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Studies on preparation of paneer impregnated with dragon fruit

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Abstract
Paneer, though nutritionally rich, lacks functional compounds such as fibre, phenolics, flavonoids, and vitamins. This study aimed to enhance paneer quality by incorporating dragon fruit. Preliminary trials identified paste from the white-fleshed, pink-skinned variety as most suitable. Incorporation at 15% produced the most acceptable paneer, comparable to control in sensory scores. The optimized paneer contained 20.89% fat, 18.91% protein, 59.09% moisture, and pH 5.48, with improved vitamin C (15.0 mg/100 g), phenolics (0.49 mg GAE/g), flavonoids (0.17 mg QE/g), and dietary fibre (2.82%). Colour analysis showed enhanced red-purple tones, while texture profiling revealed reduced hardness and improved cohesiveness and springiness. Production cost decreased to ₹303.40/kg with higher recovery and benefit-cost ratio. Microbiological analysis confirmed safety. Overall, 15% dragon fruit paste significantly improved nutritional, functional, sensory, and economic qualities, making paneer a promising functional dairy product.

Keywords: Paneer**,** dragon fruit**,** optimized, preparation**,** level

Introduction

Material and Methods

Materials

Standardized, toned, double-toned, and skimmed milk were procured from the local dairy cooperative. Fully ripened dragon fruits of three varieties—white-fleshed (*Hylocereus undatus*), red-fleshed (*H. costaricensis*), and yellow-skinned white-fleshed (*H. megalanthus*) were obtained from the local market. Food-grade citric acid was used for coagulation, and refined cottonseed oil was used for frying. Muslin cloth and a stainless-steel paneer press were employed for whey drainage and block formation. Essential laboratory equipment included stainless-steel vessels, glassware, digital weighing balance, hot air oven, muffle furnace, texture analyzer, pH meter, and colour analyzer. A hand blender and mixer-grinder were used for homogenization and fruit paste preparation. For frying, a heavy-bottomed stainless-steel *kadhai*, skimmer, and fine mesh strainer were used. All equipment was cleaned and sterilized, and hygienic conditions were maintained throughout the study.

Methodology

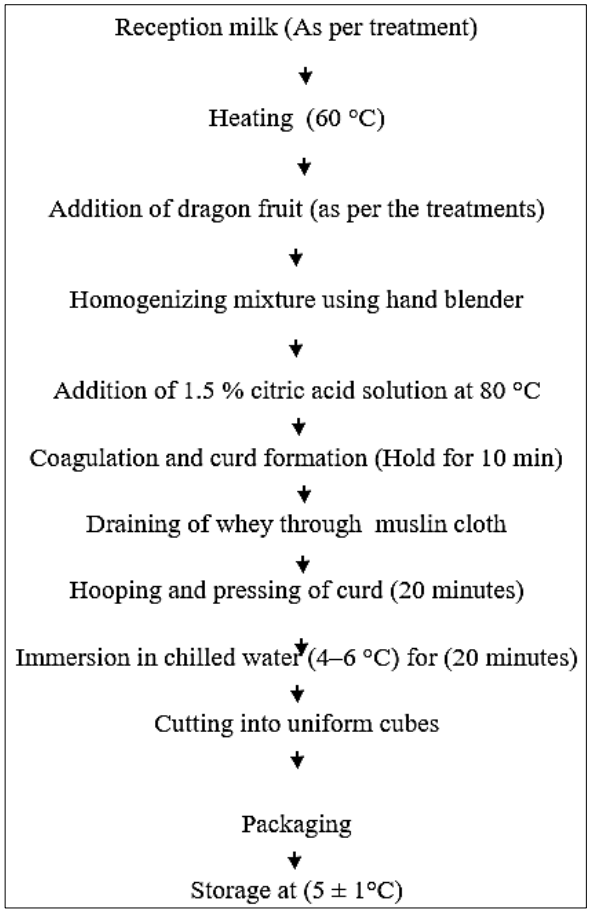
Preparation of different forms of dragon fruit

The aqueous form was prepared by washing, despiking, and crushing fresh dragon fruits with potable water (1:2 w/v) as per Khairnar (2024) [19]. The paste was obtained by washing, despiking, and grinding whole fruits into a fine homogenate following Susanti et al. (2022) [34]. The powder form was prepared by washing, despiking, grating, oven-drying at 65 °C, and grinding the fruit into fine powder, as described by Patel (2022) [25].

Preparation of Paneer Using Dragon Fruit

Paneer was prepared following the method of Badola et al. (2018) [4] with modifications. Filtered milk was heated to 60 °C, blended with the required form of dragon fruit, and further heated to 80 °C. Coagulation was carried out using 1.5% citric acid solution, and the curd was allowed to settle for 10 min. The coagulum was drained through muslin cloth, pressed at ~2 kg/cm² for 20 min, and then immersed in chilled water (7±1 °C) for 15–20 min. The

paneer was cut into 1 cm^3 cubes, packed in polythene pouches, and stored at 5±1 °C for analysis.



Selection of Dragon Fruit Forms

To evaluate suitability, the white-fleshed and pink skin variety was incorporated in milk in different forms. Treatments were coded as: DF_0 – control (no dragon fruit), DF_1 – paste, DF_2 – aqueous extract, and DF_3 – powder.

Selection of Dragon Fruit Varieties

After finalizing the form, dragon fruit was incorporated at 10% level to evaluate different varieties. Treatments were coded as: DV_0 – control, DV_1 – white-fleshed, DV_2 – red-fleshed, and DV_3 – yellow-skinned white-fleshed. The best variety was selected based on sensory evaluation.

Optimization of Dragon Fruit Level in Paneer

The selected form and variety of dragon fruit were incorporated at different levels to assess their effect on paneer quality. Treatments included DL_0 (control), DL_1 (5%), DL_2 (10%), DL_3 (15%), and DL_4 (20%) dragon fruit paste. Samples were evaluated for sensory, physicochemical, colour, textural, and microbial attributes, and the optimal level was identified based on sensory acceptability.

Frying Study of Dragon Fruit Paneer

Paneer cubes (1.5 × 1.5 × 1.5 cm) were prepared following Kalab et al. (1988) [18] and fried in refined oil at 175±5 °C for 5 min, ensuring uniform texture and colour development (Sharma et al., 1998) [30]. Excess oil was drained before evaluation. Treatments included F_1 (raw control), F_2 (fried control), F_3 (raw dragon fruit paneer), and F_4 (fried dragon fruit paneer). Both raw and fried samples were subjected to sensory evaluation.

Analytical Methods

Physico-chemical analysis of dragon fruit incorporated paneer: The pH was measured using a calibrated digital pH meter (AOAC, 2012) [2], and titratable acidity was determined by titration with 0.1 N NaOH using phenolphthalein as indicator (BIS: 1479, 1960, Part-I). Fat content was estimated by acid digestion and Mojonnier extraction (FSSAI, 2022) [11], protein by Kjeldahl method with nitrogen-to-protein factor 6.38 (AOAC, 2012) [2], and total carbohydrates by Lane-Eynon's method after reducing sugar extraction (IS: 1479 Part-II, 1961). Moisture was determined by oven drying at 102 ±1°C until constant weight (AOAC, 2003) [1], ash by incineration in a muffle furnace at 550 °C (AOAC, 2012) [1], and total solids were calculated as 100 − moisture (FSSAI, 2022) [11].

Determination of functional properties of dragon fruit incorporated paneer: Total phenolic content was measured by Folin-Ciocalteu method and expressed as µg GAE/mL (Kähkönen et al., 1999) [17]. Total flavonoid content was determined by aluminum chloride colorimetric method and expressed as mg QE/g (Jia et al., 1999) [16]. Dietary fiber was estimated by enzymatic-gravimetric method with sequential digestion, ethanol precipitation, and ashing (AOAC, 2012) [2]. Ascorbic acid was determined by titration with 2, 6-dichlorophenolindophenol after extraction with 3% metaphosphoric acid (Ranganna, 1986) [28].

Instrumental Hunter colour analysis of dragon fruit incorporated paneer: Colour measurements were performed using a Colour Scanning Machine (Color Flex EZ, Premier Colourscan, Thane, Maharashtra) based on the CIELAB scale with D65 illuminant. The instrument recorded L* (lightness), a* (red–green), and b* (yellow–blue) values after calibration with standard white and black tiles. Hue, representing the specific shade; chroma, indicating colour intensity; and energy index, reflecting overall colour vividness, were calculated according to CIE standard Illuminate (ISO 1164-2:2007, 2006).

Texture profile analysis of dragon fruit incorporated paneer: The texture of paneer samples was evaluated using the Stable Micro Systems TAXT2 Plus Texture Analyzer. Uniform paneer cubes (20 × 20 × 20 mm) were analyzed using a P/75 stainless steel compression plate under standardized conditions (50 kg load cell, 5 g trigger force, 10 mm/s return speed, 600 mm/min crosshead speed). Textural parameters—including hardness, adhesiveness, springiness, cohesiveness, chewiness, and gumminess—were determined from the two-cycle compression test simulating mastication (Stable Micro Systems, 2009).

Microbial analysis of dragon fruit incorporated paneer: Dragon fruit paneer was analyzed for Standard Plate Count (SPC) using Plate Count Agar (HiMedia, Mumbai; IS: 5402, 1969), coliform count using Violet Red Bile Agar (HiMedia, Mumbai; IS: 5887, 1976), and yeast and mold count using Potato Dextrose Agar (HiMedia, Mumbai; IS: 5401, 1969).

Comparative evaluation of control and optimized paneer: Control and 15% dragon fruit incorporated paneer

were compared for sensory, physico-chemical, and textural properties to assess the impact of dragon fruit addition and identify the most acceptable formulation.

Cost of production: The cost was calculated using current market prices of dragon fruit paste, milk, additives, fuel, and packaging, summing all expenses to estimate total production.

Statistical analysis: Data were analyzed using CRD and FCRD with four replicates, and one- and two-way ANOVA was performed to determine significant differences among means (Panse and Sukhatme, 1985) [24].

Results and discussion

Effect of Form of Whole Dragon Fruit on Sensory Attributes of Paneer

Paneer prepared with dragon fruit paste showed superior colour, texture, and flavour scores, closely matching the control, whereas aqueous extract and powder forms resulted in lower values due to pigment degradation, softer or gritty texture, and reduced flavour, findings consistent with Yankey et al. (2023) [40], Sameem et al. (2018) [29] and Susanti et al. (2022) [34]. Overall acceptability was highest in control and paste-incorporated paneer, while aqueous extract and powder forms were significantly less acceptable, in agreement with Ojha et al. (2022) [23].

Table 1: Effect of form of whole dragon fruit on sensory attributes of paneer

Form of dragon fruit	Sensory Properties			
	Colour and appearance	Body and texture	Flavour	Overall acceptability
DF_0	8.14^{a}±0.03	8.22^{a}±0.04	8.21^{a}±0.05	8.19^{a}±0.02
DF_1	7.78^{b}±0.07	7.86^{b}±0.05	8.11^{a}±0.06	7.91^{b}±0.05
DF_2	5.28^{d}±0.08	7.30^{c}±0.08	7.65^{b}±0.05	6.74^{c}±0.06
DF_3	5.65^{c}±0.06	5.49^{d}±0.06	7.01^{c}±0.04	6.05^{d}±0.02
SEm	0.07	0.07	0.06	0.05
CD	0.24	0.23	0.20	0.15

*Means ± SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Effect of Variety of Dragon Fruit on Sensory Attributes of Paneer: DV_1 (pink skin with white flesh) emerged as the most suitable variety for paneer fortification, offering superior colour, flavour, and overall acceptability compared to DV_2 and DV_3, consistent with earlier findings (Lande et al. 2024; Tarte et al. 2023;; Unal et al. 2025) [20, 35, 38].

Table 2: Effect of variety of dragon fruit on sensory attributes of paneer:

Variety of dragon fruit	Sensory Properties			
	Colour and appearance	Body and texture	Flavour	Overall acceptability
DV_1	7.74^{a}±0.06	7.93^{a}±0.02	8.13^{a}±0.08	7.94^{a}±0.05
DV_2	5.28^{c}±0.08	7.94^{a}±0.03	7.65^{b}±0.06	6.95^{b}±0.04
DV_3	5.72^{b}±0.09	7.91^{a}±0.02	5.60^{c}±0.04	6.86^{b}±0.05
SEm	0.08	0.06	0.06	0.04
CD	0.30	NS	0.24	0.18

*Means ± SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Optimization of Dragon Fruit Level in Paneer on sensory attributes: Paneer prepared with varying levels of dragon fruit showed that colour and appearance improved with increasing fruit levels, peaking at 15% due to optimal pigment saturation and homogeneous dispersion, while 20% addition reduced visual appeal, consistent with Sameem et al. 2018 [29]. Body and texture were highest at 15%, likely from balanced pectin–protein interactions and uniform moisture distribution, whereas lower firmness at 5% and structural disruption at 20% reduced scores, aligning with Izalin et al. 2016, Wusigale et al. 2020, and Zenyu et al. 2024 [15, 39, 41]. Flavour increased progressively, peaking at 15% and remaining high at 20%, reflecting a balance between sweetness and aromatic compounds, corroborating Susanti et al. 2022 [34]. Overall acceptability was maximal at 15%, indicating harmonious integration of sensory attributes, while minimal and excessive inclusion reduced acceptability, consistent with Tarte et al. 2023 [35] and Tong et al. 2025 [37]

Table 3: Effect of level of whole dragon fruit on sensory attributes of paneer

Dragon fruit level	Sensory Properties (Score*)			
	Color	Body and texture	Flavor	Overall acceptability
DL_1	7.13^{c}±0.05	7.09^{c}±0.03	7.01^{d}±0.09	7.08^{d}±0.04
DL_2	7.54^{b}±0.07	7.34^{b}±0.05	7.28^{c}±0.02	7.25^{c}±0.03
DL_3	8.19^{a}±0.02	8.22^{a}±0.04	8.35^{a}±0.02	8.36^{a}±0.01
DL_4	7.10^{c}±0.09	6.88^{d}±0.11	8.20^{a}±0.06	7.39^{b}±0.03
SEm	0.07	0.04	0.07	0.04
CD	0.23	0.23	0.19	0.11

*Means±SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Effect of levels of dragon fruit on physico- chemical attributes of paneer: The physico-chemical analysis of dragon fruit-incorporated paneer (Table no 4) indicated that increasing levels of fruit significantly affected the composition and stability of the product. Fat content declined progressively, likely due to the presence of dietary

fibers enhancing water retention and reducing fat entrapment during coagulation, consistent with Raju and Pal (2014) [26]. Protein content showed a slight decrease, reflecting minimal influence of dragon fruit on casein coagulation, in agreement with. Carbohydrate content increased with higher fruit levels, indicating additional sugars contributed by the fruit, consistent with Singh et al. 2022 [32], while moisture content rose due to the high water-holding capacity of dragon fruit, corroborating Raibagkar et al. 2024 [27]. Ash content increased with fruit incorporation owing to its mineral richness, as reported by Lim et al. 2024 [21], whereas total solids decreased correspondingly due to dilution from higher moisture, in agreement with Roy et al. Titratable acidity increased progressively with fruit addition because of natural organic acids, consistent with Bhagat et al. 2024 [5], and pH decreased correspondingly, reflecting acidification of the paneer matrix, as reported by Chavan et al. 2025 [7].

Table 4: Effect of levels of dragon fruit on physico- chemical attributes of paneer

Level of Dragon Fruit	Physico- chemical attributes							
	Fat (%)	Protein (%)	Moisture (%)	Carbohydrate (%)	Ash (%)	Total Solid (%)	Acidity (%)	pH
DF_1	24.09^{a}±0.01	18.45^{ac}±0.09	60.48^{d}±0.06	1.75^{d}±0.02	1.52^{c}±0.01	39.5^{a}±0.06	0.37^{d}±0.01	5.69^{a}±0.04
DF_2	23.12^{b}±0.01	18.38^{abc}±0.03	61.20^{c}±0.03	2.30^{c}±0.02	1.55^{bc}±0.01	38.8^{b}±0.03	0.45^{c}±0.01	5.59^{b}±0.01
DF_3	22.18^{c}±0.01	18.22^{ab}±0.01	62.00^{b}±0.03	2.85^{b}±0.03	1.60^{b}±0.01	38.0^{c}±0.03	0.49^{b}±0.01	5.51^{c}±0.01
DF_4	21.13^{d}±0.01	18.09^{a}±0.02	62.96^{a}±0.02	3.40^{a}±0.02	1.66^{a}±0.01	37.0^{d}±0.04	0.56^{a}±0.01	5.43^{d}±0.02
SEm	0.01	0.06	0.05	0.02	0.01	0.05	0.01	0.02
CD	0.04	0.20	0.14	0.09	0.04	0.20	0.03	0.08

*Means±SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Effect of levels of dragon fruit on functional properties of paneer:

The incorporation of dragon fruit into paneer significantly enhanced its functional properties (Table 5). Total phenolic content increased from 0.24 mg GAE/g in DL_1 to 0.49 mg GAE/g in DL_4, reflecting improved phenolic extraction, consistent with Coelho et al. (2024) [8] Total flavonoid content rose to 0.17 mg QE/g in DL_4, indicating effective integration of bioactive compounds into the protein matrix, in agreement with Lim et al. (2024.)Vitamin C content increased from 10.2 mg to 15.0 mg, highlighting the fruit's antioxidant contribution, consistent with Bhagat et al. (2024) [5]. Dietary fiber increased from 1.88% to 2.82%, improving water retention, texture, and functional benefits, corroborating Chavan et al. (2025) [7]. These findings demonstrate that dragon fruit fortification markedly enhances the antioxidant, nutritional, and functional quality of paneer.

Table 5: Effect of levels of dragon fruit on functional properties of paneer

Level of Dragon fruit	Functional content			
	Phenols(mgGAE/g)	Flavonoids(mgQE/g)	Vit c (mg/ml)	Fiber (%)
DL_1	0.24^{c}±0.01	0.04^{b}±0.01	10.2^{d}±0.1	1.88^{d}±0.01
DL_2	0.37^{b}±0.02	0.08^{b}±0	12.2^{c}±0.2	2.00^{c}±0.01
DL_3	0.47^{a}±0.01	0.13^{a}±0.01	13.2^{b}±0.3	2.56^{b}±0.01
DL_4	0.49^{a}±0.01	0.17^{a}±0.01	15.0^{a}±0.1	2.82^{a}±0.03
SEm	0.01	0.01	0.06	0.02
CD	0.05	0.03	0.68	0.06

*Means ±SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Effect of levels of dragon fruit on instrumental colour value parameter of paneer: The instrumental colour of paneer was significantly influenced by graded dragon fruit incorporation (Table 6). Lightness (L*) decreased from 78.06 in DL_1 to 71.14 in DL_4 due to betacyanin accumulation, consistent with Hafiz et al. 2025. Redness (a*) and yellowness (b*) increased from 4.78 to 6.82 and 8.83 to 11.27, respectively, reflecting betalain and carotenoid pigments, as reported by Silaturahmi et al. 2020 and Manihuruk et al. 2017 [33, 22]. Chroma rose from 8.98 to 11.43, indicating greater colour saturation, in agreement with. Hue angle slightly declined from 78.28 to 79.14, while colour index peaked at DL_2 before decreasing, suggesting an optimal pigment incorporation threshold. These results demonstrate that dragon fruit addition enhances redness and saturation while modulating lightness and hue.

Table 6: Effect of different levels of whole dragon fruit on colour value of paneer

Level of Dragon fruit	Colour characteristics					
	L^*	a^*	b^*	Chroma value	Hue value	Color Index
DL_1	78.06^{a}±0.04	1.83^{d}±0.02	8.83^{d}±0.03	8.98^{d}±0.02	78.28^{c}±0.6	2.66^{c}±0.03
DL_2	76.28^{b}±0.02	1.97^{c}±0.01	9.18^{c}±0.01	9.29^{c}±0.02	77.87^{d}±0.3	2.81^{a}±0.03
DL_3	74.05^{c}±0.04	2.04^{b}±0.02	10.12^{b}±0.04	10.19^{b}±0.5	78.54^{b}±0.4	2.72^{ba}±0.05
DL_4	71.14^{d}±0.05	2.16^{a}±0.02	11.27^{a}±0.02	11.43^{a}±0.2	79.14^{a}±0.3	2.1^{d}±0.05
SEm	0.04	0.02	0.04	0.04	0.05	0.04
CD	0.13	0.06	0.11	0.19	0.16	0.15

*Means ± SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Effect of levels of dragon fruit on textural properies of paneer: The textural attributes of paneer were significantly influenced by graded incorporation of dragon fruit (Table 7). Hardness decreased from 5.47 in DL_1 to 2.18 in DL_4 due

to higher moisture and fiber content disrupting the protein matrix, consistent with Wusigale et al., 2020. Cohesiveness increased from 0.48 to 1.20, reflecting reinforcement of the protein–polysaccharide network by dragon fruit polysaccharides (Thakur and Saxena, 2000) [36]. Elasticity rose from 1.03 cm to 1.22 cm, indicating enhanced resilience likely due to interactions between milk proteins and soluble fibers (Singh et al., 2020; Kalab et al., 1988) [31, 18]. Gumminess peaked at DL_3 (3.39 kg/N) and declined at DL_4, showing optimal matrix integrity at moderate fruit levels (Hosseini et al., 2015) [14]. Chewiness followed a similar trend, reaching 3.91 kg·cm at DL_3 and slightly decreasing at DL_4, reflecting the balance between hardness, cohesiveness, and elasticity, which aligns with observations in fiber-enriched burfi (Singh et al., 2020) [31]. Overall, moderate incorporation of dragon fruit improved textural resilience and mouthfeel, while excessive addition softened the paneer and reduced structural integrity.

Table 7: Effect of different levels of whole dragon fruit on textural properties of paneer

Level of Dragon Fruit	Textural Properties				
	Hardiness (kg)	Cohisiveness	Elasticity (cm)	Guminess s(Kg/N)	Chewiness (Kg-cm)
DL_1	5.47^{a}±0.01	0.48^{d}±0.01	1.03^{d}±0.02	2.61^{bc}±0.05	2.69^{c}±0.08
DL_2	4.83^{b}±0.02	0.58^{c}±0.01	1.07^{c}±0.01	2.80^{b}±0.04	3.00^{b}±0.05
DL_3	4.11^{c}±0.02	0.83^{b}±0.01	1.16^{b}±0.01	3.39^{a}±0.04	3.91^{a}±0.05
DL_4	2.18^{d}±0.03	1.20^{a}±0.02	1.22^{a}±0.01	2.61^{bc}±0.06	3.09^{b}±0.10
SEm	0.02	0.01	0.01	0.07	0.08
CD	0.08	0.05	0.05	0.19	0.28

*Means ± SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Effect of levels of dragon fruit on microbial count of paneer:

The microbiological evaluation of dragon fruit-incorporated paneer (Table 8) revealed a slight, yet statistically significant (p<0.05) increase in yeast and mould counts from 1.05 to 1.12 log CFU/g with progressive fruit incorporation (DL_1–DL_4), while coliforms were absent in all treatments, confirming adherence to hygienic standards. Total viable bacterial counts increased modestly from 3.14×10^3 CFU/g in DL_1 to 3.35×10^3 CFU/g in DL_4 but remained below spoilage thresholds, indicating minimal impact on shelf life under refrigerated conditions. The incremental rise in microbial load may be attributed to the additional organic substrates provided by dragon fruit, whereas the betalain pigments likely exerted antimicrobial effects, limiting the proliferation of spoilage or pathogenic organisms (Manihuruk et al., 2017; Bhagat et al., 2024) [22, 5]. These results demonstrate that dragon fruit incorporation maintains the microbiological safety and stability of paneer while providing bioactive benefits.

Table 8: Effect of levels of dragon fruit on microbial count of paneer

Level of Dragon Fruit	Microbial count		
	Yeast And Mould Count (CFU/gm)	Coliform Count (CFU/gm)	Standard Plate Count (CFU×10^3/gm)
DL_1	1.05^{b}±0.01	N.D.	3.14^{d} ±0.01
DL_2	1.08^{a}±0.01	N.D.	3.21^{c}±0.01
DL_3	1.1^{b}±0.01	N.D.	3.27^{b}±0.01
DL_4	1.12^{a}±0.0	N.D.	3.35^{a}±0.02
SEm	0.01	0.0	0.02
CD	0.03	0.0	0.05

*Means±SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Effect of frying on paneer with and without dragon fruit: Frying significantly influenced the sensory attributes of paneer. Colour scores were highest in F_2 (8.19) and F_4 (8.21) due to browning and stable betalain pigments from dragon fruit (Esquivel et al., 2007; Sharma et al., 1998; Goyal and Goyal, 2016) [10, 30, 12]. Body and texture improved in F_4 (8.20) and F_2 (8.11) from fiber and mucilage enhancing the gel matrix (Badola et al., 2018; Arivalagan et al., 2021) [4, 3]. Flavour was highest in F_4 (8.31) and F_2 (8.22), reflecting Maillard reaction compounds and fruity notes from dragon fruit (Eresam et al., 2013; Goyal and Goyal, 2016) [9, 12]. Overall acceptability peaked in F_4 (8.21), showing that frying combined with dragon fruit incorporation optimally enhanced consumer preference (Singh et al., 2022) [32].

Table 9: Effect of frying on paneer with and without dragon fruit

Paneer Samples	Sensory Properties(Score)*			
	Colour and appearance	Body and texture	Flavour	Overall acceptability
F_1	8.03^{a}±0.05	7.89^{b}±0.03	8.01^{b}±0.03	7.98^{b}±0.02
F_2	8.19^{a}±0.03	8.11^{a}±0.04	8.22^{a}±0.04	8.17^{a}±0.03
F_3	7.61^{b}±0.05	7.66^{c}±0.07	7.65^{c}±0.04	7.63^{c}±0.04
F_4	8.12^{a}±0.03	8.20^{a}±0.08	8.31^{a}±0.05	8.21^{a}±0.04
SEm	0.05	0.07	0.05	0.03
CD	0.16	0.22	0.16	0.13

*Means±SE of 4 replications within column followed by same letter are non-significantly different at (p<0.05)

Comparative Evaluation of Control and Optimized Paneer Sample.

The optimized dragon fruit-incorporated paneer exhibited significant improvements in sensory, physicochemical, functional, and textural attributes. Colour and appearance were slightly reduced, whereas flavour and overall acceptability increased significantly ($p<0.05$), likely due to the mild fruity and sweet notes imparted by dragon fruit. Moisture content increased, accompanied by a reduction in total solids and fat, while protein, carbohydrate, ash, and acidity showed notable enhancement. Functional constituents including phenolic content, flavonoids, dietary fibre, and vitamin C were markedly elevated, indicating improved nutritional value. Textural properties revealed decreased hardness with concomitant increases in cohesiveness, elasticity, and gumminess, while chewiness exhibited a non-significant rise. These findings collectively indicate that dragon fruit incorporation positively influenced the quality, nutritional profile, and consumer acceptability of paneer.

Table 10: Comparative Evaluation of Control and Optimized Paneer Sample.

Sensory attributes				Control Sample		Optimized Sample	t- static
Sr	Particular	Quantity	Rate(Rs)	Control paneer sample		Optimized Paneer sample	
				Quantity	₹	Quantity	₹
1	Colour and appearance			8.49±0.03		8.19±0.02	8.32*
2	Body and texture			8.22±0.04		8.22±0.04	0.00
3	Flavour			7.78±0.07		8.35±0.02	7.83
4	Overall acceptability			8.06±0.05		8.36±0.01	5.88
Physico-chemical attributes							
1	Fat			25.01±0.01		22.18±0.01	200.11
2	Protein			18.01±0.03		18.38±0.01	11.70
3	Carbohydrate			1.50±.0.02		2.85±0.03	37.44
4	Moisture			59.95±0.04		62.00±0.03	41.00
5	Total solid			40.0±0.04		38.0±0.03	40.00
6	Ash			1.46±0.02		1.60±0.01	6.26
7	Acidity			0.32±0.01		0.49±0.01	17.00*
8	pH			5.85±0.01		5.51±0.01	24.04
Functional properties							
1	Phenols			0.01±0.00		0.47±0.01	79.67
2	Flavonoids			0.05±0.03		0.13±0.01	4.38
3	Dietary Fiber			0.74±0.02		2.56±0.01	81.39
4	Vitamin C			0.05±0.03		13.2±0.03	309.95
Textural properties							
1	Hardness			6.84±0.02		4.11±0.02	96.52
2	Cohisiveness			0.34±0.01		0.83±0.01	34.65
3	Elasticity			0.92±0.01		1.16±0.01	16.97
4	Guminess			2.34±0.09		3.39±0.04	10.66
5	Chewiness			2.14±0.06		3.19±0.05	1.44

*Means±SE of 3 replications within column followed by same letter are non-significantly different at ($p<0.05$)

Cost of production of whole dragon fruit impregnated paneer

A comparative economic evaluation of control (DL_0) and dragon fruit-incorporated (DL_3) paneer showed that both treatments produced a yield of 500 kg. The DL_3 treatment required less milk, 2173 L compared to 2947 L for DL_0, resulting in a higher recovery percentage of 23 % versus 17 %. The total production cost was lower in DL_3 at ₹151,700 compared to ₹172,239 in DL_0, leading to a reduced cost per

Table 11: Cost of production of 500 kg whole dragon fruit impregnated paneer:

Sr	Particular	Quantity	Rate (Rs)	Control paneer sample		Optimized Paneer sample	
				Quantity	₹	Quantity	₹
1	Standardized Milk	1litre	50	2947 lit	147350	2173 lit	106850
2	Dragon Fruit	1kg	100	-	-	300 kg	30000
3	Citric Acid	1kg	96	41.67 gm	4000	30gm	2850
4	Packaging	/1kg	4	-	2000	-	2000
5	Fuel charges	/litre milk	5	-	18889	-	10000
7	Total cost of product			500kg	172239	500kg	151700
8	Cost of 1 kg	-	-	-	344.47	-	303.4
9	Selling price	-	-	-	480	-	500
10	BC ratio	-	-	-	1.39	-	1.64

Conclusion

The study concluded that the incorporation of 15 percent white-fleshed, pink-skinned dragon fruit paste in milk produced superior paneer. The optimized paneer demonstrated enhanced sensory attributes with overall acceptability of 8.36, improved colour and appearance 8.19, body and texture 8.20, and flavour 8.35. It also exhibited favorable physicochemical properties with fat 22.18 percent, protein 18.22 percent, moisture 62.00 percent, carbohydrate 2.85 percent, ash 1.60 percent, total solids 38 percent, acidity 0.49 percent, and pH 5.41, along with enriched functional components including total phenolics 0.47 mg

GAE per gram, flavonoids 0.13 mg QE per gram, dietary fibre 2.56 percent, and vitamin C 13.2 mg per 100 grams, while maintaining microbial counts within acceptable limits.

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