



ORIGINAL RESEARCH PAPER

Use of Pomegranate Peel Powder as an Alternative to Artificial Antioxidant in Chicken Meatballs

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Abstract

Pomegranate peel powder (PPP) is a potential source of antioxidants because of its higher content of polyphenols and ascorbic acid. The objective of the study is to prepare the PPP, investigate the physico-chemical properties and its effects as a natural antioxidant on the chicken meatballs. Meat samples with added PPP, reference antioxidant TBHQ, and the blank sample was run without any additives. Fat oxidation by peroxide value, pH, Sensory and functional properties of meatballs were compared. High fat content in meat is a major cause of oxidative deterioration, which can be resolved by the addition of antioxidant-rich sources like pomegranate peel. The study revealed that the PPP possesses average values of moisture content, crude fiber, crude fat, total ash, acid-insoluble ash (AIA), and L-ascorbic acid within the range of 7.998±0.238%, 10.362±1.608%, 1.0195±0.145%, 5.589±0.251%, 0.516±0.026%, 92.5±1.05mg/kg, respectively. Increasing peroxide value (PV) with time was reduced on adding PPP, which was in the order of Free sample > 1% PPP > 3% PPP > 6% PPP > 100 ppm TBHQ. On the 6th day, 100 ppm TBHQ and 6% PPP show no significant difference in peroxide value (9.271±0.04, 9.604±0.11 mEq/Kg, respectively) and are below the limit (10 mEq/Kg), which suggests that TBHQ can be replaced with 6% PPP in meatballs as a natural antioxidant. The study revealed that adding PPP will improve the oxidative stability and cooking quality of chicken meatballs by reducing fat oxidation.

Keywords:

Pomegranate peel
Lipid oxidation
Antioxidant
Meatballs
Peroxide value

Article history:

Received: 12 Dec 2024

Received in revised form: 04 Mar 2025

Accepted: 07 May 2025

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Introduction

The pomegranate (*Punica granatum*) comes from the Latin malum “granatum”, which means grainy apple (Holland et al, 2009). Among the five major parts of pomegranate fruits (i.e., Peel, Endocarp, aril, seeds, and Mesocarp), Peel, commonly considered as an agro-industrial waste, is a potential source of antioxidants as it is a good source of phenolic compounds such as punicalagins, ellagic acid and gallic acid, which exhibit significant free radical scavenging and metal-chelating activities and vitamin C (Smith et al., 2014). The incorporation of PPP into bakery products has been shown to enhance the nutritional and functional properties of biscuits. PPP and its

extract with high contents of β-carotene, dietary fiber, and polyphenols have been documented to improve the nutritional quality, sensory characteristics, and overall quality of food products like cookies and bakery (Ismail et al., 2014; Srivastava et al., 2014). At 1% concentration, pomegranate peel extract effectively improved microbiological quality, oxidative stability, and sensory attributes of minced beef during 21 days of refrigeration, with strong correlations found between lipid oxidation and sensory changes, suggesting its potential to extend shelf life and produce healthier meat products (Fourati et al., 2019). ElBeltagy et al. (2022) investigated the effect of nano-pomegranate peel powder on beef meatballs during refrigeration as a source of lipid oxidation. Turgut et al. (2017) also investigated the antioxidant activity of pomegranate peel extract against protein and lipid oxidation in beef meat, while Devatkal et al. (2009) investigated the antioxidant activity of pomegranate rind extract on goat meat patties cooked from goat meat. Despite the highly established antioxidant capacity of PPP in various food systems, its application in poultry-based processed meat products remains significantly uninvestigated. This constitutes a critical research gap, particularly considering the susceptibility of such products to oxidative spoilage.

Meatball is a kind of comminuted product. Comminution is a process by which particle size is reduced for the incorporation of meat raw materials into finished products. Comminuted/emulsion meat products are made by chopping meat and water with the addition of common salt (NaCl) until a fine, protein-rich slurry is formed (Bolger et al., 2016). This process makes them more vulnerable to oxidative rancidity, which can be controlled by adding an antioxidant. The replacement of artificial antioxidants

with natural alternatives offers the potential to reduce the health risks linked to the use of synthetic antioxidants in food systems (Munekata et al., 2020). This study hypothesized that the incorporation of 6% PPP would confer oxidative stability in chicken meatballs comparable to that provided by 100 ppm TBHQ.

Materials and Methods

Pomegranate peel was collected from the local vendors in Jawalakhel. Spoiled and damaged peels were neglected. It was cleaned, cut into pieces of 2×2 cm manually, and dried for 12 h at 60 °C. It was then ground and sieved with a 300-micron size sieve, and fine powder was obtained. Physical and chemical properties of PPP were determined following the methods described by AOAC (2010). A different proportion of PPP was used against the additive-free sample and artificial antioxidant (100 ppm TBHQ), and a comparison was made. The formulation was done according to Ozturk et al., (2015) with some modifications. The best proportion was selected by the combined result from peroxide value analysis, pH analysis, and sensory analysis. Proximate content (moisture, fat, protein, ash, crude fiber, carbohydrate) and sensory analysis were determined following the methods described by AOAC (2010), pH by Viuda-Martos et al., (2012), L-Ascorbic acid and Peroxide value by AOAC (2010). Physical and Chemical properties of meatballs (cooking yield, moisture retention, fat retention, juiciness and folding test) were conducted following the methods described by Ozturk et al., (2015) and Lanier et al., (1992). Triplicate measurements of chemical and physical parameters were averaged and sensory evaluation data (n = 15) which were subjected to analysis of variance (ANOVA) using SPSS software (version 20) at a significance level of $p < 0.05$. Means were separated with Duncan Post Hoc Test. Graphical representations of the data were generated using Microsoft Excel.

Results and Discussion

Proximate composition and physical properties of PPP

Proximate composition and physical properties of PPP are shown in Table 1. Moisture, crude fiber, crude protein, fat, carbohydrate, total Ash, acid insoluble ash (AIA), ascorbic acid and pH were determined to be $7.998 \pm 0.238\%$, $10.362 \pm 1.608\%$, $6.78 \pm 0.22\%$, $1.0195 \pm 0.145\%$, $68.27 \pm 1.62\%$, $5.589 \pm 0.251\%$, $0.516 \pm 0.026\%$, 92.5 ± 1.05 mg/kg and 4.36 ± 0.04 respectively. These outcomes support earlier reports that pomegranate peel is a valuable source of crude fiber, ash, and carbohydrates, whereas the seeds are rich in crude protein, fat, and fiber (Opara et al., 2009; Soni et al., 2010) and Ranjitha et al., 2018). These findings clearly demonstrate that pomegranate peel possesses significant nutritional potential, making it a valuable by-product from the juice industry that can be utilized in other food products as a source of functional ingredients. Bulk density, water absorption capacity, oil absorption capacity and solubility of PPP were found to be 0.41 ± 0.01 (g/ml), 2.24 ± 0.04 , 5.05 ± 0.06 (g water/ g of dry sample) and 6.68 ± 0.82 (g of solute/100 g of dry sample) respectively. These results were similar to the results by

(Sreerama et al., 2009; Vazquez et al., 2009 and Sanchez et al., 2010). These results suggest that while PPP can moderately retain water and oil, their incorporation into food products would not lead to excessive water and oil retention, making them suitable functional ingredients for various food applications.

Table 1

Chemical and physical properties of PPP

Parameters	Contents
Moisture content	$7.99 \pm 0.23\%$
Crude fiber	$10.36 \pm 1.60\%$
Crude protein	$6.78 \pm 0.22\%$
Carbohydrate	$68.27 \pm 1.62\%$
Crude fat	$1.01 \pm 0.14\%$
Total ash	$5.58 \pm 0.25\%$
AIA	$0.51 \pm 0.02\%$
Ascorbic acid	92.5 ± 1.05 mg/kg
pH	4.36 ± 0.04
Bulk density	0.41 ± 0.01 (g/ml)
Water absorption	2.24 ± 0.04 (g water/g of dry sample)
Oil absorption capacity	5.05 ± 0.06 (g of oil/g of dry sample)
Solubility	6.68 ± 0.82 (g of solute/100 g of dry sample)

Note. Values are average of triplicate samples \pm standard deviation.

Study Of meatballs

Three different formulations containing varying proportions PPP, a sample with added artificial antioxidant TBHQ, and a control sample without any antioxidant were prepared. The pH levels and oxidative stability (study of the PV of fat extracted) were monitored for eight consecutive days at intervals of two days. The values obtained are presented in Table 2.

Oxidative stability

PV of meat samples continually increased during the entire storage period regardless of adding the antioxidant factors. At the 8th day storage period, PV of meat were lower if PPP was added at a concentration of 6% (12.217 ± 0.152 mEq O₂/Kg) rather than 1% PPP (18.689 ± 0.292 mEq O₂/Kg) but was greater than the use of 100 ppm TBHQ (10.744 ± 0.076 mEq O₂/Kg) but the PV in the free sample without any additives was significantly larger than the value of free sample (42.011 ± 2.885 mEq O₂/Kg). Also, investigation done by Fourati et al. (2020) showed that PV of 14.75 mEq O₂/ Kg meat in minced beef meat incorporate with 1% aqueous pomegranate peel extract on the 21st day of storage and 28.59 mEq O₂/Kg meat on the controlled sample. The difference in the value may be due to the different varieties of meat and fat content in different meat types. Bioactive constituents contribute to the inhibition of lipid oxidation in meat

products by donating hydrogen atoms to lipid radicals and stabilizing punicalagins (the major ellagitannin present in pomegranate peel) demonstrates particularly strong antioxidant efficacy due to its high molecular weight and abundance of hydroxyl groups, which facilitate effective radical neutralization

in complex food systems (Viuda-Martos et al., 2010). Lipid oxidation rates are directly related to the time of storage and the presence of antioxidant factors. Light, oxygen, and water activity, among others, influence the rate of fat oxidation (Johnson & Decker, 2015).

Table 2

Effect of addition of PPP on the PV and pH of meatballs

Days	Free sample	100 ppm TBHQ	1% PPP	3% PPP	6% PPP
	PV (mEqO ₂ /Kg)	PV (mEqO ₂ /Kg)	PV (mEqO ₂ /Kg)	PV (mEqO ₂ /Kg)	PV (mEqO ₂ /Kg)
0	1.43±0.07 ^a	1.34±0.02 ^a	1.32±0.02 ^a	1.35±0.04 ^a	1.33±0.03 ^a
2	10.45±0.02 ^a	3.92±0.18 ^c	5.94±0.230 ^b	5.44±0.21 ^b	5.13±1.71 ^b
4	22.81±0.13 ^a	6.04±0.68 ^c	10.73±0.26 ^b	8.41±0.05 ^c	6.88±0.12 ^d
6	32.57±0.43 ^a	9.27±0.04 ^c	16.07±0.21 ^b	16.06±0.59 ^b	9.60±0.11 ^c
8	42.01±2.88 ^a	10.74±0.07 ^c	18.68±0.29 ^b	17.29±0.20 ^b	12.21±0.15 ^c
Days	pH	pH	pH	pH	pH
0	6.06±0.04 ^a	6.06±0.04 ^a	6.05±0.04 ^a	5.93±0.04 ^b	5.86±0.09 ^b
2	6.16±0.04 ^a	6.06±0.04 ^{ab}	6.13±0.04 ^a	5.96±0.04 ^{bc}	5.86±0.04 ^c
4	6.33±0.04 ^a	6.16±0.04 ^{bc}	6.2±0.08 ^b	6.06±0.04 ^c	5.93±0.04 ^d
6	6.46±0.04 ^a	6.16±0.08 ^b	6.26±0.04 ^b	6.16±0.04 ^b	5.96±0.04 ^c
8	6.56±0.04 ^a	6.2±0.08 ^c	6.33±0.04 ^b	6.26±0.04 ^{bc}	6.03±0.04 ^d

Note. Results are the average of triplicate test ± standard deviation. Samples with similar alphabets in the subscript in the same row represents not significantly different by LSD at $p > 0.05$ (Duncan Post Hoc Test).

Changes in pH during storage

Meatballs containing 6% PPP, 3% PPP, 1% PPP, 100 ppm TBHQ, and free sample has pH of 5.86±0.09, 5.93±0.04, 6.05±0.04, 6.06±0.04, 6.06±0.04 at zero-day and increase to the pH of 6.03±0.04, 6.26±0.04, 6.33±0.04, 6.2±0.08, and 6.56±0.04 respectively at the 8th day. Decrease in pH on the addition of PPP during zero-day may be due to the influence of pH of the PPP i.e 4.36±0.04 (Table 2). Meat pH is one of the most important meat quality parameters, which is also associated with the rate of the glycolytic pathway during post-slaughtering. The recent study demonstrated the reduction in the pH of chicken breast meat after a long storage duration (after 24 h storage), consistent with the argument by Leygonie et al. (2011). Results show that meat before storage had a pH of 6.1, which was greater than what was reported by Lee et al. (2017) of 5.79 for breast. It is an indication that some primary lactic acid production had taken place from glycogen conversion before storage in meat. The acidity and hygroscopic nature (can absorb water by sorption forming hydrate, diffusion of water molecules within their structure or binding by surface energy) of pomegranate peel powder, along with lactic acid bacteria growth in meat during storage (Elgasim

& Al-Wesali, 2000), contribute to a reduction in product pH. Husein et al. (2019) reported that pomegranate peel powder reduced sausages pH by 2.5% during storage.

Cooking yield and functional properties

The effect of adding antioxidant factors on the physical properties of meatballs was studied by observing cooking yield, moisture retention, fat retention, juiciness, and folding test. Table 3 shows the cooking characteristics of meatballs incorporated with PPP. Cooking yield is a critical parameter in the meat industry, as it reflects the behavior of products during and after cooking, including interactions with non-meat ingredients. In this study, the initial addition of PPP resulted in a reduction in cooking yield, likely due to moisture and fat loss. However, as the concentration of PPP increased, cooking yield improved. This trend may be attributed to the disruption of water-holding bonds in muscle tissue at lower PPP levels, while higher concentrations of PPP functioned as a moderate water and fat binding agent, thereby enhancing cooking yield. Additionally, the increased fat retention observed could be explained by fat absorption during frying and the accumulation of oil on the surface of the cooked meatballs.

Table 3
Cooking characteristic of meatballs incorporated with PPP

Sample	% Yield	Moisture retention %	Fat retention %	Juiciness %	Folding test
Free	96.3 ±0.41 ^d	63.16±0.20 ^b	121.24±0.52 ^d	13.04±0.04 ^a	2.33±0.47 ^a
100 ppm TBHQ	93.05±0.24 ^b	63.01±0.58 ^b	117.16±0.31 ^b	14.99±0.08 ^b	3.33±0.47 ^{ab}
1% PPP	89.06±0.09 ^a	59.42±0.08 ^a	111.72±0.72 ^a	15.24±0.06 ^c	3.33±0.47 ^{ab}
3% PPP	95.22±0.40 ^c	65.51±0.25 ^c	119.21±1.32 ^c	15.68±0.14 ^d	3.66±0.47 ^b
6% PPP	96.09±0.14 ^d	67.07±0.37 ^d	120.98±0.17 ^d	16.16±0.16 ^c	4.33±0.47 ^b

Note. Results are the average of triplicate test ± standard deviation. Samples with similar alphabets in the subscript in the same column represent not significantly different by LSD at p>0.05 (Ducan Post Hoc Test).

Initially, adding PPP decreases the moisture retention compared to “free sample”, but further increasing the PPP increases the moisture retention in meatballs. A similar pattern was observed in fat retention. This may be due to the moderate water and oil holding capacity of PPP. Water holding capacity (WHC) is greatly affected by pH. Increasing or decreasing the pH on either side will result in increased WHC by creating a charge imbalance (Lawri et al., 2006). Table 2 shows the change in pH in addition to PPP where it shows that on adding a smaller amount of PPP no great change in pH is observed whereas higher concentration of PPP shows greater change in the pH. This supports the

increase in water retention with increasing concentration on meat balls. Similar properties imply fat retention in meatballs.

Juiciness increases on adding PPP as well as increasing PPP concentration. A similar pattern was observed on the folding test too. Juiciness is directly related to water holding properties of meat. The greater the water-holding property, the greater is the juiciness. It also depends upon the size/cuts of meat or muscle size and cooking time. Higher the cooking time, lower is the moisture retention and less juicers the product. Results in the (Table 3) support the statement. The results are supported by research done by Cheng & Sun (2008).

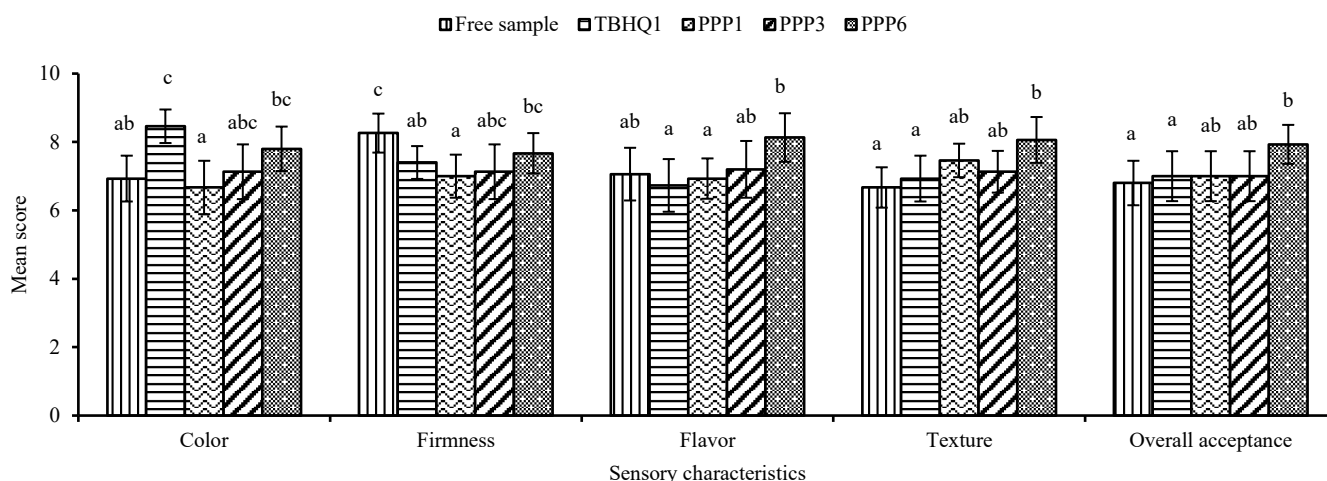


Figure 1
Sensory evaluation of chicken meatballs

Note. Vertical line and bars indicate means ± standard deviation (n=15) Bars having similar alphabets (a, b, c) are not statistically significantly different by LSD at p>0.05 (Ducan Post Hoc Test). Sample Code PPP6, PPP3, PPP1, TBHQ1 and Free Sample are Meatballs with 6%, 3%, 1% PPP, 100 ppm TBHQ and no added additives respectively.

Sensory evaluation

Fifteen semi-trained panelists evaluated samples for color, firmness, texture, flavor, and overall acceptability using a 9-point hedonic scale, which is shown in Figure 1. The result obtained shows that the addition of PPP to meat balls has a

significant impact on color, flavor, texture and overall acceptance (OA) (p≤0.05). Firmness of the free sample shows the highest mean score while the color of 1% PPP was lowest among all of them. The sensory evaluation shows that addition of PPP has a positive effect on texture and OA whereas lower concentration on PPP reduces the firmness but increases on

higher concentration PPP. Similarly, meatballs with 100 ppm TBHQ have great color preservation in meat balls but reduce the flavor at the same time. Relatively higher color rating in 6% PPP incorporated meat balls may be due to the reddish-brown color of PPP, which enhances the meat-like coloration of the meatballs, compensating for the color degradation that occurs during cooking.

Conclusions

The findings of this study demonstrated that PPP can be effectively utilized as a natural antioxidant for the formulation of chicken meatballs. Incorporation of PPP significantly improved color and textural characteristics of the product, in addition to elevating cooking yield, moisture retention, and fat retention. Notably, the addition of 6% PPP had superior oxidative stability and sensory properties compared to other products. These results illustrate the effectiveness of PPP as a viable ingredient in the formulation of meat products with a natural substitute for synthetic antioxidants. Based on the collective physicochemical, oxidative, and sensory parameter evaluation, the 6% PPP formulation was the most acceptable formulation.

Acknowledgements

The authors express their sincere gratitude to Lalitpur Valley College, affiliated with Tribhuvan University, Jawalakhel, Nepal, for providing the necessary resources, laboratory facilities, and institutional support required to successfully conduct this research.

Conflict of Interest

The authors declare that they have no known financial interests or personal relationships that could have influenced, or appeared to influence, the work reported in this paper.

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