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**Research Article**

# Storage stability of bael (*Aegle marmelos)* supplemented whey beverage: changes in physico-chemical, antioxidant, sensory and microbial quality

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## Abstract

**Beverages were prepared by supplementing 14% bael pulp, 10% sugar, and 1% whey protein. The storage stability of the beverages was assessed at 7±2°C and 37±2°C in glass bottles for 4 weeks. The samples were drawn at a weekly interval and analysed for antioxidant activity, total phenolic content (TPC), pH, total soluble solids (TSS), ascorbic acid content, sensory properties and microbiological quality. The ABTS radical scavenging activity at 7±2°C slightly decreased at the 2nd week of storage, and no significant (p>0.05) changes were observed up to the 4th week of storage. At 37±2°C storage, the decrease in antioxidant activity was significant (p<0.05) during entire storage period. Decreasing trend in TPC was also observed during the storage at both temperatures; however, the decrease was non-significant (p>0.05) during the 3rd week of storage, thereafter the TPC decreased appreciably at the 4th week of storage at 7±2°C. Further, the changes in the TPC were significant throughout the storage period at 37±2°C. The ascorbic acid content decreased significantly throughout the storage period at both the experimental temperature of storage. The pH was shown to decrease during storage at different temperatures. It was observed that the changes in the pH were non-significant (p>0.05) in the samples stored at 7±2°C during entire storage period. However, significant changes were observed after the 2nd week of storage at 37±2°C, till the end of the storage period. The total bacterial count and yeast & mould counts increased with an increase in storage period. Sensorial analysis revealed that beverages storage at 7±2°C was not acceptable after 3rd week and the beverage storage at 37±2°C was not acceptable after the 2nd week of storage. From the results, it is concluded that the developed beverages could be stored without affecting the sensorial quality for 3 weeks at 7±2°C and 2 weeks at 37±2°C.**

**Keywords:** Bael, Beverage, Fruit pulp, Physico-chemical, Sensory properties

## Highlights

- Whey-based beverage using beal pulp was developed and evaluated for its stability during storage.
- During storage, TPC, pH, TSS, ascorbic acid, sensory, and microbiological qualities were affected.
- Beverage was acceptable for 3 weeks at 7±2°C and 2 weeks at 37±2°C during storage.

## INTRODUCTION

Whey is obtained during the manufacture of *paneer*, *cheese*, *casein*, *chhana* and *shrikhand.* In India, the major source of whey is from production of *chhana* and *paneer* (Macwan et al., 2016). Whey is also a most potent pollutant among all dairy wastes, as it possesses high organic content contributing to high biological oxygen demand (BOD) and chemical oxygen demand (COD). Further, the treatment of whey before disposal is very costly. To overcome problem, various technological methods have been employed to convert whey into value-added products (Krolczyk et al., 2016)

Fruits and vegetables contain various bioactive compounds, and a great number of these naturally occurring substances have been recognized to have antioxidant potential. Flavonoids and phenolic compounds are among the major contributors to antioxidant activity. These compounds may work independently or synergistically (Kang et al., 2003). The underutilized fruits, *viz.*, *bael, karonda, ber* and *wood apple* are cheap but highly nutritious. Exploitation of underutilized fruits in the development of value added food products has been gaining considerable interest because of the high nutritional and health benefits of these fruits (Singh & Nath, 2004; Vino et al., 2016; Jadhao et al., 2019)

Currently, the potential health benefits of the phytochemicals and their ability to be incorporated

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into dairy foods as nutraceuticals has received considerable interest in dairy and food industry. Recent studies have shown these compounds to be good contributors to the total antioxidant capacity of the foods that contain them. Milk and milk products including whey combined with fruit preparation will be a good source of antioxidants, provided the antioxidant capacity of these preparations are not depleted through oxidation-reduction reactions upon mixing, processing and storage of the products.

Bael (*Aegle marmelos)*, also known as stone apple, is one of the most widely used medicinal fruit. It contains vitamins like Vitamin A, Vitamin C, thiamine, riboflavin, niacin, and minerals like calcium and phosphorus (Bag et al., 2011). Wijewardana et al. (2016) also studied the antioxidant activity of dried bael fruit powder based on the ability of fruit extract to scavenge DPPH radical scavenging activity. Bael is such a fruit which may be preferred by the consumer in the form of value-added products than consumed directly because of bitterness of its seeds present in the pulp.

Development of a ready-to-drink fruit-supplemented beverage from whey, whey protein concentrate, fruit concentrate and other ingredients is one of the ways for utilization of whey and whey proteins in the development of protein-enriched beverages with high antioxidant potential. Despite of high nutritional and medicinal value, bael fruit is not utilised much in the development of value-added dairy products. The development of protein-enriched whey drinks admixed with bael fruit rich in vitamins, minerals and antioxidant components is expected to provide a healthy nutritive drink and may also enhance the antioxidant status of the body when consumed, thus preventing the life style related diseases due to oxidative stress. Further, the changes in the antioxidant components and activity in the beverages during storage need to be investigated to assess the storage stability of the beverages.

Changes in the most critical parameters, such as pH, acidity and total soluble solids (TSS) are most important and are monitored to provide information on whether there is any microbial change in the beverages during storage. However, it is also necessary to analyze the relevant components like Vitamin C contributing for antioxidant activity when monitoring of reduction of nutritional compounds. Further, it is necessary to study whey beverages at 7±2°C and 37±2°C, because storage conditions directly affect microbial quality, sensory and shelf life of the product. Comparing two helps to know the need for refrigeration during storage or self stable product. Bankar et al. (2021), studied the changes in composition and chemical characteristics of the protein-enriched bael whey beverage during storage. Recently, the effects of storage conditions on physical, chemical, microbial safety and sensory parameters of bael-based RTS beverage have been investigated by Nivetha et al. (2025). However, there are no or limited reports available on the changes in the antioxidant activity during storage of bael supplemented beverages. In view of this, the study was carried out to assess the storage stability of bael-based whey beverage by investigating the changes in antioxidant activity, TPC, TSS, Vitamin C content, sensory properties and microbial quality during storage at 7±2°C and 37±2°C.

## MATERIALS AND METHODS

### Raw materials and chemicals

Pasteurized *paneer* whey (TS 6.27%, fat 0.35%, protein 0.56%, lactose 4.74%, ash 0.62%, Titratable acidity 0.21 % lactic acid, and pH 5.60) was obtained from Banas Dairy, Palanpur, Gujarat. Fresh and ripened bael fruits were procured from the Horticulture Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Whey protein concentrates (WPC 80) was purchased from Charotar Casein Company Pvt. Ltd., Nadiyad, Gujarat. Food grade citric acid was obtained from SD Fine Chemicals. All the chemicals used in the research work were of analytical grade (AR) and HPLC grade.

### Preparation of bael fruit pulp

The fresh-ripened bael fruits were thoroughly cleaned with potable water to remove adhering dirt. The shell was broken, the pulp with seeds and fibers were scooped. The pulp was obtained by sieving to remove seeds. The pulp was packed in a 150 mL sterile plastic container and stored at -20°C till further use.

### Physico-chemical analysis and antioxidant activity bael pulp and beverage

Physico-chemical analysis of *paneer* whey was carried out as per the method of Bureau of Indian Standards [BIS] (1981). Bael pulp and beverages were analysed for total solids (TS), total soluble solids (TSS), pH, titratable acidity (TA) and ascorbic acid by the method of Ranganna (2012). Total phenolic content (TPC) of bael pulp and its hydrophilic and lipophilic extracts was determined by the method of Kahkonen et al. (1999). ABTS radical scavenging assay was done by the method described by Re et al. (1999), and DPPH radical scavenging assay as described by Brand-Williams et al. (1995) with slight modification.

**Optimisation of level of addition of bael pulp for development bael supplemented whey beverage**

The flow diagram for the preparation of bael fruit beverage is presented in Fig. 1. The whey based beverage supplemented with bael fruit pulp was prepared by maintaining sugar concentration of 10%. The protein level was standardised to 1% with WPC 80. After blending of the ingredients, pH of the mixture was adjusted to 4.0 using 2.5 M citric acid before filling into bottles, followed by thermal treatment.

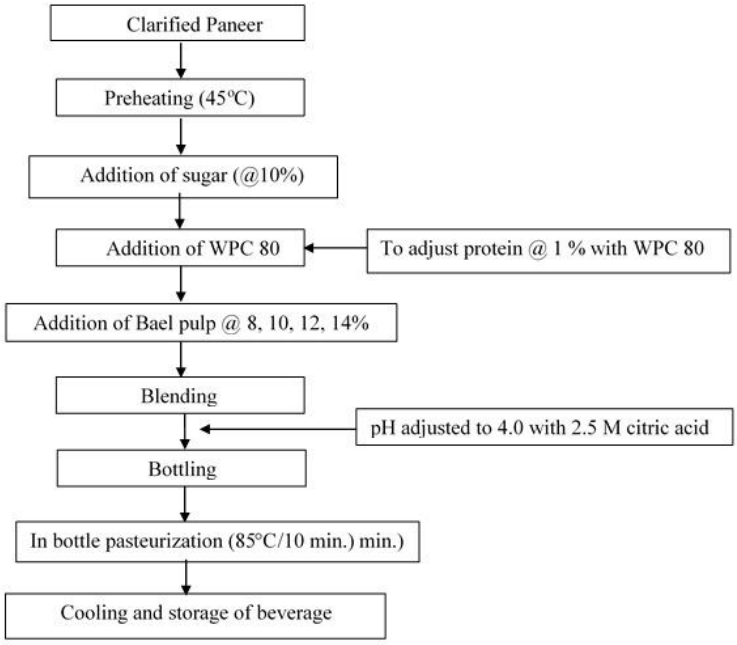



**Fig. 1. Flow diagram for preparation of bael supplemented whey beverage**

**Sensory evaluation of the beverages**

The sensory evaluation of beverage samples with different levels of bael fruit pulp was done by a panel of 7 semi trained faculty members from the college using 9-point hedonic Scale. The panellists were asked to score for various sensory attributes like taste, aroma, mouthfeel, colour and appearance and overall acceptability. The final score for each attribute was determined by averaging the scores provided by all panellists. Participation was voluntary, and verbal informed consent was obtained from each panellist before starting the sensory evaluation.

**Assessment of storage stability of optimised beverage**

The developed beverages were stored at two different temperatures (7±2°C and at 37±2°C) in 200 mL glass bottles wrapped with aluminium foil for a period of 4 weeks. The samples were periodically drawn at weekly intervals and analysed for physico-chemical, sensory and microbiological quality during storage.

**Microbiological quality analysis**

Microbiological assessments of bael-supplemented whey beverage samples were conducted to determine aerobic plate counts (APC), yeast and mould counts, and coliform counts. TPC was performed using plate count agar, yeast and mould counts were carried out using acidified potato dextrose agar (PDA) and coliform counts were measured using violet red bile agar (Hi-Media Laboratories Pvt. Ltd., Mumbai), following the standard protocols outlined by Ranganna (2012). All media were sterilized in an autoclave, and the analyses were performed under sterile conditions in a laminar airflow chamber (Super Scientific Works Pvt. Ltd., Vadodara, India).

**Aerobic plate counts:** To measure the total plate count, 1 mL of appropriately serially diluted samples of beverage was plated in duplicate. Approximately 15 mL of molten plate count agar was then aseptically added to the plates, mixed, and allowed to cool. The plates were incubated at 37±0.5ºC for 24 h. The resulting colonies were counted using a digital colony counter and reported as colony-forming units per mL (cfu/mL).

**Yeast and mould counts:** Beverage sample, 1 mL was pour-plated in duplicate. Molten PDA was aseptically added (about 15 mL), mixed, and allowed to cool. The plates were incubated in an inverted position at 25±0.5ºC for 3 days. Colonies were then counted using a colony counter and reported as cfu/mL.

**Coliform counts:** Coliform counts were determined by plating 1 mL of beverage sample in duplicate on pour-plates containing molten 20 mL of violet red bile agar. The plates were gently mixed, allowed to solidify, and incubated at 37±0.5ºC for 48 hours in an inverted position. The colonies were then counted with a colony counter and expressed as colony- forming units per milliliter (cfu/mL).

**Statistical analysis**

The data related to physico-chemical and sensory characteristics of beverage samples were analysed

using a statistical design CRD with an equal number of observations as per the method of Snedecor & Cochran (1994).

## RESULTS

The bael fruit pulp was analysed for its chemical characteristics, *viz.,* TS, total soluble solids (TSS), titratable acidity (TA), pH, and ascorbic acid, the results are presented in Table 1. The TS, TSS, pH, TA and Ascorbic acid content of bael fruit pulp were 40.26%, 38.4 °Brix, 4.82, 0.32% as citric acid and 65.32 mg/100 g of pulp, respectively.

**Table 1. Physico-chemical characteristics of bael fruit pulp**

| Physico-chemical characteristic | Values |
|---|---|
| Total Solids (%) | 40.26±0.58 |
| Total Soluble Solids (°Brix) | 38.4±0.30 |
| pH | 4.82±0.03 |
| Titratable Acidity (% Citric acid) | 0.32±0.04 |
| Ascorbic Acid (mg/100 g of pulp) | 65.32±0.72 |

Data are presented as means±SD (n=3)

bael pulp were evaluated on a 9 point hedonic scale. The mean sensory scores obtained for taste, aroma, mouthfeel, color and appearance and overall acceptability are presented in Table 3. It was observed that the sensory scores increased significantly ($p<0.05$) with increasing levels of bael pulp up to 12%. Beyond this level, there was no significant increase in scores observed.

The antioxidant capacity, TPC, and vitamin C of the optimized bael-supplemented whey beverage during storage at 7±2°C and 37±2°C are presented in Table 4. At 7±2°C, the ABTS radical scavenging activity showed a decrease from 11.86±0.02 µmol TE/mL initially to 10.97±0.02 µmol TE/mL after four weeks. A significant ($p<0.05$) reduction was observed after the 1st week, which has remained stable until the end of the storage period. Similarly, the DPPH scavenging activity showed no significant ($p<0.05$) change up to the third week but dropped significantly ($p<0.05$) by the fourth week, from 5.64±0.04 µmol TE/mL to 3.44±0.03 µmol TE/mL. The TPC decreased marginally from 38.54±0.10 µmol GAE/mL to

**Table 2. Antioxidant activity of bael fruit pulp**

| Bael fruit pulp | Antioxidant capacity (µmol *TE/g) | | Total phenolic content |
|---|---|---|---|
| | ABTS | DPPH | (µmol GAE**/g) |
| Hydrophilic Extract | 8.65±0.03$^{b}$ | 5.32±0.02$^{b}$ | 10.32±0.15$^{b}$ |
| Lipophilic Extract | 2.98±0.01$^{c}$ | 1.96±0.04$^{c}$ | 3.84±0.15$^{c}$ |
| Total antioxidant activity | 11.63±0.02$^{a}$ | 7.28±0.03$^{a}$ | 14.16±0.14$^{a}$ |

Means with different superscripts in each column (a, b, c) were significantly different from each other. Data are presented as means±SD (n=3); *TE- trolox equivalent **GAE- gallic acid equivalent

**Table 3. Sensory scores for protein enriched whey-bael beverages prepared using different levels of bael pulp**

| Bael pulp (%) | Scores on 9 point hedonic scale | | | | |
|---|---|---|---|---|---|
| | Taste | Aroma | Mouthfeel | Colour & appearance | Overall Acceptability |
| 8 | 7.8±0.21$^{b}$ | 7.5±0.14$^{c}$ | 7.9±0.23$^{c}$ | 8.0±0.27$^{c}$ | 7.8±0.28$^{c}$ |
| 10 | 8.0±0.29$^{b}$ | 7.8±0.15$^{b}$ | 8.2±0.05$^{b}$ | 8.5±0.19$^{b}$ | 8.1±0.16$^{b}$ |
| 12 | 8.4±0.17$^{a}$ | 8.3±0.16$^{a}$ | 8.5±0.17$^{a}$ | 8.5±0.18$^{a}$ | 8.5±0.18$^{a}$ |
| 14 | 8.6±0.18$^{a}$ | 8.4±0.15$^{a}$ | 8.6±0.16$^{a}$ | 8.7±0.05$^{a}$ | 8.6±0.14$^{a}$ |

Means with different superscripts in each column (a, b, c) were significantly different from each other. Data are presented as means±SD (n=21)

The antioxidant potential of bael fruit pulp was evaluated by preparing hydrophilic and lipophilic extracts and analyzing them for antioxidant activity and TPC (Table 2). The total antioxidant activity, obtained by combining both extracts, was 11.63 mmol and 7.28 Trolox equivalent/g of sample using ABTS and DPPH methods, respectively. A similar trend was observed for the TPC of the extracts.

The sensory evaluation scores for whey-based beverages prepared by incorporating various levels of

37.72±0.11 µmol GAE/mL, while vitamin C content declined steadily from 1.43±0.02 mg/100 mL to 0.76±0.02 mg/100 mL by the end of storage. At 37±2°C, the reduction trend was more prominent with the ABTS scavenging activity decreased significantly ($p<0.05$) from 11.86±0.04 µmol TE/mL to 6.59±0.04 µmol TE/mL after four weeks. Similarly, the DPPH scavenging activity declined sharply from 5.80±0.02 µmol TE/mL to 3.10±0.02 µmol TE/mL. The TPC and vitamin C contents also exhibited significant

**Table 4. Antioxidant capacity, total phenol content and vitamin C of bael supplemented whey beverage during storage**

| Parameters | Storage period (week) at 7±2°C. | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| ABTS (µmol TE/mL) | 11.86±0.02$^{a}$ | 11.70±0.03$^{a}$ | 11.16±0.02$^{b}$ | 11.05±0.03$^{b}$ | 10.97±0.02$^{b}$ |
| DPPH (µmol TE/mL) | 5.8±0.02$^{a}$ | 5.62±0.01$^{a}$ | 5.44±0.03$^{a}$ | 5.64±0.04$^{a}$ | 3.44±0.03$^{c}$ |
| TPC (µmol GAE/mL) | 38.54±0.10$^{a}$ | 38.43±0.01$^{a}$ | 38.41±0.14$^{a}$ | 37.90±0.15$^{b}$ | 37.72±0.11$^{b}$ |
| Vitamin C (mg/100 mL) | 1.43±0.02 $^{a}$ | 1.33±0.02$^{b}$ | 1.16±0.02$^{c}$ | 0.96±0.03$^{d}$ | 0.76±0.02$^{e}$ |
| **Parameters** | **Storage Period (week)** at 37±2°C. | | | | |
| | 0 | 1 | 2 | 3 | 4 |
| ABTS (µmol TE/mL) | 11.86±0.04$^{a}$ | 10.42±0.02$^{b}$ | 8.71±0.03$^{c}$ | 7.68±0.02$^{d}$ | 6.59±0.04$^{e}$ |
| DPPH (µmol TE/mL) | 5.8±0.02$^{a}$ | 4.91±0.03$^{b}$ | 4.46±0.02$^{c}$ | 3.82±0.01$^{d}$ | 3.10±0.02$^{e}$ |
| TPC (µmol GAE/mL) | 38.54±0.10$^{a}$ | 37.14±0.02$^{b}$ | 36.89±0.03$^{c}$ | 35.7±0.01$^{d}$ | 33.88±0.02$^{e}$ |
| Vitamin C (mg/100 mL) | 1.43±0.02$^{a}$ | 1.13±0.03$^{b}$ | 0.98±0.01$^{c}$ | 0.79±0.01$^{d}$ | 0.58±0.02$^{e}$ |

Means with different superscripts in each row (a, b, c, d and e) were significantly different from each other. Data are presented as means±SD (n=3)

decreases, reaching 33.88±0.02 µmol GAE/mL and 0.58±0.02 mg/100 mL, respectively, by the end of the storage period.

As shown in Fig. 2, the initial pH of the bael-supplemented whey beverage was 4.0 on the 0 day of storage. A steady decrease in pH was observed throughout the storage period under both temperature conditions. It was observed that the change in the pH was non-significant ($p>0.05$) in the samples stored at 7±2°C during entire storage period. In contrast, significant changes were observed after 2$^{nd}$ week of storage at 37±2°C, till the end of the storage period. These findings clearly demonstrate that elevated storage temperature exerts a measurable influence on the pH stability of the beverage.

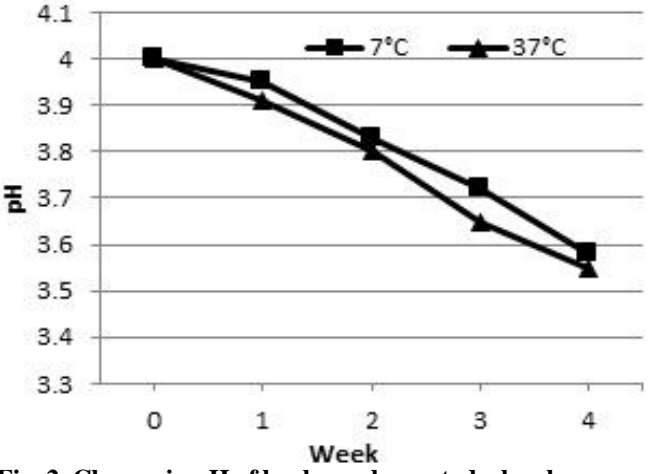



**Fig. 2. Change in pH of bael supplemented whey beverage during the storage**

The changes in total solids (TS) and total soluble solids (TSS) of bael-supplemented whey beverages during storage at 7±2°C are shown in Table 5. The initial TS and TSS values were 19.8% and 19.8 °Brix, respectively. Slight variations were observed throughout the four weeks of storage, with TS ranging between 19.7–19.85% and TSS between 19.85-20.05 °Brix. Statistical analysis indicated that these changes were non-significant ($p>0.05$).

**Table 5. Changes in total soluble solids content of protein enriched whey beverages during storage at 7±2°C**

| Parameter | Storage Period (Weeks) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | |
| TS (%) | 19.8 | 19.85 | 19.70 | 19.75 | 19.80 | NS |
| TSS ( °Brix) | 19.8 | 19.85 | 20.05 | 19.90 | 19.90 | NS |

Data are presented as means (n=3); NS - Non-significant

The sensory scores of bael-supplemented whey beverage stored at 7±2°C and 37±2°C are presented in Fig. 3 and Fig. 4, respectively. Initially, taste, aroma, mouthfeel, colour and appearance, and overall acceptability were scored between 8.4 and 8.7. As storage progressed, all sensory attributes decreased to approximately 6.0–6.2, while colour and appearance remained comparatively stable. At 7±2°C, only a gradual decline in sensory attributes was observed over four weeks. The scores for taste and aroma decreased from about 8.6 to 6.3. In contrast, samples stored at 37±2°C showed a significant reduction in sensory scores and overall product acceptability compared to samples stored at 7±2°C.

The microbial load of bael-supplemented whey beverages stored at 7±2°C and 37±2°C for four weeks is presented in Table 6. The total bacterial count (TBC) showed a gradual increase during the storage period at both temperatures. At 7±2°C, TBC increased from 0.43 to 2.75 log CFU/mL, whereas at 37±2°C, it rose more rapidly, reaching 3.92 log CFU /mL by the fourth week. Yeast and mould counts followed a similar trend,

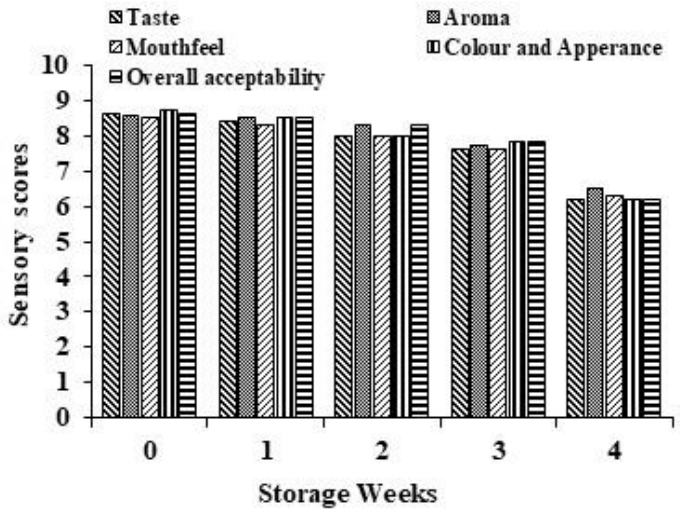



**Fig. 3. Sensory attributes of bael supplemented whey beverage stored at 7±2°C**

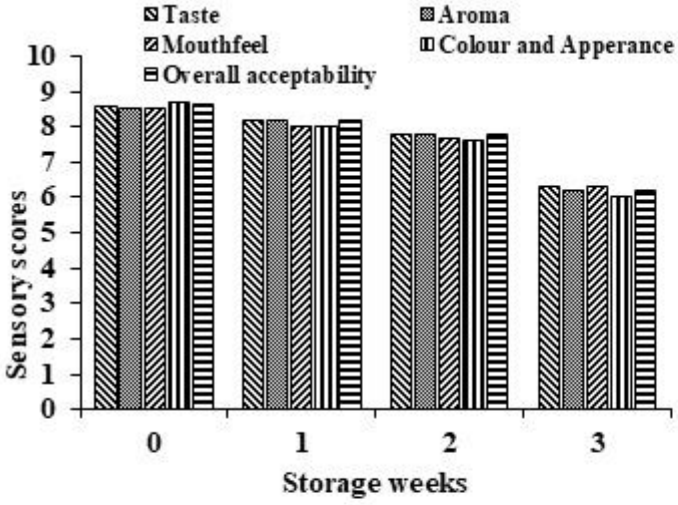



**Fig. 4. Sensory attributes of bael supplemented whey beverage stored at 37±2°C**

## DISCUSSION

The physicochemical parameters of bael fruit pulp observed in this study were consistent with previously reported values. Kaur and Kalia (2017) recorded TA and pH values of 0.30% and 4.95, while Tarsem and Gehlot (2006) reported TSS, TA, and pH values of 36.3 °Brix, 0.46%, and 4.5, respectively. Minor variations could be attributed to cultivar, maturity stage, and agro-climatic differences influencing fruit composition.

The total antioxidant capacity, determined as the sum of hydrophilic and lipophilic fractions, revealed higher activity in the hydrophilic extract, indicating that water soluble polyphenols and phytochemicals largely contribute to the antioxidant potential of bael pulp. These findings support previous reports emphasizing the contribution of phenolic compounds in fruit to antioxidant activity.

The protein-enriched whey bael beverage was formulated with 8–14% bael pulp, 10% sugar, and 1% protein (WPC 80). Sensory evaluation showed improvement up to 12% bael pulp, beyond which no significant enhancement was noted. However, considering nutritional enrichment, the 14% formulation was selected for storage trials. In contrast, Landge et al. (2020) reported a decline in sensory scores at higher bael levels, suggesting formulation dependent differences among products.

During storage, antioxidant parameters declined due to degradation of phenolics and vitamin C, with a more pronounced decrease at 37±2°C than at 7±2°C. This confirms that elevated temperature accelerates oxidative loss of bioactive compounds. Similar reductions in ABTS and DPPH scavenging activities indicated the depletion of

**Table 6. Changes in microbial load of bael supplemented whey beverage during storage**

| Storage Temperature | Microbial load (log CFU/mL) | Storage Period (Weeks) | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 |
| 7±2°C | APC* | 0.43 | 0.92 | 1.43 | 1.76 | 2.75 |
| | Yeast and Mould | 0 | 0 | 0.31 | 0.51 | 0.92 |
| | Coliform | Nil | Nil | Nil | Nil | Nil |
| 37±2°C | APC | 0.43 | 1.23 | 1.77 | 2.88 | 3.92 |
| | Yeast and Mould | 0 | 0.14 | 0.41 | 0.92 | 1.54 |
| | Coliform | Nil | Nil | Nil | Nil | Nil |

Data are presented as means (n=3); *Aerobic Plate Count

showing a slow increase at (0 to 0.92 log CFU/mL) and a faster increase at 37±2°C (0 to 1.54 log CFU/mL). Coliform bacteria were not detected in any of the samples throughout the storage period.

radical-quenching compounds. These observations align with earlier reports (Prior et al., 1998; Kalt et al., 1993; Connor et al., 2002; Chavda et al., 2016) that phenolics, rather than ascorbic acid, are the primary

contributors to total antioxidant capacity. Ames et al. (1993) similarly noted that blueberries stored at 5°C retained antioxidant capacity despite ascorbate loss, reaffirming that phenolic compounds play a key role in maintaining antioxidant stability under low-temperature conditions.

The storage stability of bael-supplemented whey beverage was influenced by temperature, affecting its physicochemical, microbial, and sensory properties. A gradual decrease in pH during storage agreed with the observations of Chavda (2016) in whey protein-enriched fruit beverages and Ismail et al. (2011), who reported a reduction from 4.86 to 4.75 in cheese whey-based mango beverage during 30 days of storage. Mohamed et al. (2014) also noted a decrease from 5.30 to 4.90 in papaya whey beverage, confirming that mild acidification is typical in whey-fruit formulations. In the present study, it was observed that the change in the pH was non-significant ($p>0.05$) in the samples stored at 7±2°C and significant after 2nd week of storage at 37±2°C , till the end of the storage period. These results demonstrated that the elevated temperature of the storage greatly influences the pH stability of the beverages. The gradual decrease in pH and increase in the acidity in sugar-based beverages over the storage period can be attributed to fermentation of sugar and formation of organic acids as result of microbial growth (Huang et al., 2024). The proteolysis of the whey protein and release of the peptides might have also contributed for reduction in the pH at elevated temperatures of storage. The observed pH remains non-significant ($p>0.05$) during storage at 7±2°C which indicates that pH within this range, ensures both microbial quality and sensory acceptability.

Non-significant ($p>0.05$) variations in TSS content in the beverages were observed during storage under different temperature of storage, similar to results of Naik et al. (2009) for watermelon whey beverage and Sakhale et al. (2012) for mango RTS beverage. The increase in microbial load during storage may be due to acidophilic and aciduric microorganisms, as also reported by Krishnaiah et al. (1989), who found plate counts rising from 2.0 to 7.9 SPC/mL after 30 days of refrigeration. Khamrui and Rajorhia (1998) observed that beverage acidification restricted microbial growth, allowing a shelf life of about three weeks at 7°C and two weeks at 37°C, which supports the present findings.

The beverage with 14% bael pulp, 10% sugar, and 1% whey protein was found optimal in terms of sensory and antioxidant properties. During storage, vitamin C, pH, and total phenolic content decreased, while TSS remained stable. Off-flavour development was detected in samples stored at 7±2°C after four weeks and at 37±2°C after three weeks. Sensory evaluation indicated that the beverage remained acceptable for up to three weeks under refrigerated conditions (7±2°C) and up to two weeks at elevated temperature (37±2°C). However, *in-vivo* studies are needed to validate the antioxidant potential of the developed beverage.

**Conflict of interest:** The authors declare that they have no competing interests.

**Author's contribution:** VR**:** Conception, design and interpretation of the data; GM: Prepared draft of the manuscript; AD, MJ: Acquisition of data; SS: Statistical analysis of data; AK: Literature searches and manuscript checking. All authors have approved the final submitted version. All authors approved to submit the article.

**Data availability statement:** Data set generated during research will be available from the corresponding author on reasonable request.

**Ethical approval:** Work done in research paper was not involved any animal studies, hence there is no need for approval of the ethical committee.

**Use of artificial intelligence tools:** No artificial intelligence tools were used for preparation of the work.

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