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THE POTENTIAL OF THE STARCHY RED ONION PEELS EXTRACT AS AN EDIBLE COATING FOR IMPROVING QUALITY AND SHELF LIFE OF CHILLED BEEF KOFTA

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ABSTRACT

This study aimed to develop a natural and safe method to preserve the quality and extend the shelf life of raw beef kofta. It compared raw kofta samples coated with red onion peel (ROP) extract and starch to uncoated control samples. All samples were stored at 4°C ± 1°C for seven days. The effectiveness of the coating was evaluated by analyzing sensory properties, microbial growth (total bacteria, psychrotrophic bacteria, yeast, and mold counts), and physicochemical changes (pH and thiobarbituric acid [TBA] levels). The results demonstrated that the starchy ROP coating was highly effective in extending the shelf life of raw beef kofta. Compared to uncoated control samples, which spoiled by day 5, the coated samples remained edible for 7 days, with a significant ($p<0.01$) delay in quality deterioration, starting at day 3 and becoming highly significant ($p<0.01$) by day 5. Sensory attributes of raw and cooked samples remained higher in coated samples throughout storage. Microbiological analysis revealed a lower bacterial load and slower growth in coated samples, particularly after 3 days. The ROP coating also maintained lower pH and TBA levels. These findings suggest that starchy red onion peel (ROP) extract coating has promising potential as an edible, natural, and safe method to extend the shelf life and preserve the quality of raw beef kofta.

***Keywords**:* Red onion peels, Edible coating, Beef kofta, Shelf life, meat coating.

Abbreviations: ROP= Red Onion Peel, ROPE= Red Onion Peel Extract, TBC= Total Bacterial Count, TBA= Thiobarbituric Acid, PBC= Psychrotrophic bacteria Count.

INTRODUCTION

Agro-wastes such as garlic, ginger, onion, and potato peels possess powerful antimicrobial and antioxidant properties, making them suitable for various medicinal purposes (Naqvi *et al*., 2020). Red onion (Allium cepa L.) peels exhibit antimicrobial activity (Faluyi *et al*., 2020), antibiofilm action (Mounir *et al*., 2023), and antiproliferative and antioxidant properties attributed to their flavonoid content (da Cruz *et al*., 2023; Murayyan *et al*., 2017), including quercetin, thiosulfides, and fructooligo-saccharides (FOS) (Murayyan *et al*., 2017). The main flavonoid in onions, quercetin, has several beneficial characteristics, including

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antibacterial and antioxidant actions (dos Santos Dias *et al*., 2020; Murayyan *et al*., 2017).

Egyptian kofta, a popular comminuted meat product enjoyed across all social classes, presents a lucrative opportunity for meat processors. However, its inherent vulnerability to spoilage due to chemical, physical, and microbiological changes poses a challenge. Proteolysis (protein breakdown) and lipid peroxidation (fat degradation) can occur naturally due to oxygen exposure, endogenous meat enzymes, and microbial byproducts (Aboah and Lees, 2020)**.**

The shift in consumer attitudes toward synthetic antimicrobial compounds, which are used to extend shelf life and ensure the safety of meat products, has challenged food researchers to find natural compounds with antimicrobial properties (H. Ismail, 2011). Recently, using edible films and coatings for food protection and preservation has grown due to their numerous advantages over synthetic materials, such as being biodegradable and environmentally friendly (Karnwal and Malik, 2024; Tharanathan, 2003).

Edible coatings offer a sustainable solution for food preservation. These thin layers, made from natural polymers and potentially infused with essential oils or enzymes, can reduce moisture loss, minimize microbial contamination, and decrease the environmental impact associated with traditional packaging materials (Kocić-Tanackov and Pavlović, 2023; Sánchez-González *et al*., 2011).

The use of new technologies to enhance the quality and prolong the shelf life of food products has grown significantly. This trend is driven by the considerable potential of alternative techniques for food preservation, which are often used in conjunction with traditional methods. These techniques have proven effective in minimizing undesirable biochemical effects, such as lipid oxidation and protein degradation, especially in the meat industry (Silva *et al*., 2020). Tests on mutagenicity and cytotoxicity have verified the safety of these biomaterials for use as edible coatings in the food industry (Ramos *et al*., 2021). Coating with antimicrobial and antioxidant natural materials can address these challenges. This issue has prompted various research efforts to explore red onion peel as a food coating preserving agent, as recommended by Kocić-Tanackov and Pavlović (2023).

Maintaining the hygienic quality and safety of refrigerated beef kofta is crucial. This study investigates the potential of red onion (*Allium cepa L*.) peel extract as an edible coating to extend the shelf life and enhance the microbiological quality of kofta.

MATERIAL AND METHOD

Materials

Plate count agar and Sabouraud dextrose agar were purchased from HiMedia (Pvt., India). Ethanol (90%), Whatman filter paper (No. 1), and peptone water were sourced from Dar-ElHekma Co. (Assiut City, Egypt). Thiobarbituric acid (TBA), butylated hydroxytoluene (BHT), trichloroacetic acid (TCA) powder, and TEP standard were obtained from the Animal Health Research Institute, Assiut Lab, Egypt. Deionized and distilled water were obtained from the Molecular Biology Unit at Assiut University.

Preparation of ROP Extract and Coating Solution:

Obtain fresh red onions and carefully remove the outer peels, avoiding any discolored or damaged areas. Wash the peels thoroughly with running water to remove any dirt or debris, and then allow them to dry. In a pot, combine the red onion peels with distilled water at a ratio of 1:10 (w/v). Warm the mixture to 50–55 °C for 45 minutes. Allow the extract to cool completely, then filter it using Whatman filter paper (No. 1), following the method of Irkin and Arslan (2010) with modifications. Prepare a 10% starch solution by dissolving the desired amount of food-grade corn starch in the red onion peel extract, using gentle heating and constant stirring until a clear, viscous, homogeneous coating solution is formed.

Kofta Preparation and Application of Coating:

Traditional Egyptian kofta is made from finely ground fresh beef, purchased from a local market in Assiut City, Egypt, on the day of preparation under complete aseptic conditions. The ground meat was formed into finger shapes, each weighing 50 grams, with a length of 11 cm and a diameter of 2.5 cm (Mohamed et al., 2023). The kofta samples were divided into two main groups: a control group (uncoated samples) as shown in Figure 1, and a coated beef kofta group, illustrated in Figure 2.

Figure 1: The uncoated raw beef kofta samples (control).

Figure 2: The coated raw beef kofta samples

Coating Method: Utilize a dipping method for uniform coverage by immersing each kofta sample (coated group) in the prepared coating solution for 10 seconds, allowing excess solution to drip off onto a clean mesh rack for reuse. Allow the coated kofta samples to rest for 15–20 minutes on a sterile wire rack inside a laminar flow hood to let the coating set before refrigeration (0-day sampling). Samples from both groups were cooked on a preheated grill, turning until each side reached a core temperature of 70 °C. Organoleptic evaluations were conducted for color, odor, texture, taste, and overall acceptability after cooking, as shown in Figure 3.

Figure 3: The coated and uncoated kofta samples after cooking.

All kofta sample groups (raw and cooked) were stored in a chilled environment at 4 °C ± 1 °C for 0, 1, 3, 5, and 7 days. Samples were periodically evaluated for sensory, physicochemical, and bacteriological assessments.

Sensory Evaluation: A group of six individuals from the Animal Health Research Institute's Assiut Branch and Assiut University hospitals was carefully selected to serve as the evaluation team for this task. These panel members underwent comprehensive training in sensory evaluation techniques.

The sensory assessment focused on evaluating the characteristics of the kofta samples, both raw and cooked. This included appraising color, odor, texture, and overall acceptability (OAA) for raw kofta samples, as well as taste for the cooked samples. A 5-points hedonic scale was utilized, as outlined by A.M.S. (2015) and ASTM (1968), where 5 = like excellent and 1 = dislike poor (see Table 1). This scale enabled panel members to express their perceptions of each sensory attribute.

Table 1: Five-point hedonic scale for sensory evaluation.

Score	Quality Items for Kofta Samples Quality
5	Natural flavour, color (Rosy red) and odor (Fleshy odor)
4	No sensible change in natural flavor, color and odor
3	Sensible discoloration. Slightly sour odor and incipient rancidity in flavor, Greasy texture.
2	No natural color, moderately off-odor and off-flavor.
1	Sharply sour and extremely rancid flavor, extremely discolored, squeeze fluidly content.

Physicochemical evaluation:

pH levels of the examined samples were measured at room temperature using a portable, foldable pH tester (model AD11, waterproof Adwa pH-Temp, Romania), following the methods outlined by Sabikun *et al*. (2019) and Tolba and Abdel-Aziz (2024), in accordance with the ISO 2917 (1999) standard.

Determination of TBA values:

The thiobarbituric acid (TBA) values were determined according to the protocol described by Buege and Aust (1978) and Sabikun *et al*. (2019). Absorbance measurements were taken in triplicate at 531 nm using a Thermo Scientific Evolution 300 UV-Vis spectrophotometer, and the values were quantified in milligrams of malonaldehyde (MDA) per kilogram of the samples.

Microbiological examination:

Precisely 225 ml of 0.1% sterile peptone water was added to 25 grams of the sample and thoroughly mixed for 1.5 minutes using a stomacher (Seward Stomacher BA 7021, England). Following this, ten-fold serial dilutions were prepared from this mixture, in accordance with the guidelines specified in ISO/TS 11133-1 (2013).

The microbiological analysis was conducted on both control and coated beef kofta samples, with samples collected from the core of the tested kofta to assess four sanitary parameters: total viable bacterial count (TVBC), psychrotrophic count, and total yeast and mold counts. These were determined using plate count agar (Himedia, India) and Sabouraud dextrose agar (Himedia, India). The incubation conditions included 37°C for 24 hours for TVBC, 0°C–4°C for 5 days for psychrotrophic counts, and 25°C for 5 days to evaluate total yeast and mold counts. This methodology adheres to the guidelines specified in ISO 4833-1 (2013) and ISO/TS 11133-1 (2013).

Statistical analysis: All experiments were conducted in triplicate, and results are reported as averages with standard errors. One-way analysis of variance (ANOVA) and t-tests were performed using SPSS software (version 21.0) to determine the statistical significance of differences between groups. Results with $p < 0.01$ were considered statistically significant.

RESULTS

The data in Table 2 indicates that both uncoated and coated kofta samples began with high quality in terms of color, odor, texture, and the overall acceptance. However, the uncoated samples experienced a rapid decline in all sensory attributes by the third day and were deemed spoiled by the seventh day. In contrast, the coated samples maintained significantly better quality over time ($p < 0.01$), with a slower decline in sensory attributes, remaining within acceptable levels up to the seventh day.

By the fifth day, noticeable differences in color and odor emerged. The uncoated samples appeared duller and compromised, while the coated samples retained their vibrancy. A significant difference ($p < 0.01$) in odor was observed between the two groups on the third and fifth days, with uncoated samples developing a more unpleasant and corrupted smell. Meanwhile, the coated samples preserved the characteristic onion aroma until the seventh day.

Additionally, the uncoated samples exhibited a softer and more collapsed texture compared to the coated samples. Overall acceptance ratings were significantly lower (p < 0.01) for the uncoated control samples compared to their coated counterparts, further highlighting the effectiveness of the ROPE coating in preserving the sensory quality of beef kofta.

Table 2: Statistical analysis of sensory attributes (color, odor, texture, and the overall acceptance) of the examined uncoated (control) and coated raw beef kofta samples during chilled storage.

Sensory attributes	Storage time/day	uncoated samples (control)	Coated samples
Color	0 day	5± 0.0	5± 0.0
	1st	4.7± 0.33	5± 0.0
	3rd	2.7± 0.33	4.4± 0.33*
	5th	1.7 ±0.33	4.3± 0.33**
	7th	spoiled	3.3 ±0.33 [a]
Odor	0 day	5± 0.0	5± 0.0
	1st	4± 0.0	5± 0.0
	3rd	3± 0.5	4.3 ±0.33*
	5th	1.3± 0.33	3.7± 0.33**
	7th	spoiled	2.7± 0.33 [a]
Texture	0 day	5± 0.0	5± 0.33
	1st	4.7± 0.33	4.7± 0.33
	3rd	3.33± 0.33	4.3± 0.33
	5th	1.6± 0.6	3.6± 0.33 [a]
	7th	spoiled	3.3± 0.33
Overall acceptance	0 day	5± 0.0	5± 0.0
	1st	4.7± 0.33	5± 0.0
	3rd	4.3± 0.33	4.6± 0.33
	5th	2.0± 0.5	4.3± 0.33*
	7th	spoiled	3.6± 0.33[a]

-Note: Data are presented as the mean ± standard error (SE) of triplicate measurements.
- (*) indicates a significant difference ($p < 0.01$) between the uncoated samples (control) and the coated samples.
(a) Indicates that the coated sample on the 7th day of storage remained at an acceptable level, compared to the uncoated (control) samples, which had spoiled.

The data in Table 3 reveals that there were no significant sensory differences between coated and uncoated cooked kofta samples at the beginning of the storage period. However, a notable deterioration in sensory attributes- such as color, odor, texture, taste, and overall acceptability was evident in the uncoated samples by day three. This decline escalated quickly, resulting in spoilage by day seven, which made the uncoated kofta unfit for consumption.

In contrast, the coated cooked kofta samples exhibited a significantly slower decline (p < 0.01) in sensory quality. The characteristic onion flavor and aroma were maintained in the coated samples until the seventh day. While all sensory attributes in the coated samples decreased over time, they remained within acceptable limits throughout the storage period, underscoring the effectiveness of the ROPE coating in preserving sensory quality during refrigeration.

Table 3: Statistical analysis of sensory attributes (color, odor, texture, taste and the overall acceptance) of the examined uncoated (control) and coated cooked beef kofta samples during chilled storage.

Sensory attributes	Storage time/day	uncoated samples (control)	Coated samples
Color	0 day	5± 0.0	5± 0.0
	1st	5± 0.0	5± 0.0
	3rd	3± 0.5	4.3± 3.33**
	5th	1.3 ±0.33	3.3± 0.33
	7th	spoiled	2.7± 0.33 a
Odor	0 day	5± 0.0	5± 0.0
	1st	4.7± 0.33	5± 0.0
	3rd	3.3 ± 0.33	4.7 ±0.33
	5th	1.6± 0.33	4± 0.00*
	7th	spoiled	3± 0.5 a
Texture	0 day	5± 0.0	5± 0.00
	1st	4.7± 0.33	5± 0.00
	3rd	2.6± 0.33	4.3± 0.33*
	5th	1.33± 0.33	3.7± 0.33**
	7th	spoiled	3.33± 0.33 a
Taste	0 day	4.7± 0.33	5± 0.00
	1st	4.7± 0.33	5± 0.00
	3rd	2.6± 0.0	4.3± 0.33*
	5th	1.3± 0.33	3.7± 0.33**
	7th	spoiled	2.7± 0.33 a
Overall acceptance	0 day	5± 0.0	5± 0.0
	1st	4.3± 0.33	5± 0.33
	3rd	3± 0.5	4.7± 0.33
	5th	1.3± 0.33	4.3± 0.33**
	7th	spoiled	3.3± 0.33a

- Note: Data are presented as the mean ± standard error (SE) of triplicate measurements.
- (*) indicates a significant difference ($p < 0.01$) between the uncoated samples (control) and the coated samples.
(a) Indicates that the coated sample on the 7th day of storage remained at an acceptable level, compared to the uncoated (control) samples, which had spoiled.

Table 4: Statistical analysis of pH and TBA levels of uncoated (control) and coated raw beef kofta samples during chilled storage.

Physicochemical parameter	Storage time/day	Uncoated samples (controle)	Coated samples
pH	0 day	5.8±0.09	5.6±0.04
	1st	5.9±0.01	5.7±0.01*
	3rd	6.2±0.2	5.9±0.01**
	5th	6.6±0.4	6.2±0.01*
	7th	spoiled	6.4±0.09 a
TBA	0 day	0.23±0.008	0.21±0.005
	1st	0.3±0.003	0.21±0.003
	3rd	0.6±0.02	0.4±0.014**
	5th	0.89±0.02	0.58±0.025***
	7th	spoiled	0.87±0.005a

- Note: Data are presented as the mean log CFU/g ± standard error (SE) of triplicate measurements.
- (*) indicates a significant difference ($p < 0.01$) between the uncoated samples (control) and the coated samples.
- (a) indicates that the coated sample on the 7th day of storage remained at an acceptable level, compared to the uncoated (control) samples, which had spoiled.

The pH values presented in Table (4) indicate that both control (uncoated) and coated raw kofta samples exhibited slightly acidic pH levels on day 0, with uncoated samples at 5.8 ± 0.09 and coated samples at 5.6 ± 0.04. Over the storage period, significant changes in pH were observed.

On the 1st day, the uncoated control samples showed a slight increase in acidity (pH 5.9 ± 0.01) compared to the coated samples, which had a pH of 5.7 ± 0.01* (p < 0.01). By the 3rd day, the pH of the control samples rose to 6.2 ± 0.2, while the coated samples exhibited a smaller, yet significant, increase to 5.9 ± 0.01** (p < 0.01). This significant difference suggests that the coating may have played a role in maintaining a lower pH compared to the control.

On the 5th day, the control samples experienced a further increase in pH to 6.6 ± 0.5. whereas the coated samples maintained a significantly lower pH at 6.2 ± 0.01* (p < 0.01). Again, this highlights the potential influence of the coating on pH stability.

By the 7th day, the uncoated samples were deemed spoiled, while the coated samples showed a stable pH of 6.4 ± 0.09.

The data presented in Table 4 indicates that both uncoated (control) and coated raw kofta samples exhibited relatively low TBA (thiobarbituric acid) values on day 0. The uncoated samples had a TBA value of 0.23 ± 0.008, while the coated samples showed a slightly lower value of 0.21 ± 0.005.

On the 1st day, there was a slight increase in TBA values for both sample types, with uncoated samples measuring 0.24 ± 0.003. By the 3rd day, a significant difference (p < 0.01) emerged, as uncoated samples experienced a notable increase in TBA to 0.6 ± 0.020, while the coated samples exhibited a lower TBA value of 0.4 ± 0.014***. This trend persisted on the 5th day, with uncoated samples showing a significantly higher TBA value of 0.89 ± 0.020 compared to the coated samples, which had a value of 0.58 ± 0.025* (p < 0.01).

By the 7th day, the uncoated samples had reached spoilage, with a significant increase in TBA value to 0.87 ± 0.005.

Table 5: Statistical analysis of Total Viable Bacterial Count (TVBC), psychrotrophic bacteria count “PBC, yeast and mould in uncoated (control) and coated raw beef kofta samples during refrigerated storage.

Microbiological parameters	Storage time/day	Uncoated samples (control)	Coated samples
TVBC	0 day	4.7±0.01	4.6± 0.01
	1^{st}	4.9±0.02	4.3±0.01**
	3^{rd}	5±0.02	4.5±0.02***
	5^{th}	5.9±0.02	4.7±0.01***
	7^{th}	spoiled	4.9±0.01 ^{a}
PBC	0 day	3.7±0.01	3.7±0.01
	1^{st}	4.5±0.01	3.7±0.02**
	3^{rd}	4.9±0.01	4.2±0.02**
	5^{th}	5.8±0.01	4.8±0.01***
	7^{th}	spoiled	4.9±0.01 ^{a}
Yeast	0 day	3±0	3±0
	1^{st}	3.2±0.14	2.7±0.1
	3^{rd}	3.3±0.12	2.7±0.07*
	5^{th}	3.5±0.04	2.6±0.07***
	7^{th}	spoiled	2.6±0.07 ^{a}
Mould	0 day	3.3±0.06	3.2±0.1
	1^{st}	3.5±0.04	3.1±0.1*
	3^{rd}	3.6±0.06	3.2±0.1*
	5^{th}	3.6±0.03	3.2±0.1*
	7^{th}	spoiled	3.1±0.1^{a}

- Note: Data are presented as the mean log CFU/g ± standard error (SE) of triplicate measurements.
- (*) indicates a significant difference (p < 0.01) between the uncoated samples (control) and the coated samples.
- (a) indicates that the coated sample on the 7th day of storage remained at an acceptable level, compared to the uncoated (control) samples, which had spoiled.

In the present study, microbiological assessment revealed significant differences between coated and uncoated raw beef kofta samples during refrigerated storage, as shown in Table 5. All measured parameters-including Total Viable Bacterial Count (TVBC), Psychrotrophic Bacterial Count (PBC), and yeast and mold counts-showed an increase over time for both coated and uncoated samples. However, the uncoated samples consistently exhibited higher microbiological counts compared to the coated samples, except on day 0, where no significant difference was noted.

The statistical analysis showed highly significant differences ($p<0.01$) in all microbiological evaluations between the two groups on days 1, 3, and 5. By day 7, the uncoated samples had reached spoilage levels, with bacterial counts surpassing the acceptable limits for safe consumption. These findings indicate that the uncoated kofta samples deteriorated much faster, making them unsafe for consumption by day 7.

In contrast, the coated samples demonstrated significantly lower microbiological counts throughout the storage period. By day 7, the coated samples had maintained acceptable microbiological levels, with counts of 4.9 ± 0.01 log cfu/g for TVBC, 4.9 ± 0.01 log cfu/g for PBC, 2.6 ± 0.07 log cfu/g for yeast, and 3.1 ± 0.1 log cfu/g for mold. These results indicate that the red onion peel extract (ROPE) coating effectively delayed microbial growth, thereby extending the shelf life of the raw kofta samples. The antimicrobial properties of the phenolic compounds present in the onion peel extract likely contributed to this inhibitory effect on bacterial, yeast, and mold growth.

Overall, the microbiological findings strongly support the effectiveness of ROPE as a natural preservative, capable of maintaining safer and more acceptable microbiological levels in meat products during refrigerated storage.

DISCUSSION

In recent years, natural bioactive materials used as edible coatings in the food industry have gained significant attention due to their potential to address environmental and consumer health concerns (Ramos *et al*., 2021). The demand for sustainable, eco-friendly packaging solutions has accelerated the development of coatings like onion peel extracts, which are rich in bioactive compounds such as polyphenols, tannins, and flavonoids, particularly quercetin (Kumar *et al*., 2022a). These natural materials provide functional benefits, extend shelf life and enhance food preservation without compromising quality. Red onion peel extract (ROPE), in particular, has the highest concentration of these bioactive compounds compared to yellow and white onion peels (Kumar *et al.*, 2022b), making it an ideal candidate for industrial food applications (Chadorshabi *et al.*, 2022).

Onion extracts have traditionally been used in meat preparations worldwide for seasoning and aroma, while it also aids in preservation (Irkin and Arslan, 2010). In this study, red onion peel extract was mixed with corn starch (10% w/v) to create a semi-pasty texture suitable for coating Egyptian kofta, a popular comminuted meat product. The coating was designed to extend the shelf life and maintain the quality of the kofta by slowing down microbial activity and lipid oxidation.

Throughout the storage period, pH levels of both coated and uncoated kofta samples increased as the meat naturally deteriorated. However, the coated samples showed a significantly slower rise in pH compared to the uncoated ones, particularly on days 1, 3, and 7 (Table 4). This suggests that ROPE coating effectively stalled microbial activity, as microbial enzymes typically break down proteins into nitrogenous compounds like ammonia and trimethylamine, which raise the pH (Moghtadaei *et al*., 2018; Alizadeh Behbahani and Imani Fooladi, 2018). By day 7, the uncoated samples had reached a pH of

6.6 ± 0.5, while the coated samples remained within a range of 6.2 ± 0.1 to 6.4 ± 0.09. This delayed pH increase can be attributed to the antimicrobial properties of phenolic compounds in the onion peel extract, which reduced microbial activity and oxygen exposure, ultimately preserving the freshness of the raw beef kofta.

The coating's ability to decrease permeability to carbon dioxide, combined with its antimicrobial properties, created an environment that inhibited bacterial growth and slowed spoilage, particularly in maintaining a lower pH level (Ghani *et al*., 2018). This protective effect further underscores the potential of ROPE as a natural preservative for meat products, offering both antimicrobial and antioxidant benefits that extend shelf life while maintaining sensory quality.

Free radicals are considered the most significant drivers of lipid oxidation in meat, leading to off-odor production and changes in both meat color and the overall quality (Huang and Ahn, 2019). Lipid oxidation processes impact key meat attributes, including flavor, aroma, taste, color, and texture (Dragoev, 2024). Additionally, protein oxidation contributes to the development of off-flavors (Dragoev, 2024; Soladoye *et al*., 2015). The appeal of fresh meat color diminishes as cherry-red oxymyoglobin undergoes oxidation, resulting in the formation of grayish brown metmyoglobin (Shleikin and Medvedev, 2014).

In the present study, the highly significant (P<0.01) elevation of TBA levels indicated that the ROP coating effectively slowed lipid peroxidation in coated kofta (Table 4). This demonstrates the antioxidant action of the ROP extract, which helped to retard lipid oxidation, thereby preserving the freshness, quality, and palatability of the kofta over an extended storage period. It has been shown that ROP extract reduced lipid peroxidation in cooked lean beef (Ifesan, 2017), primarily due to its high quercetin content-a bioactive compound abundant in ROP (Fredotović *et al*., 2021), followed by yellow onion peels (Ju and Song, 2020), which are more potent than white onion peels.

This protective effect can be attributed to the phenolic compounds present in the ROP extract, known for their free radical scavenging properties (Ergezer *et al*., 2018; Murayyan *et al*., 2017). These compounds act as antioxidants by donating hydrogen atoms to neutralize free radicals, preventing them from initiating lipid oxidation. Additionally, they chelate metal ions, such as iron, which can accelerate oxidation processes, and decompose lipid hydroperoxides-intermediate products in oxidation that further degrade fats (Ergezer *et al*., 2018; Faluyi *et al*., 2020; Hosseinialhashemi *et al*., 2021).

Studies have demonstrated that incorporating plant extracts rich in phenolic compounds into edible coatings can reduce lipid oxidation in meat products (Ergezer *et al*., 2018; Langroodi *et al*., 2018). Onions, a common source of dietary flavonoids (Lanzotti, 2006; Sidhu *et al*., 2019), are particularly rich in quercetin glycosides (Rodríguez Galdón *et al*., 2008), which possess structural properties necessary for both antioxidant and pro-oxidant activity (Rietjens *et al*., 2005). Therefore, the phenolic compounds in the ROP extract, likely derived from onions, are strong candidates responsible for the observed reduction in lipid oxidation in the coated kofta samples.

Overall, the findings convincingly demonstrate that the ROP extract coating, rich in phenolic compounds, serves as a natural antioxidant, significantly delaying lipid oxidation and improving both the quality and shelf life of raw beef kofta during refrigerated storage.

In the present study, the significant improvement in bacteriological parameters (TVBC, PBC, yeast, and mold count) (Table 5), indicates the potent antimicrobial action of the ROPE coating. The reduction in total bacterial count and psychrotrophic bacterial count in kofta samples coated with red onion peel extract can likely be attributed to the antimicrobial properties of bioactive compounds within the extract. While the specific mechanisms require further investigation, potential actions include disrupting bacterial cell membranes or inhibiting key metabolic pathways. Edible coatings, such as those made from onion extract, show great promise in meat preservation by forming a barrier against oxygen and potentially limiting microbial growth. These coatings may also protect phenolic compounds in the meat from oxidation, enhancing their natural antimicrobial properties. Phenolic compounds, with their hydroxyl groups, are known to disrupt microbial cell membranes, effectively killing bacteria. This aligns with research demonstrating the efficacy of red onion extract, rich in phenolics, in reducing microbial populations in various products, including chicken meat (Faluyi *et al*., 2020). Similarly, the application of an edible film from onion extract to beef burger patties showed a significant reduced microbial growth during storage. This highlights the potential of onion as a natural antimicrobial agent for extending the shelf life of meat products (İnanç Horuz and Maskan, 2015).

Building on studies by Alizadeh Behbahani; Imani Fooladi (2018) and Sharma and Ghoshal (2018), vegetable extracts in edible coatings enhanced meat safety and extend shelf life. These extracts work by disrupting bacteria through various mechanisms, including damaging cell membranes, interfering with essential enzymes, potentially harming genetic material, and preventing bacterial reproduction. When the active compounds from vegetable extracts interact with food surfaces, they help inhibit or delay bacterial growth, thereby improving preservation.

Yeast and mold counts are indicators of hygiene and potential environmental contamination during production. A significant difference ($p < 0.01$) was observed on the 3rd and 5th days (Table 5), indicating that the coating containing onion extract effectively limits yeast and mold growth in raw beef kofta samples. While onions naturally possess antifungal properties, research suggests that concentrated onion extracts may be even more potent against fungi (Singh and Singramau, 2017). Compounds such as quercetin and kaempferol found in onions are believed to enhance this antifungal activity (Rauha *et al*., 2000). In this study, the red onion extracts likely inhibited fungal growth in a dose-dependent manner due to its phenolic compounds and secondary metabolites. These results align with findings by Škerget *et al*. (2005), who reported antifungal activity in extracts from red onion peels and edible parts. Throughout the storage period, the coated samples consistently showed lower yeast and mold counts compared to the uncoated control samples, indicating better control of fungal growth (Babaei Sarvinehbaghi and Azizkhani, 2022).

The antimicrobial activity of red onion peel extract (ROPE) has been widely documented against various pathogens, including MRSA, *Acinetobacter baumannii, Escherichia coli,* and *Pseudomonas aeruginosa* (Ali *et al*., 2023), as well as *Streptococcus mutans, Streptococcus sobrinus, Lactobacillus acidophilus, Streptococcus sanguis, Actinobacillus actinomycetemcomitans*, and *Prevotella intermedia* (Nguyen and Bhattacharya, 2022). Additionally, it was effective against *Listeria monocytogenes, Chromobacterium violaceum* (Dhowlaghar *et al*., 2023), *Salmonella enteritidis* (ATCC 13076), *Shigella sonnei* (ATCC 25931), and the yeast *Candida albicans* (ATCC 10231). This potent antimicrobial activity may be attributed to the action of quercetin and anthocyanin derivatives (Joković *et al*., 2024; Mounir et al., 2023; Sagar and Pareek, 2020), as well as their flavonoid (Dhowlaghar *et al*., 2023) and phenolic contents (Ifesan, 2017). These compounds exhibit significant activity against biofilm formation, which has raised concerns among healthcare professionals worldwide (Ali *et al.*, 2023).

Sensory properties are vital for consumer acceptance of beef kofta. As indicated in Table 1, the sensory quality-encompassing color, odor, texture, and overall appearance-declined in all samples during storage. However, applying a red onion peel (ROP) coating significantly preserved these sensory attributes compared to uncoated samples ($p < 0.01$). This suggests ROP coating is a promising method for maintaining the sensory quality of raw kofta during storage, likely due to its effects on pH, TBA, and microbiological evaluations (Tables 4 and 5), which in turn influence sensory properties. The ROP coating maintained higher scores for color, odor, texture, and overall acceptability in raw kofta samples, whereas uncoated samples exhibited faster sensory deterioration, with spoilage evident by day 7. The coating effectively delayed these changes, highlighting its potential to preserve product quality and extend shelf life while maintaining palatability.

Odor and flavor play a crucial role in consumer perception and purchase decisions, making them essential for maintaining the quality of meat products. Our evaluation revealed that the coated samples retained acceptable color, odor, and texture throughout the storage period, lasting up to 7 days. The coating not only protects the kofta, but also imparts a characteristic odor and maintains a desirable red color. This positive influence on sensory properties may be attributed to the presence of lachrymatory and flavoring compounds naturally found in the Allium genus (Burt, 2004). In contrast, uncoated samples received lower texture scores, likely due to increased oxygen exposure, which led to lipid and protein oxidation, resulting in tougher meat.

As shown in Table 2, coating the cooked beef kofta samples helped maintain their color, odor, texture, taste, and overall acceptability for a longer period compared to the uncoated (control) samples. After cooking, the odor of the coated beef samples became more characteristic, and the coating developed a dark red color, which remained acceptable. The taste was distinctive and preferred over the uncoated kofta. The enhancement of sensory characteristics in cooked kofta treated with onion extract can be attributed to the presence of volatile organosulfur compounds. These compounds are the primary source of the onion's characteristic flavor and aroma (Manohar *et al*., 2017; Santas *et al*., 2010). The unique biological properties of onions are often attributed to thiosulfinates, a class of volatile sulfur-containing compounds responsible for the onion's strong taste and smell (Lanzotti, 2006; Rose *et al*., 2005).

Onion peel extracts are considered biodegradable tools for foods with high lipid content, as they can extend the shelf life of meat products (Ju and Song, 2020). Their inclusion can prolong shelf life without deteriorating sensory properties, particularly since pink and red onion peels can serve not only as natural preservatives, but also as antimicrobial agents in the food sector (Sagar and Pareek, 2020). Several studies (Kumar *et al*., 2022a; Sagar and Pareek, 2020) recommend using red onion peel extract (ROPE) to redesign commonly consumed processed foods, such as packaging materials and meat quality improvers, rather than focusing solely on other food sectors.

CONCLUSION

The present study concluded that edible starchy red onion peel (ROP) coatings have promising potential as a natural and effective strategy for extending shelf life and maintaining the quality of chilled beef kofta, due to their potent antimicrobial and antioxidant activities, as well as their attractive taste and flavor.

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إمكانية استخدام مستخلص قشور البصل الأحمر النشوي كغلاف صالح للأكل لتحسين جودة وإطالة فترة صلاحية كفتة اللحم البقري المبرد

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تهدف هذه الدراسة إلى تطوير طريقة طبيعية وآمنة للحفاظ على جودة كفتة اللحم البقري النيئة وتمديد فترة صلاحيتها، حيث قارنت الدراسة بين عينات الكفتة النيئة المغلفة بهذا المستخلص من قشور البصل الأحمر والنشا وبين عينات ضابطة غير مغلفة. تم حفظ جميع العينات في درجة حرارة 4 درجات ± 1 درجة مئوية لمدة سبعة أيام. تم تقييم فعالية الغلاف من خلال تحليل الخصائص الحسية، ونمو الميكروبات (إجمالي البكتيريا، والبكتريا المحبة للبرودة، والخمائر، والعفن)، والتغيرات الفيزيائية الكيميائية ومستويات الرقم الهيدروجيني "درجة الحموضة pH" ومستويات حمض الثايوباربيتوريك (TBA). أظهرت النتائج أن الغلاف النشوي مع مستخلص قشور البصل الأحمر أثبت فعاليته العالية في تمديد فترة صلاحية كفتة اللحم البقري النيئة. مقارنةً بعينات الضوابط غير المغلفة، التي أفسدت بحلول اليوم الخامس، ظلت العينات المغلفة صالحة للأكل لمدة 7 أيام مع تأخير كبير (*p<0.01*) في تدهور الجودة، بدءًا من اليوم الثالث وأصبح ذات دلالة عالية (p<0.01) بحلول اليوم الخامس. ظلت الصفات الحسية للعينات النيئة والمطبوخة أعلى في العينات المغلفة طوال فترة الحفظ والتخزين. كشف التحليل الميكروبيولوجي عن حمولة بكتيرية أقل ونمو أبطأ في العينات المغلفة، خاصة بعد 3 أيام. كما حافظ غلاف قشور البصل الأحمر على درجة حموضة pH منخفضة ومستويات حمض الثايوباربيتوريك (TBA). تشير هذه النتائج إلى أن غلاف مستخلص قشور البصل الأحمر النشوي (ROP) يمتلك إمكانات واعدة كطريقة طبيعية وآمنة وصالحة للأكل لتمديد مدة صلاحية الكفتة البقرية النيئة والحفاظ على جودتها.