

VALORIZATION OF WHEY FOR PRODUCTION OF AN INNOVATIVE WHEY DRINK FORTIFIED WITH CUMIN AND ASAFOETIDA

¹Dr. Seema Tanwar, ²Dr. Shailesh Kumar Meena, ³Dr. Aparna Singh, ⁴Dr. Deepak Chand Meena

¹Assistant Professor, Department of Food Processing Engineering, College of Dairy and Food Technology, Bassi, Jaipur, mail: drseemacdf@gmail.com-303301, 0000-0002-1769-6708.

²Teaching Associate, Dairy Technology, College of Dairy and Food Technology, Bassi, Jaipur-303301, mail: shaileshmeena53@gmail.com, orcid I'd: 0000-0002-5442-7689.

³Teaching Associate, Food Technology, College of Dairy and Food Technology, Bassi, Jaipur-303301, mail: aparna.s.bhadoria@gmail.com, orcid I'd: 0009-0003-1757-4481.

⁴Assistant Professor, Department of Dairy Business Management, College of Dairy Science, Uttar Pradesh Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan (DUVASU), Mathura – 281001, mail: demndri@gmail.com, orcid I'd: 0000-0001-8147-8636.

ABSTRACT

The present study was undertaken to develop a value-added innovative whey drink (IWD) fortified with cumin and asafoetida. Fresh curd Whey was pasteurized and concentrated in open pan to prepare a whey drink using sugar, salt, cumin and asafoetida at different combination. The effect of ingredients on IWD formulated using 42 factorial experiment (16 treatment combination) were determined through two-way ANOVA method in IBM SPSS Statistics 26 for its sensorial and antioxidant activity. Two level of sensory evaluation was done to optimize the salt, sugar, cumin and asafoetida. The salt and sugar mainly influence the flavour and overall acceptability of IWD. The combination of 2% salt and 7.5% sugar recorded the highest flavour score (8.00 ± 0.45) and overall acceptability (8.13 ± 0.27) based on 9-point hedonic scale. Cumin and asafoetida significantly influenced the sensory parameters and antioxidant activity of IWD. The formulation containing 0.125% cumin and 0.125% asafoetida exhibited the highest flavour (8.17 ± 0.29), body and texture (8.08 ± 0.30) and overall acceptability (7.92 ± 0.35). However, the highest ABTS antioxidant activity (41.48 ± 1.15) was observed with 3% cumin and 5% asafoetida. The findings demonstrate that increasing spice concentrations can enhance antioxidant activity but may adversely affect sensory acceptability. The level of ingredients was selected based on the sensorial parameters. The study demonstrates the potential of cumin and asafoetida for developing a value-added whey beverage with desirable sensory and functional properties.

KEYWORDS: Whey beverage, Paneer whey, Cumin, Asafoetida, Functional beverage, Sensory evaluation, Antioxidant activity, ABTS, Product optimization, Value addition.

1. INTRODUCTION

The dairy industry generates whey as a major by-product during the manufacturing of cheese, paneer, casein and other dairy products. Whey disposal at the household or industrial scale contributes to environmental pollution owing to its high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Whey contains considerable amounts of lactose, soluble proteins, minerals, vitamins and other nutritionally valuable constituents. Over the few decades, the researcher's attention has been increased towards the utilization of whey as a functional ingredient due to its valuable nutritional, functional and bioactive properties. Whey proteins possess high biological value and contain essential amino acids, while whey-derived peptides have been reported to exhibit several biological activities, including antioxidant, antimicrobial and antihypertensive properties (Brandelli et al., 2015; Zhao et al., 2022). Thus, conversion of whey into value-added beverages represents an attractive approach for improving its utilization and reducing the environmental pollution associated with whey disposal.

Whey-based beverages have gained interest as refreshing and nutritious products owing to their nutritional and health promoting attributes. Earlier studies on commercial whey drinks have demonstrated that whey can be effectively incorporated into beverages formulations comprising whey, water, fruit juice, sweeteners and other ingredients. Depending on the formulation and processing conditions, whey beverages can be developed with desirable nutritional and sensory characteristics. Recent research also emphasizes the potential of whey proteins and their peptides as functional ingredients in foods and beverages, further supporting the development of innovative whey-based products.

However, the development of an acceptable whey beverage requires appropriate formulation as the characteristic acidic flavour, mineral content and potential instability of whey may influence product acceptability. The addition of spices and plant-derived ingredients improve the sensorial and functional attributes of beverage. Among the spices, cumin (*Cuminum cyminum* L.) has considerable potential for

incorporation into functional food products. Cumin is an aromatic seed spice widely used as a flavouring ingredient and contains volatile compounds, of which cumin aldehyde being one of its principal bioactive constituents. Various studies have reported the antioxidant and other biological activities associated with cumin and its phytochemical constituents, indicating its potential as both a flavouring and functional ingredient in food formulations (Srinivasan, 2018; Singh & Upadhyay, 2021).

Cumin powder may also contribute to the characteristic aroma, flavour and overall sensory profile of whey-based beverage. Its application in dairy beverage is particularly relevant in the Indian context, where cumin is incorporated into several savoury and refreshing beverages. Its incorporation may therefore provide a familiar flavour profile while introducing naturally occurring phytochemicals into the product. Nevertheless, the higher concentration of cumin may impart strong or pungent flavour and consequently reduce consumer acceptability.

Asafoetida (*Ferula asafoetida* L.), another widely used Indian spice, is characterized by its distinctive sulphur-containing volatile compounds and strong aroma. Traditionally, it has been used as a culinary condiment and digestive aid. Scientific investigations have identified several classes of bioactive compounds in asafoetida and have reported antioxidant, antimicrobial, antispasmodic and digestive-related activities. Amalraj and Gopi (2017) reviewed the phytochemistry and biological activities of asafoetida and highlighted its potential functional properties. Experimental research has further demonstrated antioxidant and antimicrobial activities in *F. asafoetida* preparations, supporting continued interest in its potential application within food systems.

The combination of whey with cumin powder and asafoetida could therefore provide an interesting approach for developing a value-added functional beverage. Whey can serve as the nutritional base, particularly providing high-quality proteins and other dairy nutrients, whereas cumin and asafoetida may contribute characteristic flavour, aroma and naturally occurring bioactive compounds. The present study was undertaken to develop a whey-based drink incorporating cumin and asafoetida and to evaluate its sensorial and, antioxidant attributes. Different concentrations of cumin powder and asafoetida may be optimized to obtain a product with desirable sensory acceptability while retaining the nutritional advantages of whey. Such a product could contribute to the value addition and sustainable utilization of whey and provide a novel dairy-based beverage using traditionally Indian spices.

2.MATERIAL AND METHOD

2.1 Materials

Whey produced from fresh curd was procured from a local market Bassi, Jaipur. Cumin and asafoetida powder were procured from local market of Ajmeri gate, Jaipur. All the chemicals were procured from Hi-media Laboratories Pvt. Ltd.

2.2 Preparation of innovative whey drink (IWD)

Whey was preheated at $45 \pm 1^\circ\text{C}$ and the cream was separated. The obtained whey was pasteurized at 72°C for 15 S and concentrated to 10% total solid in open pan. Concentrated whey was cooled to room temperature (37°C). Sugar and salt were added into concentrated whey and blended for 2 min to obtained uniform whey mix. The spiced whey drink was prepared by addition of cumin and asafoetida powder at different level (Table 1) into uniform whey mix and blended for 2 min. The obtained innovative whey drink was packed into PET jar and stored at $5 \pm 1^\circ\text{C}$ (Fig. 1).

2.3 Optimization of innovative whey drink based on antioxidant analysis

The antioxidant activity of cumin, black paper and asafoetida were measured using the ABTS (2, 2-Azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) method given by (García-Casas et al. 2022).

Sample Preparation: Exactly 10 g of IWD was added in 15 mL, of 100% methanol and mixed using magnetic stirrer for 15 minutes at 700 RPM followed by centrifuge at $2500 \times g$ for 10 min. The supernatant was collected and second extraction was performed by adding 7.5 mL of methanol/ water (70:30, v/v). The collected supernatants of both stages were combined.

The working solution of ABTS^{•+} was prepared by mixing 2.45 mM potassium persulfate with 7 mM ABTS before 12–16 h. The absorbance of ABTS working solution was adjusted to 0.70 ± 0.02 at 750 nm wavelength using 5 mM phosphate buffer. Twenty μL of the sample extract was mixed with 280 μL ABTS working solution and allowed to react in dark for 20 min before taking the absorbance at 750 nm against a standard curve of Trolox (0- 400 $\mu\text{g/mL}$).

2.4 Optimization of innovative whey drink based on sensory attributes

All the combination of prepared innovative whey drink were evaluated by 6 trained panellists on the basis of 9-point hedonic scale for colour and appearance, flavour, body and texture and overall acceptability. The sample were served at refrigeration temperature ($< 7^\circ\text{C}$). The innovative whey drink was optimized based on the statistical analysis.

2.5 Statistical analysis

The data obtained through triplicate analysis of each test were analysed using the two-way ANOVA method in IBM SPSS Statistics 26 software. Results are expressed as mean $\pm$ standard Deviation (SD). A 42 factorial

analysis was employed to select the levels of sugar and salt based on sensory analysis (Table 1). Further, 42 factorial experiments were employed for selecting the level of cumin and asafoetida (Table 1).

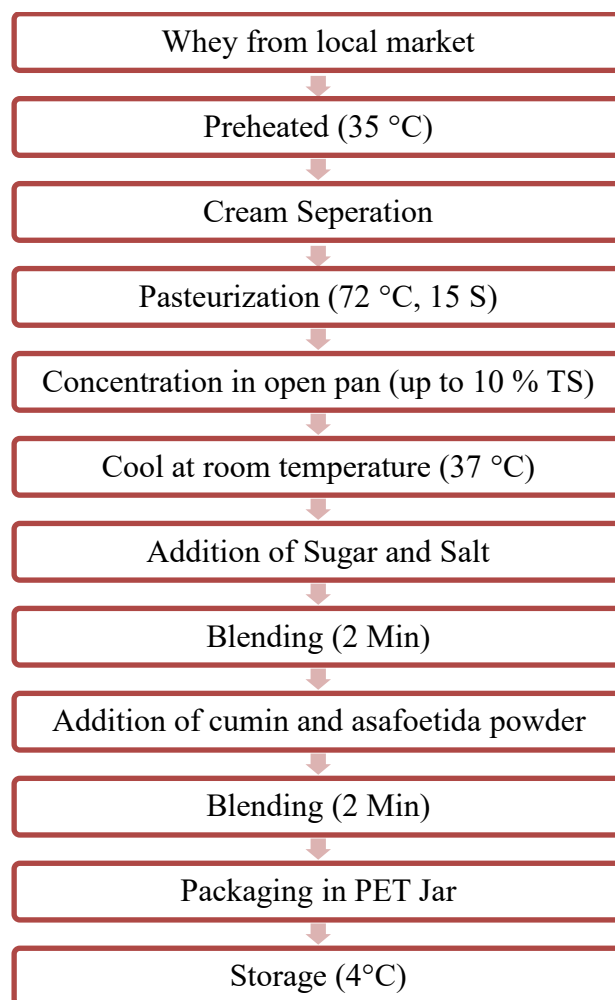


Fig. 1 Schematic for manufacture of Innovative whey drink

3. RESULTS AND DISCUSSION

Two sequential stages of sensory analysis were used to optimize the levels of the ingredients, namely sugar, salt, cumin, and asafoetida, to develop an innovative whey-based beverage. Salt and sugar concentrations were optimized in the first stage based on sensory parameters, while the levels of cumin and asafoetida were finalized based on the second stage of sensory analysis and antioxidant activity. Optimization to determine the best combination of the variable ingredients was carried out by evaluating the individual effects of each ingredient and their interactions across the 16 treatments obtained from the 4² factorial experiment (Tables 1 and 3).

3.1 Effect of Salt and Sugar Levels on Sensory Attributes of Innovative Whey Drink

Table 1 presents the sensory evaluation data for the 16 treatment combinations arising from the interaction of salt (0, 1, 2, and 3%) and sugar (0, 2.5, 5.0, and 7.5%), while the corresponding main effects on individual sensory parameters are reported in Table S1. The statistical significance of the effects of salt and sugar, individually and in combination, on the sensory attributes is presented in Table 2. The product was evaluated for colour and appearance, flavour, body and texture, packaging and overall acceptability by a panel of six panellists. The results are expressed as mean $\pm$ standard deviation.

The colour and appearance scores ranged from 6.00 ± 0.63 to 7.00 ± 0.32 across the treatment. The highest score was obtained for the treatment containing 2% salt and 7.5% sugar, whereas the lowest score was observed at 2% salt and 5% sugar. Table 2 revealed that the effects of salt, sugar and their interaction on colour and appearance were non-significant ($P > 0.05$), indicating that variation in salt and sugar concentration did not significantly affect this attribute.

The flavour scores ranged from 5.15 ± 0.21 to 8.00 ± 0.45 . The highest flavour score was observed in the treatment containing 2% salt and 7.5% sugar, indicating a favourable balance between sweetness and saltiness. The lowest score was recorded for 2% salt and 0% sugar. The ANOVA revealed that salt, sugar and their interaction had a significant effect on flavour ($P < 0.05$).

Body and texture scores ranged from 6.17 ± 0.26 to 7.33 ± 1.17 , with the highest values recorded for the 2% salt + 2% sugar and lowest 1% salt + 7.5% sugar treatments. However, the effects of salt, sugar and their interaction were statistically non-significant ($P > 0.05$). Thus, the variation in salt and sugar levels did not significantly modify the perceived body and texture of the whey drink.

Table 1. Effect of different levels of ingredients on sensorial attributes of innovative whey drink

Ingredients		Sensory attributes				
Salt (%)	Sugar (%)	Color and appearance	Flavor	Body and texture	Packaging	Overall acceptability
0	0.00	6.87 ± 0.58	5.18 ± 0.19	6.50 ± 0.84	7.00 ± 1.05	6.32 ± 0.23
0	2.00	6.75 ± 0.59	5.68 ± 0.26	6.58 ± 0.49	7.17 ± 0.93	6.83 ± 0.27
0	5.00	6.87 ± 0.49	5.83 ± 0.24	6.75 ± 0.61	7.08 ± 1.20	6.83 ± 0.16
0	7.50	6.98 ± 0.40	5.75 ± 0.24	7.00 ± 0.71	7.50 ± 0.77	6.92 ± 0.15
1	0.00	6.97 ± 0.52	5.67 ± 0.18	7.31 ± 0.52	7.58 ± 0.49	6.55 ± 0.15
1	2.00	6.55 ± 0.39	6.22 ± 0.28	7.25 ± 0.42	7.25 ± 1.17	7.22 ± 0.25
1	5.00	6.92 ± 0.13	6.57 ± 0.38	7.25 ± 0.76	7.17 ± 0.75	7.23 ± 0.26
1	7.50	6.58 ± 0.38	7.18 ± 0.26	6.17 ± 0.26	6.25 ± 0.42	6.93 ± 0.12
2	0.00	6.58 ± 0.38	6.17 ± 0.20	6.42 ± 1.36	6.33 ± 1.33	6.50 ± 0.33
2	2.00	6.50 ± 0.45	6.65 ± 0.23	7.33 ± 1.17	6.83 ± 1.03	7.37 ± 0.24
2	5.00	6.00 ± 0.63	7.23 ± 0.29	6.42 ± 1.02	6.50 ± 0.84	7.57 ± 0.25
2	7.50	7.00 ± 0.32	8.00 ± 0.45	7.00 ± 0.32	7.25 ± 0.61	8.13 ± 0.27
3	0.00	6.53 ± 0.45	5.15 ± 0.21	6.83 ± 0.98	6.92 ± 0.80	6.23 ± 0.26
3	2.00	6.67 ± 0.61	5.70 ± 0.27	7.08 ± 0.66	6.58 ± 0.92	6.60 ± 0.25
3	5.00	6.50 ± 0.45	5.22 ± 0.20	7.08 ± 0.49	6.50 ± 1.00	6.80 ± 0.18
3	7.50	6.58 ± 0.49	6.15 ± 0.21	7.17 ± 0.75	7.33 ± 0.41	7.30 ± 0.14

Mean $\pm$ SD, (For sensorial parameters: n = 6)

Flavour & Overall Acceptability: significant difference ($P < 0.05$)

Color and appearance; Body and texture & Packaging: non-significant Difference ($P > 0.05$)

The packaging scores ranged from 6.25 ± 0.42 to 7.58 ± 0.49 . The highest score was recorded for 1% salt and 0% sugar, while the lowest score was observed for 1% salt and 7.5% sugar. The ANOVA indicated that the effect of salt, sugar and their interaction on packaging was non-significant ($P > 0.05$).

The overall acceptability scores varied from 6.23 ± 0.26 to 8.13 ± 0.27 . The highest overall acceptability was observed for 2% salt + 7.5% sugar (8.13 ± 0.27), followed by 2% salt + 5% sugar (7.57 ± 0.25) and 2% salt + 2% sugar (7.37 ± 0.24). The lowest overall acceptability was observed for 2% salt + 0% sugar. Both salt and sugar, as well as their interaction, significantly affected overall acceptability ($P < 0.05$).

Therefore, on the basis of sensory evaluation, 2% salt and 7.5% sugar may be considered the most acceptable salt-sugar combination, as it resulted in the highest flavour and overall acceptability scores.

Table 2 ANOVA for effect of Salt (SL) and Sugar (SG) (individually and in combination) on sensorial attributes of innovative whey drink

Source	DF	Mean Square				
		Color and appearance	Flavor	Body and texture	Packaging	Overall acceptability
Salt%	3	0.62	11.64*	0.62	1.05	2.35*
Sugar%	3	0.25	6.14*	0.38	0.29	3.74*
Salt $\times$ Sugar%	9	0.38	0.62*	1.05	1.26	0.42*

* Indicate significant difference ($P < 0.05$)

The ANOVA results clearly demonstrate that flavour and overall acceptability were significantly influenced by salt and sugar levels, whereas colour and appearance, body and texture, and packaging were not significantly affected. The interaction between salt and sugar was also significant for flavour and overall acceptability. These findings support the sensory observations in Table 1 and indicate that the appropriate combination of salt and sugar is important for improving the palatability and acceptability of the whey beverage.

3.2 Effect of Cumin and Asafoetida on Sensory Attributes and Antioxidant Activity

The influence of varying cumin and asafoetida concentrations on the sensory attributes and antioxidant activity of the whey beverage is presented in Table 3, with antioxidant activity determined via the ABTS radical scavenging assay.

The colour and appearance scores ranged from 6.50 ± 0.37 to 7.80 ± 0.21 . The highest score was recorded at 0.125% cumin and 0.50% asafoetida, while the lowest score was recorded at 0.5% cumin and 0.5% asafoetida

(Table 3). The significant effect observed in the ANOVA indicates that the concentration of cumin and asafoetida influenced the colour and appearance of the beverage (Table 4).

The flavour scores ranged from 6.15 ± 0.21 to 8.17 ± 0.29 . The highest flavour score was recorded for 0.125% cumin and 0.125% asafoetida, indicating a favourable sensory response to this level of cumin without asafoetida (Table 3). Increasing the level of asafoetida at this cumin concentration resulted in a reduction in flavour score. Cumin, asafoetida and their interaction were all significant for flavour ($P < 0.05$) (Table 4).

Table 3. Effect of different levels of ingredients on sensorial attributes and Antioxidant activity of innovative whey drink

Ingredients		Sensory attributes					Antioxidant activity
Cumin (%)	Asafoetida (%)	Color and appearance	Flavor	Body and texture	Packaging	Overall acceptability	ABTS Assay
0.00	0.00	6.55 ± 0.38	6.38 ± 0.19	7.32 ± 0.31	7.88 ± 0.29	6.35 ± 0.33	1.24 ± 0.20
0.00	0.125	7.32 ± 0.31	6.75 ± 0.25	7.93 ± 0.23	7.97 ± 0.33	7.15 ± 0.41	3.19 ± 0.31
0.00	0.25	7.70 ± 0.21	7.23 ± 0.23	7.53 ± 0.15	7.92 ± 0.20	6.95 ± 0.23	6.08 ± 0.53
0.00	0.50	7.77 ± 0.23	7.48 ± 0.31	6.52 ± 0.33	7.82 ± 0.28	6.83 ± 0.24	10.04 ± 0.51
0.125	0.00	6.90 ± 0.24	6.82 ± 0.22	8.02 ± 0.26	7.78 ± 0.23	7.15 ± 0.27	6.28 ± 0.53
0.125	0.125	7.40 ± 0.28	8.17 ± 0.29	8.08 ± 0.30	7.95 ± 0.23	7.92 ± 0.35	10.78 ± 0.81
0.125	0.25	7.72 ± 0.26	7.53 ± 0.27	7.67 ± 0.20	7.88 ± 0.28	7.65 ± 0.23	16.96 ± 0.60
0.125	0.50	7.80 ± 0.21	6.75 ± 0.25	7.43 ± 0.14	7.87 ± 0.27	7.37 ± 0.29	23.81 ± 0.35
0.25	0.00	7.72 ± 0.29	6.25 ± 0.22	7.65 ± 0.33	7.80 ± 0.28	6.90 ± 0.25	9.77 ± 0.58
0.25	0.125	7.48 ± 0.37	6.88 ± 0.24	7.27 ± 0.23	7.88 ± 0.25	7.47 ± 0.23	19.51 ± 0.47
0.25	0.25	7.07 ± 0.21	7.33 ± 0.23	7.37 ± 0.32	7.87 ± 0.29	7.00 ± 0.18	22.40 ± 0.40
0.25	0.50	6.85 ± 0.27	7.13 ± 0.32	6.97 ± 0.23	7.90 ± 0.26	6.97 ± 0.15	26.16 ± 0.65
0.50	0.00	7.18 ± 0.22	6.15 ± 0.21	7.35 ± 0.21	7.83 ± 0.21	7.25 ± 0.25	16.22 ± 0.47
0.50	0.125	7.48 ± 0.21	6.77 ± 0.29	7.08 ± 0.24	7.77 ± 0.29	7.68 ± 0.22	24.75 ± 0.71
0.50	0.25	7.20 ± 0.30	6.68 ± 0.21	6.70 ± 0.27	7.73 ± 0.23	6.98 ± 0.31	32.08 ± 1.01
0.50	0.50	6.50 ± 0.37	6.18 ± 0.22	6.28 ± 0.23	7.80 ± 0.28	6.35 ± 0.22	41.48 ± 1.15

Mean $\pm$ SD, (For sensorial parameters: n = 6)

For Sensorial Attributes

Flavour; Color and appearance; Body and texture & Overall Acceptability: significant difference ($P < 0.05$)

Packaging: non-significant Difference ($P > 0.05$)

For Antioxidant activity

ABTS Assay: significant difference ($P < 0.05$)

The body and texture scores ranged from 6.28 ± 0.23 to 8.08 ± 0.30 . The highest score was obtained with 0.125% cumin + 0.125% asafoetida, whereas the lowest score was obtained with 0.50% cumin + 0.50% asafoetida (Table 3). The significant effects of cumin, asafoetida and their interaction suggest that spice concentration influenced the perceived body and texture of the beverage.

The packaging scores were comparatively stable, ranging from 7.73 ± 0.23 to 7.97 ± 0.33 (Table 3). The ANOVA showed that cumin, asafoetida and their interaction did not significantly ($P > 0.05$) affect packaging scores (Table 4). Thus, the incorporation of these ingredients did not substantially change the panellists' evaluation of the packaging attribute.

The overall acceptability scores ranged from 6.35 ± 0.22 to 7.92 ± 0.35 . The highest overall acceptability was observed for 0.125% cumin + 0.125% asafoetida (7.92 ± 0.35), followed by 0.50% cumin + 0.125% asafoetida

(7.68 ± 0.22) and 0.125% cumin + 0.25% asafoetida (7.65 ± 0.23). The lowest score was observed at 0.5% cumin + 0.5% asafoetida (6.35 ± 0.22).

3.4 Effect of Cumin and Asafoetida on Antioxidant Activity

The ABTS antioxidant activity showed considerable variation among the different cumin–asafoetida combinations. Values ranged from 1.24 ± 0.20 to 41.48 ± 1.15 . The highest antioxidant activity was recorded in the treatment containing 0.50% cumin + 0.50% asafoetida (41.48 ± 1.15). This was followed by 0.5% cumin + 0.25% asafoetida (32.08 ± 1.01) and 0.25% cumin + 0.50% asafoetida (26.16 ± 0.65). The antioxidant activity increased with increasing cumin concentration up to the treatment containing 0.50% cumin and 0.50% asafoetida. The statistical analysis confirmed that cumin, asafoetida and their interaction significantly affected ABTS antioxidant activity ($P < 0.05$).

Table 4 ANOVA for effect of Cumin (CU) and Asafoetida (AS) (individually and in combination) on sensorial attributes and antioxidant activity (ABTS assay) of innovative whey drink

Source	DF	Mean Square					
		Sensory Attributes					Antioxidant ABTS assay
		Color and appearance	Flavo r	Body and texture	Packaging	Overall acceptability	
Cumin %	3	0.55*	3.07*	3.58*	0.06	2.03*	1154.46*
Asafoetida %	3	0.63*	3.17*	3.31*	0.02	2.32*	624.37*
Cumin × Asafoetida %	9	1.40*	0.98*	0.39*	0.02	0.44*	29.12*

* Indicate significant difference ($P < 0.05$)

Importantly, the treatment with the highest antioxidant activity was not the treatment with the highest sensory acceptability. The 0.50% cumin + 0.50% asafoetida treatment recorded the highest ABTS value but comparatively low flavour and overall acceptability scores. In contrast, 0.125% cumin + 0.125% asafoetida showed the highest flavour and overall acceptability scores but a lower antioxidant activity. Based on sensory parameters, 0.125% cumin and 0.125% asafoetida were found to be the best combination for the preparation of the innovative whey drink.

The ANOVA results demonstrate that cumin significantly affected colour and appearance, flavour, body and texture, overall acceptability and antioxidant activity, whereas its effect on packaging was non-significant. Similarly, asafoetida significantly affected all sensory attributes except packaging and significantly influenced antioxidant activity. The interaction between cumin and asafoetida was also significant for colour and appearance, flavour, body and texture, overall acceptability and antioxidant activity, while its effect on packaging remained non-significant.

3.5 Overall Discussion and Selection of the Promising Formulation

Collectively, these results demonstrate that the sensory quality of the whey-based beverage was strongly dependent on the formulation levels of salt, sugar, cumin, and asafoetida. In the salt–sugar optimization experiment, the 2% salt + 7.55% sugar treatment yielded the highest flavour score (8.00 ± 0.45) and overall acceptability (8.13 ± 0.27).

In the cumin–asafoetida optimization experiment, the 0.125% cumin + 0.125% asafoetida treatment produced the highest flavour score (8.17 ± 0.29), body and texture score (8.08 ± 0.30), and overall acceptability score (7.92 ± 0.35), whereas the highest antioxidant activity was obtained with the 0.50% cumin + 0.50% asafoetida treatment (41.48 ± 1.15).

These findings reveal a clear divergence between sensory optimization and antioxidant optimization: elevated cumin and asafoetida concentrations enhance antioxidant activity but may compromise flavour and overall acceptability at higher levels. Consequently, selection of the final formulation should balance desired sensory quality against functional antioxidant activity rather than optimizing either parameter in isolation.

4. ACKNOWLEDGMENT

The corresponding author gratefully acknowledges the laboratory facilities and support provided by the College of Dairy and Food Technology (CDFT), Bassi, Jaipur, which facilitated the successful completion of the experimental work. The support and cooperation of the laboratory staff are also sincerely appreciated.

5. CONCLUSION

The present study demonstrated the potential of whey as a suitable base for the development of an innovative, value-added functional beverage fortified with cumin and asafoetida. The sequential optimization of sugar, salt, cumin, and asafoetida concentrations showed that formulation levels had a significant influence on the sensory and functional characteristics of the beverage.

Among the salt-sugar combinations, 2% salt and 7.5% sugar produced the most acceptable beverage, recording the highest flavor score (8.00 ± 0.45) and overall acceptability score (8.13 ± 0.27). Further optimization of cumin and asafoetida indicated that 0.125% cumin and 0.125% asafoetida was the most suitable combination from a sensory perspective, with the highest flavour (8.17 ± 0.29), body and texture (8.08 ± 0.30), and overall acceptability (7.92 ± 0.35).

The ABTS antioxidant assay demonstrated that increasing the concentration of cumin and asafoetida enhanced the antioxidant activity of the whey beverage. The highest antioxidant activity (41.48 ± 1.15) was observed at 0.50% cumin and 0.50% asafoetida. However, this formulation showed comparatively lower sensory acceptability. Thus, the study revealed a clear balance between sensory quality and antioxidant potential, indicating that higher spice concentrations may improve antioxidant activity but can adversely affect consumer acceptability.

Overall, the optimized formulation containing 2% salt, 7.5% sugar, 0.125% cumin, and 0.125% asafoetida can be considered a promising formulation based primarily on sensory acceptability. The developed beverage provides an effective approach for value addition and utilization of whey, while incorporating traditionally used spices to improve its sensory and functional characteristics. Further studies on nutritional profiling, physicochemical properties, microbial quality, storage stability, and consumer acceptance are recommended to establish its potential for commercial scale production.

REFERENCES

1. Brandelli, A., Daroit, D. J., & Corrêa, A. P. F. (2015). Whey as a source of peptides with remarkable biological activities. *Food Research International*, 73, 149-161.
2. Zhao, C., Chen, N., & Ashaolu, T. J. (2022). Whey proteins and peptides in health-promoting functions—A review. *International Dairy Journal*, 126, 105269.
3. Mohiuddin, A. K. (2019). *Nature and nutrition: a new era of therapeutic herbs*. Nova Science Publishers.
4. Singh, N., Yadav, S. S., Kumar, S., & Narashiman, B. (2021). A review on traditional uses, phytochemistry, pharmacology, and clinical research of dietary spice *Cuminum cyminum* L. *Phytotherapy Research*, 35(9), 5007-5030.
5. Kavooosi, G., Tafsiry, A., Ebdam, A. A., & Rowshan, V. (2013). Evaluation of antioxidant and antimicrobial activities of essential oils from *Carum copticum* seed and *Ferula assafoetida* latex. *Journal of food Science*, 78(2), T356-T361.
6. Jelen, P., Currie, R., & Kadis, V. W. (1987). Compositional analysis of commercial whey drinks. *Journal of Dairy Science*, 70(4), 892-895.
7. Mirzakulova, A., Sarsembaeva, T., Suleimenova, Z., Kowalski, L., Gajdzik, B., Wolniak, R., & Bembenek, M. (2025). Whey: Composition, processing, application, and prospects in functional and nutritional beverages—A review. *Foods*, 14(18), 3245.
8. Barukčić, I., Lisak Jakopović, K., & Božanić, R. (2019). Pregled mogućih načina iskorištenja sirutke i mlaćenice u proizvodnji funkcionalnih napitaka. *Food Technology and Biotechnology*, 57(4), 448-460.
9. Jelen, P. (2009). Whey-based functional beverages. In *Functional and speciality beverage technology* (pp. 259-280). Woodhead Publishing.
10. Sowbhagya, H. B. (2013). Chemistry, technology, and nutraceutical functions of cumin (*Cuminum cyminum* L): an overview. *Critical reviews in food science and nutrition*, 53(1), 1-10.
11. Amalraj, A., & Gopi, S. (2017). Biological activities and medicinal properties of Asafoetida: A review. *Journal of traditional and complementary medicine*, 7(3), 347-359.
12. Niazmand, R., & Razavizadeh, B. M. (2021). *Ferula assafoetida*: chemical composition, thermal behavior, antioxidant and antimicrobial activities of leaf and gum hydroalcoholic extracts. *Journal of Food Science and Technology*, 58(6), 2148-2159.
13. Boghrati, Z., & Iranshahi, M. (2019). *Ferula* species: A rich source of antimicrobial compounds. *Journal of herbal medicine*, 16, 100244.