Theme: Safe, Sustainable and Innovative Dairy and Food Systems for One Health

RESEARCH ARTICLE Asian Journal of Dairy and Food Research, Volume 45 Special Issue: 32-41 (2026)

Evaluating the Efficacy of Alcoholic Pumpkin Peel Extract as a Sustainable Natural Active Ingredient in Preserving Cow's Milk Cream

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10.18805/ajdfr.DRF-685

ABSTRACT

Background: There is a great interest in the application of sustainable development in the food sector through the use of natural food waste containing valuable bioactive compounds, such as pumpkin peels, which are a good source of phenols, flavonoids, and carotenoids with antioxidant and antibacterial properties. The aim of this study was to assess the effectiveness of an alcoholic extract of dried pumpkin peels and its use as a natural preservative to enhance the oxidative stability, microbial quality and sensory attributes of cow's milk cream stored refrigerated.

Methods: Dried pumpkin peels were extracted with ethanol to obtain an alcoholic extract with a yield of 25.6%. Phenolic and flavonoid content, as well as reducing power and DPPH measurements, were used to assess its antioxidant capacity. FTIR spectroscopy was used to detect the functional groups. The extract was incorporated into the cream to make experimental formulations: T0 (control sample with no additives), T1 (cream + 0.1 g extract), T2 (cream + 0.2 g extract), and T3 (cream + 0.3 g extract). The treatments were stored at 4°C for 21 days, and peroxide value, pH, level of total lipophilic bacteria and sensory analysis were carried out.

Result: The extract had high content of phenols (61.3 mg/100 g) and flavonoids (52.9 mg/100 g), as well as high reducing and radical scavenging activity that was concentration dependent. FTIR indicated the transfer of the active groups to the extract. This was observed in the cream, as treatment T3 had the lowest peroxide value (3.60 meq O_2/kg) during storage (9.50 meq O_2/kg for T0 at 21 days), as well as a lower decrease in pH and a reduction in bacterial count compared to the control. Moreover, the fortified treatments (especially T3) showed improved sensory quality over time. These findings suggest that pumpkin peel extract can be used as a natural antioxidant and antibacterial agent, increasing the shelf life and enhancing the quality of cream.

Key words: Alcoholic extract, Cream, Natural antioxidants, Pumpkin peel, Sustainable development.

INTRODUCTION

Plant products have been utilized for millennia as medicinal components in human nutrition. The popularity of pumpkin as both a food and a medicine in traditional medicine for many diseases (Antidiabetic, antihypertensive, antitumor, immunomodulatory, antibacterial, anti hypercholesterolemic and intestinal) Antiparasitic, anti-inflammatory and analgesic properties have garnered the interest of numerous researchers (Batool *et al*., 2022). Pumpkin (*Cucurbita maxima*) is a significant source of carotenoids, various amino acids, vitamins, minerals and beneficial fibers, thus possessing considerable therapeutic and health benefits, along with substantial nutritional and technological potential (Kaur *et al*., 2020).

Studies have indicated that pumpkin peel contains several important compounds, including antioxidants such as phenols, flavonoids and tannins, as well as fiber (Lima *et al*., 2019; Gavril *et al*., 2024a).

The pumpkin peel extract is a rich source of natural pigments, especially carotenoids, as well as phenolic compounds that have antioxidant activity. The study showed that using modern extraction methods like ultrasound or microwave with corn oil as a natural solvent was much more effective than traditional methods that use chemical solvents. The amount of carotenoids extracted almost doubled when these modern methods were used and the extract's antioxidant activity increased. The results showed that the pumpkin peel contains more carotenoids and phenolic compounds than the pulp. So, pumpkin peels and other pumpkin waste can be used to extract pigments and bioactive compounds that can be used safely and sustainably in food, cosmetics and pharmaceuticals (Chopde and Adil, 2015; Sharma and Bhat, 2021).

Cream is a dairy product consisting of the layer of fat that rises to the surface of milk. It is characterized by its creamy taste and is a rich source of energy due to its high fat content (Nath *et al*., 2025). Because of its susceptibility

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How to cite this article: Mohammed, T., Ahmed, L., Mahmood, S. and Albadrane, Z. (2026). Evaluating the Efficacy of Alcoholic Pumpkin Peel Extract as a Sustainable Natural Active Ingredient in Preserving Cow's Milk Cream. *Asian Journal of Dairy and Food Research*. **45(Special issue):** 32-41. doi: 10.18805/ajdfr.DRF-685.

Submitted: 06-05-2026 **Accepted:** 26-05-2026 **Online:** 09-06-2026

to oxidative and microbial spoilage, natural plant extracts are used in its preservation due to their antioxidant and antimicrobial properties, aligning with the trend towards safer and more sustainable alternatives in food preservation (Wazzan *et al*., 2024).

Enhanced free radical scavenging activity and reduction of microbial count were observed in creams containing plant extracts such as neem and lime leaves (Anerao *et al*., 2026; Nath *et al*., 2025). It also slightly changes the color, smell and pH of the creams (Nosheen and Kaleem, 2023).

Numerous studies have shown that the widespread use of artificial colorings and additives in food manufacturing may be linked to potential negative health effects. This is due to their ability to induce catalytic reactions or possess mutagenic properties, as well as their accumulation and the accumulation of their metabolic byproducts in the consumer's body. Increased public health awareness has led to growing concern about these additives, prompting regulatory bodies, including the European Union since 2010, to require companies to include warnings on products containing certain artificial colorings (Sharma *et al*., 2023; Amchová *et al.*, 2024).

In this context, the scientific and practical need has emerged to adopt safe and sustainable natural alternatives to artificial additives. This aligns with the principles of sustainable development by reducing health risks, decreasing reliance on synthetic chemicals and utilizing renewable plant resources. This approach aims to achieve multiple objectives, including enhancing food safety, supporting consumer health, reducing environmental impact and utilizing natural resources efficiently within a more sustainable food production system (Velázquez *et al*., 2025).

The research gap lies in the limited number of studies addressing the practical application of pumpkin peels as a sustainable source of natural antioxidants in preserving dairy products, despite their richness in phenolic compounds. Furthermore, the relationship between the precise chemical characterization of these peels and their functional performance within a high-fat diet remains unclear. The practical importance lies in the potential to utilize this agricultural byproduct as a natural additive that contributes to extending shelf life and reducing reliance on synthetic preservatives. Therefore, this study aimed to characterize the chemical composition of an alcoholic extract of pumpkin peels, evaluate its antioxidant activity and assess the effect of its addition on the qualitative characteristics and shelf life of cow's milk cream.

MATERIALS AND METHODS

Collection and preparation of pumpkin peels

Twenty ripe pumpkins, weighing between 5-6 kg, were collected from the local market in Mosul, Iraq. The pumpkin samples were then transported to the Food Science Department at the College of Agriculture and Forestry, University of Mosul, for use in this research.

Extraction of pumpkin peels

Ultrasound was used to extract the active compounds from pumpkin peels after they were dried in a pneumatic oven at 45°C for 48 hours. The peels were then ground and sieved to obtain a powder with a particle size ranging from 250 to 500 µm. The powder was stored in airtight bags, protected from light and moisture, at room temperature until extraction. Extraction was carried out using 70% ethanol at a 1:10 (w/v) ratio for 30 minutes at 20°C and a frequency of 50 kHz. The sample was then centrifuged for 5 minutes at 10,000 rpm. The filtrate was collected and concentrated using a rotary evaporator and finally dried in a laboratory desiccant at 40°C to obtain the extract powder. The powder was then stored in airtight, dark glass containers at 4°C until use.

Extraction yield estimation

The percentage of extraction yield was calculated according to the method described by Alcazar *et al*. (2017) using the following equation:

$$\% \text{ Yield} = \frac{\text{Dried extract wt.}}{\text{Dried sample wt.}} \times 100$$

Estimation of total phenols

The total phenol content of the extract was determined using Folin ciocalteu reagent as described by Laouini and Ouahrani (2017) which consists on mixing 100 µL of the extract with 500 µL of Folin reagent, then adding 1.5 mL of 20% sodium carbonate and completing to 10 mL with distilled water. The mixture was left to stand for 2 hours in the dark and the absorbance was measured at 760 nm. The results were expressed as mg/g of gallic acid equivalent (Fig 1). The total phenolic content was expressed as mg/g of gallic acid equivalent (dry weight) of the sample, according to the equation described by Nurhasnawati *et al*. (2019) which states:

$$\text{TPC} = \frac{\text{C.V}}{\text{W}}$$

Estimation of total flavonoid

The flavonoid content was estimated according to the method described by Kingne *et al*. (2018), where 50 µL of the extract was mixed with 4 mL of distilled water, then 0.3 mL of $NaNO_2$ (5%) was added. After 5 minutes, 0.3 mL of AlCl3 (10%) was added, followed by 2 mL of NaOH (1 mol/L). The volume was then brought up to 10 mL and after 15 minutes, the absorbance was measured at 510 nm. The results were expressed in rutin equivalent units mg/g as shown in Fig 2.

Detection of active groups in pumpkin extract

The Silverstein and Bassler (1962) method was used to identify the functional groups in the extract using Fourier transform infrared spectroscopy (FTIR). The analysis was performed at the Central Laboratory, College of Agriculture and Forestry, University of Mosul, using a Shimadzu IRTracer-100 FTIR spectrometer. The extract was dried and

finely ground, then mixed with potassium bromide (KBr) at a ratio of 1:100 and pressed into transparent discs to prepare the samples. The spectrum was recorded in the 4000-4000 cm^{-1} range with an analytical resolution of 4 cm^{1} and 16 scans per sample.

Evaluation of free radical scavenging efficacy using DPPH

The DPPH solution (400 µg/mL) was prepared by Anantharaman (2025) dissolving 0.04 g of DPPH in 100 mL of methanol. A standard solution (vitamin C) was also prepared at an initial concentration of 5000 ppm. Different concentrations (30-500 ppm) were prepared from both the standard solution and sample. These solutions were added to DPPH solution and left in the dark for 30 minutes at room temperature. The absorbance was read at 520 nm by UV-Vis spectrophotometer. The IC_{50} value was then determined from the dose-response curve, where the lower the absorbance, the greater the antioxidant activity, using the following formula:

$$\% \text{ Inhibition} = \frac{A_0 - A_1}{A_0} \times 100$$

Assessment of reducing power

The reducing power of the extract was measured according to the method of Benslama and Harrar (2016) by combining the extract with a solution of phosphate and potassium cyanide and incubated for 20 minutes at 50°C. Then the solution was mixed with trichloroacetic acid and centrifuged. This was then combined with water and ferric chloride and absorbance was read at 700 nm. The greater the absorbance, the higher the reducing power. The values are reported as µg equivalents of ascorbic acid per mg of extract.

Table cream production

Preparing the cream

Fresh cow's milk was heated to 40°C and the cream was separated using a cream separator (Funke gerber). The fat content of the cream was then standardized to 33% by adding measured amounts of skimmed milk while continuously stirring to ensure homogeneity. The cream was filtered through sterile gauze to remove impurities and then divided into four equal-sized treatments (500 ml each). All treatments were heated in stainless steel vessels to 62°C for 30 minutes with continuous stirring to ensure even heat distribution. After pasteurization, the cream was cooled to 40°C and dried pumpkin seed extract was gradually added while mixing with a magnetic stirrer for 5 minutes to ensure homogeneous distribution of the extract. The instructions of Wazzan *et al*. (2024) were followed in determining the addition ratios to obtain the following groups: T0 (control group with no additives), T1 (cream + 0.1 g of extract), T2 (cream + 0.2 g of extract) and

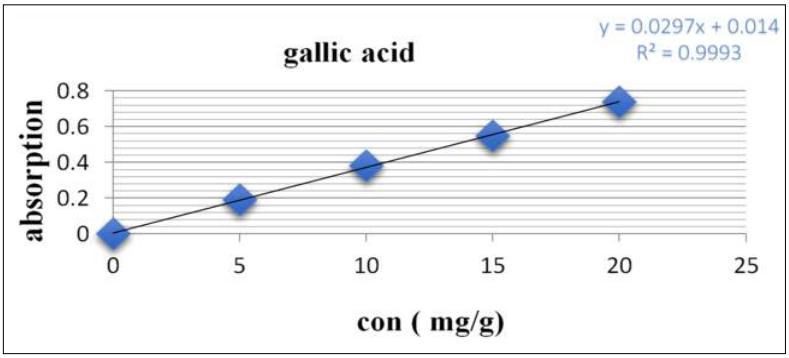


Fig 1: Standard curve for gallic acid.

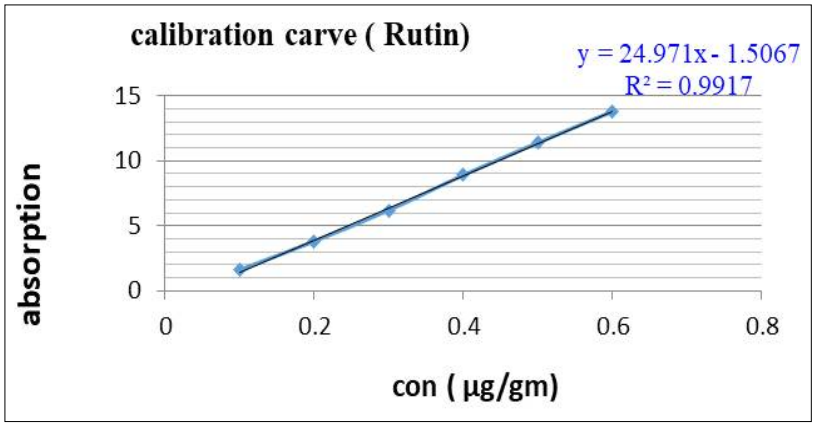


Fig 2: Standard curve of rutin.

T3 (Cream + 0.3 g of extract). The samples were then packaged in sterile, airtight containers and stored at 4°C until testing, during storage periods of 1, 7, 14 and 21 days.

Peroxide number estimation

The peroxide value was determined following the method in A.O.C.S. (2017). It consisted of mixing 5 ml of sample in a 2:3 ratio of chloroform: Glacial acetic acid and then adding 1 ml of KI solution and keeping it in darkness for 10 minutes. Then, distilled water was added and the mixture titrated with 0.01 N sodium thiosulfate with starch indicator. The peroxide value was expressed in milliequivalents of oxygen/kg of fat and the equation used was:

$$\text{Peroxide value (mEq/kg of oil)} = \frac{(V1 - V2) \times N \times 1000}{W}$$

V1 = Volume of sodium thiosulfate used in titrating the sample.
V2 = Volume of sodium thiosulfate used in titrating the sample in the control titration.
N = Normality of 0.01 N sodium thiosulfate.
W = Weight of the sample.

Measurement of the exponent pH

The method of Larionov *et al*. (2020) was followed, whereby 10 g of cream was weighed and thoroughly mixed with 10 mL of distilled water. The pH of the filtrate was read by immersing a pH meter electrode in the solution after maintaining a temperature of 25°C.

Total count of lipophilic bacteria

The number of lipophilic bacteria was estimated using the Harrigan and McCance (1976) pour-in method. Sequential decimal dilutions of the sample were prepared using sterile peptone water and 1 mL of the appropriate dilution was inoculated into plates containing nutrient agar supplemented with 1% oil and 1% glycerol. After incubation at 28°C for 4-5 days, the colonies were exposed by adding 20% copper sulfate solution for 5 minutes, followed by washing with distilled water. Plates containing 30-300 colonies were counted and the results were recorded in CFU/g of sample.

Sensory evaluation

The cream produced was sensory-evaluation by 20 reviewers, including professors and graduate students from the Department of Food Science, College of Agriculture and Forestry, University of Mosul, aged 27-40 (10 males and 10 females). Participants' informed consent was obtained before the evaluation, with the study's objective and the nature of the tests being conducted clearly explained. The review panel members were selected based on their experience and prior knowledge in the sensory evaluation of food products, specifically their experience conducting sensory tests and analyzing the quality characteristics of dairy products. The evaluated characteristics included taste, color, aroma, texture and overall appearance. The evaluation was based on a 9-point Heddon scale, where 9 represents very high satisfaction and 1 represents very low satisfaction. Samples were randomly presented in coded containers, with water provided for rinsing between samples to minimize sensory interference (Peasura *et al.,* 2020).

We used a completely randomized design (CRD) with three replicates of each treatment to make sure the results were correct and to reduce the chance of making mistakes during the experiment. We used the advanced software SAS (2012) and duncan's multiple range test to compare the means of the treatments at a significance level of $P<0.05$.

REULTS AND DISCUSSION

Yield of extraction

The pumpkin peels' alcoholic extraction yield was 25.6%, which is a good sign that the extraction was effective. This result can be explained by the fact that pumpkin peelshave phenols, flavonoids and polar compounds that dissolve in alcohol. This makes it easier to extract them with ethanol. Also, using an alcoholic solvent makes it easier to extract a wider range of active compounds, which

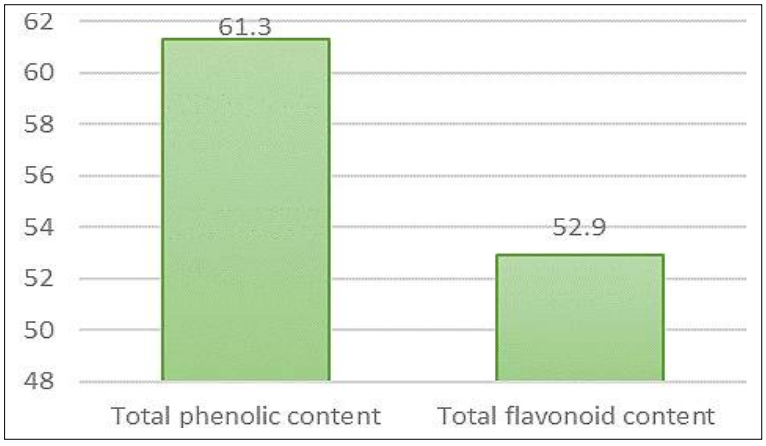


Fig 3: Phenolic and flavonoid content in pumpkin peel extract.

increases the overall yield. The results are in line with what Rau *et al*. (2024) found.

Amount of phenols and flavonoids in alcoholic pumpkin peel extract

The results, shown in Fig 3. indicate that the total phenolic content of the alcoholic extract of pumpkin peels was 61.3 mg/100 g peels, while the total flavonoid content was 52.9 mg/100 g peels. These values suggest that the extract is a good source of active compounds with antioxidant properties, with phenols being more prevalent than flavonoids. The high phenolic content is attributed to the ability of the alcoholic solvent to extract polar and subpolar compounds associated with plant cell walls. This was demonstrated by Avila *et al*. (2018), who reported that the alcoholic solvent and ultrasound yielded the highest phenolic extraction rates from pumpkin peels. Flavonoids, which are part of the phenolic compounds, play an important role in inhibiting free radicals and reducing oxidation. The results were consistent with those of Ahmed *et al*. (2025) in their alcoholic extract of pumpkin.

The reducing power of the extract

Table 1 shows that the lowest value of the reducing power of the alcoholic pumpkin peel extract was 40.98 at a concentration of 2%, while the highest value was recorded at 66.78 at a concentration of 6%. This increase indicates a direct relationship between the concentration of the extract and its ability to reduce ferric ions, which indicates its high antioxidant activity. This is attributed to the peels containing phenolic compounds, flavonoids and carotenoids capable of donating electrons or hydrogen atoms. The extract's superiority over vitamin C may be due to the synergistic effect between its active components. The results are consistent with Ahmed *et al*. (2025), who indicated that plant extracts rich in phenols increase in their reducing power with increasing concentration.

Table 1: Evaluation of the reducing capacity of pumpkin peel extract.

Sample	Concentrations		
	2%	4%	6%
Vit C	20.47	29.61	39.57
Pumpkin peel extract	40.98	53.75	66.78

The effectiveness of the extract in scavenging free radicals using DPPH

The percentage of free radical inhibition ranged from 29.66% at a concentration of 1000 ppm to 63.52% at a concentration of 6000 ppm (Table 2). This shows that the extract's antioxidant activity increases as the concentration increases because a greater amount of active compounds are available to react with the DPPH radical. This is also due to the presence of phenolic acids, flavonoids and carotenoids, which makes it a natural antioxidant that prevents rancidity and so can be used as a food preservative. This is in agreement with Mohsen and Abas (2024) and Gavril *et al*. (2024b), who reported the presence of carotenoids in pumpkin peels, which give them antioxidant properties.

FTIR analysis of active groups

Fig 4 shows the FTIR spectrum of raw pumpkin peel, revealing multiple absorption bands that reflect the peel's

Table 2: Extract ability to scavenge DPPH free radicals.

Sample	Concentrations			
	1000 ppm	2000 ppm	4000 ppm	6000 ppm
Vit C	13.81	20.78	32.64	40.96
Pumpkin peel extract	29.66	40.78	54.36	63.52

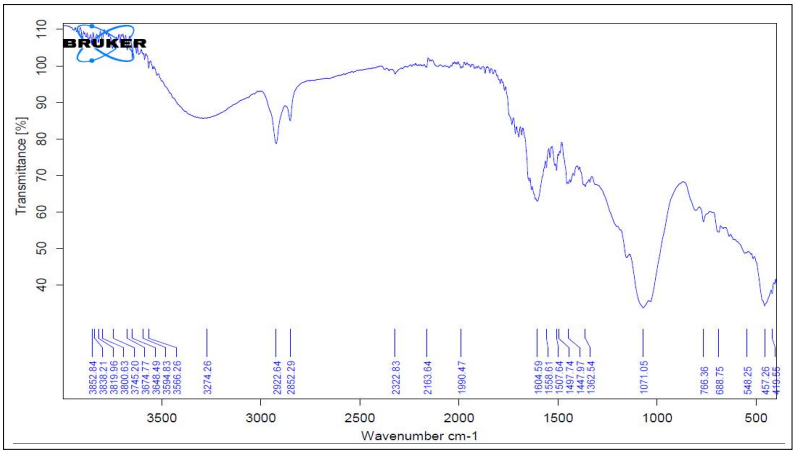


Fig 4: Identifying functional groups in raw pumpkin peels using FTIR technology.

chemical complexity and its richness in fibrous components and bioactive compounds. A broad band at 3200-3600 cm^{-1} is attributed to O-H group vibrations, indicating an abundance of hydroxyl groups in cellulose, hemicellulose, pectin and phenolic compounds. These groups are directly responsible for donating hydrogen to free radicals, thus explaining the crucial role of these peaks in interpreting the extract's antioxidant activity. Peaks at 2850-2950 cm^{-1} are attributed to aliphatic C-H bonds, reflecting the presence of hydrocarbon chains of organic components in the plant cell wall. The peak near 1730 cm^{-1} is attributed to C=O groups associated with pectin, organic acids and esters, groups known for their ability to bind to and stabilize phenolic compounds within the fibrous structure. Peaks between 1600 and 1650 cm^{-1}, attributed to aromatic (C=C) vibrations in the phenolic rings, were observed. These peaks are a direct indicator of the presence of phenolic compounds responsible for the antioxidant activity through their ability to scavenge free radicals via resonance. Distinct peaks between 1020 and 1250 cm^{-1}, related to C-O and C-O-C bonds in carbohydrates, were also noted, representing the fibrous structure that carries these compounds. The significance of these peaks extends beyond identifying functional groups. They demonstrate that pumpkin peels possess a fibrous structure rich in hydroxyl, carbonyl and aromatic groups, which are efficient sites for the retention of phenolic compounds. This explains the efficient release of these compounds when polar solvents are used during extraction and the resulting high antioxidant capacity of the extract. These results are consistent with what Gowtham *et al*. (2022) indicated, that vegetable and fruit peels show similar FTIR patterns as a result of their richness in fiber and phenolic compounds associated with plant cell walls.

Fig 5 shows the FTIR spectrum of pumpkin peel extract, revealing distinct absorption bands that reflect the concentration of bioactive compounds after extraction. A broad band at 3200-3600 cm^{-1}, attributed to O-H group vibrations, is direct evidence of an abundance of phenols, alcohols and organic acids. These hydroxyl groups are efficient hydrogen donor and free radical scavenger sites, directly linking this peak to the antioxidant and reducing action of the extract. Peaks at 2850-2950 cm^{-1}, attributed to aliphatic C-H bonds, indicate the presence of organic chains supporting the structural composition of the extracted compounds. The peak between 1700 and 1750 cm^{-1} is attributed to the carbonyl (C=O) group in organic acids and esters, which contributes to stabilizing the phenolic structure and enhancing its reactivity. Clear peaks emerged between 1500-1650 cm^{-1}, attributed to the aromatic (C=C) vibrations of phenolic and flavonoid rings. These peaks provide a direct spectral indicator of compounds responsible for free radical scavenging *via* resonance. Peaks were also recorded in the 1000-1300 cm^{-1} range, resulting from C-O and C-O-C bonds in sugars and phenolic compounds. This reflects the persistence of some of the carbohydrate structure supporting these compounds. These results demonstrate the efficiency of alcoholic extraction in releasing and concentrating phenolic compounds from their structural attachment to the fibers in the crude shell. This is further evidenced by the greater prominence of the aromatic and carbonyl peaks in the extract compared to the shell. This release makes the functional groups more susceptible to free radical scavenging, which scientifically explains the significant increase in the antioxidant activity and reducing capacity of the extract. These observations are consistent with what Mohsen and Abbas (2024) reported regarding the effectiveness of alcoholic extraction in concentrating the active phenolic compounds.

Peroxide number of cream

The peroxide number Table 3 shows a gradual increase in peroxide values (meq O_2/kg fat) with increasing storage duration in all treatments. In treatment T0, the values increased from 0.60 on day 0 to 0.90 at 7 days, then to 4.20 at 14 days and reached 9.50 at 21 days. This reflects the accelerated oxidation over time due to the fat's exposure

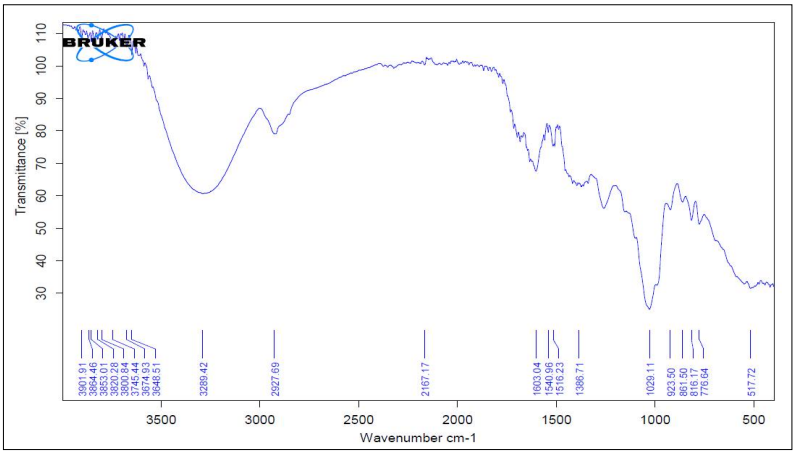


Fig 5: Identifying functional groups in pumpkin peels extract using FTIR technology.

to oxygen and the formation of hydroperoxides. Treatments containing the extract showed a clear decrease in peroxide values compared to the control treatment. Treatment T3 (0.3 g) recorded the lowest values during the storage period, at 0.30 on day 0, 0.50 on day 7, 1.80 on day 14 and 3.60 on day 21, respectively. This was followed by treatment T2 (0.2 g) with values of 0.40, then 0.70, then 2.40, then 4.90, while treatment T1 (0.1 g) recorded the highest values relatively among the added treatments, reaching 0.50 on day zero, 0.90 on day seven, 3.10 on day fourteen and 6.80 on day twenty-one. This is because pumpkin peel extract is rich in phenolic compounds and hence it is an antioxidant, decreasing the oxidation reaction and formation of peroxides and increasing the stability of fats during storage. This was confirmed by Mapoung *et al*. (2021), who stated that plant extracts rich in phenols possess significant antioxidant properties that slow down the rise in the peroxide number of cream.

Cream pH

The pH, Table 4 shows a gradual decrease in cream pH values during storage (0-21 days) in both the control treatment and the treatments containing pumpkin peel extract. However, the decrease was most pronounced in the control treatment (T0) compared to the other treatments. In T0, the pH decreased from 4.60 to 4.48. This is attributed to the continued slow microbial activity during refrigerated storage, which leads to the production of lactic acid as a result of lactose fermentation, thus gradually increasing acidity. In treatments T1, T2 and T3, the pH values remained relatively high, especially at the highest concentration (T3),where a slower decrease was observed. This can be explained by the presence of phenolic compounds in the pumpkin peel extract, which reduce microbial growth and limit acid formation, thus contributing to maintaining pH stability for a longer period (Akhi *et al*., 2025).

Table 3: Peroxide value of milk cream with added pumpkin peel extract, stored at 4°C for 21 days.

Treatment	Peroxide value meq O_2/kg fat			
	Storage period/day			
	0	7	14	21
T0	0.60±0.02fg	0.90±0.03ef	4.20±0.05bc	9.50±0.08a
T1	0.50±0.02gh	0.90±0.02ef	3.10±0.04cd	6.80±0.06b
T2	0.40±0.01hi	0.70±0.02fg	2.40±0.03de	4.90±0.05c
T3	0.30±0.01i	0.50±0.01gh	1.80±0.02e	3.60±0.04d

Values are expressed as mean ± standard deviation (Mean±SD). Different letters within the same row indicate significant differences at a probability level (P<0.05). Data represent the mean of three replicates per treatment.

Table 4: pH of milk cream with added pumpkin peel extract, stored at 4°C for 21 days.

Treatment	pH			
	Storage period/day			
	0	7	14	21
T0	4.60±0.02ef	4.55±0.02fg	4.50±0.01g	4.48±0.02h
T1	4.62±0.01de	4.58±0.02ef	4.54±0.01fg	4.52±0.02g
T2	4.63±0.02cd	4.60±0.01de	4.57±0.02ef	4.55±0.01fg
T3	4.65±0.01c	4.63±0.02cd	4.61±0.01de	4.60±0.02ef

Values are expressed as mean±standard deviation (Mean±SD). Different letters within the same row indicate significant differences at a probability level (P<0.05). Data represent the mean of three replicates per treatment.

Table 5: Total count of milk cream with added pumpkin peel extract, stored at 4°C for 21 days.

Treatment	Total count of lipophilic bacteria (log_{10} cfu/g)			
	Storage period/day			
	0	7	14	21
T0	0.90±0.02h	1.10±0.03g	2.40±0.04c	3.50±0.05a
T1	0.85±0.02hi	1.00±0.03gh	2.10±0.04d	3.10±0.05b
T2	0.80±0.02ij	0.95±0.03hi	1.80±0.03e	2.80±0.04c
T3	0.75±0.02j	0.90±0.02i	1.60±0.03f	2.40±0.04d

Values are expressed as mean±standard deviation (Mean±SD). Different letters within the same row indicate significant differences at a probability level (P<0.05). Data represent the mean of three replicates per treatment.

Table 6: Sensory evaluation of milk cream with added pumpkin peel extract, stored at 4°C for 21 days.

Storage period/ day	Treatment	Sensory qualities out of 10 degrees				
		Color	Taste	Smell	Texture	Overall appearance
0	T0	9.0±0.2a	9.2±0.2a	9.1±0.2a	9.3±0.2a	9.2±0.2a
	T1	9.1±0.2a	9.3±0.2a	9.2±0.2a	9.4±0.2a	9.3±0.2a
	T2	9.2±0.2a	9.4±0.2a	9.3±0.2a	9.5±0.2a	9.4±0.2a
	T3	9.3±0.2a	9.5±0.2a	9.4±0.2a	9.6±0.2a	9.5±0.2a
7	T0	8.2±0.2b	8.0±0.2b	7.8±0.2b	8.1±0.2b	8.0±0.2b
	T1	8.5±0.2ab	8.6±0.2ab	8.4±0.2ab	8.6±0.2ab	8.5±0.2ab
	T2	8.8±0.2ab	8.9±0.2a	8.7±0.2a	9.0±0.2a	8.9±0.2a
	T3	9.0±0.2a	9.2±0.2a	9.1±0.2a	9.3±0.2a	9.2±0.2a
14	T0	6.8±0.2d	6.2±0.2d	6.0±0.2d	6.5±0.2d	6.3±0.2d
	T1	7.2±0.2c	7.0±0.2c	6.8±0.2c	7.3±0.2c	7.1±0.2c
	T2	7.8±0.2b	7.6±0.2b	7.4±0.2b	8.0±0.2b	7.7±0.2b
	T3	8.2±0.2a	8.5±0.2a	8.3±0.2a	8.6±0.2a	8.4±0.2ab
21	T0	5.0±0.3d	4.5±0.3d	4.2±0.3d	4.8±0.3d	4.6±0.3d
	T1	5.8±0.2c	5.6±0.2c	5.4±0.2c	6.0±0.2c	5.7±0.2c
	T2	6.8±0.2b	6.5±0.2b	6.3±0.2b	7.0±0.2b	6.7±0.2b
	T3	7.5±0.2a	7.8±0.2a	7.6±0.2a	8.0±0.2a	7.7±0.2a

Values are expressed as mean±standard deviation (Mean±SD). Different letters within the same row indicate significant differences at a probability level ($P<0.05$). Data represent the mean of three replicates per treatment.

Total count of lipophilic bacteria in cream

In the Table 5. the total count of lipophilic bacteria (log_{10} CFU/g) shows a progressive increase in bacterial growth with the time of storage in all treatments. This is a result of microbial growth in the cream stored at refrigeration temperature. In treatment T0, the count increased from 0.90 log_{10} CFU/g on day 0 to 1.10 on day 7, then to 2.40 on day 14, reaching 3.50 on day 21. This is due to the presence of suitable media (Fat and protein) that enhances the growth of lipophilic bacteria in the absence of inhibitors. Treatments T1, T2 and T3 had a lower bacterial count than the control treatment. The lowest bacterial growth during the storage period was observed in treatment T3 (0.3 g) with values of 0.75 on day 0, 0.90 on day 7, 1.60 on day 14 and 2.40 on day 21. It was followed by T2 and then T1, suggesting that the higher the concentration of the extract, the greater the decrease in bacterial growth. This is due to the presence of active components in pumpkin peel extract, like phenols and flavonoids, which can inhibit bacterial growth by interacting with the bacterial cell wall and increasing its permeability. It also affects some of the essential processes of the bacterial cell, such as enzyme activity and nutrient transport, which slow down the bacterial growth (Donadio *et al*., 2021).

Sensory evaluation of cream

The sensory evaluation in Table 6 shows that the sensory qualities of the cream were gradually affected as the storage period progressed (0, 7, 14 and 21 days) in all treatments, with a clear advantage for the treatments enriched with pumpkin peel extract. For color, the highest value was recorded at the beginning of storage (day 0) in treatment T3 (9.3), while the lowest value was recorded at the end of storage (day 21) in the control treatment T0 (5.0). This is attributed to the increased oxidation reactions and deterioration of milk pigments with the passage of time. For taste, the highest value was also recorded on day 0 in T3 (9.5), while the lowest value was on day 21 in T0 (4.5). This is explained by the accumulation of lipid and protein breakdown products, which impart an undesirable taste as storage continues. In terms of aroma, the highest value was recorded on day 0 at T3 (9.4) and the lowest value on day 21 at T0 (4.2). This is due to the development of volatile compounds from bacterial activity and oxidation of the lipids of the unenriched treatment. In terms of texture, the highest value was recorded on day 0 at T3 (9.6) and the lowest value on day 21 at T0 (4.8). This is due to the separation of fat and breaking of protein structure in the cream. In terms of appearance, the highest value was on day 0 at T3 (9.5) and the lowest value was on day 21 at T0 (4.6). This is in line with the finding of Peasura *et al.* (2020) plant extracts containing phenolic compounds have contributed to delaying this process and maintaining the quality of dairy products for as long as possible.

CONCLUSION

The outcomes of this study demonstrate that the alcoholic extract of dried pumpkin peel is a good source of phenolic and flavonoid compounds with antioxidant and antimicrobial properties, as was observed in cow's milk cream. Higher extract concentrations (T1 to T3) progressively produced a more stable product, as indicated by a reduction in the peroxide values (PV) compared to the control sample throughout the storage time. The pumpkin peel extract also

played a role in stabilising the pH and facilitated decreased microbial load, suggesting an antimicrobial effect. The treatments improved, especially T3, retained better sensory properties over time, indicating the possibility of using the extract as a natural additive instead of synthetic preservatives. These findings confirm the possibility of using pumpkin peel, an underutilised agricultural by-product in sustainable development, to minimize food waste and obtain high quality dairy products with an extended shelf life by natural and safe means.

Conflict of interest

All authors declare that they have no conflict of interest.

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