, as shown in Table 6, yellow hue (b* value) of beverage powders was most prominent in the control treatment (T0) with 100% mango powder, which exhibited the highest b* value of 5.23±0.01. The inclusion of aloe vera reduced yellow intensity, with T1 and T3 showing lower b* values of 3.62±0.01 and 3.66±0.02, respectively. The lowest b* value of 2.75±0.04 was observed in treatment T5, indicating minimal yellow hue contributed by aloe vera. These findings are consistent with those reported by Alam *et al.* (2021), who highlighted that ingredient processing, such as drying and pulverizing, alters pigment concentrations and thereby influences color properties. Overall, the results suggest that aloe vera moderates the color intensity of beverage powders across all dimensions of L*, a*, and b* values. The color parameters of products strongly depend on the ratio of plant materials used because they are good source of carotenoids and other coloring materials (Hussain *et al.*, 2024a). Our findings are also in line with those of Yiğitvar and Hayaloğlu (2025), reporting that higher concentrations of aloe vera gel could cause a slightly greenish or opaque tint because of its natural clarity. Similarly, the color of our beverage mix powder was also influenced by mango's vibrant pigments, which aligned with the results of Deen (2024) and Sharma *et al.* (2024), demonstrating that blending aloe vera with fruits such as pomegranate and aonla, changes the color of final beverage on the basis of dominant fruit.

Table 6. Color analysis (L*, a*, and b*) of beverage.

Treatments	L*	a*	b*
T0	44.6±0.4^{d}	5.1±0.03^{c}	5.2±0.01^{a}
T1	41.9±0.5^{f}	4.7±0.01^{d}	3.6±0.01^{e}
T2	43.9±0.1^{e}	3.7±0.01^{e}	4.5±0.01^{b}
T3	51.5±0.4^{b}	6.1±0.01^{a}	3.7±0.02^{d}
T4	49.6±0.3^{c}	5.7±0.04^{b}	4.1±0.02^{c}
T5	59.3±0.4^{a}	3.5±0.02^{f}	2.8±0.04^{f}
Total	49.3±0.3	4.7±0.02	3.7±0.02

Mean values in a row that have the same superscript alphabetical letters are statistically nonsignificant (p < 0.05), and values that have different superscript alphabetical letters are statistically significant (One-Way ANOVA).
T0: Treatment with 100% mango powder.
T1: Treatment with 95% mango powder and 5% aloe vera powder.
T2: Treatment with 90% mango powder and 10% aloe vera powder.
T3: Treatment with 85% mango powder and 15% aloe vera powder.
T4: Treatment with 80% mango powder and 20% aloe vera powder.
T5: Treatment with 100% aloe vera powder.

Mineral analysis of beverage

Minerals present in plant materials are important elements in regulating various body functions of plants, and the consumption of such plant materials directly or through different food formulations provide necessary amount of minerals to the body (Ebrahim *et al.*, 2020; Hussain *et al.*, 2024c). The data presented in Table 7 show that the aloe vera and mango-based instant beverage mix is rich in essential minerals, particularly phosphorus (P), zinc (Zn), calcium (Ca), sodium (Na), and potassium (K), which contribute to its therapeutic benefits and enhance its nutritional value. However, reduced magnesium (Mg) proportion was observed in the beverage mix treatments having high concentrations of aloe vera. These findings aligned with the mineral profile analysis conducted by Anwar *et al.* (2020), with only slight variations observed due to differences in components and temperature conditions. Findings from the work of Mondhe *et al.* (2018) showed a rise in mineral contents of the beverage mix developed from aloe vera and mango powder. Another relevant work done by Sharma *et al.* (2021) showed that when a low-calorie beverage was developed through addition of aloe vera, a significant increase in the mineral contents of the beverage was noted. These high mineral contents in beverage formulations having high proportion of aloe vera could be due to high proportion of minerals present in the plant (Rajeswari *et al.*, 2012). However, the contribution of minerals from mango powder could not be neglected, as several studies showed mango to be a good source of important macro- and micro-minerals (Hussain *et al.*, 2024b), and in case mango powder is incorporated in food products, a significant increase in mineral contents of the products was observed (Hussain *et al.*, 2024b). Our findings are agreed with the results of Perez-Meza *et al.* (2024), establishing that mango offers a notable amount of mineral content with varied levels of potassium, magnesium, calcium, sodium, and zinc, depending upon the variety. This supports variations in mineral contents observed in our instant beverage mix formulations, potentially because of the varied concentrations of mango powder used. The addition of aloe vera also may have contributed to the mineral enhancement of the instant beverage mix. Our results are also in accord with those reported by Jahangeer *et al.* (2025), who discovered that blending mango with other plant-based sources improves the nutritional value of functional beverages.

Sensory evaluation of beverage

Acceptance or rejection of any food formulation developed through a combination of different plant materials depends upon the sensory scores provided by consumers to that specific product. The data presented in Table 8 show different sensory parameters, which received different scores from consumers. It is observed that the treatment significantly affects the flavor of beverage, with a highly significant *p*-value ($p < 0.01$). The control treatment (T0) with 100% mango powder received the highest flavor score of 9.01±0.06, indicating a strong preference for pure mango flavor. As the proportion of aloe vera increased, flavor scores decreased progressively, with T1 and T2 receiving scores of 8.08±0.01 and 7.05±0.02, respectively, reflecting a slight reduction in product's flavor. A more noticeable decrease in flavor was observed in treatments T3 and T4, with scores of 6.05±0.01 and 5.28±0.03, respectively, while the control treatment (T5) with 100% aloe vera powder had the lowest score of 3.06±0.02. These results suggest that higher proportions of aloe vera significantly impact the overall flavor profile, with aloe vera's naturally mild but potentially bitter taste being less favorable among consumers. These findings agreed with the results of Prescott *et al.* (2004), who also noted the importance of flavor in the consumer acceptance of beverages.

Furthermore, Alam *et al.* (2021) also validated the current findings by providing relevant results in terms of sensory acceptance of aloe vera powder-added beverages. The data presented in Table 8 show that the treatment significantly affects color of the beverage ($p < 0.01$). The mean color scores for different treatments varied, with T0 and T1 receiving the highest color scores of 8.01±0.08 and 7.00±0.08, respectively. In contrast, treatment T5, which was prepared with 100% aloe vera powder, had the lowest color score of 6.00±0.04. Judges preferred the color of the treatments having higher mango content, as they had a more appealing appearance compared to the cloudy or gel-like texture of aloe vera-based treatments. These findings were consistent with the results of Chaudhary *et al.* (2017), observing similar trends in color preferences for aloe vera-based beverages.

The data presented in Table 8 further show that the treatment significantly affects the taste of the beverage, with highly significant results ($p < 0.01$). The mean taste scores were highest in treatments T0 and T1, with scores of 8.00±0.01 and 7.00±0.02, respectively, indicating a favorable taste profile. In contrast, the lowest taste score was observed in T5, with a score of 3.06±0.02, because of the distinctive bitter taste of aloe vera powder. These results aligned with the findings of Chaudhary *et al.* (2017), demonstrating that the bitter flavor of aloe vera negatively impacted the overall taste acceptance in their studies. According to Akhter *et al.* (2010), the presence of mango powder in juice formulations provided better taste to juices, with good sensorial acceptance from consumers.

Table 8 further shows that different treatments significantly affect the appearance of the beverage ($p < 0.01$).

Table 7. Mineral analysis (mg/L) of beverage.

Treatments	Na	K	Ca	Mg	P	Zn
T0	22.8±0.0^{e}	0.6±0.1^{d}	12.8±0.1^{c}	70.9±0.2^{a}	46.4±5.3^{d}	1.6±0.1^{b}
T1	26.8±0.1^{d}	1.9±0.1^{a,b}	13.8±0.9^{a,b}	65.3±3.7^{b}	48.4±0.5^{c,d}	0.8±0.0^{c}
T2	22.7±0.2^{e}	1.4±0.1^{b,c}	14.2±0.3^{a}	53.8±0.7^{c}	50.7±0.5^{b,c}	1.9±0.0^{a}
T3	34.5±0.2^{b}	2.2±0.9^{a}	13.0±0.5^{b,c}	44.5±0.7^{d}	52.8±0.3^{a,b}	0.2±0.0^{e}
T4	36.8±0.9^{a}	1.2±0.1^{c,d}	14.0±0.6^{a}	42.0±0.4^{d,e}	52.5±2.2$^{a–c}$	0.3±0.0^{d}
T5	31.2±1.1^{c}	1.6±0.1$^{a–c}$	13.9±0.6^{a,b}	39.8±0.6^{e}	55.0±0.4^{a}	0.3±0.0^{d}
Total	30.4±0.5	1.7±0.2	13.6±0.6	49.1±1.2	51.9±0.8	0.7±0.0

Mean values in a row that have the same superscript alphabetical letters are statistically nonsignificant ($p < 0.05$), and values that have different superscript alphabetical letters are statistically significant (One-Way ANOVA).
T0: Treatment with 100% mango powder.
T1: Treatment with 95% mango powder and 5% aloe vera powder.
T2: Treatment with 90% mango powder and 10% aloe vera powder.
T3: Treatment with 85% mango powder and 15% aloe vera powder.
T4: Treatment with 80% mango powder and 20% aloe vera powder.
T5: Treatment with 100% aloe vera powder.

Table 8. Sensory evaluation of beverage.

Treatments	Flavor	Color	Taste	Appearance	Overall acceptability
T0	9.0±0.1^{a}	8.0±0.1^{b}	8.0±0.4^{a}	8.0±0.4^{a,b}	8.0±0.4^{a}
T1	8.1±0.0^{b,c}	7.0±0.1^{a,b}	7.0±0.1^{b}	7.0±0.1^{b}	6.4±0.6^{b}
T2	7.1±0.0^{c}	8.0±0.1^{a,b}	7.1±0.3^{a}	7.0±0.1^{a}	6.4±0.6^{b}
T3	6.1±0.0^{a}	6.5±0.0^{b}	6.0±0.1^{a}	8.0±0.5^{a,b}	7.7±0.9^{a}
T4	5.3±0.0^{a,b}	6.0±0.0^{a}	6.0±0.7^{a}	7.0±0.3^{a,b}	6.0±0.7^{b}
T5	3.1±0.0^{d}	4.1±0.0^{a}	4.1±0.2^{c}	3.0±0.2^{c}	3.0±0.9^{c}
Total	6.8±0.1	7.1±0.3	6.8±0.3	5.2±0.3	6.3±0.5

Mean values in a row that have the same superscript alphabetical letters are statistically nonsignificant ($p < 0.05$), and values that have different superscript alphabetical letters are statistically significant (One-Way ANOVA).
T0: Treatment with 100% mango powder.
T1: Treatment with 95% mango powder and 5% aloe vera powder.
T2: Treatment with 90% mango powder and 10% aloe vera powder.
T3: Treatment with 85% mango powder and 15% aloe vera powder.
T4: Treatment with 80% mango powder and 20% aloe vera powder.
T5: Treatment with 100% aloe vera powder.

Treatments T0 and T1 received the highest scores of 8.00±0.44 and 7.00±0.13, respectively, for appearance, while treatment T5, with 100% aloe vera powder, had the lowest score of 3.00±0.20 for appearance. A lower appearance score for T5 is attributed to the cloudy or gel-like texture characteristic of aloe vera, which was less appealing visually, compared to the more uniform appearance of the mango-based treatments. These findings agreed with the results of Abid and Zahid (2018), establishing that aloe vera-based beverages tend to have a less appealing visual appearance because of their texture.

The data presented in Table 8 indicate that the overall acceptability of the beverage is highly influenced by its flavor, appearance, and taste. Treatments T0 and T1, with higher mango content, received the highest overall acceptability scores of 8.00±0.44 and 6.44±0.56, respectively. In contrast, treatment T5, which contained 100% aloe vera powder, had the lowest overall acceptability score, reflecting less favorable flavor, appearance, and taste. These findings highlight the importance of balanced formulations in achieving higher consumer acceptance and are consistent with the results of Abid and Zahid (2018), who discovered similar trends in the overall acceptability for aloe vera-based beverages. A 15% aloe vera juice along with 85% litchi juice was a good formulation in terms of sensory acceptance, as reported by Hulle *et al.* (2017), and these results strongly supported the current trials. Our findings agreed with those of Hapsari *et al.* (2024), who reported improved functional and sensory properties of mango peel-based drinks with added red ginger and honey. Similarly, Kaur *et al.* (2025), also observed that incorporating aloe vera gel into mango toffee influenced sensor acceptability, with concentration levels playing a crucial role. These studies support the sensory enhancement observed in our aloe vera- and mango-based instant beverage mix.

Conclusion

In the present study, aloe vera and mango powder were evaluated for their functional and sensory properties prior to the development of a functional beverage mix powder. Aloe vera powder demonstrated superior levels of protein, fiber, and ash, compared to mango powder, while mango also showed considerable fiber and ash content. Proximate composition of different formulations of instant beverage mix showed significantly different contents of moisture, ash, fat, fiber, and protein. Mineral analysis of instant beverage mix revealed that blending of two powders provided a nutritionally balanced profile of beverage rich in essential minerals, such as sodium, potassium, calcium, and magnesium, because of their complementary compositions. Formulation T3 (85% mango powder and 15% aloe vera gel powder) was discovered to be optimal, offering improved moisture balance, enhanced protein levels, and increased phenolic compounds and antioxidant activity. Inclusion of aloe vera contributes significantly to antioxidant capacity, especially at moderate levels. However, higher concentrations of aloe vera slightly reduced TPC and increased the pH of beverage. Colorimetric analysis showed that aloe vera improved lightness (L*) while reducing redness (a*) and yellowness (b*), thereby enhancing the visual appeal. Moreover, aloe vera enriched the beverage with Na, Mg, and K, thus boosting its overall functionality. Sensory evaluation indicated that beverage mixes (T2 and T3) containing 10–15 % aloe vera with 85–90% mango powder were most preferred options by consumers. This blend offers a nourishing, visually appealing, and antioxidant-rich beverage for health-conscious individuals.

Data Availability

All the data generated in this research work has been included in the manuscript.

Ethical Statement

The sensory evaluation was conducted in accordance with the guidelines for sensory studies as outlined by the Ethics committee of Institute of Faculty of Food and Home Sciences, MNSUA, Multan, with approval No. MNSUA/FFHS/2023/02. Informed consent was obtained from all participants included in the study.

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Conflict of Interest

The authors declared that they had no known competing financial or personal interests that could influence the work reported in this paper.

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