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Utilization of Pomegranate Dips to Improve the Nutritional Properties, Antioxidant Activity, and Shelf Life of Processed Cheese

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ABSTRACT

This study evaluated the impact of varying pomegranate dips (Po. Dips) concentrations (0%, 1%, 3%, and 5%) on the physicochemical, functional, and sensory properties of processed cheese over a 30-day storage period. Results showed that increasing Po. Dip levels led to a decrease in pH and moisture content while acidity and ash content increased. The highest acidity (1.17) and mineral content were observed in the 5% Po. dips sample. Protein and fat content showed minor reductions due to dilution effects, while soluble nitrogen levels increased, indicating enhanced proteolysis during storage. Functionally, Po. dip improved reliability (peaking at 434.30% in the 5% Po. Dip sample, enhanced flowability, and initially increased oil separation before stabilizing over storage. Rheological analysis confirmed shear-thinning behavior, with Po. Dips -enriched samples exhibited higher viscosities, suggesting a stronger structural network. Sensory analysis favored the 1% Po. Dip sample, which maintained the best scores for flavor (8.4), texture (8.4), and overall acceptability (8.6), while higher Po. Dips levels negatively affected appearance, taste, and texture due to excessive acidity and darker coloration. Overall, moderate Po. Dip levels (1–3%) optimized both technological and sensory properties, making Po. Dip is a promising functional ingredient for processed cheese formulations.

Keywords: Processed cheese, Pomegranate dips, Sensory evaluation, Antioxidants, Physicochemical and functional analysis

INTRODUCTION

Processed cheese is one of the most widely consumed dairy products, known for its versatility, convenience, and extended shelf life. It is typically made by combining natural cheese with emulsifying salts, fats, and other additives to achieve desired textural and flavor profiles. Over the years, innovations in processed cheese production have aimed its nutritional value and functional properties while maintaining its sensory appeal. One such approach is the incorporation of functional ingredients, which can offer added health benefits without compromising the sensory qualities of the final product (Rafiq and Ghosh, 2017).

Incorporating fruit-based ingredients into processed cheese formulations is a growing trend due to their potential health benefits and ability to enhance flavor profiles. Pomegranate, an antioxidant-rich fruit, has gained significant attention due to its wide range of bioactive compounds, including polyphenols, tannins, and flavonoids, which are known for their health-promoting properties (Singh *et al.*, 2016). These bioactive compounds possess antioxidant, anti-inflammatory, and anti-cancer effects, making pomegranate an ideal ingredient for inclusion in dairy products (Wang *et al.*, 2018).

Pomegranate dips, which are prepared by extracting the juice or pulp from the fruit, have been explored for use in various food products, including beverages, desserts, and sauces (Cetin *et al.*, 2013). However, the application of pomegranate dips in processed cheese formulations has not been extensively studied. Enriching processed cheese with pomegranate dips could provide a unique blend of flavors while enhancing the nutritional profile of the product. Additionally, the inclusion of pomegranate dips may offer functional benefits, such as improved oxidative stability and enhanced health-promoting properties due to the presence of antioxidants (Kaur *et al.*, 2020).

The objective of this study is to develop a processed cheese product enriched with pomegranate dips and evaluate its physicochemical, sensory, and functional properties. By assessing the effect of different concentrations of pomegranate dips on the composition, texture, flavor, and antioxidant activity of processed cheese, this study aims to provide insights into the potential of pomegranate-enriched processed cheese as a functional dairy product.

MATERIALAS AND METHODS

Processed cheese materials

A 4 kg block of commercially matured Edam cheese was utilized to produce processed cheese. The cheese had an average composition of 45% moisture, 23% protein, 28% fat, and 3.5% ash. It was cut into small pieces to enhance mixing and processing. Pomegranate dips were purchased from the local market and stored refrigerated until used. Trisodium citrate (Sigma-Aldrich Chemie GmbH, Munich, Germany) was used as the emulsifying salt to facilitate the processing of the cheese. The other chemicals used in the study were obtained from (Sigma-Aldrich Chemie GmbH, Munich, Germany, and AL-Gomhoria company. Egypt).

Methods

Physicochemical Analysis of pomegranate dips

The digital pH meter (Model WTW PH320) was used to measure the pH values of the pomegranate dip samples.

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The Total soluble solids (T.S.S.) content of pomegranate dips was determined by using an Abbe refractometer using a Carl Zeiss refractometer at 20°C and expressed in degrees of Brix (Babu *et al.,* 2017). Titratable acidity was measured by titration to an endpoint pH of 8.2. Firstly, 10 grams of the sample were completed with 100 ml of distilled water. Then it was titrated with 0.1 N NaOH solution until the pH value reached 8.2. (Anonymous, 2002).

Chemical analysis of pomegranate dips

According to A.O.A.C. (2006), the protein and ash contents of pomegranate dips were measured. Using the Folin–Ciocalteu reagent and gallic acid as a standard, the total phenolic contents of pomegranate dips were calculated in accordance by Singelton *et al.* (1999). The results were reported as milligrams of gallic acid equivalent/100 milliliters. According to Yang *et al.* (2009), total flavonoids were quantified using spectrophotometry at 510 nm and expressed as milligrams of quercetin acid equivalents/100 milliliters. The antioxidant activity of the samples was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity method. To homogenize 2 grams of the sample with 10 ml of 96% ethanol were used. A 1 mL solution of DPPH was added to 1 mL of this mixture. The absorbance was measured at 517 nm following a half-hour wait in a dark setting (Sahu *et al.,* 2013).

Processing processed cheese with PO. DIPS

Four distinct processed cheese formulations were developed using Edam cheese as the base, incorporating varying levels of Po. Dips. The formulation process was adapted from the method described by (Rafiq and Ghosh, 2017. At first, the Edam cheese was milled and transferred to a pilot-scale cheese cooker (Stephan Machinery Corp., New York, NY, USA). Water (10–20% of the cheese weight) and emulsifying salt (3%) were added, and the mixture was heated to 85–90°C while being continuously stirred at 1500 rpm for 5 minutes, ensuring the formation of a homogenous cheese mass. Po. Dips were then incorporated into the base mixture at concentrations of 0%, 1%, 3%, and 5% (w/w). Each formulation was further cooked at 75–80°C for 5 minutes with continuous mixing to achieve uniform distribution. The hot, molten cheese was then portioned into individual 250 mL plastic containers, allowed to cool at room temperature for 2 hours, and subsequently stored in a refrigerator at 4 ± 1°C for further analysis.

Physicochemical and functional analysis

The titratable acidity, moisture, fat, ash, soluble nitrogen, and protein contents of the processed cheese samples were analyzed in triplicate following (AOAC, 2010). The pH of the samples was measured using a Kent EIL 7020 pH meter.

Meltability was assessed using a modified Schreiber test (Altan *et al.,* 20025). Three cheese discs (4 cm in diameter, 10 mm in thickness) from each formulation were placed in a glass Petri dish and heated in an air-circulated oven at 110°C for 10 minutes. The samples were then allowed to cool at room temperature for 15 minutes. Meltability (%) was calculated using the formula:

$$\text{Meltability}(\%) = \frac{\text{area of melted disc} - \text{area of original disc}}{\text{area of original disc}} \times 100$$

The oil separation index was determined according to the method described by (Thomas, 1973). Three cheese discs from each sample were placed onto Whatman No. 41 filter paper and heated in an oven at 110°C for 10 minutes. The fat released from the melted cheese was absorbed by the filter paper, forming a grease ring around the disc. Oil separation (%) was calculated using the following formula:

$$\text{Oil separation}(\%) = \frac{\text{area of fat ring and disc} - \text{area of original disc}}{\text{area of original disc}} \times 100$$

The flowability of the processed cheese samples was evaluated using a standardized method (Altan *et al.*, 2025) with slight modifications. Three cheese discs (4 cm in diameter, 10 mm in thickness) were placed on a glass Petri dish and heated in an air-circulated oven at 250°C for 5 minutes. After heating, the samples were immediately cooled at room temperature for 15 minutes. Flowability (%) was calculated as follows:

Meltability, oil separation index, and flowability values were recorded as the means of three independent measurements for each treatment.

$$\text{Flowability}(\%) = \frac{\text{diameter of melted disc} - \text{diameter of original disc}}{\text{diameter of original disc}} \times 100$$

Viscosity

The viscosity of different processed cheese samples was measured at 25 ± 2°C using a Brookfield DV-III viscometer (Brookfield, MA, USA). The analysis was performed at varying rotational speeds (rpm) using spindle No. 93, and the results were expressed in centipoise (cP) (Su *et la.,* 2018).

Sensory Evaluation

The processed cheese samples were subjected to organoleptic evaluation for appearance, texture, flavor, aroma, and overall acceptability by a panel of 15 untrained panelists (faculty members and students). The panel comprised eight men and seven women aged between 22 and 45 years, all of whom were familiar with processed cheese. Cheese samples were presented in white plastic cups under natural room lighting to ensure uniform evaluation conditions. The sensory assessment was conducted one day after production, using a nine-point hedonic scale, where 1 represented "dislike extremely" and 9 represented "like extremely" (Amini *et al.*, 2019). To prevent flavor carryover, panelists were provided with water to cleanse their palate between sample evaluations.

Extraction and determination of total phenols content (TPC) and the antioxidant activity (AOA) in processed cheese

For extracting the phenolic compounds, (4 g) of the processed cheese was mixed with an aqueous methanolic solution (50 ml, 80:20 v/v) with agitation for 24 h at room temperature. After centrifugation for 20 min at 4000 g, the supernatant was collected, and the residue was re-extracted with an additional 30 ml of the same solution and recombined together. The obtained supernatant has been utilized in the estimation of TPC, and AOA.

Total phenols content (TPC) has been estimated according to (Elfalleh *et al.* (2009) and the results were expressed as mg GAE/g. Antioxidant activity (AOA) has been estimated to use DPPH as radical scavenging activity of methanolic extracts according to (Okonogi *et al.* (2007). and antioxidant activity (AOA).

Statistical Analysis

All analyses were performed in triplicate, and the results were expressed as mean values ± standard deviation. Statistical differences among the mean values were assessed using one-way analysis of variance (ANOVA), followed by the Least Significant Difference (LSD) test at a significance level of $p \leq 0.05$. Data analysis was conducted using XLSTAT Statistical Software, version 2007 (Addin soft, Paris, France).

RESULTS AND DISCUSSION

Physical and Chemical Parameters of Po. Dips

To ascertain the physicochemical characteristics of the pomegranate dips sample, measurements of TSS, protein, ash, pH, total acidity, total phenolic compounds and total flavonoids and antioxidant activity were made. Table 1 displays the findings of the physicochemical examination of pomegranate dips. Results showed that the pH of pomegranate dip was 2.46 ± 0.08. According to Inceday *et al.* (2010), seven distinct commercial pomegranate dip samples had pH values ranging from 0.87 to 1.98. Additionally, Kaya and Sozer's (2005) investigation found that the pH value of pomegranate molasses was 2.05. Depending on the pomegranate fruit type, sugar content, amount of organic acid, and growing region, the pH value can change.

Table 1. Physiochemical and biochemical properties of pomegranate dips (Po. Dips).

Parameters	Value
T.S. S	32.57 ± 1.88
% Protein	0.35 ± 0.02
% Ash	1.13 ± 0.07
PH	2.46 ± 0.08
Titratable acidity (%)	6.78 ±0.36
TP (mg GAE/ g)	69.07 ± 1.60
TF (mg QE/ g)	46.69 ± 1.12
AOA IC50	0.88 ± 0.01

The Protein content of the pomegranate dips was observed to be 0.35 ± 0.02 %. Yılmaz *et al.* (2007) reported that the protein content of the pomegranate molasses was 0.23 ± 0.06 and according to the researchers, filtration and clarification of pomegranate juice during commercial processing may be the main reason for the low protein content of pomegranate molasses in comparison to fresh pomegranate (Valero *et al.*, 2014). The protein levels in certain samples were raised in percentage terms by concentrating on the products, whereas others experienced a reduction due to protein denaturation caused by heating (Mukhiddinov *et al.*, 2021)

Because it is an objectively measured criterion used to evaluate the sweetness or flavor of foods, determining the concentration of soluble solids (brix) in fruits and vegetables is crucial (Lister et al., 2017). While the TSS level was measured in the pomegranate dips (32.57 ± 1.88 %), pH and titratable acidity are related variables that have a special impact on the quality of food. However, titratable acidity Rather than pH is a more accurate measure of how acid affects flavor (Sadler and Murphy, 2010). The titratable acidity (as citric acid) value of the pomegranate dips was measured as 6.78 ±36. The obtained results of ash content showed that the percentage of ash in the pomegranate dips sample was (1.13 ± 0.07 %).

Fruits and vegetables, particularly those with a red color, naturally contain phenolic substances, which are vital for human health (Tzulker *et al.*, 2007). The total phenolic content of pomegranate dips is displayed in Table 1 and observed that the total phenolic content of pomegranate dips was (69.07 ± 1.60 mg GAE/gm). The authors found that the pomegranate arils had the maximum phenolic content during 20 days of fruit set, at roughly 5 mg gallic acid equivalent (GAE)/g. According to our findings, the total phenolic concentration of pomegranate dips was approximately 69.07 ± 1.60 mg GAE/gm). This indicates that the pomegranate molasses accessible in the market has a total phenolic content that is five to ten times higher than that of fresh pomegranate arils. The evaporation of water during processing is primarily responsible for the increase in the total phenolic content of pomegranate dips (Alper *et al.*, 2005). According to the current study's findings, a small number of pomegranate dips, which have a total phenolic concentration of (69.07 ± 1.60 mg GAE/gm) can significantly increase a person's daily intake of dietary phenolics. Foods that have a high phenolic content are also known to have strong antioxidant properties. Karadeniz *et al.* (2005), reported that eating foods high in antioxidants helps shield cells by preventing oxidation events in the body. Pomegranate fruit is one of the foods with significant antioxidant impact. The high antioxidant activity of pomegranate dips might appear due to a high phenol concentration. The human body uses a variety of processes to manufacture antioxidants, which are either naturally occurring in the body, or externally supplied through foods and/or supplements (Ghassan *et al.*,2017)

The radical scavenging activity of each molasses sample against DPPH was examined. The percentage of DPPH radical, which is a measure of antioxidant activity expressed as IC50 of pomegranate dips was (0.88 ± 0.012). Pomegranate dips potent antioxidant properties may be due to the presence of phenolic components, which may have medicinal applications in the future by shielding cells from oxidative stress. These findings are comparable to those of Karaali *et al.* (2006), who discovered that commercial molasses had an antioxidant value of 54.8%.

Total phenolic content and Antioxidant Properties of cheese containing 0, 1, 3, and 5% pomegranate dips (Po. Dips).

Cheese antioxidant qualities are displayed in Table 2. Pomegranate antioxidant activity is mostly attributed to the presence of ascorbic acid and phenolic compounds such as ponicagelin, picoline, gallic acid, ethanolic acid, and anthocyanins (Gil *et al.*, 2000). Pomegranate polyphenolic components have three to fifteen times the ability to remove and neutralize free radicals compared to other antioxidants like vitamins C and E Zarban *et al.* (2007). With the increase in the percentage of pomegranate dips added to processed cheese, the number of phenolic compounds significantly increased. 5% Po. Dips recorded the highest level of TP (3.91 ± 0.08 mg GAE/ g) followed by 3% Po. Dips (2.74 ± 0.12 mg GAE/ g), then 1% Po. Dips, while control samples recorded the lowest TP (12 ± 0.71). These results are like the findings of Trigueros *et al.* (2012).

The findings demonstrated a considerable increase in antioxidant activity with increasing pomegranate juice content. In their investigation, Zarban *et al.* (2007) discovered that pomegranate juice has a greater inhibitory impact (96%) than other fruits. Furthermore, Han *et al.* (2011) discovered that adding phenolic compounds to cheese could improve its antioxidant qualities; they discovered that cheese containing 0.15 mg/mL of phenolic compounds had notable antioxidant qualities. Additionally, comparable findings were obtained when pomegranate dips were added to yogurt, and the antioxidant qualities of the yogurt improved as the pomegranate dips content increased. The data obtained shows that processed cheese supplemented with PM had higher antioxidant activity than control. Moreover, the data showed that the radical scavenging activity (DPPH) (%) of processed cheese increased with increasing Po. Dips concentration in all treatments. 5% Po. Dips recorded the highest level of % inhibition (55.70 ± 1.33) followed by 3% Po. Dips (41.55 ± 0.85), then 1% Po. Dips, while control samples recorded the lowest % inhibition (12 ± 0.71). These findings concur with those of Amarowicz *et al.* (2004). Po. Dips can be utilized as industrial dairy byproducts as a natural preservation agent to delay oxidation and increase the shelf life.

Table 2. Total phenolic content and Antioxidant activity (% inhibition) in processed cheese containing 0, 1, 3 and 5% pomegranate dips (Po. Dips).

Parameters	**TP**	**Antioxidant activity**
Samples	**(mg GAE/ g)**	**(% inhibition)**
Con.	0.74 ± 0.01 d	12.00 ± 0.71d
1% Po. Dips	1.45 ± 0.07 c	32.71 ± 0.61 c
3% Po. Dips	2.74 ± 0.12 b	41.55 ± 0.85 b
5% Po. Dips	3.91 ± 0.08 a	55.70 ± 1.33 a

Physiochemical characteristics of processed cheeses

Table 3 presents the physiochemical characteristics of processed cheeses with varying percentages of pomegranate dips (Po. Dips) presumably a type of dairy ingredient or additive) over different storage periods. The attributes measured include pH, acidity, moisture content, fat, protein, ash, and Soluble Nitrogen (SN).

Table 3. Physiochemical characteristics of processed cheeses containing 0, 1, 3, and 5% pomegranate dips (Po. Dips).

Attributes	**Storage (days)**	**Samples**			
		Control	**1 % Po. Dips**	**3 % % Po. Dips**	**5 % % Po. Dips**
pH	Fresh	$5.88^{a}\pm0.01$	$5.76^{b}\pm0.03$	$5.74^{c}\pm0.02$	$5.73^{c}\pm0.01$
	15	$5.87^{a}\pm0.01$	$5.74^{b}\pm0.02$	$5.72^{c}\pm0.03$	$5.70^{d}\pm0.01$
	30	$5.87^{a}\pm0.02$	$5.72^{b}\pm0.01$	$5.69^{c}\pm0.02$	$5.68^{c}\pm0.01$
Acidity (%)	Fresh	$0.90^{a}\pm0.00$	$0.93^{a}\pm0.05$	$0.95^{a}\pm0.03$	$0.96^{a}\pm0.06$
	15	$0.91^{b}\pm0.01$	$0.97^{a}\pm0.02$	$0.99^{a}\pm0.00$	$1.01^{a}\pm0.04$
	30	$0.91^{d}\pm0.01$	$1.03^{c}\pm0.05$	$1.11^{b}\pm0.02$	$1.17^{a}\pm0.02$
Moisture (%)	Fresh	$59.78^{a}\pm0.15$	$59.14^{b}\pm0.03$	$58.12^{c}\pm0.19$	$57.81^{c}\pm0.25$
	15	$59.25^{a}\pm0.\ 16$	$58.21^{ab}\pm0.12$	$57.49^{b}\pm0.08$	$57.00^{b}\pm0.08$
	30	$59.02^{a}\pm0.56$	$57.98^{b}\pm0.12$	$57.15^{c}\pm0.08$	$56.63^{c}\pm0.21$
Fat (%)	Fresh	$19.83^{a}\pm0.29$	$18.17^{b}\pm0.28$	$18.17^{b}\pm0.27$	$17.33^{c}\pm0.29$
	15	$20.50^{a}\pm0.50$	$19.17^{b}\pm0.29$	$19.33^{b}\pm0.28$	$18.17^{c}\pm0.27$
	30	$21.00^{a}\pm0.00$	$19.83^{b}\pm0.29$	$19.83^{b}\pm0.29$	$19.33^{b}\pm0.58$
Protein (%)	Fresh	$16.84^{a}\pm0.03$	$16.32^{b}\pm0.04$	$16.31^{b}\pm0.02$	$16.28^{b}\pm0.03$
	15	$16.84^{a}\pm0.02$	$16.33^{b}\pm0.02$	$16.32^{bc}\pm0.02$	$16.29^{c}\pm0.01$
	30	$16.86^{a}\pm0.02$	$16.34^{b}\pm0.02$	$16.34^{b}\pm0.02$	$16.30^{c}\pm0.01$
Ash (%)	Fresh	$2.88^{c}\pm0.04$	$3.04^{b}\pm0.01$	$3.12^{b}\pm0.01$	$3.23^{a}\pm0.07$
	15	$2.91^{d}\pm0.02$	$3.10^{c}\pm0.01$	$3.16^{b}\pm0.02$	$3.27^{a}\pm0.02$
	30	$2.94^{d}\pm0.01$	$3.12^{c}\pm0.02$	$3.18^{b}\pm0.01$	$3.28^{a}\pm0.01$
SN (%)	Fresh	$1.05^{a}\pm0.02$	$1.05^{a}\pm0.01$	$1.06^{a}\pm0.02$	$1.06^{a}\pm0.03$
	15	$1.05^{b}\pm0.03$	$1.06^{ab}\pm0.02$	$1.07^{ab}\pm0.02$	$1.08^{a}\pm0.01$
	30	$1.07^{b}\pm0.01$	$1.08^{b}\pm0.01$	$1.10^{ab}\pm0.01$	$1.11^{a}\pm0.02$

Results are expressed as mean ± SD; means with different superscripts in a row differ significantly ($p \leq 0.05$).

In keeping with previous studies on cheese storage, the pH of every cheese sample gradually decreased over time (El-Bakry and Mehta, 2022). The pH range of fresh samples was 5.88 to 5.73, with 5% Po. The dips sample have the lowest pH (5.73) and the control (0% Po. Dips) sample has the highest pH (5.88). The acidic character of pomegranates, which contain organic acids like citric and malic acid, is the reason why pH decreases as Po. Dips levels rise (Viuda-Martos *et al.,* 2010).

According to earlier research on cheese storage, each cheese sample's pH progressively dropped over time (El-Bakry and Mehta, 2022). The fresh samples had a pH range of 5.88 to 5.73, with the control (0% Po. Dips) sample having the highest pH (5.88) and the 5% Po. Dips samples have the lowest pH (5.73). As Po. Dip levels grow, and pH falls because pomegranates, which include organic acids like citric and malic acid, have an acidic nature (Viuda-Martos *et al.,* 2010). All samples showed a significant rise in acidity over time, suggesting that cheese gets more acidic with age. All the samples had comparable acidity levels when they were first stored, however by day 30, the 5% Po. Dips sample had increased to 1.17 and the control sample to 0.91. This implies that acid formation during storage may be accelerated by increased Po. Dips concentrations.

This finding is consistent with earlier research showing that fruit-based additions, especially those high in organic acids, can make dairy products more acidic (Azarpazhooh *et al.,* 2019). Furthermore, the metabolic activities of ambient bacteria or leftover starting cultures may have caused the natural fermentation process during storage to contribute to the rise in acidity (Chen *et al.*, 2020).

Moisture Content:

As the shelf-life extended, the moisture level decreased in all samples, which is normal for cheese products because they lose moisture as they age. The moisture content of the control sample was higher than that of the samples with additional Po. Dips, especially on day 30, when it was 59.02% as opposed to 56.63% for the 5% Po. Dips sample. The binding qualities of Po. Dips or their interactions with other ingredients in cheese may be the cause of this decrease in moisture.

Pomegranate compounds' water -binding characteristics, which alter the cheese matrix and decrease the amount of free water available, could be the cause of this moisture decrease (Mulsow *et al.,* 2007). All samples showed an overall decrease in moisture content over storage, with samples with higher Po. Dips levels see the most moisture loss. Cheese often goes through a gradual decrease in moisture, primarily because of water evaporation and syneresis (Fox *et al.,* 2017).

Fresh samples had fat contents ranging from 17.33% to 5% Po. Dips cheese to 19.83% in the control. Since pomegranate dip doesn't add extra fat, the dilution effect is responsible for the decline in fat % as Po. Dip levels rise (Mulsow *et al.,* 2007). Studies using plant-based components or fruit extracts in dairy products have shown similar patterns (Viuda-Martos *et al.,* 2010). The fat content increased during the 30-day storage period; the control sample had the greatest value (21.00%), while the 5% Po. Dips cheese was the lowest (19.33%). The relative concentration of fat in cheese may have increased because of moisture loss over time.

When pomegranate dip was added, the protein content somewhat dropped; at the fresh stage, the control sample had the highest protein percentage (16.84%), while the 5% Po. Dips cheese had 16.28%. The partial substitution of pomegranate dip, which does not supply protein, for dairy ingredients may be the cause of the decrease in protein levels in samples with higher Po. Dips content (Lashkari *et al* 2020). Proteolysis and the disintegration of casein molecules into peptides and amino acids are probably the causes of the slight increases in protein content that occurred during storage (Parafati, 2021). The statistical significance of the differences between the treatments, however, suggests that the addition of Po. Dips had a minor impact on the cheese's protein level.

Pomegranate dip increased the amount of ash, which is a measure of the overall mineral content. At the fresh stage, 5% the Po. dips sample had the highest ash concentration (3.23%), while the control sample had the lowest (2.88%). Given that pomegranates include minerals including potassium, calcium, and phosphorus, the rise in ash content is to be expected (Mahajan et al., 2015). 5% Po. Dips sample had the greatest concentration (3.28%) at 30 days, and this trend persisted throughout the storage period. This result is consistent with earlier studies that show plant-based fortification can improve the mineral composition of dairy products (Parafati, 2021).

Proteolysis and protein degradation are indicated by soluble nitrogen (SN), which influences the texture and flavor development of cheese. The samples' SN level at the fresh stage varied very little (1.05–1.06%), suggesting that the addition of Po. Dips had no discernible effect on the first proteolysis. All samples, however, showed a progressive rise in SN content over storage, with 5% Po. Dips sample showing the highest values at 30 days (1.11%). Because of microbial metabolism and residual enzyme activity, processed cheese frequently exhibits proteolytic activity, as indicated by this rise in SN concentration (Mahajan *et al.,* 2015). Pomegranate bioactive components may alter proteolysis rates and enhance cheese ripening properties, as seen by the slightly increased SN levels in PO. DIPS -containing samples.

Functional characteristics of processed cheeses

The data presented in Table 4 illustrates the functional characteristics of processed cheeses with varying percentages of Po. Dips (presumably a type of dairy ingredient or additive). The results indicate significant differences in reliability, oil separation, and flowability among the samples containing 0%, 1%, 3%, and 5% Po. Dips.

Meltability is a crucial aspect of processed cheese quality that influences how well it works in cooking and food processing. The findings show that greater Po. Dips concentration significantly increases meltability. The meltability of fresh cheese samples ranged from 49.41% (control) to 185.26% (5% Po. Dips), suggesting that the addition of Po. Dips considerably improved melting behavior. This pattern persisted through out of storage, with 5% Po. Dips sample having the maximum meltability at 30 days (434.30%). Pomegranate compounds like organic acids and phenolic compounds disrupt protein networks, which may interfere with casein interactions and result in a softer and more heat-responsive structure. This is why Po. Dips addition increases reliability **(**Mulsow *et al.,* 2007). Dairy products enhanced with fruit-based ingredients have shown similar results, altered protein-fat interactions, and affected mouthfeel (Kandyliari *et al.,* 2023). Ongoing proteolysis, in which protein breakdown weakens the cheese matrix and promotes increased melting, may be the cause of the gradual rise in meltability (Fox *et al*., 2017).

Regarding cheese stability and fat distribution, oil separation is a crucial factor. Oil separation in fresh samples rose as Po. Dips were added; They ranged from 177.78% in the control sample to 278.11% in the 5% Po. Dips sample. However, oil separation declined during storage in all samples; after 30 days, 5% Po. Dips cheese had the lowest oil separation (115.11%). Because pomegranate polyphenols interfere with fat binding in the cheese matrix, the first increase in oil separation with Po. Dips enrichment may be the result of changed fat-protein interactions (Lashkari *et al.,* 2020).

Table 4. Functional characteristics of processed cheeses containing 0, 1, 3, and 5% pomegranate dips (Po. Dips).

Attributes	Storage (days)	Samples			
		Control	1 % PO. DIPS	3 % PO. DIPS	5 % PO. DIPS
Meltability	Fresh	49.41^{c}±4.68	128.37^{b}±5.84	131.74^{b}±5.84	185.26^{a}±6.48
	15	200.44^{c}±0.00	232.07^{bc}±6.99	256.81^{b}±7.25	394.44^{a}±43.30
	30	208.22^{c}±6.74	244.33^{b}±7.12	265.26^{b}±7.38	434.30^{a}±23.62
Oil separation (%)	Fresh	177.78^{c}±0.00	192.81^{b}±6.61	204.33^{b}±6.74	278.11^{a}±7.51
	15	135.11^{a}±0.00	125.00^{b}±0.00	125.00^{b}±0.00	118.41^{c}±5.71
	30	138.56^{a}±5.97	121.70^{b}±5.71	118.41^{b}±5.71	115.11^{b}±0.00
Flowability (%)	Fresh	102.50^{c}±0.00	125.83^{b}±1.44	130.83^{a}±1.44	131.67^{a}±1.44
	15	101.67^{d}±1.44	129.17^{c}±1.44	131.67^{b}±1.44	135.00^{a}±0.00
	30	100.83^{c}±1.44	130.83^{b}±1.44	134.17^{a}±1.44	136.67^{a}±1.44

Results are expressed as mean ± SD; means with different superscripts in a row differ significantly ($p \leq 0.05$).

The decrease in oil separation over storage, however, points to either protein restructuring or moisture loss as factors that improve fat retention. This could be because polyphenol-protein interactions help to stabilize the cheese's structure over time (Parafati *et al.,* 2021). The ability of cheese to spread when heated is known as flowability, and it's crucial for use in pizza, sauces, and baked goods. According to the findings, the flowability of Po. Dips enriched cheese was noticeably higher than that of the control sample; fresh samples showed values rising from 102.50% (control) to 131.67% (5% Po. Dips). Flowability improved over time, reaching 136.67% in the 30-day 5% Po. Dips sample.

Because Po. Dips affect protein interactions and water retention capacity, it softens the cheese matrix, which explains the increase in flowability (Lashkari *et al.*, 2020). Pomegranate acids and phenolic compounds may also alter the cheese's microstructure, increasing its fluidity when heated (Viuda-Martos et al., 2010). The result is consistent with other studies on fruit-enriched dairy products, which indicate that plant-based additives can improve the functional qualities of cheese by making it more spreadable and less stiff (Parafati *et al.*, 2021).

Viscosity of processed cheese

Figure 1 presents the viscosity (cP) of different processed cheese formulations as a function of shear rate (rpm). The samples include C (control) and three different formulations containing pomegranate dips T1(1% Po. Dips), T2 (3% Po. Dips), and T3 (5% Po. Dips. All samples exhibit shear-thinning behavior, with viscosity decreasing as the rate rises, as seen by the results. According to Tabilo-Munizaga and Barbosa-Cánovas (2005), this pattern is typical of non-Newtonian fluids, especially pseudoplastic materials, where higher shear stress causes intermolecular connections to break down, lowering the viscosity. The viscosity of every processed cheese sample dropped as the shear rate rose, a phenomenon known as shear-thinning. Due to the disruption of protein and fat networks caused by the applied shear stress, which promotes flow, this is common for dairy-based emulsions (Lucey *et al.*, 2003). Increasing the shear rate appears to improve molecular alignment and decrease flow resistance, as indicated by the observed exponential decrease in viscosity. Consistently exhibiting the lowest viscosity, the control sample (C) suggested a weaker structural network with fewer component interactions. As observed in T1, T2, and T3, the viscosity rose as the amount of pomegranate dipping increased, indicating that the cheese matrix structure is impacted by the pomegranate's inclusion. Viscosity was greatly impacted by the addition of pomegranate dips, with T3 exhibiting the greatest values, followed by T2 and T1. This suggests that pomegranate dip concentrations that are greater lead to a more complex or robust cheese matrix. Potential causes include.

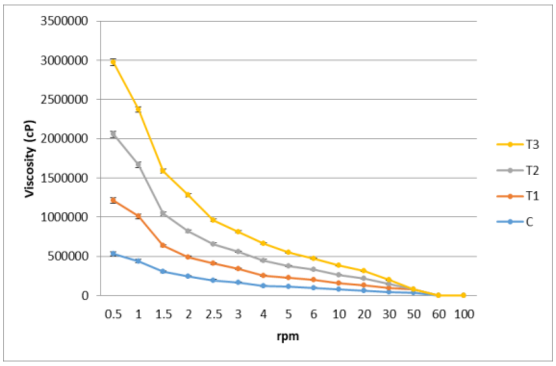

Figure 1. Viscosity of processed cheeses containing 0, 1, 3, and 5% Po. Dips.

Pectins, tannins, and polyphenols found in pomegranates may increase viscosity by improving the fruit's ability to hold water and encouraging interactions between molecules (Viuda-Martos *et al.*, 2010). According to Sharma *et al.* (2019), pomegranate polyphenols could alter the structure of casein and whey proteins and improve their resistance to shear forces. According to Mashayekh *et al.* (2015), the presence of bioactive chemicals obtained from pomegranates may affect the interactions between proteins and result in a more structured matrix. Stronger casein micelle interactions may result from higher amounts of ash and acidity in Po. Dips enriched samples (as seen in the preceding tables), which would impact viscosity. The following practical implications of viscosity differences affect cheese meltability, spreadability, and consumer acceptability. Lower viscosity (C and T1) may improve meltability and flowability, making them more appropriate for cooking applications. Higher viscosity (T3) suggests a thicker consistency, which may be advantageous for applications requiring a firm texture, such as cheese spreads or processed cheese slices (Guinee, 2016).

Sensory characteristics of processed cheeses

Table (5) presents the sensory characteristics of processed cheese formulated with different concentrations (0%, 1%, 3%, and 5%) of pomegranate dip (Po. Dips) over a 30-day storage period. The attributes assessed include appearance, flavor, texture, aroma, and overall acceptability, which are critical determinants of consumer preference and market potential.

Table 5. Sensory characteristics of processed cheeses containing 0, 1, 3, and 5% Po. Dips .

Attributes	Storage (days)	Samples			
		Control	1 % Po. Dips	3 % Po. Dips	5 % Po. Dips
Appearance	Fresh	$8.5^{a}\pm0.53$	$8.5^{a}\pm0.71$	$6.9^{b}\pm\pm1.60$	$5.6^{c}\pm1.96$
	15	$7.8^{a}\pm0.42$	$8.1^{a}\pm0.57$	$7.0^{b}\pm0.67$	$6.3^{c}\pm0.82$
	30	$7.1^{ab}\pm0.57$	$7.4^{a}\pm0.52$	$6.7^{bc}\pm0.48$	$6.3^{c}\pm0.67$
Flavour	Fresh	$8.0^{ab}\pm0.82$	$8.4^{a}\pm0.70$	$7.3^{b}\pm0.82$	$6.2^{c}\pm1.32$
	15	$7.8^{a}\pm0.63$	$8.4^{a}\pm0.52$	$7.1^{b}\pm0.57$	$6.2^{c}\pm0.79$
	30	$7.5^{a}\pm0.53$	$8.3^{b}\pm0.67$	$6.9^{b}\pm0.57$	$5.6^{c}\pm0.97$
Texture	Fresh	$8.1^{ab}\pm0.88$	$8.4^{a}\pm0.70$	$7.4^{bc}\pm0.97$	$6.8^{c}\pm1.03$
	15	$7.7^{ab}\pm0.48$	$8.0^{a}\pm0.67$	$7.2^{b}\pm0.63$	$6.5^{c}\pm0.71$
	30	$6.8^{b}\pm0.63$	$7.9^{a}\pm0.57$	$6.3^{b}\pm0.67$	$5.5^{c}\pm1.08$
Aroma	Fresh	$8.0^{a}\pm0.94$	$8.5^{a}\pm0.85$	$7.0^{b}\pm0.67$	$6.7^{b}\pm0.95$
	15	$8.1^{a}\pm0.57$	$8.5^{a}\pm0.53$	$7.2^{b}\pm0.63$	$5.7^{c}\pm0.82$
	30	$7.7^{a}\pm0.67$	$8.0^{a}\pm0.82$	$6.1^{b}\pm0.74$	$5.9^{b}\pm0.99$
Overall acceptability	Fresh	$8.0^{ab}\pm0.67$	$8.4^{a}\pm0.97$	$7.6^{b}\pm0.52$	$6.9^{c}\pm0.99$
	15	$7.7^{b}\pm0.67$	$8.6^{a}\pm0.52$	$7.0^{c}\pm0.82$	$6.4^{c}\pm0.97$
	30	$6.7^{b}\pm0.67$	$8.6^{a}\pm0.52$	$6.7^{b}\pm0.67$	$5.5^{c}\pm0.85$

Results are expressed as mean ± SD; means with different superscripts in a row differ significantly ($p \leq 0.05$).

The control and 1% Po. Dips samples received the highest ratings (8.5), while 5% the Po. dips sample received the lowest (5.6). Fresh cheese samples demonstrated a substantial decrease in attractiveness scores as Po. Dips levels increased. After 30 days of storage, the appearance score declined across all samples, possibly due to moisture loss and structural changes in the cheese matrix. In contrast to the 3% (6.7) and 5% Po. Dips (6.3) samples, the 1% Po. Dips sample (7.4) maintained a higher visual appeal. Given that pomegranate-derived anthocyanins can change the natural color of cheese, the darker coloring in higher Po. Dips samples would have contributed to lower appearance rankings (Viuda-Martos *et al.*, 2010). Similar results have been noted in fruit-enriched dairy products, where consumers' perceptions are impacted by excessive pigmentation (Görgüç, and Yılmaz, 2022).

5% Po. Dips sample had the lowest flavor score (6.2) in the fresh stage, whereas the 1% Po. Dips sample had the highest flavor score (8.4) of all formulations. All samples gradually lost flavor over storage; after 30 days, the control (7.5) and 1% Po.

Dips (8.3) samples continued to receive the highest ratings, while 5% Po. Dips sample had the lowest acceptability (5.6). According to Sun *et al.*, (2017), the taste perception might have been adversely affected by the greater amounts of pomegranate polyphenols at 3% and 5%, which are more acidic and astringent. The slight fruitiness that optimal levels of Po. Dips (1%) offered without dominating dairy characteristics may have improved the flavor of the cheese.

In fresh samples, the 1% Po. Dips sample had the greatest texture score (8.4), whereas the 5% Po. Dips sample had the lowest (6.8). The best structure (7.9) was maintained by 1% Po. Dips cheese throughout the course of 30 days, while the 5% Po. Dips cheese's texture score decreased to 5.5. Since increased acidity and proteolysis weaken the cheese matrix and cause excessive softening or moisture separation, the textural degradation in higher Po. Dips samples may be the result of these factors (Mulsow *et al.*, 2007). Similar studies on dairy products made from fruit have demonstrated that interactions between polyphenols and proteins can change the texture of cheese over time, resulting in variations in hardness (Yildirim-Elikoglu and Erdem,2018). While the 3% and 5% Po. Dips samples had somewhat lower ratings (7.0 and 6.7, respectively), control (8.0) and 1% Po. Dips (8.5) samples had higher aroma scores. All samples showed a decrease in aroma scores during storage, with 5% Po. Dips cheese showing the biggest decline (5.9 at 30 days). Oxidation reactions, in which increased storage alters the volatile chemicals that give dairy its freshness, could be the cause of the decline in smell acceptability (Fox *et al.*, 2017). While high Po. Dips levels (5%) brought off-flavors, and moderate pomegranate dip levels (1%) improved scent, probably because of the presence of natural fruit volatiles (Viuda-Martos *et al.*, 2010).

The control sample (8.0) was closely followed by the 1% Po. Dips sample, which had the highest overall acceptability (8.4) in fresh samples. 5% Po. Dips sample had the lowest score (5.5) at 30 days, whereas the 1% Po. Dips cheese retained the highest acceptability (8.6) over the course of storage. Increased acidity, texture changes, and color changes that adversely impacted consumer preference are associated with the loss in acceptability at higher Po. Dips levels (Görgüç, A., Gençdağ and Yılmaz, 2022). Fruit-based additives should be optimized to maximize functional benefits without losing sensory qualities, according to earlier research (Sun *et al.*, 2017).

CONCLUSION

This study highlights the potential of pomegranate dip (Po. Dips) as a functional ingredient in processed cheese formulations. Increasing Po. Dips concentrations significantly influenced the physicochemical properties of cheese, leading to reduced pH and moisture content, while enhancing acidity, mineral content, and proteolysis. Functionally, Po. Dips improved meltability and flowability, although excessive levels (5%) negatively impacted sensory attributes due to heightened acidity and darker coloration. Sensory evaluation indicated that a moderate Po. Dips concentration (1–3%) provided the best balance between technological and sensory properties, ensuring optimal texture, flavor, and overall acceptability. These findings suggest that Po. Dips can be successfully incorporated into processed cheese to enhance its functional and nutritional value, offering a novel approach to product innovation in the dairy industry. Future research could further explore the bioactive properties of Po. Dips and its potential health benefits in cheese applications.

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استخدام دبس الرمان لتحسين الخواص الغذائية والنشاط المضاد للأكسدة ومدة صلاحية الجبن المطبوخ

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الملخص

تهدف هذه الدراسة إلى تقييم تأثير إضافة مستويات مختلفة من دبس الرمان (Po. Dips) (٠٪، ١٪، ٣٪، و ٥٪) على الخصائص الفيزيائية والكيميائية والوظيفية والحسية للجبن المطبوخ وذلك خلال فترة تخزين مدتها ٣٠ يومًا. أظهرت النتائج أن زيادة مستويات إضافة دبس الرمان أدت إلى انخفاض في pH ومحتوى الرطوبة بينما زادت الحموضة ومحتوى الرماد لعينات الجبن المطبوخ . لوحظت أعلى حموضة (١,١٧٪) ومحتوى عناصر معدنية في العينة المحتوية على دبس الرمان بنسبة ٥٪. بينما أظهر محتوى البروتين والدهون انخفاضًا طفيفًا فى حين زادت مستويات النيتروجين الذائب، مما يشير إلى زيادة التحلل البروتيني أثناء فترة التخزين. كما أظهرت النتائج أيضا تحسن في قابلية الجبن المطبوخ للانصهار (بلغت ذروتها ٤٣٤,٣٠ % في عينة الجبن المطبوخ المضاف اليها الدبس بنسبة ٥٪)، وعززت القابلية للفرد بينما زادت مستويات فصل الزيت خلال مدة التخزين. وأكد التحليل الريولوجي سلوك مختلف لعينات الجبن المختلفة حيث أظهرت العينات المحتوية على مستويات مختلفة من دبس الرمان لزوجة أعلى، مما يشير إلى شبكة هيكلية وتركيب بنائي أقوى. وقد فضل المحكمين خلال التقييم الحسي عينة الجبن المحتوية على ١٪ دبس رمان والتي حافظت على أفضل درجات للنكهة (٨,٤)، والملمس (٨,٤)، والقبول العام (٨,٦)، بينما أثرت مستويات دبس الرمان الأعلى سلبًا على المظهر والطعم والملمس بسبب الحموضة الزائدة واللون الداكن. بشكل عام، أثرت مستويات دبس الرمان المنخفضة من (١-٣٪) على تحسن كل من الخصائص التكنولوجية والحسية، مما يجعل الدبس مكونًا وظيفيًا واعدًا لتركيبات الجبن المطبوخ.

الكلمات الدالة: الجبن المطبوخ – دبس الرمان – النشاط المضاد للأكسدة – الخصائص الفزيائية والكيميائية – التقييم الحسي