COMPARATIVE STUDY OF CONVENTIONAL AND VACUUM PACKAGING ON THE QUALITY OF TURKEY BREAST STORED UNDER REFRIGERATION

D.I. Marcu[1], L. Stef[1], N. Corcionivoschi[1,2], I. Pet[1], C. Julean[1], D. Dronca[1], M. Neagu-Nicula[1], C. Zoican[1], L. E. Olariu-Jurca[1], A. Marcu[1*]

[1]Faculty of Bioengineering of Animal Resources, University of Life Sciences"King Mihai I" from Timisoara, Calea Aradului, No.119, 300645, Timisoara, Romania
[2]Bacteriology Branch, Veterinary Sciences Division, Agri-Food and Biosciences Institute, Belfast BT4 3SD, Northern Ireland, UK

Abstract

Our study investigated the influence of packaging method and storage temperature on the stability and shelf life of turkey meat under refrigeration. The samples consisted of turkey breast packed in clipped polyethylene bags (A) and vacuum-packed bags (B), then stored at temperatures between 2 and 4°C. Quality was evaluated over a 10-day period through organoleptic examination and physicochemical determinations (pH, volatile nitrogen compounds, and water-holding capacity). The results showed that vacuum packaging, combined with lower storage temperature (2°C), had a favorable effect on sensory attributes and physicochemical indicators. Thus, shelf life was extended, and both sensory and physicochemical quality were better maintained compared to conventional packaging. In addition, vacuum-packed samples exhibited lower water-holding capacity values.

Key words: *turkey breast, water holding capacity, pH, packaging, refrigeration*

INTRODUCTION

Turkey meat is a highly nutritious food, and due to this, it is highly regarded by consumers. Turkey meat nutrients comprise high biological value protein, indispensable amino acids, vitamins, and minerals which are required to maintain health. Turkey meat has lower fat content than the meat of other animals [1, 2]. Due to its high nutritive value, mild flavor, and healthiness, turkey meat holds a particular place in today's human diet.

Because of its high water and protein content, turkey meat is a highly perishable item that undergoes microbiological and physicochemical changes during storage [2, 3]. Meat quality and shelf life are determining parameters influencing consumer acceptance and food safety. Maintaining the physicochemical and sanitary parameters within the desirable ranges during refrigerated storage is still a major challenge to the meat industry [3-6].

To extend the shelf life of perishable products, packaging methods are also seen as an adequate physical barrier against external contamination, gas exchange, and water loss [7]. In the meat industry, the most commonly used packaging methods are: vacuum packaging, modified atmosphere packaging, controlled atmosphere packaging, packaging in a tray covered with shrink wrap, as well as modern packaging systems (intelligent and active packaging) [6-8]. These types of packaging have a positive effect on the quality of the raw meat because they provide a protective barrier against external factors, extending shelf life, increasing safety, and preserving

*Corresponding author: adelamarcu@usvt.ro
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sensory characteristics [6-10]. However, in each of packaging systems certain changes take place during storage of the product. In the meat industry, the selection of packaging materials and technology should be adapted to the properties of the product, and this is particularly important in the case of poultry meat [7].

Packaging in polyethylene bags sealed by clip-on (conventional packaging) offers little protection during storage, as the presence of air facilitates the oxidation of unsaturated fats and the development of microorganisms [10]. On the other hand, removal of air from the package, for example, vacuum packaging, reduces the oxygen level, which limits oxidative reactions and microbial growth [11]. Therefore, vacuum packaging maintains meat sensory qualities (color, flavor, and texture) for a longer period compared to the conventional methods.

Refrigeration temperature is a further key factor influencing meat stability [12]. Storage temperature has a significant impact on both microbial growth and enzyme reactions [12, 13], which determines the rate of spoilage. Even small variations within the recommended range of 2 to 4°C can have a pronounced impact on product quality and shelf life [12-15].

Water-holding capacity (WHC) is one of the useful technological characteristics of meat quality since it defines the ability of the muscle tissue to retain water within its structure following handling, storage, and processing [16, 17]. WHC significantly affects the texture, juiciness, and overall appearance of the meat and is regulated by pH, packaging, temperature, and storage time [16, 18]. Lower WHC increases drip losses, which has a negative effect on the sensory quality as well as yield of processing [19].

The aim of this study was to compare the effects of packaging methods (vacuum and traditional) and storage temperatures on the quality and stability of chilled turkey meat. The quality of meat was determined through organoleptic and physicochemical evaluation, including measurements of pH, volatile basic nitrogen, and water-holding capacity. The study has also aimed to analyse how vacuum packaging contributes to maintaining the sensory and technological quality of meat during the entire period of storage.

MATERIAL AND METHODS

The research material consisted of 10 turkey breast muscles, raised in a conventional system and slaughtered at the age of 8 months (Figure 1).

Immediately after evisceration (20–30 minutes after slaughter), carcasses were cut up, the breast was deboned, and each pectoral muscle was divided into four equal parts. The 40 muscle pieces obtained after sectioning were randomly distributed into four equal groups (10 samples per group). Each sample was divided into six slices of approximately 100 g each. The samples prepared in this way were vacuum-packed for groups T2 and T4, while for T1 and T3, the samples were places in polyethylene bags.

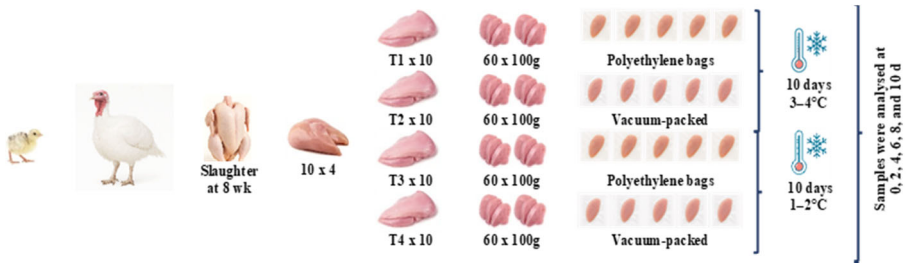

Figure 1. Experimental design

For the next 10 days, all samples were kept cold at temperatures of 1–2°C for T3 and T4, and 3–4ºC for groups T1 and T2.

Meat quality parameters, including pH, easily hydrolysable nitrogen (mg NH_3/100 g), thiobarbituric acid (TBA, mg malondialdehyde/kg), and water-holding capacity (WHC, %) were determined on day 0 and during the refrigerated storage period on days 2, 4, 6, 8, and 10.

pH was measured directly in the pectoral muscle with an FC 232D glass electrode connected to a Hanna HI99163 portable meat pH meter. The pH was measured at three different places on each sample. The electrode was also cleaned after each sample and calibrated frequently.

Easily hydrolysable nitrogen, expressed as mg NH_3/100 g, was determined according to the STAS 9065/7-74 method.

To determine the degree of lipid oxidation, the thiobarbituric acid (TBA) method was used, known as the TBARS (Thiobarbituric Acid Reactive Substances) test. this method is based on the detection of malonaldehyde (MDA), expressed in mg malondialdehyde/kg sample [20]. Thus, 0.5 g of meat was homogenized in 10 mL of a mixture containing TBA (0.375 g/100 mL), TCA (15 g/100 mL) and HCl (0.25 mol/L). The mixture was heated in a boiling water bath for 10 minutes and then cooled with tap water.

In the presence of lipid oxidation products such as MDA, a pink-colored complex is formed as a result of the reaction with TBA. The degree of lipid oxidation was quantified spectrophotometrically by measuring the absorbance of this complex at a wavelength of 532 nm. The TBARS value was calculated based on the standard curve of malonaldehyde and expressed as mg MDA/kg sample.

The water holding capacity (WHC) of meat samples was determined using the filter paper press method [17]. A meat sample of 0.3–1 g was placed on a filter paper and pressed between two Plexiglas plates under constant pressure for 5 minutes. After pressing, the area of the meat spot and the expressed juice were outlined and measured. The WHC was calculated as the ratio between the area of the meat sample and the total moisture area, and the results were expressed as a percentage of the total sample water.

Statistical analysis: The raw data obtained from the measurements were processed using biostatistical methods in Microsoft Excel.

Data were analyzed using repeated measures ANOVA, followed by the Tukey post-hoc test for multiple comparisons, using the online platform Social Science Statistics. Statistical significance was set at $p \leq 0.05$, and differences between means were considered significant at this probability level.

RESULTS

Table 1 presents the pH values throughout the storage period of the samples at refrigeration temperatures (3–4°C, for T1 and T2, and 1–2°C, for T3 and T4, respectively).

The first determination was performed ≈30 minutes after evisceration, representing the initial pH of the meat. Thus, the initial pH values ranged between 6.349 to 6.455, which are considered normal for pectoral muscle immediately after slaughter.

After two days of refrigerated storage, the mean pH values ranged from 5.752 (T1) and 6.206 (T4). The analysis of variance Anova test indicated significant differences between samples ($p < 0.00001$).

According to the Tukey HSD test, significant differences ($p \leq 0.05$) were found between T1 and T2, and between T3 and T4, while highly significant differences ($p \leq 0.001$) were recorded between T1 and T3, T1 and T4, and T2 and T4, respectively.

However, no statistically significant differences ($p > 0.05$) were observed between T2 and T3.

Table 1. pH values in turkey breast samples during refrigerated storage

Storage time	T1 (Mean ± SD)	T2 (Mean ± SD)	T3 (Mean ± SD)	T4 (Mean ± SD)	*P* value
N	10	10	10	10	
Initial	6.455 ± 0.1745^{a}	6.433 ± 0.1247^{a}	6.349 ± 0.1958^{a}	6.412 ± 0.1407^{a}	p = 0.37383
2 Days	5.752 ± 0.0907^{a}	5.932 ± 0.1786^{b}	6.028 ± 0.1433^{b}	6.206 ± 0.0923^{c}	p< 0.00001
4 Days	5.551 ± 0.1311^{a}	5.662 ± 0.0774^{ab}	5.758 ± 0.0747^{b}	5.858 ± 0.1074^{c}	p = 0.00200
6 Days	5.903 ± 0.1480^{a}	5.856 ± 0.1246^{a}	5.788 ± 0.0909^{ab}	5.698 ± 0.0847^{b}	p< 0.00001
8 Days	6.261 ± 0.0964^{a}	6.116 ± 0.0828^{b}	6.009 ± 0.1017^{c}	5.931 ± 0.0667^{c}	p< 0.00001
10 Days	6.415 ± 0.0796^{a}	6.306 ± 0.0853^{b}	6.253 ± 0.0476^{bc}	6.088 ± 0.0553^{c}	p< 0.00001

Different superscript letters in the same row indicate significant differences ($p \leq 0.05$), according to the Tukey HSD test. Legend: T1 and T2 – samples packed in polyethylene bags (3–4°C); T3 and T4 – vacuum-packed samples (1–2°C); SD – standard deviation.

These results show lower pH values in the T1 (samples packed in polyethylene bags and stored at 3–4°C), compared to T4, which were vacuum-packed and stored at 1–2°C, showing the highest average pH value among all experimental variants. Samples T2 and T3 showed intermediate pH values.

After four days of refrigerated storage, the Tukey HSD test revealed highly significant differences ($p \leq 0.001$) between T1–T3, T1–T4 and T2–T4, while no significant differences ($p > 0.05$) were observed between T1–T2, T2–T3 and T3–T4. These results indicate a progressive reduction in the differences for pH values from treatment T1 (samples packaged in polyethylene and stored at 3–4°C) to T4 (samples vacuumed and stored at 1–2°C), which showed the highest average pH value, respectively the lowest rate of reduction for this indicator. The intermediate values recorded for treatments T2 and T3 suggest a combined influence of the type of packaging and storage temperature on the pH value during the storage period.

After six days of refrigerated storage, the Tukey HSD test revealed significant differences between treatments T1–T4 ($p \leq 0.01$) and T2–T4 ($p \leq 0.05$), while no significant differences ($p > 0.05$) were observed among the other comparisons (T1–T2, T1–T3, T2–T3, T3–T4). The pH values showed a slight upward trend from T1 (5.903 vs. 5.551) to T2 (5.856 vs. 5.662) and T3 (5.788 vs. 5.758), whereas the opposite trend was observed in T4, which recorded a reduction of approximately 0.160 pH units.

At eight days of refrigerated storage the Tukey HSD test revealed significant differences among all treatments, except for T3–T4 ($p > 0.05$). The highest pH values were recorded in treatment T1 (6.261), followed by T2 (6.116), while the lowest values were observed in T3 (6.009) and T4 (5.931).

At the end of the experimental period, significant differences were still observed among most treatments, except for the T2–T3, where no significant differences were found ($p > 0.05$). The mean pH values recorded a progressive decrease from T1 (6.42) to T4 (6.09), with highly significant differences ($p \leq 0.001$) between the extreme treatments

Table 2 shows the variations for easily hydrolysable nitrogen content mg (NH_3/100 g) during the storage period of the samples at refrigeration temperatures (1-4°C).

Immediately after evisceration, the mean values of easily hydrolysable nitrogen (NH_3) in turkey pectoral muscle were approximately 16.125 mg NH_3/100 g.

After two days of cold storage, NH_3 values ranged from 18.788 mg NH_3/100 g in T4 to 21.555 mg NH_3/100 g in T1. Analysis of variance (ANOVA) revealed highly significant differences between samples

($p < 0.00001$). According to the Tukey HSD test, very highly significant differences ($p \leq 0.001$) were found between T1–T2, T1–T4 and T3–T4; significant differences ($p \leq 0.05$) between T2–T3, while no significant differences ($p > 0.05$) were observed between T1–T3 and T2–T4.

The highest NH_3 values were recorded in T1 (samples packed in polyethylene bags and stored at 3–4°C), followed by T3, while the lowest values were observed in T4 (samples vacuum-packed and stored at 1–2°C). These results suggest a higher intensity of enzymatic activity at higher temperatures and in polyethylene bags.

After four days of cold storage, the values of NH3 (mg NH_3/100 g) varied between 20.088 (T4) to 25.055 (T1). Analysis of variance using the Tukey HSD test, showed significant differences ($p \leq 0.05$) between the T1–T2, T1–T4, T3–T4 and T1–T3. No significant differences were recorded between T2–T3 and T2–T4 ($p > 0.05$).

After six days of cold storage, the values of easily hydrolysable nitrogen (mg NH_3/100 g) increased significantly, ranging from 23.635 (T4) to 28.455 (T1). According to the Tukey HSD test, significant differences ($p \leq 0.05$) were observed between the T1–T2, T1–T4, T2–T3 and T3–T4 treatments, while no significant differences were recorded between T1–T3 and T2–T4 ($p > 0.05$).

After eight days of cold storage, readily hydrolysable nitrogen values (mg NH_3/100 g) showed a pronounced increase, ranging from 26.835 in T4 to 34.855 in T1. The results show that, except for the T2–T4 combination, the differences between all other treatments (T1–T2, T1–T3, T1–T4, T2–T3, T3–T4) were statistically significant for $p \leq 0.05$, which highlights the significant impact of storage conditions on the intensity of metabolic processes in post-slaughter muscle.

Table 2. NH_3 (mg NH_3/100 g) values in turkey breast samples during refrigerated storage

Storage time	T1 (Mean ± SD)	T2 (Mean ± SD)	T3 (Mean ± SD)	T4 (Mean ± SD)	*P* value
N	10	10	10	10	
Initial	16.055 ± 1.8718^{a}	16.155 ± 1.8143^{a}	16.255 ± 1.8425^{a}	16.155 ± 1.7976^{a}	$p = 0.99613$
2 Days	21.555 ± 0.6222^{a}	19.650 ± 1.2573^{b}	20.844 ± 0.5200^{a}	18.788 ± 0.7316^{cb}	$p < 0.00001$
4 Days	25.055 ± 1.8164^{a}	21.350 ± 1.3303^{b}	23.044 ± 1.6424^{cb}	20.088 ± 0.9453^{db}	$p < 0.00001$
6 Days	28.455 ± 1.5389^{a}	24.771 ± 1.0184^{b}	26.875 ± 1.3419^{a}	23.635 ± 1.3121^{b}	$p < 0.00001$
8 Days	34.855 ± 2.2109^{a}	27.171 ± 1.9535^{b}	30.431 ± 1.6744^{c}	26.835 ± 1.4420^{db}	$p < 0.00001$
10 Days	42.955 ± 2.9083^{a}	33.371 ± 2.5105^{b}	35.731 ± 2.9240^{cb}	31.335 ± 3.5261^{b}	$p < 0.00001$

Different superscript letters in the same row indicate significant differences ($p \leq 0.05$), according to the Tukey HSD test. Legend: T1 and T2 – samples packed in polyethylene bags (3–4°C); T3 and T4 – vacuum-packed samples (1–2°C); SD – standard deviation.

At the end of the storage period (10 days), NH_3 values reached maximum levels in all experimental variants, ranging between 31.335 mg NH_3/100 g in T4 and 42.955 mg NH_3/100 g in T1. Also, the Tukey HSD test showed highly significant differences ($p \leq 0.001$) between treatments T1–T2, T1–T3 and T1–T4, significant differences ($p \leq 0.05$) between T3–T4, while no significant differences ($p > 0.05$) were found between T2–T3 and T2–T4.

Thiobarbituric acid (TBA), expressed in mg malondialdehyde per kilogram of meat (mg MDA/kg), was used as an indicator of the lipid oxidation during storage. The evolution of this parameter during the 10 days of refrigeration temperature storage is presented in Table 3.

Thiobarbituric acid (TBA) values, expressed in mg malondialdehyde per kilogram of sample (mg MDA/kg), were determined as an indicator of lipid oxidation during cold storage. Initial TBA values were similar in the four experimental variants, ranging between 0.251 and 0.257 mg MDA/kg, with no statistically significant differences (p = 0.88889), but after two days of storage, a slight increase in TBA values was observed in all samples, however, the differences between treatments were not statistically significant (p = 0.08947).

Table 3. TBA (mg MDA/kg) values in turkey breast samples during refrigerated storage

Storage time	T1 (Mean ± SD)	T2 (Mean ± SD)	T3 (Mean ± SD)	T4 (Mean ± SD)	*P* value
N	10	10	10	10	
Initial	0.257 ± 0.0164^{a}	0.252 ± 0.0333^{a}	0.251 ± 0.0057^{a}	0.251 ± 0.0129^{a}	p = 0.88889
2 Days	0.274 ± 0.0097^{a}	0.267 ± 0.0211^{a}	0.263 ± 0.0106^{a}	0.258 ± 0.0114^{a}	p = 0.08947
4 Days	0.287 ± 0.0221^{a}	0.271 ± 0.0208^{ab}	0.273 ± 0.0134^{ab}	0.262 ± 0.0114^{b}	p = 0.02575
6 Days	0.331 ± 0.0597^{a}	0.290 ± 0.0194^{ab}	0.278 ± 0.0199^{b}	0.272 ± 0.0175^{b}	p = 0.00185
8 Days	0.407 ± 0.0645^{a}	0.299 ± 0.0256^{b}	0.302 ± 0.0316^{cb}	0.280 ± 0.0105^{db}	p < 0.00001
10 Days	0.507 ± 0.0853^{a}	0.309 ± 0.0351^{b}	0.316 ± 0.0353^{cb}	0.289 ± 0.0152^{db}	p < 0.00001

Different superscript letters in the same row indicate significant differences ($p \leq 0.05$), according to the Tukey HSD test. Legend: T1 and T2 – samples packed in polyethylene bags (3–4°C); T3 and T4 – vacuum-packed samples (1–2°C); SD – standard deviation.

After four days, higher TBA values were recorded in T1 (0.287 mg MDA/kg) while the lowest were observed in T4 (0.262 mg MDA/kg). The Tukey HSD test showed that T1 recorded significantly higher values compared to T4, while T2 and T3 presented intermediate values that did not differ significantly from the other treatments.

After six days of storage, the differences became more pronounced (p = 0.00185). TBA values increased in all samples, with the highest values found in T1 (0.331 mg MDA/kg), followed by T2 (0.290 mg/kg), while the lowest were observed in the samples T3 and T4, stored at 1–2°C.

After eight days, highly significant differences were recorded (p < 0.00001), with values ranging from 0.280 mg MDA/kg (T4) to 0.407 mg MDA/kg (T1). This trend was maintained until the end of the storage period (day 10), when TBA values reached their highest levels: 0.507 mg MDA/kg at T1 and the lowest average values at T4 (0.289 mg/kg), with significant differences between T1-T2, T1-T3 and T1-T4 (p < 0.00001).

Overall, TBA values increased steadily during storage, indicating progressive lipid oxidation processes. The results show that samples stored in polyethylene bags at 3–4°C (T1) showed a higher oxidation rate compared to vacuum-packed samples stored at 1–2°C (T4). This confirms that vacuum packaging and lower temperatures significantly reduce lipid oxidation and prolong the oxidative stability of turkey meat during cold storage.

The mean values of water holding capacity (WHC, %) in turkey pectoral muscle during cold storage are presented in Table 4. Initial values of water holding capacity (WHC) were similar among all treatments, ranging from 68.135% to 68.395%, with no statistically significant differences. After two days of storage, WHC values decreased significantly in all samples, with the lowest values recorded for T2 (52.753%) and T4 (53.853%), while T3 (65.203%) maintained the best water retention capacity. Tukey HSD test revealed significant differences ($p \leq 0.05$) among all treatments, except for the combination between T2 and T4.

Table 4. Water holding capacity (WHC, %) of turkey breast samples during refrigerated storage

Storage time	T1 (Mean ± SD)	T2 (Mean ± SD)	T3 (Mean ± SD)	T4 (Mean ± SD)	*P* value
N	10	10	10	10	
Initial	68.135 ± 1.4367^{a}	68.395 ± 0.8288^{a}	68.303 ± 0.7482^{a}	68.186 ± 0.9943^{a}	$p < 0.00001$
2 Days	60.835 ± 5.2941^{a}	52.753 ± 2.6165^{b}	65.203 ± 3.3387^{c}	53.853 ± 2.1881^{db}	$p < 0.00001$
4 Days	55.835 ± 2.3501^{a}	50.153 ± 3.1811^{b}	60.503 ± 4.1701^{c}	50.753 ± 1.4995^{db}	$p < 0.00001$
6 Days	52.135 ± 1.9510^{a}	49.553 ± 2.8965^{a}	56.103 ± 3.8524^{b}	49.753 ± 0.8012^{a}	$p < 0.00001$
8 Days	50.498 ± 1.7388^{a}	44.900 ± 3.2035^{b}	54.504 ± 2.7914^{c}	45.285 ± 1.7933^{db}	$p < 0.00001$
10 Days	49.312 ± 2.3600^{a}	43.151 ± 3.8642^{b}	52.524 ± 2.0581^{a}	43.796 ± 2.2870^{db}	$p < 0.00001$

Different superscript letters in the same row indicate significant differences ($p \leq 0.05$), according to the Tukey HSD test. Legend: T1 and T2 – samples packed in polyethylene bags (3–4°C); T3 and T4 – vacuum-packed samples (1–2°C); SD – standard deviation.

At four days, a similar trend was observed, with decreases in WHC, particularly in T2 and T4 samples, while highest values remained for T3 (60.503%), followed by T1 (55.835%).

As the storage time increased, a progressive decline in WHC was observed for all across samples. Thus, after six days, the values ranged between 49.553% (T2) and 56.103% (T3), and after eight days, between 44.900% (T2) to 54.504% (T3).

At the end of the experimental period (10 days), WHC values were significantly lower in all treatments, with the lowest values being recorded at T2 (43.151%) and T4 (43.796%), compared to T1 (49.312%) and especially T3 (52.524%), which maintained the highest water retention capacity. The analysis of variance test confirmed the maintenance of significant differences ($p \leq 0.05$) between all treatments, except for the combination of T2 and T4, where no statistically significant differences were found.

DISCUSSIONS

The initial pH ranged from 6.349 to 6.455, and during storage, the increase in pH values was associated with biochemical processes occurring in the muscle tissue after slaughter [21, 22]. The decrease in pH values is the result of lactic acid accumulation, generated through post-mortem anaerobic glycolysis [23, 24]. As the storage time progresses, enzymatic activity and protein degradation processes lead the release of volatile nitrogen compounds and ammonia, which contributes to the increase in pH [25, 26].

The higher pH values in T3 and T4 can be correlated with the lower storage temperature (1–2°C), which reduces the rate of enzymatic reactions and delays the decomposition processes, maintaining the stability of muscle proteins. Conversely, at higher temperatures (3–4°C, T1 and T2), protein degradation occurs more rapidly, favoring the accumulation of basic metabolites and a slight increase in pH. Thus, pH variations can be considered sensitive indicators of the freshness degree and the intensity of biochemical processes in meat during storage [27]. In contrast, samples T1 and T2, stored at higher temperatures (3–4°C) and packaged in oxygen-permeable polyethylene bags, showed a slight increase in pH as a result of intensified of metabolic activity and the formation of basic metabolites. Therefore, the evolution of pH can be considered a sensitive indicator of freshness and the degree of biochemical degradation of poultry meat during refrigerated storage [24, 28].

After six days of storage, the decrease in pH values may be associated with the reduction of enzymatic activity and the intensity of metabolic processes in T4 samples, which were vacuum-packed and stored at lower temperatures (1–2°C).

Vacuum packaging limits oxygen exposure, thereby reduces the growth of aerobic microorganisms and delays protein degradation [29, 30]. Similar results were reported by Balamatsia et al. [31], who observed that storing poultry meat in vacuum at 1°C caused a slower decrease in sensory and biochemical quality, maintaining a more stable pH compared to samples stored in permeable packaging. Conversely, the T1 and T2 samples, packed in polyethylene bags and stored at higher temperatures [3–4°C), recorded higher pH values. This indicates a more intense post-mortem metabolic activity and an accumulation of basic compounds, such as amines and ammonia, resulting from proteolytic processes [21, 25].

After eight days, the differences observed can be attributed to the interaction between the type of packaging and the storage temperature. The T1 and T2 samples showed higher pH values, reflecting the intensification of protein degradation and an increase in volatile nitrogen compounds, as also reported by Mir et al. [28] in studies on poultry meat stored at 4°C. In contrast, the T3 and T4 samples, vacuum-packed and stored at 1–2°C, showed lower pH values, indicating better biochemical stability and a reduced degree of spoilage. This protective effect of vacuum packaging was also confirmed by Fernández-López et al. [29] and Balamatsia et al. [31], who demonstrated that reducing oxygen levels in the packaging limits oxidative reactions and the development of bacterial flora. The constant increase in easily hydrolysable nitrogen (NH_3) values in turkey pectoral muscle samples, observed during the 10 days of storage, reflects the intensification of protein degradation processes and accumulation of volatile nitrogen compounds, associated with post-mortem enzymatic activity. Higher NH_3 values in treatments T1 and T2 (stored at 3–4°C, in oxygen-permeable packaging) indicate a faster rate of proteolysis reactions and a more rapid decline in meat freshness. In contrast, vacuum-packed samples stored at lower temperatures (T3 and T4, 1–2°C) showed a slower evolution of NH_3 values, demonstrating the protective effect of vacuum packaging on protein stability and the delay of spoilage processes. Similar results were also reported by Balamatsia et al. [31] and Kruk et al. [32], who showed that storing poultry meat in vacuum or modified atmosphere reduces the formation of ammonia and volatile nitrogen compounds, extending the period of freshness.

The thiobarbituric acid (TBA) values, expressed in mg MDA/kg, increased progressively during storage, as a result of lipid oxidation processes in turkey meat samples. The highest values were recorded in treatment T1 (polyethylene packaging, 3–4°C), and the lowest in T4 (vacuum packaging, 1–2°C), with highly significant differences. These results confirm that vacuum packaging and low temperatures reduce lipid oxidation and maintain the oxidative stability of meat during storage, a conclusion also supported by the studies of Zhang et al. [25] and Balamatsia et al. [31].

The water holding capacity (WHC) values showed a progressive decrease during the storage period, indicating significant water loss in all treatments. The highest WHC values were consistently observed in T3 samples (vacuum-packed and stored at 1–2°C), while the lowest values were recorded in T2 and T4, stored at higher temperatures (3–4°C) or in oxygen-permeable packaging. This trend demonstrates that vacuum packaging combined with lower storage temperatures contributes to reducing of myofibrillar activity and minimizing water loss from muscle tissue.

Water holding capacity (WHC) is an essential indicator of meat quality, being correlated with its juiciness, texture and appearance. The gradual decline in WHC was observed during storage is due to

structural changes and protein denaturation, which affect the binding of water in the muscle matrix. Similar results were reported by Balamatsia et al. [31] and Zhang et al. [25], who showed that vacuum packaging and low-temperature storage maintain the structural integrity of proteins and stabilize meat quality. Also, Qiao et al. [27] showed that a higher WHC is associated with juicier meat and less prone to oxidation and dehydration during storage.

CONCUSIONS

The results clearly demonstrate the significant effect of packaging type and storage temperature on the quality of turkey meat during storage. Vacuum packaging combined with lower storage temperature (1–2°C), contributed to maintaining the biochemical stability of the samples, by reducing lipid oxidation (lower TBA values), the accumulation of volatile nitrogen compounds (NH_3) and by preserving higher water retention capacity (WHC).

Conversely, samples packaged in polyethylene bags and stored at 3–4°C showed accelerated protein and lipid degradation, reflected by increased pH, NH_3 and TBA values and a decrease in WHC.

Therefore, vacuum packaging and storage at lower temperatures is an effective method to maintain the freshness and quality of poultry meat during cold storage.

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