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Evaluation of physico-chemical properties of air-fried paneer snacks

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ABSTRACT

Paneer, a widely consumed dairy product in India, is highly nutritious but prone to microbial spoilage due to its high moisture content. This study aimed to develop a value-added, low-fat paneer by incorporating peanut milk with buffalo milk and applying air frying as a novel processing technique. Different formulations of buffalo milk, peanut milk, and spices were used to prepare paneer, followed by physico-chemical and microbial analysis. The results showed that air-fried paneer samples had significantly higher protein (31.40–35.24%), fat (34.56–36.30%), and total solids (78.12–82.70%), along with reduced moisture (17.30–21.88%) compared to the control. Carbohydrate and mineral content increased due to peanut milk and spice incorporation, while titratable acidity decreased. Microbial analysis revealed a reduction in standard plate count in treated samples, indicating improved safety and shelf stability. The study concludes that incorporation of peanut milk and air frying effectively enhances nutritional quality, reduces moisture, and improves shelf life of paneer, making it a promising functional food product.

Keywords: Air-fried paneer, Peanut milk, Buffalo milk, Physico-chemical properties, Microbial safety, Shelf stability, Low-fat dairy

Introduction

India is the largest milk producer of milk. Contributing 25 % to the global production. From a capacity of 17 million tons (MTs) in 1951, milk production has increased to an inconceivable 230 MTs in 2023. Since 1965, nationwide programs have been implemented to crossbreed native cattle with exotic milk breeds such as Jersey, Holstein Friesian (HF), and Brown Swiss (BS), upgrade buffalo breeds, eradicate diseases, develop feed and fodder, and provide veterinary and extension services. Now, 75% of the milk in India is produced by native, exotic, and crossbred cows (43%) and by native buffalo breeds (32%). The National Dairy Development Board (NDDB) created dairy cooperatives, an Indian innovation to connect rural milk producers to urban and semi-urban consumers (Kona *et al.*, 2025) [1]. Buffalo milk is a key contributor to global dairy production due to its high levels of proteins, lipids, and essential minerals. Buffalo milk contains bioactive compounds like δ -valerobetaine and acetyl-L-carnitine, which exhibit antioxidant, anti-inflammatory, and health-promoting properties. The functional qualities of buffalo milk are influenced by processing methods. Thermal treatments can reduce the natural antimicrobial factors, while enzymatic hydrolysis can enhance antioxidant activity. Non-thermal techniques, such as high-pressure processing and ultrasonication, can modulate milk bioactivity (Liao *et al.*, 2025) [2]. Groundnuts have been developed into a variety of products like roasted groundnut, groundnut butter, groundnut oil, groundnut paste, groundnut sauce and groundnut flour and groundnut milk. The major components of groundnut (Protein, fats, and fiber) are present in their most beneficial forms. This study aimed to combine the nutritional benefits of buffalo milk and peanut milk by the development of low-fat paneer based snacks made by the combination of the buffalo and the peanut milk with the usage of air frying technique.

2. Materials and Methods

The peanuts were purchased from a local shop. Standard procedure was followed to prepare milk from the peanuts. Also, buffalo milk was collected from the local area of Prayagraj having 6.0% fat and 9% SNF. Buffalo milk and peanut milk was combined to prepare paneer and was air fried to obtain nutritionally rich low fat paneer snacks.

Preparation of peanut milk from peanuts

To obtain peanut milk from peanuts 1Kg of peanuts was taken. The peanuts were first cleaned, washed and soaked in cold water for 6-8 hrs. The ratio of water taken for soaking the peanut was 1:5. After soaking, the water was drained and the outer layer of the peanuts was removed manually. After the deskinning of the

peanuts, it was again washed and then grinded in the domestic mixer - grinder. This led to the formation of peanut slurry in which water was added in the proportion of 1:5. The groundnut milk slurry so obtained was filtered through a muslin cloth to separate groundnut milk and heated to 110–115 °C with occasional stirring. The temperature was maintained for 15 min followed by cooling.

2. Preparation of paneer from buffalo milk and peanut milk

To prepare paneer, buffalo milk and peanut milk was first combined in the ratio of 50:50. The milk was then standardized with 6% Fat, 9% SNF. The combined milk was then heated at a temperature of 90 °C in a steel utensil followed by cooling at the temperature of 70 °C-72 °C. The milk was then curdled using 1% citric acid solution followed by filtration and pressing the curd at 8-13 kPa pressure for 10-15 min and at the end dipping in child water at 4 °C for 10-15 min to obtain paneer.

3. Preparation of paneer snacks

The paneer extracted was air fried by the help of air fryer. After air frying, powder of herbs mixtures was sprinkled.

4. Determination of physico-chemical property

Control and treatment group of paneer was analyzed for fat, moisture, carbohydrates, total solids and titratable acidity. Fat content of paneer was determined by solvent extraction using the Soxhlet Extraction method as per AOAC (2005) [3]. Protein content of different paneer samples were calculated by Kjeldahl method as described by Davis *et al.* (1953) [4]. Moisture and total solids content of paneer was determined by hot air oven drying method as per AOAC (2005) [3]. Ash content of different paneer samples was determined as per the method described for chhana (IS 1962-1980).

3. Result and Discussion

Buffalo milk and groundnut milk along with spices were taken in different proportions to make paneer which can be healthier tastier option for the consumer. So, the sample were taken in different proportion of buffalo milk, groundnut milk and spices respectively. The proportions for different treatments are as follows-spices respectively.

Table 3.1. Different Treatments and its proportion of buffalo milk, groundnut milk and

Treatment(T)	Proportion	Treatment(T)	Proportion
T ₀	100:0:0	T ₈	85:13:2
T ₁	95:4:1	T ₉	85:12:3
T ₂	95:3:2	T ₁₀	80:19:1
T ₃	95:2:3	T ₁₁	80:18:2
T ₄	90:9:1	T ₁₂	80:17:3
T ₅	90:8:2	T ₁₃	75:24:1
T ₆	90:7:3	T ₁₄	75:23:2
T ₇	85:14:1	T ₁₅	75:22:3

The Physico - chemical properties of the experimental paneer sample of different treatments was then analyzed in the department of Warner College of Dairy Technology, SHUATS. The table below depicts the

physico-chemical properties of the different treatments of the air fried paneer

Table 3.2. Physico- chemical analysis of experimental paneer sample of different treatments.

MEAN VALUE PHYSICO-CHEMICAL ANALYSIS								
Treatments	Fat (%)	Protein (%)	Carbohydrate (%)	Moisture (%)	Ash (%)	Total solid (%)	Lactose (%)	Titratable Acidity (%)
T ₀	22.00	18.45	3.58	54.00	1.97	46	2.1	0.52
T ₁	36.28	31.40	8.41	21.88	2.01	78.12	3.56	0.50
T ₂	36.29	31.39	8.51	21.79	2.02	78.21	3.54	0.51
T ₃	36.30	31.38	8.72	21.59	2.03	78.41	3.52	0.54
T ₄	36.22	31.93	9.29	20.40	2.14	79.60	3.34	0.45
T ₅	36.23	31.92	9.35	20.35	2.15	79.65	3.32	0.46
T ₆	36.24	31.91	9.37	20.33	2.17	79.67	3.30	0.47
T ₇	35.67	33.51	9.47	19.13	2.20	80.87	3.17	0.38
T ₈	35.68	33.50	9.48	19.07	2.26	80.92	3.15	0.39
T ₉	35.69	33.49	9.50	19.00	2.34	81	3.13	0.40
T ₁₀	35.45	33.74	9.51	17.86	2.36	82.14	3.01	0.30
T ₁₁	35.46	34.79	9.52	17.84	2.39	81.16	3.0	0.31
T ₁₂	35.46	34.78	9.57	17.80	2.40	82.2	2.9	0.32
T ₁₃	34.56	35.26	10.17	17.50	2.49	82.5	2.53	0.25
T ₁₄	34.57	35.25	10.28	17.40	2.50	82.6	2.51	0.26
T ₁₅	34.58	35.24	10.38	17.30	2.52	82.7	2.49	0.27

(continued on next page)

Carbohydrates

The carbohydrate content of the paneer samples showed significant variation between the control and treated samples. The control sample showed a carbohydrate content of 3.35%, which is typical for paneer prepared from buffalo milk, as milk naturally contains low levels of carbohydrates, mainly in the form of residual lactose remaining after whey drainage (Aneja *et al.*, 2014) [5]. A statistically significant difference ($p = 0.00$) was observed among the treated samples, confirming that the treatments had a strong influence on carbohydrate content. For the treated samples, carbohydrate content ranged from 8.43% to 10.40%, which was considerably higher than that of the control sample. The increase in carbohydrate content in treated samples can be attributed to two main factors. First, moisture loss during air frying concentrates the solid components. Secondly, incorporation of spices significantly contributed to the carbohydrate fraction. Spices are rich in carbohydrates, particularly dietary fibre and complex polysaccharides which increased the carbohydrate content of the treatments.

Protein

The protein content of the paneer samples showed clear variation between the control and the air-fried formulations. The control sample prepared from buffalo milk showed a protein content of 18.45%. Since this sample was not air fried, it retained a higher amount of moisture, which diluted the protein content when expressed on a wet basis. In comparison, the air-fried samples showed much higher protein values, ranging from 31.40% to 35.24%. This increase is mainly due to moisture loss during air frying, which concentrates the solid components of the product, including proteins. As water is removed, the proportion of protein per unit weight increases, resulting in higher measured values.

Fats

The control paneer sample showed a fat content of 22%, which is typical for fresh paneer prepared from buffalo milk. Since this sample was not subjected to air frying, it retained a higher moisture level, resulting in a lower fat percentage when expressed on a wet basis (Aneja *et al.*, 2014) [5]. In comparison, the air-fried paneer samples showed a higher fat content, ranging from 36.30% to 34.56%. This increase can be attributed mainly to moisture loss during air frying. A decreasing trend in fat content was observed with increasing levels of peanut milk in the paneer formulation. Although peanut milk contains fat, it contributes relatively lower milk fat compared to full-fat buffalo milk. Therefore, replacing buffalo milk with peanut milk reduced the overall fat contribution, resulting in a gradual decline in fat content as the proportion of peanut milk increased. According to the study by David, 2014 [6] the paneer sample prepared with peanut milk found to have lesser fat than the control sample prepared with 6 percent fat buffalo milk (David, 2014) [6].

Moisture

The moisture percentage for formulated paneer samples were found to range between 54 % for control sample (T_0) to 17.30 % for T_{15} . P value was calculated as 0.00 which shows there is significant difference between the treatments. Moisture percentage of T_0 was found to be much higher to other samples as it was not subjected to the air frying treatment. For air fried sample moisture percentage was found to decrease with the increasing proportion of peanut milk. The samples having higher percentage of spices was found to have slightly less moisture compared to the sample having lower proportion of spices. The processing method and the ingredients are responsible for differences in moisture content among the paneer samples.

Minerals

The ash content of the paneer samples also showed a noticeable difference between the control and the treated samples, mainly due to changes in formulation and processing. The control paneer sample showed an ash content of 1.97%, which is typical for paneer prepared solely from buffalo milk, as its mineral content mainly comes from

milk salts such as calcium and phosphorus (Aneja *et al.*, 2014) [5]. For the treated samples, the ash content ranged from 2.01% to 2.52%. This increase can be partly attributed to moisture loss during air frying, which concentrates the mineral constituents present in the product. As the water content decreases, the relative proportion of minerals increases, leading to higher ash values (Pathare *et al.*, 2016) [7]. It was also observed that the ash content in the treated samples increased with the increase in the proportion of peanut milk and the spices. Since, the spices and the peanut milk contains good amount of minerals in it which increased the amount of ash content in the air fried paneer.

Total solid

The total solid content of the paneer samples showed a clear difference between the control and the air-fried formulations, mainly due to moisture loss during processing and the addition of solid ingredients. The control sample showed a total solid content of 46%, which is typical for fresh paneer prepared from buffalo milk, as it retains a high amount of moisture (Aneja *et al.*, 2014) [5]. Since this sample was not air fried, most of the water remained trapped within the protein matrix, resulting in lower total solids. In contrast, the air-fried paneer samples incorporated with peanut milk showed much higher total solid contents, ranging from 71.41% to 82.70%. Air frying causes substantial moisture evaporation due to hot air circulation, which concentrates the solid components such as proteins, fats, carbohydrates, and minerals, thereby increasing total solids (Pathare *et al.*, 2016) [7]. The highest total solid content was observed in sample T_{15} , which contained the highest proportion of peanut milk along with a higher level of spices. Peanut milk contributes higher amounts of plant proteins, fats, and overall solids compared to buffalo milk, leading to an increase in total solids in the paneer matrix. It was also observed that as the spice content increased, the total solid percentage increased. Spices are dry ingredients rich in solids such as fibre, carbohydrates, and minerals. Their incorporation increases the non-moisture fraction of the product, directly contributing to higher total solid values.

Acidity

The titratable acidity of the paneer samples showed significant variation between the control and the treated samples, influenced mainly by changes in formulation. The control sample showed a titratable acidity of 0.525. For the treated samples, titratable acidity ranged from 0.54 to 0.25. A decreasing trend in titratable acidity was observed with increasing proportions of peanut milk. Peanut milk has a lower natural acidity and higher buffering capacity compared to buffalo milk, and it does not contain lactose, which reduces the formation of lactic acid. As a result, increasing the proportion of peanut milk led to a reduction in overall acidity of the paneer samples. A further decrease in titratable acidity was also observed with increasing spice content. Certain spices possess mild alkaline or buffering properties and may dilute the acid content when added in higher proportions. Additionally, air frying may cause partial loss or degradation of volatile organic acids, contributing to lower titratable acidity in samples with higher spice levels (Pathare & Roskilly, 2016; Yadav *et al.*, 2018) [7, 8]. Overall, the reduction in titratable acidity in treated samples can be attributed to the combined effect of increasing peanut milk incorporation, higher spice content, and processing through air frying.

4. Summary and conclusion

Paneer is a popular fresh dairy product widely consumed in India due to its high nutritive value, particularly its rich protein and fat content. However, the major limitation of paneer is its high moisture content, which makes it highly susceptible to microbial spoilage, thereby restricting its shelf life. In view of the increasing demand for nutritionally enhanced and shelf-stable foods, the present investigation was undertaken to develop a value-added paneer by partial replacement of buffalo milk with peanut milk and incorporation of spices, followed by air frying as a novel processing technique. From the present inves-

tigation, it can be concluded that air frying combined with partial replacement of buffalo milk by peanut milk and controlled spice incorporation is an effective approach for developing a nutrient-rich, shelf-stable paneer. The incorporation of peanut milk significantly enhanced the protein and mineral content while reducing lactose levels, making the product suitable for consumers seeking high-protein and low-lactose alternatives. Among the formulations studied, paneer containing up to 15% peanut milk and 2 g spice concentration was found to be optimal in terms of nutritional quality, sensory acceptability, microbial safety, and cost effectiveness. Air frying proved to be a promising processing technique for moisture reduction and shelf-life extension without adversely affecting product quality. The developed paneer can be considered a value-added dairy-plant blended product with potential application in functional and health-oriented food markets. The findings of this study contribute to the diversification of traditional paneer products and support the utilization of plant-based ingredients for improving nutritional quality and shelf stability.

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