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Using orange and pomegranate peel extracts in meatball processing and evaluating their impacts on bacteriological, physicochemical and sensory quality

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ABSTRACT

Plant peel extracts are an innovative way to substitute harmful synthetic meat additives. So, the aim of this study was to keep sustainability, decrease harm effect of plant peel on the environment, and provide an economic solution to the food industry by using orange peel extract (OPE) and pomegranate peel extract (PPE) in meatball processing and evaluate their impacts on bacteriological, physicochemical and sensory quality of meatballs. It was found that values of APC, coliform count, psychotrophic bacterial count, and *S. aureus* count in examined meatball groups fortified with OPE, PPE, and their mixture decreased greatly than a control group. Pomegranate peel extract showed a marked antioxidant efficacy that delayed the physico-chemical deterioration of meatballs followed by a group treated with a mixture of OPE and PPE. Regarding sensory characters, OPE, PPE, and mixture treated groups remained at an acceptance level for 18 days in contrast to a control group that spoiled at 6th day of cold storage, so, peel extracts of plants provide an economic preservative to the meat industry.

1. INTRODUCTION

Meatballs are one of the most consumed meat products worldwide (Oz and Cakmak, 2016). However, it deteriorates rapidly during storage (Turp, 2016), due to protein and lipid oxidation (Vuorela et al., 2005), leading to decreased product acceptability, resulting in off-flavor, discoloration, drip losses, decreased storage stability, and causing health problems for customers (Domínguez et al., 2019). This deterioration can be reduced by using synthetic or natural antioxidants (Ledesma, et al., 2015). However, Consumers tend to preserve products with natural-based preservatives instead of chemicals (Ibrahim et al. 2024). Natural plant extracts have antioxidants and antibacterial properties to be important in the food products industry (Shindia et al., 2024). Plant peel is rich in flavonols, phenolics, and anthocyanins than the pulp tissue of plants (Tom´ as-Barber´ et al., 2001). So, it has potent antioxidant and antibacterial qualities (Olatunde et al., 2021). Hence, the use of plant peel extracts is an innovative way to substitute harmful synthetic meat additives. Moreover, the use of plant by-products has become a promising new frontier in the quest for creative and sustainable food production (Ronie et al., 2024). According to Rațu et al. (2023) the abundant bioactive chemicals found in plant by-products make them valuable for a range of industrial uses that promote health and nutrition, so the utilization of these cheap waste plant by-products to produce the value-added products is a revolutionary step in their sustainable application.

Moreover, there is an increase in the waste of fruits that threatens the environment as food waste is about ~16% and leads to ~6% of global greenhouse gas emissions. So, it becomes a challenge to invest it to reduce waste and keep the environment. Peel reduces the negative impact on the environment (Skwarek and Karwowska, 2023).

Pomegranate peel is one of the most valuable by-products in industry to be about 40–50% of the overall fruit's weight (Ali et al., 2019). Orange also, is rich source of bioactive compounds, such as carotenoids, phenolic acids, flavonoids, and vitamin C. These substances have been researched for possible health advantages because of their strong antioxidant qualities (Chen et al., 2017).

So, the aim of this study was to keep sustainability, decrease harm effect of plant peel on the environment, and provide ~~an~~ economic solution to the food industry by using orange peel extract (OPE) and pomegranate peel extract (PPE) in meatball processing and evaluate their impacts on bacteriological, physicochemical and sensory quality of meatballs.

2. MATERIAL AND METHODS

2.1. Plant peel extract preparation

The ethanoic Extraction, purification of pomegranate, and orange peel extract were performed according to Abu-Niaaj et al. (2024) at the National Research Centre, Dokki, Cairo, Egypt.

2.2. Experimental design

Raw beef meatball was supplied from a local store in Menofiya governorate, Egypt. This experiment were performed at January 2024 Meatballs were prepared following the processing recipe of Morsy et al. (2018). Samples were divided into 4 groups the 1st group (control), 2nd group (2% OPE), 3rd group (2% PPE group), and 4th group (mixture of OPPE). Meatballs (100±5gm) were

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formed by hand under strict hygienic conditions, placed into plastic trays, sealed with one layer of wrapping film, and stored at 4 ± 1 °C till spoilage. The samples were analyzed periodically at 0, 2^{nd} , 4^{th} , 6^{th} ,8^{th}, 10^{th}, 12^{th}, 14^{th} , 16^{th} and 18 days of storage for bacteriological, physico-chemical and sensory evaluation. This study was triplicated.

The experimental design was approved by Scientific Research Ethics Committee, Faculty of Veterinary Medicine, Benha University with ethical approval number BUFVTM06-11-23

2.3. Bacteriological quality evaluation

Sample preparation was performed according to ISO 6887-1 (2013). The total bacterial count (TBC) using the pour plate method on plate count agar (HIMDIA, M091S) at 35°C (ISO 4833- 1, 2013), *Staph. aureus* count on Baird Parker agar base (HIMEDIA, M043) (incubated at 37°C for 48 hours (FDA, 2001), Psychrotrophic bacterial count (PBC) on plate count agar (HIMEDIA, M091S) at 4°C (FDA, 2001) and total coliform count according to ISO 4832 (2006) on violet, red bile agar media (HIMEDIA, M049) then incubated at 37°C for 24 hours.

2.4. Physico-chemical evaluation

The pH values were measured using the method given in AOAC (2009), and the Thiobarbituric acid reactive substances (TBARS) values were analysed following AOAC (2009), with the results used to determine the samples' oxidative condition. The TVB-N amount was determined following the procedure given in AOAC (2009) and reported as mg/100 g of sample.

2.5. Sensory evaluation

Each sample has been evaluated by nine highly experienced panelists. Participants were given 100 ± 10 g meatball samples of each plant extract and asked to rate their sensory attributes (color, odor, and overall acceptability). Samples were coded with random numbers; panelists were unaware of the experimental approach. They were asked to rate the color, odor, and texture of each sample. A ten-point descriptive scale was employed; a score of 10 was the highest, while a score of 1 was the lowest (ISO 13299, 2003).

2.6. Statistical analysis

The data was processed with the graph pad prism program. All data were analyzed using one-way ANOVA. Values were reported as means and standard deviations. Significant values (p≤ 0.05) were obtained at a 95% confidence level (Steel and Torrie, 1980).

3. RESULTS

Results in Figure (1) illustrated the impacts of plant peels extracts on the bacteriological quality of chilled meatballs all over the storage period. Values of TBC, total coliform count, total Psychotrophic count, and *S. aureus* count revealed that there was a considerable difference between control and treated samples (PPE, OPE, OPPE) (P < 0.05). There was an increase in the values of bacterial quality parameters all over the storage period markedly increased in the control group till 6^{th} day of storage, with a marked delay in PPE, and OPPE treated group till 18^{th} and 16^{th} day of cooled storage.

Concerning the physio-chemical quality of chilled meatballs, results in Figure (2) illustrated values of PH, TBARS, and TVN. The results showed a considerable difference (P < 0.05) between the control and treated groups (PPE, OPE, OPPE).

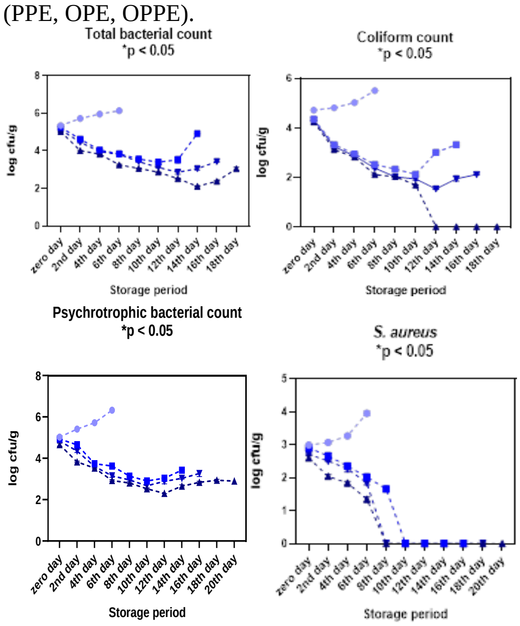

Fig. 1 Impacts of OPE,PPE and OPPE on bacteriological quality (total bacterial count, coliform count, psychrotrophic bacterial count and *S. aureus* count) of meatballs in control (●), OR 2% (■), PO 2% (▲) and OR:PO (1:1) 1% (▼) during refrigerated storage period at 4°C E.O.S.

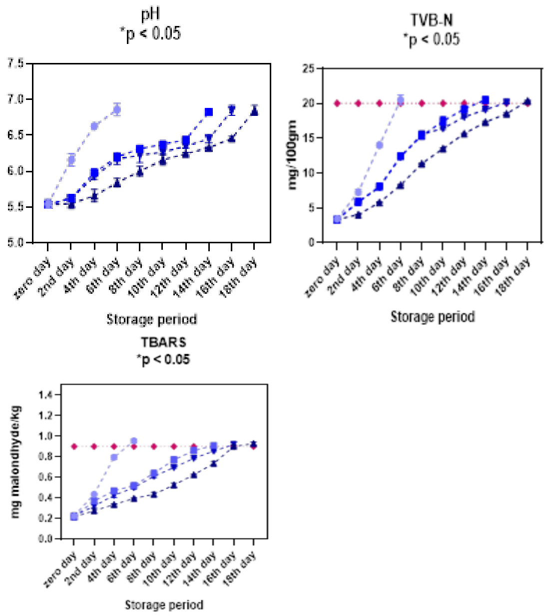

Fig. 2 Impacts of OPE, PPE and OPPE on physicochemical quality (pH, TVB-N and TBAs) of meatballs in control (•), OR 2% (■), PO 2% (▲) and OR:PO (1:1) 1% (▼) during refrigerated storage period at 4^{0} c E.O.S. (♦) referred to the permissible limit.

There was an increase in the values of physico-chemical parameters all over the storage period markedly increased in the control group till 6^{th} day of storage, with a marked delay in the PPE, and OPPE-treated group till 18^{th} and 16^{th} day of cooled storage.

A sensory evaluation involves assessing color, odor, and texture. From 2^{nd} day of refrigeration, there were significant differences between all examined groups. Sensory characters significantly deteriorated in the control group at 6^{th} of storage. While, in OPE treated group, PPE treated group and mixture treated group still accepted till 12^{th} day, 16^{th} day and 14^{th} day of cooled storage respectively (Table 1).

Table 1 Impacts of OPE, PPE and OPPE on Sensory characters of meatballs during refrigerated storage period at 4 °C

groups / Extracts period	Control	OPE (2%)	PPE (2%)	OPPE (1%)
zero day	9.25 ± 0.35[a]	9.60 ± 0.14[a]	9.60 ± 0.10[a]	9.60 ± 0.14[a]
2nd day	6.70 ± 0.14[a]	8.10 ± 0.14[b]	8.65 ± 0.10[c]	8.30 ± 0.13[b]
4th day	5.35 ± 0.21[a]	7.25 ± 0.35[b]	8.05 ± 0.14[c]	7.55 ± 0.10[b]
6th day	3.88 ± 0.10[a]	6.40 ± 0.10[b]	7.40 ± 0.13[c]	6.55 ± 0.10[b]
8th day	S	5.60 ± 0.14[a]	6.85 ± 0.10[b]	5.80 ± 0.14[a]
10th day	S	5.10 ± 0.14[a]	6.12 ± 0.10[b]	5.30 ± 0.10[a]
12th day	S	4.85 ± 0.10[a]	5.7 ± 0.14[b]	4.92 ± 0.14[a]
14th day	S	3.25 ± 0.10[a]	5.00 ± 0.10[a]	4.71 ± 0.14[a]
16th day	S	S	4.7 ± 0.28[b]	3.25 ± 0.10[b]
18th day	S	S	3.35 ± 0.21[b]	S

4. DISCUSSION

Meatballs are prone to bacterial infection, which promotes a rapid occurrence of rancid or putrid odor during storage and preparation. Many researchers have recently concentrated on using natural active ingredients to enhance the antioxidant properties of meat balls made from beef (Meng et al., 2022). The usage of agrifood wastes has gained significant attention in recent years as they contain many compounds that can be used to make functional foods. Also, it has been discovered that the beneficial effects of many substances on the health of the human are directly correlated with their availability of phytochemicals and antioxidants (Das et al., 2021) .

Since meat is perishable and vulnerable to oxidation of lipids and proteins, the industry always looking for alternative additives that can delay the spoilage and help create healthier, longer-lasting goods (Das et al., 2021). The debate over artificial antioxidants and antimicrobials, which have been connected to serious health issues, has pushed directors and consumers alike to use natural preservatives. Fruits and vegetables are great providers of bioactive compounds that can be added to raw meat processing ingredients. Utilizing natural antioxidants is therefore essential to protect meat from microbial development (Zhang et al., 2022; Smaoui et al., 2019; Kandylis et al., 2020). Numerous plants extract high in phenolic compounds have been shown to benefit various meat systems by inhibiting the oxidation of proteins and/or lipids (Njia et al., 2012).

Whereas Plant by-products are abundant in bioactive chemicals and have many industrial uses that can improve nutrition and promote health, it also indicates that plants by-products can be added to a range of foods to improve their antioxidant capacity, fiber content, and bioactive profile without compromising their sensory acceptability. Overall, using plant by-products in food formulation can improve consumer health (Rațu et al., 2023)

In this study, OPE and PPE were added to beef meatballs preserved in a refrigerator at 4C○. Results revealed that PPE has the greatest effect among OPE and even OPPE on enhancing shelf life and sensory characteristics of beef meatballs during the refrigeration period for 18 days , similar to results obtained by Ahmed et al., 2024; Kanatt et al.,(2010). This could be because PPE had a 45% total phenolic content (mg Gallic acid/g extract) and approximately 25% higher antioxidant activity than OPE samples (Selahvarzi et al., 2021). Pomegranate peel extract is defined by the presence of phenolic components such as elligic acid, and vanillic acid (Zhao et al., 2022). Orange peel extract contains active phenolic components such as galleic acid, protocatechuic acid, rutin trihydrate, trans-cinamic acid, quercetin, apigenin, and hesperidin (Anagnostopoulou et al., 2006) .

Pomegranate peel extract clearly has an impact on the bacteriological quality of meatballs by decreasing counts of aerobic plate count, S. aureus, total coliform, and psychrotrophic bacteria. This is regarding those plant components such as pomegranate and orange fruit by-products that contain polyphenolic chemicals (flavonoids, tannins) that have antibacterial activity (Akhtar et al., 2015). These findings were analogous to those of Morsy et al., (2018) by using LPP-NPs, and pomegranate peel extract nanoparticles in chilled meatball.

Pomegranate's antibacterial effect has been connected with polyphenolic tannins, including punicalagin and elagic acid levels in the extract (Al-Zoreky,2009) and (Tehranifar et al., 2011), by forming interactions with proteins and sulfhydryl groups, these secondary metabolites hinder the growth of bacteria by rendering them unavailable to the microbe (Akhtar et al., 2015)

The phenolic and flavonoid substances such as ellagitannins, gallic acid, anthocyanins, and ellagic acid are what give PPE its antioxidant properties (de Oliveira et al., 2020; Derakhshan et al., 2018).

It was demonstrated that OPE, PPE, and their combination had a favorable impact on the physicochemical characteristics of beef meatballs, analogous to those of Morsy et al., (2018) and Ahmed et al .(2024) ,.

During this experiment, it was found that there was a great improvement in sensory characteristics (color, flavor, aroma and texture) of all treated samples similar to the data obtained by Morsy et al., (2018), and Hama et al., (2018). Certain data indicated that the existence of plant-derived antioxidants can postpone the degeneration of red color by slowing down the synthesis of met myoglobin (Muthukumar et al., 2014). Also, Morsy et al., (2018) proved that PPE prevents beef meatballs from discoloring on their surface. These findings might be explained by the flavonoid chemicals and catechins found in pomegranate peel extracts, which effectively reduce myoglobin and prolong the storage period of meat by delaying the synthesis of met-myoglobin. (Naveena et al., 2008).

Pomegranate peel extract greatly improved the smell and overall acceptability of the meatballs, which was consistent with the findings for TBA. This could be because the extracts preserved the meat by reducing lipid oxidation due to their antioxidant concentration, which prevents the generation of peroxide molecules such as ketones, aldehydes, and carboxylates (Devatkal et al. 2010); Zahin et al., (2010).

5. CONCLUSIONS

Plant peel extracts such as PPE and OPE are an innovative way to substitute harmful synthetic meat additives, it provides an economic solution to the food industry. Peel extracts especially PPE enhanced the bacteriological, physicochemical, sensory quality, and shelf life of chilled meatballs.

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