Assiut Vet. Med. J. Vol. 59 No. 138 July 2013

IMPACT OF PACKAGING METHOD AND STORAGE CONDITIONS ON CHICKEN MEAT QUALITY

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Received at: 30/6/2013

Accepted: 18/7/2013

ABSTRACT

The results of the study showed that the sensory quality of poultry meat deteriorated when the time of cold storage was prolonged to 20 days. The average thiobarbituric acid values of the examined packaged samples stored for 5, 10, 15 and 20 days at chilling temperature were 0.140±0.06, 0.252±0.10, 0.561±0.07 and 0.782±0.08 respectively and unpackaged samples were 0.387±0.06, 0.792±0.03, 0.916±0.02 and 1.061±0.01 respectively. Total volatile nitrogen (TVN) was markedly detected in fresh chicken (12.6 mgN/100g sample), and its level increased with storage time. TVN was slower in packed samples (14.2±0.2, 16.4±0.6, 16.9±0.5, and 23.8±0.7 mgN/100g sample compared with unpacked samples 17.5±0.6, 20.9±0.8 and 26.1±1.1 and 35.1±0.4 mgN/100g sample after 5, 10, 15, and 20 day of storage respectively. The rate of these undesirable changes was faster in unpacked samples than in packed ones. A microbiological analysis of breast muscles, based on total microbial count per g, indicated that microbial contamination was at a safe level in packed samples stored under controlled atmosphere conditions at 4ºC for 20 days, and in unpacked samples stored at 4ºC for 15 days. The results suggest that the method of controlled atmosphere storage applied in this study contributed to extending the keeping quality of chilled broiler chicken breast meat.

***Key words**: Packaging method, storage, chicken meat quality*

INTRODUCTION

Fresh poultry meat is offered to consumers in the form of whole carcasses, cuts and muscle fillets which retain their taste and flavor after thermal treatment (Kijowski *et al.,* 2001). Chilled meat, compared with deep-frozen meat, is characterized by better sensory and technological properties and therefore it is preferred by consumers (Kondratowicz and Kawałko, 2003).

Depending on the degree of processing following slaughter, poultry meat spoilage varies between 4 and 10 days under refrigeration (Marenzi, 1986). In a model system, packaging provides a physical barrier between the protected product and the external environment. The protective functions performed by packaging can be interpreted as the capability to selectively reduce the effects of mechanical and climatic factors, combined with the lack of own, harmful impacts (Czerniawski and Michniewicz, 1998).

Numerous studies have been conducted (Krala, 1999; Pfeiffer and Menner, 1999; Skandamis and Nychas, 2002) to investigate the effect of modified atmosphere packaging and vacuum packaging on the microbial quality and shelf-life of cold-stored poultry meat, whereas there is a scarcity of information regarding the quality of poultry meat stored under controlled atmosphere conditions. Czerniawski and Michniewicz (1998) found that the vacuum inside the packaging may change considerably during meat storage due to the diffusion of gas through the film and oxygen penetration from the outside into the packaging. In consequence of these changes gas and vapor permeability of packaging material increases, and the vacuum affect decreases as the time of cold storage is prolonged. Vacuum storage of poultry meat is also restricted by the possible juice drip inside the packaging, followed by microbial contamination and sensory quality deterioration.

Meat can be stored in controlled atmosphere in chilling chambers. The main advantage of this method, in comparison with modified atmosphere packaging, is the possibility to control the composition of gaseous mixtures applied during cold storage (Eilert, 2005). Controlled atmosphere storage contributes to the microbiological safety and extended durability of meat. This technique is also cost-effective, as the gaseous mixture can be used as a chilling medium (Belcher, 2006). Nitrogen delays the onset or slows the development of rancidity due to oxidation, and it

inhibits the growth of aerobic microorganisms (Krala, 1999). Oxygen (O_2) is another main gas used commercially, in low concentration along with the other gases. O_2 retards the growth of anaerobic spoilage bacteria and stimulate the growth of aerobic bacteria (Pantazi *et al.,* 2008).

The aim of this study was to determine the physicochemical properties and the degree of microbial contamination of chicken breast muscles stored in controlled atmosphere (95% nitrogen, 5% oxygen) at a temperature of 4°C for 5 to 20 days. Meat samples were packaged in PA/PE bags or left unpackaged

MATERIALS and METHODS

The experimental materials comprised Ross 150 broilers, reared to 35 days of age on a private farm .After slaughter the carcasses were chilled for 90 min. at 4ºC. An analysis was performed on breast muscle (*musculus pectoralis*) samples of normal quality. The criterion of quality assessment was the value of pH determined in breast muscles with a digital pH-meter, 15 to 20 min. after slaughter. Normal quality muscles were those whose pH ranged from 5.9 to 6.2 (Gardzielewska *et al.,* 2003; Kijowski *et al.,* 1982; Kijowski *et al.,* 2001).

Experimental design
One hundred breast muscle samples, each weighing about 300 g, were transported in isothermal containers (approx. 2ºC) to the laboratory, where basic analyses were conducted. Samples were divided into two equal groups: 50 samples were packaged in Polyamide/ Polyethylene (PA/PE) bags (thickness 80 μm, weight 78 g/m^2), with oxygen permeability (0% RH) of 53, nitrogen permeability (0% RH) of 21, and carbon dioxide permeability (0% RH) of 134. (Czerniawski and Michniewicz, 1998) and 50 samples were left unpackaged.

In the experiment chicken breast muscles were stored in controlled atmosphere. The breast muscle samples were stored in gas-tight plastic containers. A mixture of liquefied nitrogen and oxygen was accomplished using Oxoid's Atmosphere Generation System (AGS). The storage conditions were as follows: temperature 4 ºC, concentration of gaseous nitrogen (95%), concentration of oxygen (5%), humidity (40%). Temperature was measured automatically with a thermometer, and humidity was controlled with a psychrometer. The samples were stored for 5 to 20 days.

Meat quality assessment
In order to prepare the samples for laboratory analyses, the outer membranes and fat were removed from the surface of the muscles. The following analyses were performed on muscles before storage (24hours after slaughter) and after 5, 10, 15 and 20 days of cold storage:

1. Total weight loss during storage:
Total weight loss was detected by weighting samples at the beginning and at the completion of each stage of storage, accurate to 1 g.

2. pH value:
For determination of the pH, 10 g of sample were homogenized with 50 ml distilled water and pH value was measured by a digital pH-meter.

3. The sensory properties of meat:
The investigated samples were evaluated using a panel test of a point hedonic scale (Sendecor and Cochran, 1987).

4. Determination of Thiobarbituric acid number (TBA) (mg %)
It was determined according to Vyncke (1970) by using spectrophotometer at wave length 538 nm. The TBA values were recorded as mg malonaldehyde /kg sample.

5. Measurement of total volatile nitrogen (TVN) content
The technique of Conway's test was applied (Food and Agriculture Organization "FAO" (Ang, 1988).

6. Total viable count of aerobic bacteria
Ten grams of sample was homogenized with 90 ml of sterile peptone water (0.1 %) in a laboratory homogenizer and serial dilutions were prepared, then 0.1 ml of each dilution was spread with a bent sterile glass rod on duplicate plates of pre-poured and dried standard plate count agar (APHA, 1984). After 48-h incubation at 25°C, colonies were counted and results were expressed as $\log_{10}$ CFU/g of sample.

7. Statistical analysis
The results were analyzed statistically, determining basic statistical measures (x, s). The significance of differences between groups was verified by the Duncan test (Duncan, 1955), using SPSS software.

RESULTS

Table 1: Statistical analytical results of weight loss and physicochemical properties of chicken breast muscles depending on packaging method and cold storage time at 4ºC.

Item	*Packaged samples values ± SE*				*Unpackaged samples values ± SE*			
	Time of storage (days)				Time of storage (days)			
	5	**10**	**15**	**20**	**5**	**10**	**15**	**20**
Weight losses (%)	0.25±0.49a	1.66±0.99b	4.10±1.26c	5.23±3.36d	0.68±1.11a	2.14±1.47b	2.73±2.32b	5.26±3.97c
ph value	5.53±0.11a	5.61±0.09b	5.59±0.14b	5.64±0.09b	5.57±0.08b	5.57±0.14b	5.60±0.14b	5.72±0.14c
Tenderness	4.95±0.16	4.80±0.42	4.70±0.43	4.65±0.41	4.90±0.32	4.40±0.52	4.40±0.70	4.35±0.34
Overall acceptability	5.00±0.00	5.00±0.00	4.80±0.42	4.70±0.26	5.00±0.00	4.70±0.32	4.05±0.37	3.50±0.53

Values with different litters within the same row differed significantly at $p \leq 0.01$

Table 2: TBA value of chicken breast muscles depending on packaging method and cold storage time at 4ºC:

Storage days	**TBA mg Malonaldehyde/Kg ±SE**							
	Packaged samples values ± SE				Unpackaged samples values ± SE			
	5	10	15	20	5	10	15	20
	0.140±0.06	0.252±0.10	0.561±0.07	0.782±0.08	0.387±0.06	0.792±0.03	0.916±0.02	1.061±0.01

Values represent the mean of 3 determinations (n=3)

Table 3: TVN of chicken breast muscles depending on packaging method and cold storage time at 4ºC.

Item	Before cold storage	Packaged samples values ± SE mgN/100g sample				Unpackaged samples values ± SE mgN/100g sample			
		Time of storage (days)				Time of storage (days)			
		5	10	15	20	5	10	15	20
TVN	12.6±0.1	14.2±0.2	16.4±0.6	16.9±0.5	23.8±0.7	17.5±0.6	20.9±0.8	26.1±1.1	35.1±0.4

Values are means of triplicate determinations

Table 4: Statistical analytical results of total viable microbial count in breast muscles depending on packaging method and cold storage time at 4ºC.

Item	Packaged samples values ± SE				Unpackaged samples values ± SE			
	Time of storage (days)				Time of storage (days)			
	5	10	15	20	5	10	15	20
Total microbial count (log 10 cfu/g)	1.16×10^4 a	3.16×10^4 a	3.89×10^5 a	4.76×10^5 b	2.08×10^5 b	5.68×10^5 b	3.75×10^6 c	1.28×10^8 d

Values with different litters within the same row differed significantly at $P \leq 0.01$

DISCUSSION

Weight losses and the sensory quality of breast muscles, as dependent upon the packaging method and time of cold storage, are given in Table (1). Both in vacuum-packed and unpacked samples weight losses increased with time, and reached a similar level after 20 days of storage, i.e. 5.23% and 5.26% respectively. It seems that considerable weight losses observed in packed samples could result from the difference in pressure between the outside and inside of the packaging, leading to increased forced juice drip. The use of foil providing a physical barrier between the product and the environment limited weight loss caused by evaporation (Kijowski *et al.,* 2001; Krala, 1999). In unpacked samples weight losses were most probably caused by water evaporation and spontaneous juice drip during storage (Kondratowicz and Kawałko, 2003).

The mean level of pH was 5.51 and indicated normal quality of breast muscles (Niewiarowicz and Pikul, 1979). The acidity of breast muscles, determined after 5 days of storage, was similar in both groups and indicated a normal rate of postmortem glycogenolysis. As the time of cold storage was prolonged, the pH of breast muscles displayed a growing tendency. A faster rate of pH increase was recorded in unpacked samples, compared with vacuum-packed samples. After 20 days of storage the values of pH were 5.72 and 5.64 respectively. A slightly increase of pH in this study could be due to a balance between the controlled atmosphere and the deamination reaction of amino acids, which derived from the hydrolysis of protein during the growth of microorganisms (Faber, 1991).

An analysis of the sensory properties of breast muscles stored under controlled atmosphere conditions showed statistically significant ($p \leq 0.01$) differences in meat quality, related to the packaging method and storage period. It was found that the sensory quality of meat deteriorated when the time of cold storage was prolonged. These changes were less pronounced in packed samples, in comparison with unpacked samples. These results agree with statements of Patsias *et al.* (2006), they stated that food packaging is designed to maintain the desired properties of food products for the desired period of storage and display. Over the entire storage period (20 days) changes in the sensory quality of vacuum-packed breast muscles were relatively slight. A taste-panel evaluation of unpacked samples, performed after 20 days of storage, revealed distinct changes in the aroma, especially its desirability, and a rapid decrease in juiciness and palatability. Therefore, it may be assumed that according to sensory quality criteria packed and unpacked chicken breast meat should be stored in controlled atmosphere for no longer than 20 and 15 days respectively, to preserve its good quality. These results agree with statements of Kondratowicz *et al.* (2006), they stated that changes in the sensory properties of broiler chicken breast muscles were related to the packaging method and storage time. The rate of these undesirable changes was faster in unpacked samples than in packed ones.

The main reason for undesirable qualitative changes in stored poultry meat is bacterial microflora (Blakistone, 1998). The presence and growth of harmful microorganisms are factors that negatively affect both the nutritive value and sensory properties of meat (Krala, 1999).

The thiobarbituric acid number (TBA) value was increased to critical values indicating incipient spoilage of these chicken breast muscles after different periods of chilling storage. Storage time was a significant factor for TBA value increase regardless of the packaging effect. The achieved data in table (2) showed that the average TBA values of the examined packaged breast muscles samples of chicken stored for 5, 10, 15, 20 days at chilling temperature were 0.140±0.06, 0.252±0.10, 0.561±0.07 and 0.872±0.08 respectively. TBA values of the examined unpackaged breast muscles samples of chicken stored for 5, 10, 15, 20 days at chilling temperature were 0.387±0.06, 0.792±0.03, 0.916±0.02 and 1.061±0.01 respectively. Packaged breast muscles had lower mean TBA values during the 20 days of storage as compared unpackaged. By 5 days of storage, unpackaged breast muscles had increased TBA values, whereas no significant storage changes were observed for packaged breast muscles.

The intensity of rancidity in chicken meat during the chilling storage is accompanied by an increase in TBA value indicating extensive oxidation of fats (Hassan, 2001). Thus, the shelf life of chilled chicken meat products depends greatly on the TBA value. Generally, the TBA values of 0.9 mg% represents unacceptable limit in foods (Jay, 1972). Therefore, the incipient spoilage was occurred at 20^{th} day for packed chicken breast samples, and 15^{th} day for unpacked chicken samples.

These results agree with statements of Ordonez and Ledward (1977). They stated that the concentration of O_2 in the package atmosphere is the determining factor for the rate of lipid oxidation. Exclusion or limiting of the oxygen content in packaging atmospheres limited oxidation and thus resulted in lower TBA values for these meat samples.

Total volatile nitrogen (TVN) was markedly detected in fresh chicken (12.6 mgN/100g sample), and its level increased with storage time (Table 3). Depending on the packaging method and time of cold storage in controlled atmosphere the achieved results of TVN analysis revealed that TVN was slower in packed samples (14.2±0.2, 16.4±0.2, 16.9±0.5, and

23.8±0.7 mgN/100g sample after 5, 10, 15, 20 day of storage respectively) compared with unpacked samples (17.5±0.6, 20.9±0.8, 26.1±1.1and 35.1±0.4 mgN/100g sample after 5, 10, 15, 20 day of storage respectively).

Generally the TVN value of 30 mg% represented unacceptable limit in foods (Pearson, 1984) Therefore, the explicit spoilage was occurred after 20^{th} day for packed chicken breast samples, and 15^{th} day for unpacked chicken samples.

This dynamic change in TVN level could be related to the growth of microorganisms as proliferation of the microflora contributing to spoilage changes as seen by increased TVN level. This correlation is in agreement with the findings of (Balamatsia *et al.,* 2007), which firstly reported that trimethylamine (TMA-N) and total volatile nitrogen (TVN) could be employed as potential chemical indicators in monitoring the microbial quality of fresh chicken meat during chill storage under aerobic and modified atmosphere packaging (MAP) conditions, and the findings of (Rokka *et al.,* 2004), which showed a clear relationship between the microbiological quality of poultry (protein-based) and the total amount of Total Volatile nitrogen (TVN) and biogenic amines.

The total viable count of aerobic bacteria per g of muscular tissue is also a good indicator of microbiological safety. Table (4) presents the results of a microbiological analysis of broiler chicken breast muscles stored in controlled atmosphere, depending on the packaging method and time of cold storage. It was found that during 20 days of storage, the rate of microorganism growth was slower in packed samples, compared with unpacked samples. During this period the total microbial count in packed meat did not exceed the threshold limit value of 5 x 10^6 cfu per g of meat, set in the Polska Norma (1996). In unpacked samples the level of bacterial contamination exceeded the above value on the 20^{th} day of storage, which suggested that the process of microbiological spoilage had already begun. The results of microbiological examinations show that the maximum storage life under controlled atmosphere conditions is 20 day for vacuum-packed breast muscles and 15 day for unpacked breast muscles. The above indicates that controlled atmosphere storage (95% N2 and 5% O2) contributes to extended shelf life of chicken meat.

CONCLUSIONS

There is a scarcity of information regarding the use of controlled atmosphere (95% N2 and 5% O2) in cold storage of broiler chicken breast meat. As demonstrated by Krala (1999), nitrogen delays the onset or slows the development of rancidity due to oxidation, and it inhibits the growth of aerobic microorganisms. Oxygen, as a component of controlled atmosphere, prevents the excessive growth of lactic acid bacteria and limits the growth of anaerobic pathogenic bacteria. Those bacteria are responsible for the development of an unpleasant odour that accompanies meat spoilage. Their presence is also indicative of undesirable organoleptic changes in the stored product.

The results of a study on the sensory and microbiological properties of broiler chicken breast meat stored at 4^oC for 5 to 20 days in a controlled atmosphere (95% nitrogen, 5% oxygen), affected by the packaging method and storage period, enabled to formulate the following conclusions:

1. The increase in the weight loss of broiler chicken breast muscles was proportional to cold storage time, and it was higher in unpackaged samples than in packaged meat.
2. Prolonged cold storage resulted in a gradual increase in the pH of muscles, and their colour became darker. These undesirable qualitative changes proceeded at a slower rate in packaged meat, compared with unpackaged samples.
3. Changes in the sensory properties of broiler chicken breast muscles were related to the packaging method and storage time. The sensory quality of meat deteriorated when the time of cold storage was prolonged to 20 days. The rate of these undesirable changes was faster in unpacked samples than in packed ones.
4. A microbiological analysis of breast muscles, based on total microbial count per g, showed that microbial contamination was at a safe level in packed samples stored under controlled atmosphere for 20 days, and in unpacked samples stored for 15 days.
5. The method of controlled atmosphere storage applied in our study contributed to extending the keeping quality of chilled broiler chicken breast meat.

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تأثير طريقة التعبئة وظروف التخزين على جودة لحوم الدواجن

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الهدف من هذه التجربة هو دراسة تأثير عملية التغليف على الخواص الحسية والميكروبيولوجية للحم صدور دجاج التسمين حيث تم تخزين عينات من لحم صدور الدجاج في وسط محكم يحتوي على (٩٥٪ نيتروجين، و ٥٪ من الأكسجين) عند درجة حرارة ٤ درجة مئوية لمدة من ٥ إلى ٢٠ يوما، و تم تغليف العينات في أكياس من بولي أميد / البولي ايثلين أو تركت غير مغلفة. أظهرت نتائج الدراسة أن الخواص الحسية للحوم الدواجن تراجعت عندما تم تمديد وقت التخزين البارد إلى ٢٠ يوما. وكان متوسط قيم حامض الثيوباربيتيوريك TBA للعينات المغلفة والمخزنة لمدة ٥، ١٠، ١٥ و ٢٠ يوما في درجة حرارة ٤ درجة مئوية هي ٠.١٤٠ ، ٠.٢٥٢ ، ٠.٥٦١ و ٠.٧٨٢ على التوالي والعينات الغير مغلفة كانت ٠.٣٨٧ ، ٠.٧٩٢ ، ٠.٩١٦ و ١.٠٦١ على التوالي. كذلك كان هناك زيادة في مستوى النيتروجين المتطاير (TVN) مع تمديد فترة التخزين حيث كان مستوى TVN أبطأ في العينات المغلفة (١٤.٢ ، ١٦.٤ ، ١٦.٩ ، ٢٣.٨mgN/100g), مقارنة بالعينات التي لم يتم تغليفها (١٧.٥ ، ٢٠.٩ ، ٢٦.١ و ٣٥.١ mgN/100g بعد ٥، ١٠، ١٥، و ٢٠ يوم من التخزين على التوالي). أيضا أظهرت النتائج أن العد الميكروبي الكلي ظل عند المعدل المسموح به في العينات المغلفة لمدة ٢٠ يوما عند التخزين في وسط محكم يحتوي على (٩٥٪ نيتروجين، و ٥٪ من الأكسجين) عند درجة حرارة ٤ درجة مئوية ، بينما كان في العينات الغير مغلفة لمدة ١٥ يوما. وبهذا تشير النتائج إلى أن طريقة التعبئة والتخزين التى تم تطبيقهما في دراستنا ساهمت في حفظ لحوم الدواجن لفترة أطول من التخزين البارد تصل إلى ٢٠ يوما للحوم المغلفة و ١٥ يوما للحوم الغير مغلفة.