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Research Article

Enhancing the quality and shelf life of chevon using orange peel extract

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Abstract

The experiment was conducted to find out the effect of different levels of orange peel extract as a natural antioxidant and antimicrobial agent on fresh and preserved chevon. For this purpose, fresh chevon samples were divided into four treatment groups. These were treated as T_0 (control group 0% orange peel extract), T_1 (0.2% orange peel extract), T_2 (0.3% orange peel extract) and T_3 (0.4% orange peel extract) respectively. Sensory tests (color, flavor, tenderness, juiciness and overall acceptability), proximate components (DM, CP, EE and Ash), physicochemical quality (Raw meat pH, cooking loss), biochemical properties (POV, FFA and TBARS) and microbial assessment (TVC, TCC and TYMC) examination were determined in order to evaluate the effect of orange peel extract as natural antioxidant and antimicrobial agent for maintaining chevon qualities and the shelf-life of chevon for 0, 5, 10 and 15 days of storage period under refrigeration temperature. Among the four treatments T_3 (0.4% orange peel extract) was the best in terms of nutrient quality, physicochemical properties, biochemical analysis and microbial assessment. Therefore, it is concluded that 0.4% orange peel extract may be used up to 15 days for chevon preservation.

Introduction

Livestock farming play an important role in the economy of and the total goat population is about 26.43 million (Rana et al. 2020; DLS, 2020). Goats are important nutrient source, particularly for people in the technologically developing regions, situated mainly in the tropics. These regions account for more than 90% of the estimated world goat population of 504 million, with approximately 56% in Asia, 33% in Africa and 7% in South and Central America and the Caribbean (FAO, 1988). Goat meat has an immense market potential, as it can becomes an ideal choice for health-conscious consumers (Parvin et al., 2017). In recent time, market of meat has been adapting to different requirements of contemporary consumers, insisting of lean and easily digestible meat of high quality and good taste (Sayeed et al., 2023; Azad et al. 2022a; Das et al., 2022). The consumer expects the meat he purchases to be safe and wholesome. Wholesome meat is produced hygienically, pathogen free, retains its natural state and nutritive value, has optimum fat and is unconditionally acceptable to the consumer (Islam et al. 2019). However, Bangladesh is a tropical country, with ambient temperatures conducive to the growth of microorganisms, which can rapidly render the meat unsafe for human consumption. Episodes of food borne diseases are reported in the press on many occasions, but due to lack of a surveillance network, the exact magnitude of the problem in the country remains unknown (Murshed et al., 2023).

Goat meat has been established as lean meat with favorable nutritional quality. However, goat meat tends to be less tender and less juicy than sheep meat because of some possible mitigating factors that are discussed. Goat meat has a species-specific flavour and aroma, which differ from that of sheep meat (Webb et al., 2005; Afroz et al. 2020). Citrus fruit juices, peels as well as essential oils are known to possess antimicrobial properties and hence are incorporated into some topical formulations for the management of infections (Pandey et al., 2011). Citrus fruit products such as orange-peel extract act as antimicrobial agents against the bacteria and the fungus. The citrus product an important and physiological role because of its commercial value in food and pharmaceutical industries of the entire world (Mathur et al., 2011). Peels are generally wasted while the citrus fruits are mainly used in juice processing industries. Very large amounts of by-product are formed as wastes during the production of citrus juices (Manthey and Grohmann, 2001). The pollution of environment can also be reduced by this. The oranges peel is rich in nutrients, which can used as drugs or as food supplements too (Ashok et al., 2011). The search for alternative methods to retard oxidative processes in meat and meat products has led researchers to investigate natural antioxidants. Addition of antioxidants to meat products is known to be effective in metmyoglobin formation and lipid oxidation.

Actually, orange peel extract has antioxidant and antimicrobial agents as well as prolong the shelf life of meat and meat products. So far, we know that there is no research on preservation technique of beef at refrigerated temperature using orange peel extract in Bangladesh context. Therefore, the present research was conducted to fulfill the following objectives: i. to examine sensory, proximate, physicochemical, biochemical and microbial quality of chevon after addition of orange peel extract, ii. to evaluate the effect of orange peel extract on the oxidative changes in chevon during preservation and iii. to investigate the effect of orange peel extract on meat spoilage.

Materials and Methods

Place of Experiment:

The experiment was conducted in the laboratory of the Department of Animal Science at Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh.

Experimental Samples:

The chevon (goat meat) used in this study was collected from the "Local Market" (K.R. Market), Bangladesh Agricultural University, Mymensingh at 8.30 a.m. The goat was slaughtered using the halal method, and the sample was obtained from a buck carcass that was approximately one year old and had a live weight of 10±2 kg. The meat sample was immediately transferred to the "Animal Science Laboratory" for further analysis, including sample weighting, sensory evaluation, physicochemical analysis, and microbial analysis.

Source of Orange:

Oranges used for this research were collected from the "Bangladesh Agricultural University Shesh Mor-bazar" in Mymensingh Sadar.

Preparation of Sample

The chevon sample was prepared by trimming off all visible fat and connective tissue as much as possible using a knife. The meat sample was then cut into small pieces. Fresh oranges were collected from the local market, washed with clean water, and the peels were separated from the edible portion. The peels were ground using a grinder machine, and the orange peel extract was collected by filtering it through a sieving cloth. The orange peel extract was then mixed with the chevon sample in different proportions: T_0 = control, T_1 = 0.2% orange peel extract, T_2 = 0.3% orange peel extract, and T_3 = 0.4% orange peel extract.

Experimental Layout

The meat sample was divided into four parts, and different percentages (0%, 0.2%, 0.3%, and 0.4%) of orange peel extract were mixed with each portion. The treated samples were then placed in polythene bags and stored at -4°C for 15 days. Samples were taken from each treatment at 0, 5, 10, and 15 days for various analyses.

Analysis of Different Characteristics of Chevon Samples in the Laboratory

Sensory Properties

The sensory questionnaires measured intensity on a 5-point balanced semantic scale (weak to strong) for the following attributes color, flavor, and overall acceptability. The judges evaluated the samples based on the above criterions. Panelists were selected among department staff and students and trained according to the American Meat Science Association guidelines (AMSA, 1995). Sensory evaluation was carried out in individual booths under controlled conditions of light, temperature and humidity. Prior to sample evaluation, all panelists participated in orientation sessions to familiarize with the scale attributes (color, flavor, overall acceptability) of beef using an intensity scale. Sensory scores were 5 for excellent, 4 for very good, 3 for good, 2 for fair and 1 for poor.

Proximate Analysis

Proximate composition, including Dry Matter, Crude Protein, Ether Extract, and Ash, was determined according to AOAC (1995) methods. Crude protein was determined using the micro Kjeldahl method. Ether extract content was determined using a Soxhlet apparatus with diethyl ether. Ash content was determined by pre-ashing the samples and then heating them in a muffle furnace.

Physicochemical Properties

The pH of the raw meat was measured. Samples (5 g) were homogenized in 45 ml of distilled water using a grinder (SFM1500NM, Shinil Co. China) for 1 min. Sample solutions were centrifuged for 15 min at 2000 × g, and the pH was measured using a pH meter (Seven Easy pH, Mettler-Toledo GmbH, Switzerland). Cooking loss was determined by weighing samples before and after cooking. To determine cooking loss, weighed 10±1 g sample and wrapped in a heat-stable foil paper and kept in water bath at 60°C for 30 minutes. The internal temperature was not measured, but from a previous study it was estimated that the optimum internal meat temperature (60-80°C) would be gained by 30 minutes. Samples surface are dried and weighed. Cooking loss was practiced at 0-day, 5-day, 10 day and 15 day. Cooking loss was calculated after draining the drip coming from the cooked meat as follows:

Cooking loss (%) = $[(w_2-w_3) \div w_2] \times 100$

Where, w_2 = meat weight before cooking and

w_3 = meat weight after cooking.

Biochemical Analysis

Biochemical analyses included Peroxide Value (POV), Thiobarbituric Acid Value (TBARS), and Free Fatty Acid Value (FFA) to assess lipid oxidation. FFA value was determined according to Rukunudin et al. (1998). 5 g of sample was dissolved with 30 ml chloroform using a homogenizer (IKA T25 digital Ultra-Turrax, Germany) at 10,000 rpm for 1 min. The sample was filtered under vacuum through Whatman filter paper number 1 to remove meat particles. After five drops of 1% ethanolic phenolphthalein were added as indicator to filtrate, the solution was titrated with 0.01 N ethanolic potassium hydroxide. Peroxide value (POV) was determined according to (Sallam et al., 2004). The sample (3 g) was weighed in a 250-ml glass stopper Erlenmeyer flask and heated in a water bath at 60°C for 3 min to melt the fat, then thoroughly agitated for 3 min with 30 ml acetic acid-chloroform solution (3:2 v/v) to dissolve the fat. The sample was filtered through Whatman filter paper to remove meat particles. Saturated potassium iodide solution (0.5 ml) was added to filtrate and continue with addition of starch solution. The titration was allowed to run against standard solution of sodium thiosulfate (25/1). The homogenized sample was filtered with Whatman filter paper number 4, and 2 ml of the filtrate was added to 2 ml of 0.02 M aqueous TBA solution (3 g/L) in a test tube. The test tubes were incubated at 100°C for 30 min and cooled with tap water. The absorbance was measured at 532 nm using a UV-VIS spectrophotometer (UV-1200, Shimadzu, Japan). The TBA value was expressed as mg malonaldehyde per kg chevon of sample.

Microbiological Analysis

Microbiological assessment included Total Viable Count (TVC), Total Coliform Count (TCC), and Total Yeast Mold Count (TYMC) to evaluate microbial contamination. A quantity of five (5) gram of the minced meat sample was taken aseptically transferred into a sterile container containing 90 ml of 0.1% peptone water. A homogenized suspension was made in a sterile blender. Thus 1:10 dilution of the samples was obtained. Later on, using whirly mixture machine different serial dilutions ranging from 10^2 to 10^6 were prepared according to the instruction of the standard method (ISO, 1995).

Statistical Model and Analysis:

The statistical model used for the experiment was a factorial design with two factors, A (Treatments) and B (Days of Intervals). Data analysis was performed using SAS Statistical Discovery software, and the significance of differences among treatment means was determined using the DMRT test.

Results and Discussion

Sensory evaluation

Color

The range of overall observed color score at different treatments was 4.24 to 4.57 (Table 1), which was highly significant ($p > 0.05$). Among the four treatments, the most preferable color was observed in T_2, and the least preferable color was observed in T_3. The most preferable color was observed at 0 days and the least preferable color at 15 days. The data show that the lowest test score was reduced to 4.08 at 15 days of storage, irrespective of treatment groups (Table 1). Metmyoglobin is the pigment responsible for the characteristic brown color of meat as it deteriorates during refrigerated storage (Mancini and Hunt, 2005). Changes in meat color are due to the oxidation of red oxymyoglobin to metmyoglobin (MMG), which gives meat an unattractive brown color (Nerín et al., 2006). Some reports demonstrate that natural antioxidants can retard meat color loss by extending the red color and delaying MMG formation. A decrease in appearance and color scores of meat products with increase in storage period was also reported by Singh et al. (2011) and Kandeepan et al. (2010). Anti-bacterial orange peel extract may have the effect on inhibiting the microbial decomposition of chevon which may uphold the color in treated samples.

Flavor

The range of flavor among different days of intervals was 4.07 to 4.49, and the range among different treatments was 4.24 to 4.49 (Table 1). The different superscript observed in all treatments indicates there were significant ($p<0.05$) differences in flavor among all treatments. So, we saw that the quality was deteriorating with the increased storage period. A similar value was observed in flavor, which is one of the major causes of quality deterioration (Raghavan and Richards, 2007) because it can negatively affect sensory attributes such as color, texture, and flavor as well as the nutritional quality of the product (Nunez and Boleman, 2008). These issues leave the meat and poultry industry in need of economical and effective natural antioxidants that can replace synthetic antioxidants without negatively affecting the quality of finished products or consumer perceptions. The score of off-flavor was gradually increased with storage extending, and the characteristic undesirable odor appeared to intensify due to the oxidation of polyunsaturated fatty acids. Treatments with orange peel extract resulted in a reduction of off-flavor scores to some extent, especially T_2 (0.3% orange peel extract) and T_3 (0.4% orange peel extract) treatments. The progressive decrease in flavor could be correlated with the increase in TBARS values of meat products stored under aerobic conditions. Significantly, higher scores for leaf extract-incorporated products might be attributed to the antimicrobial and antioxidant ingredients of Ocimum leaf extract (Koushik and Gopal, 2013; Pandey and Madhuri, 2010).

Tenderness

The range of the overall observed tenderness score at different treatments was 3.66 to 4.24 (Table 1). The different superscript was observed in all treatments and indicates that there were significant ($p<0.05$) differences in tenderness scores between these treatments. Among these four treatments, the most preferable tenderness was observed at T1, and less preferable tenderness was observed in the control group. The range of different days of intervals of overall observation of the tenderness score was 3.49 to 4.49 (Table 1). The different superscripts observed from 0, 5, 10, and 15 days of observation indicate there were significant ($p<0.05$) differences among these days of observation. The most preferable juiciness was observed at day 0, and the least preferable juiciness was observed at day 15. The data show that the lowest test score was reduced to 3.66 in all treatments after 15 days of storage. When chevon is frozen, ice crystals form inside the cells of muscle tissue and puncture the cell walls. That's why chevon leak moisture when they are cooked. Tenderness is interrelated with the DM content of the chevon. With the increasing storage period, DM increased, and consequently, tenderness decreased with day intervals. The result of this experiment is also related to Lui et al.'s (2010) findings. The amount and type of fat in meat influence two major components of meat quality: tenderness and flavor (Wood et al., 2008).

Juiciness

The range of the overall observed juiciness score at different treatments was 3.91 to 4.32 (Table 1). The same superscript was observed in the T_2 and T_3 treatments, indicating there were no significant ($p > 0.05$) differences in the juiciness score among the four treatments. Among these four treatments, the least preferable juiciness score was observed in the T_2 group, and the most preferable juiciness was observed in the control group. The range of different days of intervals of overall observation of the juiciness score was 3.08 to 4.57 (Table 1). The same superscript was observed in the 0th and 5th days of observation, indicating there were no significant ($p > 0.05$) differences among these two days of observation, but different superscripts were observed in the 10th and 15th days of observation. That's why meats leak juices when they are stored. If meat is refrozen, it accelerates further moisture loss, and when this meat is eventually cooked, anyone may find it dense and dry in texture. The result of this experiment is also related to Lui et al.'s (2010) findings. The results were in accordance with the findings of Raja et al. (2014) and Thomas et al. (2006), who also reported a decline in the juiciness scores of different meat products during refrigerated storage.

Overall acceptability

The range of the overall observed acceptability score at different treatments was 4.24 to 4.57 (Table 1). The same superscript was observed for all treatments, indicating there was no significant difference ($p > 0.05$) in the overall acceptability of all treatments. Among these four treatments, the most preferable overall acceptability was observed in the T_2 group, and a less preferable overall acceptability was observed in the control group. The range of different days of intervals of overall observation of the overall acceptability score was 3.99 to 4.57 (Table 1). The same superscript was observed in 0, 5, and 10 days of observation, indicating there were no significant ($p > 0.05$) differences between these three days of observation, but different superscripts were observed in 15 days of observation. The most preferable overall acceptability was observed at 5 days, and the least preferable overall acceptability was observed at 15 days. Meat and meat products are important sources of protein, fat, essential amino acids, minerals, vitamins, and other nutrients (Biesalski, 2005). This is the same trend with this experiment. The overall acceptability also decreased during storage because of the decline in the sensory score of other parameters like appearance, flavor, and taste. This decrease in overall acceptability was confirmed by the results of Malav et al. (2015) who reported that the overall acceptability of mutton patties decreased during storage. During the processing of meat and meat products, many functional compounds can be generated; many peptides produced from fermentation and enzyme-induced hydrolysis showed physiological benefits to humans.

Table 1. Effect on sensory properties of chevon using orange peel extract

Parameters	DI	Treatments				Mean	Level of significance		
		T_0	T_1	T_2	T_3		Treat.	DI	T*DI
Color	0	4.65±0.00	5.00±0.00	4.65±0.00	4.65±0.00	4.73^{a}±0.00			
	5	4.66±0.00	4.66±0.00	5.00±0.00	4.00±0.00	4.58^{b}±0.00			
	10	4.33±0.00	4.33±0.00	4.66±0.00	4.33±0.00	4.41^{c}±0.00	<0.0001	<0.0001	<0.0001
	15	4.33±0.00	4.00±0.00	4.00±0.00	4.00±0.00	4.08^{d}±0.00			
	Mean	4.49^{c}±0.00	4.49^{b}±0.00	4.57^{a}±0.00	4.24^{d}±0.00				
Flavor	0	4.33±0.00	4.33±0.00	4.66±0.00	4.66±0.00	4.49^{a}±0.00			
	5	4.33±0.00	4.66±0.00	4.33±0.00	4.33±0.00	4.41^{b}±0.00			
	10	4.66±0.00	4.33±0.00	4.33±0.00	4.00±0.00	4.33^{c}±0.00	<0.0001	<0.0001	<0.0001
	15	4.66±0.00	3.66±0.00	3.66±0.00	4.33±0.00	4.07^{d}±0.00			
	Mean	4.49^{a}±0.00	4.24^{c}±0.00	4.24^{c}±0.00	4.33^{b}±0.00				
Tenderness	0	4.33±0.00	4.66±0.00	4.66±0.00	4.33±0.00	4.49^{a}±0.00			
	5	4.33±0.00	4.66±0.00	4.66±0.00	3.66±0.00	4.32^{b}±0.00			
	10	4.33±0.00	4.00±0.00	3.66±0.00	3.33±0.00	3.83^{c}±0.00	<0.0001	<0.0001	<0.0001
	15	3.66±0.00	3.66±0.00	3.33±0.00	3.33±0.00	3.49^{d}±0.00			
	Mean	4.16^{b}±0.00	4.24^{a}±0.00	4.07^{c}±0.00	3.66^{d}±0.00				
Juiciness	0	4.66±0.00	4.66±0.00	4.66±0.00	4.33±0.00	4.57^{a}±0.00			
	5	4.66±0.00	4.66±0.00	4.66±0.00	4.33±0.00	4.57^{a}±0.00			
	10	4.66±0.00	4.00±0.00	3.66±0.00	3.66± 0.00	3.99^{b}±0.00	<0.0001	<0.0001	<0.0001
	15	3.33±0.00	3.00±0.00	2.66±0.00	3.33± 0.00	3.08^{c}±0.00			
	Mean	4.32^{a}±0.00	4.08^{b}±0.00	3.91^{d}±0.00	3.91^{c}±0.00				
Overall Acceptability	0	4.33± 0.00	4.33± 0.00	4.66± 0.00	4.66± 0.00	4.49^{b}±0.00			
	5	4.33± 0.00	4.66± 0.00	4.66± 0.00	4.66± 0.00	4.57^{a}±0.00			
	10	4.33± 0.00	4.66± 0.00	4.66± 0.00	4.33± 0.00	4.49^{b}±0.00	<0.0001	<0.0001	<0.0001
	15	4.00± 0.00	3.66± 0.00	4.33± 0.00	4.00± 0.00	3.99^{c}±0.00			
	Mean	4.24^{d}±0.00	4.32^{c}±0.00	4.57^{a}±0.00	4.41^{b}±0.00				

The mean in each row having different superscripts varies significantly at values *P < 0.05. Again, mean values with the same superscript in each row did not differ significantly at P > 0.05. T_0 = control, T_1 = 0.2% orange peel extract, T_2 = 0.3% orange peel extract, T_3 = 0.4% orange peel extract, DI = Days of Intervals, Treat = Treatment, T*DI = Interaction of Treatment and Day Intervals.

Proximate analysis

Dry Matter (DM)

The range of overall observed DM content at different treatments ranged from 25.26 to 26.68% (Table 2). Different superscripts were observed for four treatment groups, which indicates there were significant ($p<0.05$) differences in DM content. Among these four treatments, the most preferable DM content was observed in the T_2 group. The lowest amount of DM content indicates this product is most preferable. The highest amount of DM content indicates this product is less preferable. The range of overall observation of different days of intervals of DM content ranged from 22.89 to 28.55% (Table 2). The different superscripts observed from 0, 5, 10, and 15 days of observation indicate there were significant ($p<0.05$) differences among these fourth-day observations. The DM content increased with the increased storage period because moisture loss decreased with the storage period. The data show that the highest amount of DM content was increased to 28.55 in all treatments after 15 days of storage (Table 2). The primary reason would be an evaporative loss from the hot carcass as it is transferred to the refrigerator. Similar results were also found by Modi et al. (2008) and Al-Bachir and Zeinou (2014).

Crude Protein (CP)

The range of overall observed CP content at different treatments was 18.37 to 18.98% (Table 2). Less preferable CP content was observed in the control group. The range of overall observed CP content on different days of intervals was 17.80 to 20.86% (Table 2). The different superscripts observed from the 0, 05th, 10th, and 15th days of observation indicate there were significant ($p<0.05$) differences among these fourth days of observation. The CP content decreased with the increased storage period. The most preferable CP content was observed at 0 days and the least preferable CP content at 15 days. The data show that the lowest amount of CP content was decreased to 17.80 in all treatments after 15 days of storage (Table 2). The same trend was also observed by Konieczny et al. (2007) and Boby et al. (2021) and they reported that CP content decreased during frozen storage. The higher crude protein content of the Dawadawa and Curcuma products is advantageous to the consumer because proteins are required at higher levels in growing children and also for productive functions such as pregnancy and lactation because of the

increased output of proteins in the products of conception and in milk (Heinz and Hautzinger, 2007). Therefore, with higher CP levels in Curcuma products, a small quantity will be required by consumers to meet their nutrient requirements and hence reduce expenditure on meat and meat products.

Ether Extract (EE)

The range of overall observed EE content at different treatments was 7.05 to 8.41% (Table 2). The different superscripts observed between the control and antioxidant treatments indicate there were significant ($p<0.05$) differences in EE content among these treatments. Among these four treatments, the most preferable EE content was observed in the T_3 group. The lowest amount of EE content indicates this product is most preferable for consumers' health. Less preferable EE content was observed in the T_2 group. The overall observed EE content ranged from 5.76 to 9.38% on different days of the interval (Table 2). The most preferable EE content was observed at day 0, and the least preferable EE content was observed at day 5. The EE content increased with the increased storage period. Verma et al. (2013) also observed a decrease in the fat content of sheep meat nuggets with the incorporation of guava powder. Suradkar et al. (2013) also reported similar results for different meats and meat products.

Ash

The range of overall observed ash content at different treatments was 1.07 to 1.28% (Table 2). The different superscripts observed in four treatment groups indicate there were significant ($p<0.05$) differences in ash content. Among these treatments, the most preferable ash content was observed in the T_0 group. The lowest amount of ash content indicates this product is most preferable for consumers' health. The range of overall observed values for different days of intervals of ash content was 0.83 to 1.44% (Table 2). The ash content was significantly changed with the increased storage period. The most preferable Ash content was observed at 0 days and the least preferable ash content at 15 days. The ash content of Malaysian commercial beef meatballs ranged from 1.76 to 3.40%, which is a nearly similar result to this experiment. Similar results were also reported by Serdaroglu et al. (2005) on the ash content of koefte beef meatballs. The same trend was also observed by Konieczny et al. (2007), and they reported that ash content increased during frozen storage.

Table 2. Effect on proximate components of chevon using orange peel extract

Parameters	DI	Treatments				Mean	Level of significance		
		T_0	T_1	T_2	T_3		Treat.	DI	T*DI
Dry Matter	0	24.24± 1.02	22.89± 0.00	22.32± 1.02	22.11± 1.02	22.89^{d}± 0.76			
	5	23.87± 1.02	24.24± 1.02	24.24± 1.02	24.24± 1.02	24.89^{c}± 1.02			
	10	26.78± 1.02	24.24± 1.02	24.24± 1.02	24.24± 1.02	27.34^{b}± 0.51	<0.0001	<0.0001	<0.0001
	15	29.13± 1.02	24.24± 1.02	24.24± 1.02	24.24± 1.02	28.55^{a}± 0.76			
	Mean	26.01^{b}±1.02	25.7^{c}± 0.25	25.26^{d}± 1.02	26.68^{a}± 1.02				
CP%	0	21.00± 0.00	21.35± 2.05	21.00± 0.00	20.12± 1.02	20.86^{a}± 0.76	<0.0001	<0.0001	<0.0001
	5	18.37± 1.02	17.50± 0.00	18.90± 0.00	17.50± 0.00	18.06^{b}± 0.25			
	10	17.50± 0.00	17.85± 0.00	18.37± 1.02	18.20± 1.02	17.98^{c}± 0.51			
	15	16.62± 0.00	18.20± 1.02	17.67± 1.02	18.72± 0.00	17.80^{d}± 0.51			
	Mean	26.01^{b}±1.02	25.7^{c}± 0.25	25.26^{d}± 1.02	26.68^{a}± 1.02				
EE%	0	9.95± 0.00	9.65± 5.13	9.35± 5.13	8.6± 5.13	9.38^{a}± 3.84			
	5	6.00± 0.00	5.01± 0.00	5.75± 0.00	6.3± 2.56	5.76^{d}± 0.64			
	10	8.00± 0.00	8.66± 0.00	6.3± 2.56	7.75± 0.00	7.67^{c}± 0.64	<0.0001	<0.0001	<0.0001
	15	8.00± 0.00	9.75± 0.00	6.80± 2.56	11.00± 0.00	8.88^{b}± 0.64			
	Mean	7.98^{c}± 0.00	8.26^{b}± 1.28	7.05^{d}± 2.56	8.41^{a}± 1.92				
Ash%	0	0.83± 3.20	0.83± 0.00	0.83± 0.00	0.83± 6.40	0.83^{a}± 4.00			
	5	0.81± 0.00	0.93± 6.40	1.12± 6.41	1.06± 6.41	0.98^{c}± 4.80			
	10	1.12± 6.41	1.16± 6.41	1.31± 6.41	1.88± 0.00	1.37^{b}± 4.80	<0.0001	<0.0001	<0.0001
	15	1.53± 6.41	1.49± 0.00	1.40± 6.41	1.35± 6.41	1.44^{a}± 5.12			
	Mean	1.07^{d}± 4.00	1.10^{c}± 3.52	1.17^{b}± 6.40	1.28^{a}± 3.20				

The mean in each row having different superscripts varies significantly at values $P < 0.05$. Again, mean values with the same superscript in each row did not differ significantly at $P>0.05$ T_0 = control, T_1 = 0.2% orange peel extract, T_2 = 0.3% orange peel extract, T_3 = 0.4% orange peel extract, DI = Day Intervals, Treat = Treatment, T*DI = Interaction of Treatment and Day Intervals.

Physicochemical properties

pH

The range of overall observed raw pH at different treatments was 6.61 to 6.68% (Table 3). The different superscript observed from the treatments indicates there were significant differences ($p<0.05$) in raw pH among these treatments. The data showed a slight increase in the raw pH values and a decrease in the acidity values for all samples. Among these four treatments, the most preferable raw pH was observed in the T_0 group. The highest amount of raw pH indicates this product is more preferable for consumers' health than other treatment groups. The range of overall observed values for different days of intervals of raw pH was 6.51 to 6.95% (Table 3). The most preferable raw pH was observed from day 0, and the least preferable raw pH content was observed from day 15. The decrease in the raw pH values was lower in the untreated samples than the treated ones due to the effect of natural antioxidants, which retarded the formation of free fatty acids. The increasing raw pH was probably due to the secretions of microorganisms in the quail meatballs. Bacteria and mold tend to increase with increasing storage time, and they secrete components that affect the increasing raw pH. Similar results have also been found in the study of antioxidant treatments during storage time using a mixture of BHA and BHT in precooked pork patties (Bithi et al., 2020; Disha et al., 2020; Sarker et al., 2021). Spoilage of various dried meat products by mold growth can be inhibited or delayed by reducing the pH (Azad et al., 2022b; Rahman et al., 2023). There was a gradual increase in pH in all samples during storage, probably due to the accumulation of basic compounds such as ammonia derived from microbial action (Saba et al., 2018).

Cooking Loss (CL)

The range of overall observed cooking loss at different treatments was 26.24 to 31.49% (Table 3). The different superscripts were observed in all treatment groups, and CL content significantly (P<0.05) differed compared to the control. Among these three treatments, the most preferable cooking loss was observed in the T_0 group (0% orange peel extract) compared to the other groups. The lowest amount of cooking loss indicates this product is more preferable for consumers' choices than other treatment groups. The cooking loss decreased with the increased storage period. The least preferable cooking loss was observed on the 15th day, and the most preferable cooking loss was observed on the first day of observation. Cooking yield is an important piece of data that is used by the meat industry to predict the behavior of their products during processing (Hashem et al., 2022 & 2023; Hossain et al., 2023). The cooking yield of the Kung-Wan significantly decreased with higher levels of natural antioxidant extract (Hsu and Sun, 2006). The meat also tended to shrink during the cooking process due to the denaturation of meat protein; the loss of water and fat also contributed to the shrinking process (Serdaroglu et al., 2005).

Free Fatty Acid Value (FFA)

The range of overall observed FFA values at different treatments was 0.42% (Table 3). The range of FFA at different days of intervals was 0.28 to 0.56% (table 3). The FFA value increased with storage time. The most preferable FFA was observed on the first day and the least preferable FFA was observed on the 15th day of observation. Generally, the control samples and those with antioxidant treatments were slightly different. FFAs are products of the enzymatic or microbial degradation of lipids (Das et al., 2022; Khatun et al., 2022). Antioxidants have been utilized for many years to prevent or delay the autoxidation process. Antioxidants have the ability to prevent or reduce the oxidative damage of a tissue indirectly by enhancing the natural defenses of cells and/or directly by scavenging free radical species (Verma et al., 2013).

Peroxide Value (POV)

The range of overall observed peroxide values at different treatment levels was 1.65 to 1.83 (Table 3). POV value throughout the study was increasing with antioxidant doses. Among these four treatments, the most preferable POV was observed in the T_0 group. The lowest POV indicates this product is most preferable for consumers' health. The highest POV indicates this product is less preferable. The range of overall observations for different days of intervals of POV was 1.66 to 1.87 (Table 3). During storage, the peroxide value increased in all treatments. However, antioxidant treatments, generally, can minimize the POV in the food sample during storage compared with the control. Novelli et al. (1998) also showed increasing peroxide values with longer storage time in a sausage product (Salame). Georgantelis et al. (2007) found the peroxide value of frozen (-18 °C) beef burgers treated with rosemary to increase at different storage days, respectively.

Thiobarbituric Acid Value (TBARS)

The range of overall observed TBARS values at different treatment levels was 0.28 to 0.30 (Table 3). Among these four treatments, the most preferable TBARS value was observed in T_3. The range of overall observed values for different days of intervals of TBARS value was 0.08 to 0.09 (Table 3). The TBARS values increased significantly (p<0.05) during storage for all treatments. Some researchers reported that the addition of edible plant extracts significantly lowered TBARS values in fresh ground beef compared with non-treated samples (Kim et al., 2013). Similar findings were reported by Nassu et al. (2003) in goat meat sausage during refrigerated storage. Another finding reported that the restructured mutton slices treated with grape seed extract had significantly (P<0.05) lower TBARS values and free fatty acids (FFA%) compared to the control (Reddy et al., 2013).

Table 3. Effect on pH, cooking loss, FFA, POV and TBARS value of chevon using orange peel extract

Parameters	DI	Treatments				Mean	Level of significance		
		T_0	T_1	T_2	T_3		Treat.	DI	T*DI
pH	0	7.09± 0.00	6.9± 5.12	6.98± 0.00	6.85± 5.12	6.95^{a}± 2.56			
	5	6.76± 5.12	6.54± 2.56	6.42± 5.12	6.50± 0.00	6.55^{d}± 3.20			
	10	6.5± 0.00	6.52± 0.00	6.49± 5.12	6.55± 2.56	6.52^{c}± 1.92	<0.0001	<0.0001	<0.0001
	15	6.37± 2.56	6.59± 0.00	6.55± 2.56	6.60± 5.12	6.51^{d}± 2.56			
	Mean	6.68^{a}± 1.92	6.63^{b}± 1.92	6.61^{d}± 3.20	6.62^{c}± 3.20				
Cooking Loss%	0	22.42± 1.02	29.39± 0.00	33.09± 2.05	30.68± 1.02	28.90^{b}± 1.02	<0.0001	<0.0001	<0.0001
	5	30.90±1.02	29.08± 0.00	35.52± 2.05	28.30± 2.05	30.95^{a}± 1.28			
	10	27.60± 0.00	28.15± 1.02	31.20± 0.00	26.97± 2.05	28.48^{c}± 0.76			
	15	24.03± 2.05	28.47± 2.05	26.15± 0.00	23.90± 2.05	25.64^{d}± 1.53			
	Mean	26.24^{d}±1.02	28.77^{b}±0.76	31.49^{a}± 1.02	27.46^{a}± 1.79				
FFA%	0	0.282± 1.60	0.282± 1.60	0.282± 1.60	0.282± 1.60	0.282^{b}± 1.60			
	5	0.282± 1.60	0.282± 1.60	0.282± 1.60	0.282± 1.60	0.282^{b}± 1.60			
	10	0.564± 3.20	0.564± 3.20	0.564± 3.20	0.564± 3.20	0.564^{a}± 3.20	<0.0001	<0.0001	<0.0001
	15	0.564± 3.20	0.564± 3.20	0.564± 3.20	0.564± 3.20	0.564^{a}± 3.20			
	Mean	0.42^{a}± 2.40	0.42^{a}± 2.40	0.42^{a}± 2.40	0.42^{a}± 2.40				
POV%	0	1.63± 0.00	1.66± 6.41	1.66± 6.41	1.70± 6.41	1.66^{d}± 4.80			
	5	1.66± 6.41	1.66± 6.41	1.70± 6.41	1.83± 0.00	1.71^{c}± 4.80			
	10	1.66± 6.41	1.73± 1.28	1.76± 6.41	1.86± 6.41	1.75^{b}± 5.12	<0.0001	<0.0001	<0.0001
	15	1.66± 6.41	1.96± 0.00	1.93± 6.41	1.96± 0.00	1.87^{a}± 3.20			
	Mean	1.65^{d}± 4.80	1.75^{c}± 3.52	1.76^{b}± 6.41	1.83^{a}± 3.20				
TBARS%	0	0.07± 4.00	0.08± 4.00	0.08± 8.01	0.08± 8.01	0.08^{c}± 6.00			
	5	0.08± 4.00	0.08± 4.00	0.08± 8.01	0.08± 4.00	0.08^{c}± 5.00			
	10	0.87± 3.20	0.90± 3.20	0.91± 3.20	0.93± 3.20	0.90^{a}± 3.20			
	15	0.90± 8.01	0.90± 8.01	0.09± 8.01	0.10± 8.01	0.90^{b}± 8.01			
	Mean	0.28^{d}± 4.80	0.29^{d}± 4.80	0.29^{b}± 6.80	0.30^{a}± 5.80				

The mean in each row having different superscripts varies significantly at values P < 0.05. Again, mean values with the same superscript in each row did not differ significantly at P>0.05 T_0 = control, T_1 = 0.2% orange peel extract, T_2 = 0.3% orange peel extract, T_3 = 0.4% orange peel extract, DI = Day Intervals, Treat = Treatment, T*DI = Interaction of Treatment and Day Intervals.

Microbial assessment

Total Viable Count (TVC)

The initial value of TVC for fresh chevon (chevon not frozen and thawed) was 6.77 log CFU/g chevon, indicating good quality chevon (Table 4). The range of overall observed aerobic plate count from the chevon sample was 6.76–7.06 logCFU/g at different treatment levels (table 4). The different superscripts observed from different treatments indicate there were significant differences in TVC values among these four treatment groups. Among the four treatments, the plate count in the T_2 sample (7.06 logCFU/g) was significantly higher than in the samples treated with natural antioxidants (Table 4). The lower TVC value indicates this product is most preferable for consumers' health. The range of overall observed TVC values for different days of intervals was 6.73 to 6.94 (Table 4). During storage, the TVC value was increased. The antioxidant compounds blocked the deterioration of fat and helped prevent the metabolism of fat by bacteria. As a result, bacterial growth was lower in beef meatballs treated with antioxidants. Similar findings were reported that the use of fruit by-products significantly ($p< 0.05$) reduced total bacterial, lactic acid bacteria, and total mold and yeast counts and extended the shelf-life of ground meat compared with the control (Hanan et al., 2013; Disha et al. 2020). Similar results have been reported by many researchers studying the effects of natural and synthetic antioxidants on bacteria. Of the various spice combinations examined, a mixture of rosemary and liquorice extracts held particular promise; this combination exhibited strong effects against Listeria monocytogenes and several other meat spoilage bacteria. However, it is also possible that the effectiveness of the antimicrobial extracts could be reduced due to physical interactions with the food matrix (Fernández-López et al., 2005).

Total Coliform Count (TCC)

The initial TCC of fresh chevon (chevon not frozen and thawed) was 4.35 log CFU/g chevon (Table 4). At different levels of treatment, the total number of coliforms that were seen in the chevon samples ranged from 4.35 to 4.39 logCFU/g (Table 4). Table 4 shows that the total coliform count was significantly higher in the control sample (4.35 logCFU/g) than in the samples treated with natural antioxidants. The lower TCC value indicates this product is most preferable for consumers' health. The range of overall observed values for different days and intervals of TCC values was 4.30 to 4.44. During storage, the TCC value was increased. Zivanovic et al. (2005) studied the frozen storage stability of antioxidant-treated raw, restructured beef steaks made from mature cows. Another similar finding was observed by Kodal et al. (2014). They found that coliform counts in all samples gradually decreased with storage time.

Total Yeast-Mould Count (TYMC)

The different superscripts observed in all treatment groups indicate that there were significant differences ($p<0.05$) in TYMC values among these treatment groups. Among the four treatments, the total yeast-mold count in the control sample (5.05 logCFU/g) was significantly lower than other treatments (Table 4). The lower TYMC value indicates this product is most preferable for consumers' health. The range of overall observed values for different days of intervals of TYMC value was 5.00 to 5.14 (Table 4). Fernández-López et al. (2005) reported on the results of a research study related to antimicrobials in beef meatballs. They noted that the presence of mold and yeast was not detected in any cooked meatball samples. Some researchers have reported the efficacy of plant EOs as antimicrobial agents against food-borne pathogens and spoilage microflora in meat (Das et al., 2022; Azad et al., 2022b).

Table 4. Effect on Microbial parameters of chevon using orange peel extract

Parameters	DI	Treatments				Mean	Level of significance		
		T_0	T_1	T_2	T_3		Treat.	DI	T*DI
TVC	0	6.6± 0.00	6.69± 0.00	7.77± 2.56	6.69± 0.00	6.94^{a}± 0.64			
Log cfu/gm	5	6.77± 2.56	6.68± 2.56	6.69± 5.12	6.77± 2.56	6.73^{d}± 3.20			
	10	6.84± 2.56	6.77± 2.56	6.88± 2.56	6.91± 5.12	6.85^{c}± 3.20	<0.0001	<0.0001	<0.0001
	15	6.85± 2.56	6.89± 2.56	6.90± 2.56	6.95± 2.56	6.90^{d}± 2.56			
	Mean	6.77^{c}± 1.92	6.76^{d}± 1.92	7.06^{a}± 3.20	6.83^{b}± 2.56				
TCC	0	4.27± 0.00	4.30± 0.00	4.30± 0.00	4.43± 2.56	4.30^{d}± 0.64	<0.0001	<0.0001	<0.0001
Log cfu/gm	5	4.32± 2.56	4.36± 2.56	4.39± 0.00	4.38± 2.56	4.36^{c}± 1.92			
	10	4.38± 2.56	4.39± 0.00	4.43± 2.56	4.41± 2.56	4.40^{b}± 1.92			
	15	4.43± 2.56	4.43± 2.56	4.44± 2.56	4.46± 0.00	4.44^{a}± 1.92			
	Mean	4.35^{d}± 1.92	4.37^{c}± 1.28	4.39^{b}± 1.28	4.39^{a}± 1.92				
YMC	0	4.95± 2.56	5.02± 2.56	5.06± 2.56	5.00± 0.00	5.00^{d}± 1.92			
Log cfu/gm	5	5.02± 2.56	5.04± 2.56	5.07± 2.56	5.10± 2.56	5.06^{c}± 2.56			
	10	5.14± 2.56	5.11± 2.56	5.16± 0.00	5.17± 0.00	5.14^{a}± 1.28	<0.0001	<0.0001	<0.0001
	15	5.07± 0.00	5.11± 2.56	5.14± 2.56	5.17± 0.00	5.12^{b}± 1.28			
	Mean	5.05^{d}± 1.92	5.07^{c}± 2.56	5.11^{b}± 1.92	5.11^{a}± 0.64				

The mean in each row having different superscripts varies significantly at values $P < 0.05$. Again, mean values with the same superscript in each row did not differ significantly at $P>0.05$ T_0 = control, T_1 = 0.2% orange peel extract, T_2 = 0.3% orange peel extract, T_3 = 0.4% orange peel extract, DI = Day Intervals, Treat = Treatment, T*DI = Interaction of Treatment and Day Intervals.

Conclusion

There were gradually decreasing color and odor scores for all samples with increasing storage days. Chevon can be preserved for 15 days using different levels of orange peel extract. Highly significant differences were observed in the 0.4% orange peel extract group compared to the control group. Overall results in sensory evaluation, physicochemical properties, biochemical analysis, and microbial assessment indicate 0.4% orange peel extract was more acceptable and nutrient quality was satisfactory for consumer health. So, it can be recommended that 0.4% orange peel extract be used for up to 15 days of chevon preservation.

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