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Effect of Modified Atmosphere Packaging and Multilayer Flexible Films on pH of Fresh Quail Meat

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Authors' contributions

This work was carried out in collaboration between both authors. Author NZ designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Authors NZ and SJ managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: In this study, the effect of different concentrations of three gas mixture (Carbon dioxide, Nitrogen, Oxygen), and also vacuum and ordinary conditions and using different flexible multi-layer pouches were studied for evaluating pH changes of quail meat at (4℃).
Methodology: Ordinary conditions (control conditions) were compared with four types of modified atmosphere packaging: ($N_2$70%+ $CO_2$30%), ($N_2$30% + $CO_2$70%), (45%CO_2+45%N_2+10%O_2), and vacuum conditions. Samples of quail meat were packaged in flexible multilayer pouches under modified atmosphere packaging, 3-layer ($PET_{(12)}/AL_{(12)}/LLD_{(100)}$), 4-layer ($PET_{(12)}/AL_{(7)}/PET_{(12)}/LLD_{(100)}$), and 3-layer ($PET_{(12)}/AL_{(7)}/LLD_{(100)}$), in different times during 16 days, with 15 treatment, 3 run. Statistical analysis and comparison of data, were done by software SPSS (Ver: 22) and Duncan's new multiple range test, with confidence level of 95% ($P < 0.05$).
Results: Packed samples were performed chemical test (pH test). The changes of pH in fresh

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samples were not acceptable under % 30 CO_2 and also vacuum conditions in these containers. However, the best conditions belonged to CO_2 70%, and then CO_2 45%, that were acceptable. Packed samples in 4-layer under gas combination CO_2 70% had best results.

Conclusion: Protection of these meats in 4-layer container was better than 3-layer container because the steam permeability of 4-layer was lower than 3-layer and also increasing CO_2 could not adversely effect on pH ,and postponed the pH changes and preserving quail meat till 16 days.

Keywords: Modified atmosphere packaging; pH; quail meat; flexible multi-layer films.

1. INTRODUCTION

Today poultry meat as a white meat with lower risks than red meat, is used more than, and have a large role in the growth of food productions so can be replaced by other sources of animal protein. High growth rate in poultry industry, appropriate feed conversion ratio, the nutritional value of chicken meat, the proportion of amino acids contained in it, Low cholesterol, lower diseases transmitted to humans from this meat than red meat, good taste, etc... has led poultry meat to be placed more and more in household food [1,2,3,4,5]. Due to the increasing level of rigor in science and amount of food hygiene and safety of fresh meat processed and the need to produce with minimal costs and Supplying customers' demands, Food packaging industry, especially in the case of meat and meat products rapidly development. USA is largest producer and exporter of chicken meat, countries such as Brazil, Europe and Thailand are the main rivals for export [6]. In terms of zoology quail belongs to chicken family, and in general, two species are highly regarded European and Japanese quail that among these two species there is a close relationship. Japanese quail are wild birds in pairs are living in the summer in the north and in winter in the southern part of the island Japanese [7]. While European quail widely distributed in Europe, Siberia, Iran, Turkey, China and Egypt. However, there are many similarities between European and Japanese quail and the only difference is in size of body Quail meat is delicious, tasty and nourishing. Fresh quail meat can be stored in the refrigerator for two days [7]. The main characteristic of this meat contain rich in omega-3, Iron / vitamins A, B, C / Amino Acids, increasing body resistance, strengthening muscles and bones, and due to the low volume and high levels of protein than eggs, quail eggs, is recommended for athletes, particularly body builders [7]. Modified Atmosphere Packaging (MAP) is a useful technique for various researches. However, it is well known that there is a non-thermal method for inactivation microorganism, which is widely used for shelf-life prolongation, and improvement the quality of perishable foodstuffs such as meat, fishery and vegetable [8-10,11], and also there is no degradation of flavor and taste with heat denaturation of objectives [12,13,2,3,14-16]. The ability of modified-atmosphere packaging for extending the shelf life of foods has been recognized for many years. Indeed, over 100 years ago [10,17,18]. Modified atmosphere packaging is the enclosure of a food, in a package in which the atmosphere has been changed by altering the proportions of carbon dioxide, oxygen, nitrogen, water vapor and trace gases. The process limits microorganism as well as biochemical activity. This modification is performed by gas flash packaging which oxygen is removed and replaced by controlled gas compositions [9,1,4,5,19,20]. MAP inhibits some microorganisms, so can increase the quality of variety foods. However the growth of microorganisms depends on temperature, pH and water activity as the main growth-determining factors, other factors can significantly influence the growth characteristics of the microorganism. All mentioned in this study include the initial CO2/N2/O2 concentration (%) in the head space of pouches as the independent variable for the gas atmosphere demonstrated that CO2 exerts as an antimicrobial effect in the water-phase of the food product [13,17,2,3,14], therefore except the effect of intrinsic, extrinsic and processing parameters on the CO2 solubility, the concentration of dissolved CO2 in the water-phase of the food product should be incorporated in this study as independent variable [10,21,22]. Nitrogen (N2) is a non-reactive gas that has no smell or taste, unlike carbon dioxide, is not absorbed in food or water [23,1,4,5,19,20]. It is used as a filler gas to replace oxygen and thus prevent spoilage or to replace carbon dioxide and prevent package collapse and also oxygen (O2) prevents anaerobic bacteria growth [21,24,4,5,19,20]. The most common packages that have been usually used for poultry, are individual pouches formed from polymer layers or plastic layers such as polyethylene (LLD), and

polyethylene terephthalate (PET), which are barrier films and also have a metal layer such as aluminum [25,26,27-29,30,4,5,19,20]. The main goals of this study include , first, investigation about the effects of modified atmosphere packaging with different concentrations of CO2/N2/O2, and vacuum on pH changes [1,4,5,19,20], and second using three multilayer flexible films [1,31,4,5,19,20] for packaging quail meat during storage times (16 days) and controlling pH of this meat too. We want to prove MAP can substitute thermal processing in conservation industries, and control pH 1 [32,31,4,5,19,20].

2. MATERIALS AND METHODS

2.1 Preparation of Packed Quail

Quails (0.5 kg weight) were chosen for this experiment bought from local supermarket in Tehran-Iran. These samples were washed, bones were removed and cut to slices (5 cm * 5 cm). Temperature was controlled in order to decrease to ambient temperature (T=25℃). Samples were ready for packaging, pouches contain 40 g fresh quails [1,4,5,19,20]. Analytical parameters such as pH (Crison 2001 pH meter; Crison Instruments, SA, Barcelona, Spain) soluble solid content (Atago RX-1000 refract meter; Atago Company Ltd., Japan), were measured according to the ISIRI regulation [32,33].

2.2 Modified Atmosphere Packaging

Henkelman packing machine (Boxer-200A) was used in this project as shown in Fig. 1. Samples were packed into 3 types of multilayer flexible pouches, 3-layer (PET(12)/AL(12)/LLD(100)), 4-layer (PET(12)/AL(7)/PET(12)/LLD(100)), and 3-layer (PET(12)/AL(7)/LLD(100)), under modified atmosphere. Samples were ready for gas injection. Different gas compositions (%30 N2 and %70 CO2), (%70 N2 and %30 CO2), (45%CO2+45%N2+10%O2) and vacuum were transferred from modified atmosphere packaging machine. After packaging, samples were put in refrigerator immediately, for evaluation pH changes in different treatments [1,26,27-29, 30,34,4,5,19,20].

2.3 Chemical Tests

2.3.1 Evaluation of pH

PH meter was adjusted with a buffer solution to 4 -7. Sample (100 g) was uniformed, and poured into 100 ml Erlenmeyer flask and pH has been measured at ambient temperature (T=25℃) [32,33,1,4,5,19,20].

2.4 Samples Packaging and Storage

All pouches (unprocessed and processed samples), were put at refrigerator temperature (T= 4℃). Quail meat were packaged into three multilayer type of flexible pouches. Analytical characteristics of these barrier containers were shown in Table 1 [1,26,27-29,30,34,4,5, 19,20].

2.5 Statistical Analysis

In order to describe the variables of this experiment, we must design a model to analysis relationship between type of samples, type of treatments, pH amounts. Statistical analysis of the data gained in this study, was performed by Statistical Package For Social Science (SPSS Ver:22) with ANOVA test, and comparison of data was done by Duncan's new multiple range test, with confidence level of 95% [1,4,5,19,20].

(A) **(B)** **(C)**

Fig. 1. (A) Modified atmosphere packaging, (B) Gas analyzer, (C) Gas mixer [1,4,5,19,20]

Table 1. Analytical characteristics of containers [1,26,27-29,30,34,4,5,19,20]

Sample	Layers	Thickness (µ)	Tensile of sealing film (N)	O.T.R ml/m2.day	W.V.T.R g/ m2.day
PET/AL/LLD	12/12/100	124	58.88	0	0.11
PET/AL/LLD	12/7/100	119	48.89	0	0.50
PET/AL/PET/LLD	12/7/12/100	131	61.03	0	0.089

PET: Poly Ethylene Terephthalate; LLD: Low Density Poly Ethylene; AL: Aluminum

3. RESULTS

According to analysis of variance Table 2, the effect of different containers, gas compositions, times and the double interactions (layer, gas), (layer, time), and (gas, time) and the triple interaction (layer, gas, time) on pH were significant differences ($p< 0.01$). The primary effects of containers, gas compositions and times on pH were significant at %1.

According to Table 3 and Fig. 2, there was a significant difference between 3-layer, PET (12)/AL (12)/LLD (100), 4-layer, PET (12)/AL (7)/PET (12)/LLD (100), and 3-layer, PET (12)/AL (7)/LLD (100), on pH ($P\leq0.05$). Results were showed that with 3-layer (AL:7), pH was higher than other containers, but The best condition belonged to 4-layer with lowest pH, ($P\leq0.05$) due to the thickness (131 µ), low permeability of water vapor in this 4-layer container.

Table 2. Analysis of variance mean squares traits in response to treatments

Resource (Variable)	(SS) Total square	(Df) Fredom degree	(MS) Average square	(F) Variance	(P) Error
Container (C)	0.410	2	0.205	5.286**	0.006
Gas composition (A)	2.728	4	0.682	17.597**	0.000
Time (Z)	7.277	3	2.426	62.582**	0.000
Container * Gas composition (C*A)	0.022	8	0.003	0.072ns	1.000
Container * Time (C*Z)	0.009	6	0.002	0.039ns	1.000
Gas composition * Time (A*Z)	0.313	12	0.026	0.673ns	0.774
Container * Gas composition * Time*(C*A*Z)	0.028	24	0.001	0.030ns	1.000
Error	4.651	120	0.039		
Total	6972.013	180			

***, * and ns, significance at 1% and 5% and non-significance, respectively*

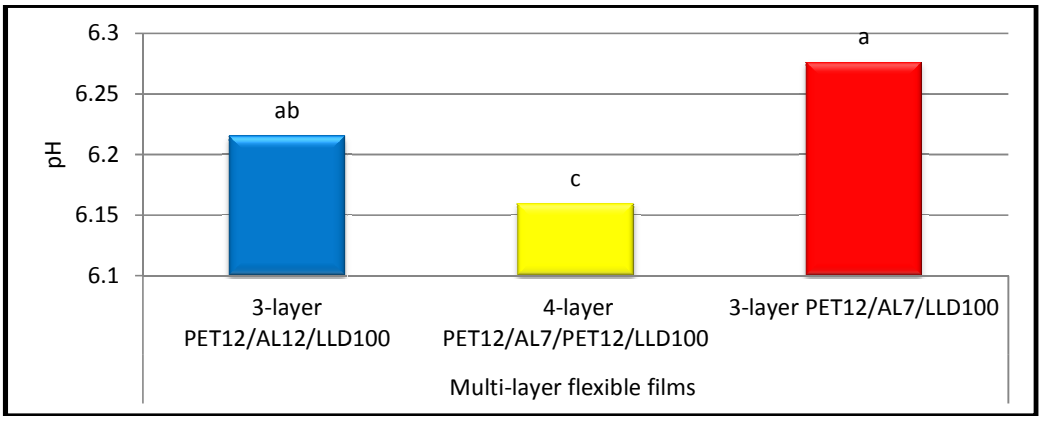

Fig. 2. The effect of different multilayer flexible films on pH (Single interaction)

According to Table 4 and Fig. 3, there was a significant difference between different gas combinations in pH (P≤0.05). Results were showed that in ordinary condition (control), pH was higher than other packaging conditions. The best condition belonged to 70% CO2+ 30% N2 with lowest pH, (P≤0.05), lowest amount of pH due to mechanism could be described by its solution in water of food tissue and produced carbonic acid which the more carbonic acid was decreased pH.

According to Table 5 and Fig. 4, there was a significant difference between different storage times in pH (P≤0.05).Results were showed that after 16 days, pH was higher than other days. The best condition belonged to day 4 with lowest pH, (P≤0.05), which caused to grow microorganisms by the times and changed pH.

According to Table 6 and (Fig. 5a, b, c, d), the amount of pH in different pouches were observed in different storage times (4, 8, 12, 16 days), the highest amount of pH belonged to C3A5, which was fresh quail samples with 3-layer pouch, PET (12)/AL (7)/LLD (100) in control condition. The lowest amount of pH belonged to C2A1 in 4-layer pouch, PET (12)/AL (7)/PET (12)/LLD (100) under gas condition 70% N2+ 30% CO2. The variables were shown by different letter in each column had not significantly level with others (P≤0.05).

Table 3. The effect of different multilayer flexible films on pH

Multilayer flexible films	pH amount
3-layer, PET (12)/AL (12)/LLD (100)	6.215±0.296ab
4-layer, PET (12)/AL (7)/PET (12)/LLD (100)	6.159±0.296c
3-layer, PET (12)/AL (7)/LLD (100)	6.276±0.282a

Table 4. The effect of different packaging conditions on pH

Packaging conditions	pH amount
70% CO2+30% N2	6.048±0.279d
30% CO2+70% N2	6.203±0.268bc
45% CO2+45% N2+10% O2	6.149±0.279c
Vacuum conditions	6.264±0.232b
Control	6.417±0.284a

Table 5. The effect of different storage times on pH

Storage time (day)	pH amount
4	5.942±0.210d
8	6.115±0.227c
12	6.351±0.192b
16	6.457±0.228a

As you see in Fig. 6, kinetics of pH of fresh quail meat during storage times was showed according to this figure, pH in all conditions followed a similar pattern and had a significant difference over storage times (p≤0.05), the conclusion showed that the triple interaction between different layers, different composition of gases in different times on pH had increased slower in gas composition 1 (% 30 N2 + % 70 CO2) and 4-layer ,and had the best effect on pH changes, over the time, and amount of pH were in limit, that was not increased rapidly, then 4-layer and gas compositions (% 45 N2 +% 45 CO2+% 10 CO2) (% 70 N2 + % 30 CO2) and 4- layer and vacuum had been affective ,so the shelf life according to pH changes had evaluated, 16,15,14 days under gas combination 1,2,3 and vacuum conditions 12 days . Samples were packed in 3-layer (AL: 12) was acceptable after 14,12,10 days under gas combination 1,2,3 and after 8 day in vacuum .But in 3-layer (AL: 7) was reported 11,10,8 days under gas combinations 1,2,3 and 6 days in vacuum condition .The usage of container with greater thickness and less steam permeability ,and the gas composition with higher amount of CO2 (gas composition 1) was more effective and had the best inhibitory effect on pH changes.

4. DISCUSSION

In this study, the best condition was belonged to samples in 4-layer container under (70% CO2) which controlled pH of quail meat till 16 days. Protection of these samples in 4-layer was better than two types of 3-layer containers {(AL: 12) & (AL: 7)}, because the steam permeability of 4-layer was lower than 3-layer pouches, so the usage of this packaging was better for preserving quail meat in long time. The lowest amount of pH was belonged to 4-layer, under 70% CO2 + 30% N2, and the highest amount of pH observed in 3-layer (AL: 7) with ordinary condition. These parameters were evaluated according to the National Standard of Iran (ISIRI 2326).The modified atmosphere packaging (MAP) was not lead to stop spoilage completely. The effect of MAP was not adequate but using this technique

inactivated microorganism and controlled chemical reactions such as pH. The best shelf life of quail fresh meat in ordinary condition at refrigerator (T=4ºC) was 2 days. According to these results pH could be controlled after 16 days for condition 70% CO2 30% N2. Changes of pH in various conditions, had significant differences between (layer, gas) (layer, time) and also (gas, time) (P<0.01).

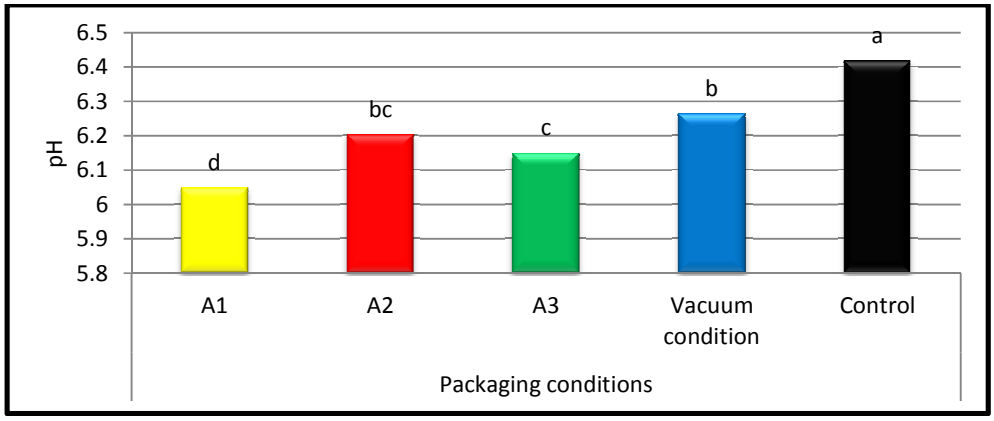

Fig. 3. The effect of different packaging conditions on pH (Single interaction)

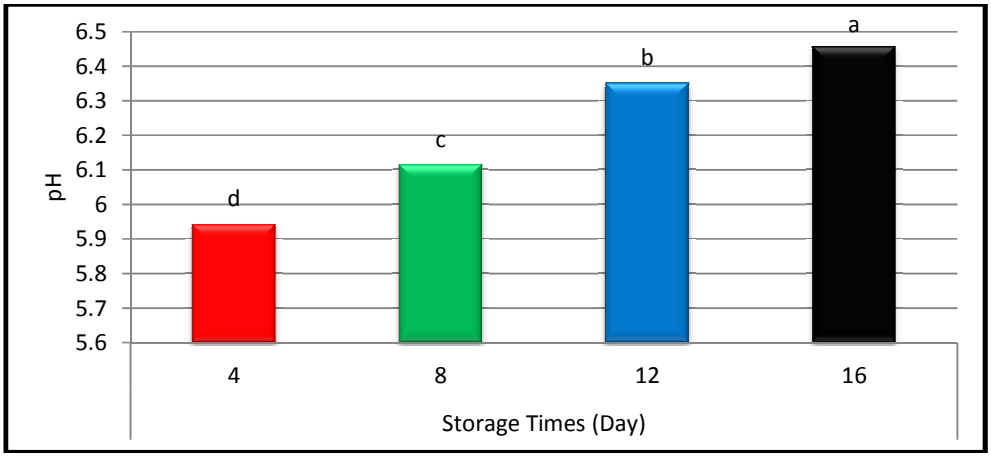

Fig. 4. The effect of different storage times on pH (Single interaction)

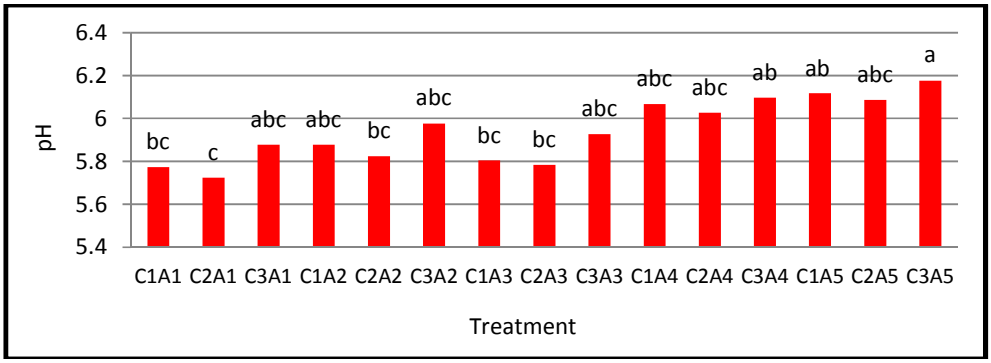

Fig. 5a. Amount of pH under different treatments after 4 days (Double interaction)

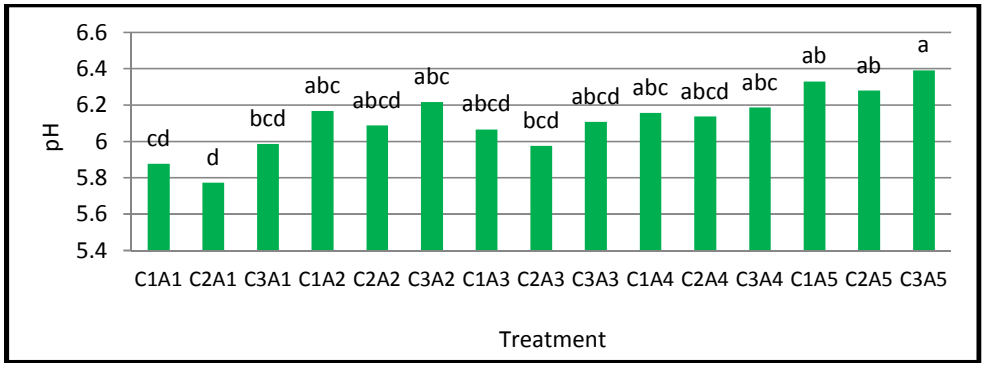

Fig. 5b. Amount of pH under different treatments after 8 days (Double interaction)

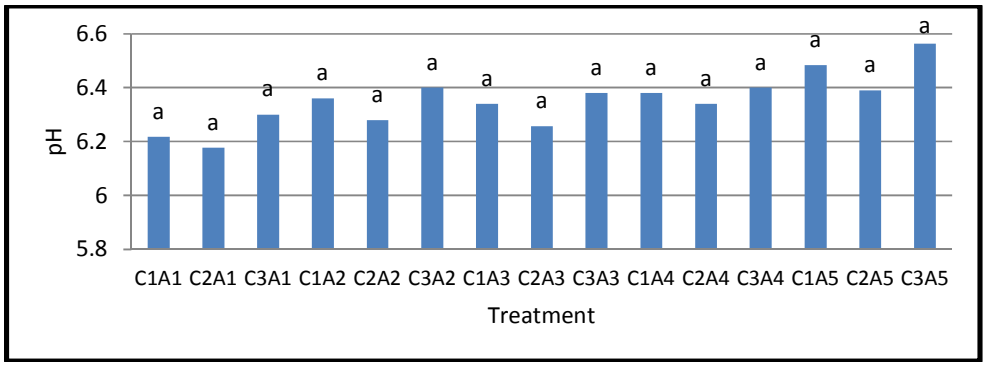

Fig. 5c. Amount of pH under different treatments after 12 days (Double interaction)

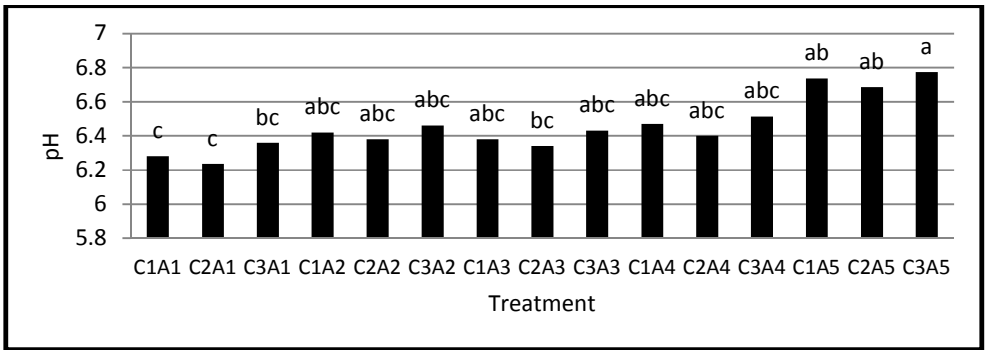

Fig. 5d. Amount of pH under different treatments after 16 days (Double interaction)

Table 6. Amount of pH in different treatments during different days

Treatment	Day 4	Day 8	Day 12	Day 16
C1A1	5.773±0.181bc	5.876±0.187cd	6.216±0.196a	6.280±0.202c
C2A1	5.723±0.181c	5.773±0.181d	6.176±0.196a	6.236±0.196c
C3A1	5.876±0.181abc	5.986±0.187bcd	6.300±0.202a	6.360±0.202bc
C1A2	5.876±0.181abc	6.166±0.196abc	6.360±0.202a	6.420±0.202abc
C2A2	5.823±0.181bc	6.086±0.196abcd	6.280±0.196a	6.380±0.202abc
C3A2	5.976±0.181abc	6.216±0.196abc	6.400±0.202a	6.460±0.202abc
C1A3	5.803±0.181bc	6.066±0.187abcd	6.340±0.202a	6.380±0.202abc
C2A3	5.783±0.181bc	5.976±0.187bcd	6.256±0.196a	6.340±0.202bc

Treatment	Day 4	Day 8	Day 12	Day 16
C3A3	5.926±0.181abc	6.106±0.196abcd	6.380±0.202a	6.430±0.202abc
C1A4	6.066±0.181abc	6.156±0.196abc	6.380±0.202a	6.470±0.202abc
C2A4	6.026±0.181abc	6.136±0.196abcd	6.340±0.202a	6.400±0.202abc
C3A4	6.096±0.196ab	6.186±0.196abc	6.400±0.202a	6.513±0.207abc
C1A5	6.116±0.196ab	6.330±0.202ab	6.483±0.207a	6.736±0.213ab
C2A5	6.086±0.196abc	6.280±0.202ab	6.390±0.202a	6.686±0.213ab
C3A5	6.176±0.196a	6.390±0.202a	6.563±0.207a	6.773±0.190a

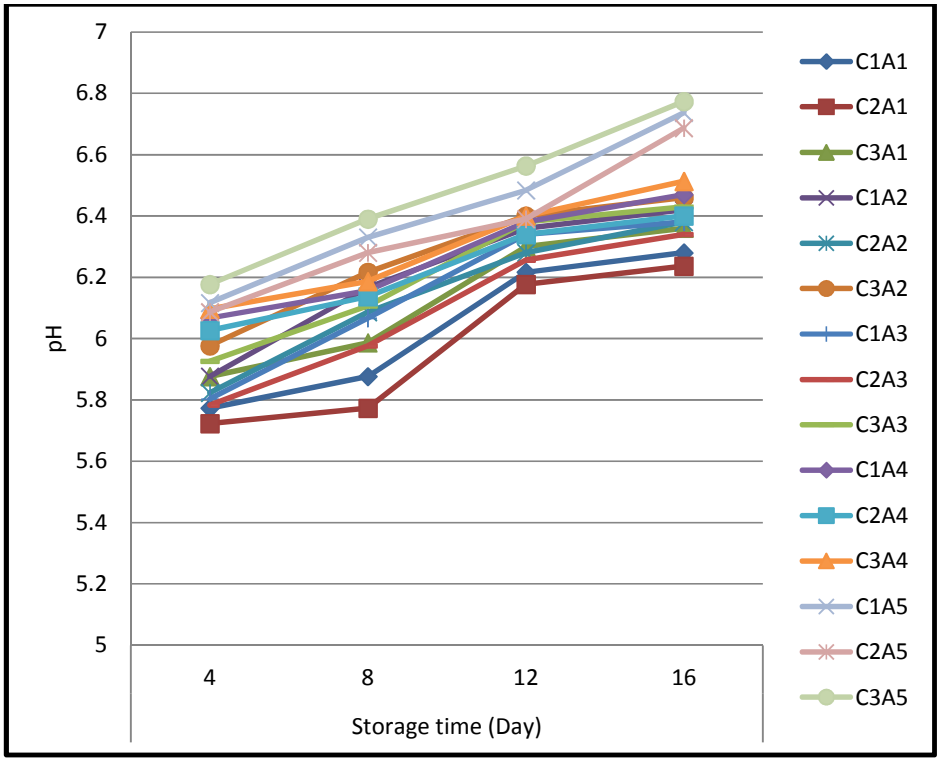

Fig. 6. The effects of storage times, packaging conditions and multilayer flexible films on pH (Triple interaction)

Pexara et al. [25], due to effect of modified atmosphere and vacuum packaging on cooked, sliced turkey fillets and cooked pork sausages at +4 and +10℃, the results were similar to these results and reliable. Gill [10] indicated that due to packaging meat under carbon dioxide, the results of this study were acceptable. Ohlsson and Bingtsson [23], due investigation about modified atmosphere packaging, in food industry, the results of this investigation were reliable. Athina et al. [12], indicated that due to formation of biogenic amines and relation to microbial flora and sensory changes in smoked turkey breast fillets stored under various packaging conditions, the results showed that the shelf life of turkey meat under %60 CO2 prolonged till 7 days, were corresponded with this investigation. Chouliara and Karatapanis [9] indicated that due to combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat, the results of pH changes, were similar to these results. Sotoudeh et al. [1], concluded due to research about usage of MAP for shelf life extension of packed spicy chicken meal in multi-layer flexible pouches, 4-layer was better than 3-layer during 3 weeks, best condition belonged to CO2 %70, the results were corresponded to these results. Zand and Sotoudeh [4,5], due to effect of packaging under gas combination %30 N2 + %70 CO2 in 4- layer flexible films (131 µ) on shelf life and pH of chicken meal, was better than 3-layer flexible films (124 µ) during 20 days, that the results were similar to this investigation. Zand and Allahyari [19,20], due to research about effect of packaging under gas combination

%30 N2 + %70 CO2 in 4-layer flexible films (131 µ) on shelf life and pH of candy bread ,was better than 3-layer flexible films (124 µ) during 20 days, that the results were corresponded with these result. Zand [35], indicated that due to shelf life extension of mushroom meal in multilayer flexible pouches 4-layer container was better than 3-layer container during 2 months, the results were similar to these results. Zand [36], concluded due to the shelf life prolongation of packed vegetables meal in multi-layer flexible pouches, 4-layer container was better than 3-layer container during 2 months, the results were corresponded with these results.

5. CONCLUSION

In the present study, it was concluded that, pH changes as a one of important factor of shelf life of packed quail meat have been affected by different flexible multi-layer pouches and different concentrations of three gas mixture (carbon dioxide, nitrogen, oxygen), and also vacuum conditions during 16 days. Our results confirmed, the modified atmosphere packaging (MAP) was not lead to stop spoilage completely but postponed it. The influence of MAP was not adequate but using this technique not only inactivated microorganism, but also had not significant adverse effect on chemical reactions such as pH changes. These parameters could be promoted substitution of MAP and these barrier containers instead of other traditional packaging in meat industries, due to a lot of privilege for shelf life extension of fresh quail meat in long times.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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