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Influence of Modified Atmosphere Packaging and Frozen-Storage Period in the Colour Characteristics of Poultry Meat

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Abstract:. This study was carried out to investigate the effect of modified atmosphere packaging and frozen storage period in the colour characteristics of chick thigh meat. The treatments were 70%CO_2+15%N_2+15%O_2, 70%CO_2 +30%N_2, 70%CO_2+ 30% O_2 ,50%N_2+50%O_2, vacuumand clove oil at different frozen storage periods (1, 30, 60,and 90 days at -18 C). An 84 chick thigh meat pieces were utilized in this study. Polyethylene bags were used in packaging meat under vacuum, then filled with different gases. Colour parameters such as lightness (L*), redness/greenness (a*), yellowness/blueness (b*), Chroma (ΔC), the total colour difference (ΔE), and hue angle (h) were studied. The results demonstration that the modified atmosphere packaging treatments have a significant (P<0.05) effect on L*, a*, h values, but b*, ΔC, and ΔE parameter were not significantly affected by the treatments. Furthermore, the frozen storage periods have a significant (P<0.05) effect on L*, a*, b*, h, ΔC, and ΔE values. The result clarified that the effect of the interference between the modified atmosphere packaging treatments and frozen storage periods on a*, ΔE, ΔC, and h values was not significant, but its effect on L* and b* was significant (P<0.05). The results also showed that the highest L* value was 54.12 by using vacuumed packaging treatment on 30 days of frozen storage period. a* value was increased by using modified atmosphere packaging treatments but decreased with the increase of frozen storage period. b* value was ranged between 0.70 by control to 16.65 by using 70%CO_2+15%N_2+15%O_2. The lowest ΔE, ΔC, and h values were 4.96, 2.70 and 0.53 by using70%CO_2+30%N_2, 70%CO_2+30%N_2 and clove oil on 30, 1 and 1 days of frozen storage period respectively.

Keywords: Chroma, Lightness, Packaging, Colour, Hue angle

Introduction

The packaging is the best way to protect and to save meat and their products. Packaging must contain all necessary information, such as transport, sale, usage and all legal and environmental matters (Zakrys*et al.*, 2008). Packaging aims to convey the food inactive way which the cost realizes the industrial requirements and consumers wishes and keeps the food safe and decreases the environmental effect. The quality of canned food-related to the features of food and packaging material. Also, it delays the growth

of bacteria which cause diseases, damages, and chemical reactions and maintains the sensory and ideal qualities and specific characteristics of the product (Han, 2005). Packaging importance contains the improvement of meats 'colour, raising of storage age, reducing of humidity lost, improvement of sensory qualities, preventing of losing taste and providing information like the expiration date and additions (Maheswarappa *et al*., 2016). Modified atmosphere packaging is a modern one which includes the vacuum of air from the canes and replacement with one gas or mix of gases (Parry, 1993). Modified atmosphere packaging usually has mix of gases as O_2 which keeps the colour stable, CO_2which inhibits microbial growth and N_2which maintains the can shape (Sorhein *et al*., 1999; Jackson & Bertelsen2000; Kerry *et al*., 2006). The colour is a very important factor for consumers to evaluate the meat. It is an indicator to the freshness and of the product (Lynch *et al*., 1986). One of the main hypotheses of modern packaging methods is keeping the desired colour for a long period (Gazalli*et al*., 2013).

The lightness (L*)shows the extent of clarity of the product if the colour is dark(the value of L*is low). The value of L*is about 0-100,blackcolour is 0 and pure white is 100. The* value represents the change in colour between the pink and red. a*value means reddish colours if it is positive and greenish colours if it is negative (Pathare *et al*., 2012; Gulrajani, 2010). a* value is -120 to 120 (Leon *et al*., 2006). b* value means yellowish colours if it is positive and bluish colours if it is negative (Gulrajani, 2010; Dathare*et al*., 2012). b*value is between -120 to 120if b*=0 the colour is neutral or gray (Yam & Papadakis, 2004). Hue angle describes the relativity amounts for reddish and yellowish where 360°\ 50° represents red\ purple, 90^0 represents yellow,180^0 represents green and 270^0 represents blue, purple or colours which close from the principle colours .As a result, the product has a red colour if the angle is at its lowest value. Hue angle gradient depends on a*and b*. It is valued between the pure red, angle=0^0 and pure yellow, angle =90^0. It refers to browning meat or increasing of yellow colour within the range of meat colours because of metmyoglobin formation when the value of this angle is high. Mancini & Hunt (2005) stated that the colour of muscles depends on myoglobin which can be converted to three cases: deoxyhemoglobin, metmyoglobin, and oxymyoglobin.

Topacka *et al*. (2016) showed the L*value has not been significantly affected by the increasing storage period of sliced beef under vacuum. Also, clarified a* value has significantly affected by the packaging method where MAP and MAP-VSP gave a high value of a*compared to packaging under vacuumed sliced beef (VSP). Additionally, the changes in red colour were paired with the transforming myoglobin on the meat surface. The reason for the decrease of a*value is oxidation of myoglobin to metmyoglobin at the increase of storage period. The colour of poultry meat is influenced by several factors such as age, sex, strain, nutrition, fat between muscles, conditions that bird exposed before slaughtering and industrial and chemical material conditions (Petrcci, 2009).

The aim of this study was to investigate the effect of modified atmosphere packaging in the colour characteristics of poultry meat during different freeze -storage times.

Materials &Methods

Birds used in the experiment

Parts of chicken thighs were used in this experiment. They were put in bags made of polyethylene which were completely vacuumed from the air and they were filled with gases, the details were as below:

Control, 70% CO_2+15% N_2+15% O_2, 70% CO_2+30% N_2, 70% CO_2+30% O_2, 50% N_2+50% O_2, vacuum and 1.5 ml clove oil at different frozen storage times (1, 30, 60 and 90 days at -18ºC). These percentages of treatments were selected based on the preliminary data and were directed by prior researches such as Kader *et al*. (1989), Parry (1993) and Brodowska *et al*. (2019).

Gas charging device

Gas filling system is designed and manufactured as shown in fig. (1) it contains three gas cylinders are CO_2,O_2,and N_2. Each cylinder has a controlling valve in the discharge of gas which connects with plastic pipe that has a control valve. The three plastic pipes connected with a delivery valve through a pipe existing on polyethylene cover which contains the meat, while putting it on a digital balance. (Fig. 1)

Mechanism of Operation

In the beginning, delivery valve is fixed on the bags of packaging. Then, wholes are made in the bag by a needle, and after that they are filled with meat, are emptied from air and are tight closed thermally.

The bag is put on sensitive zeroed balance, then, the charge pipe is fixed to the delivery valve and one of gases valve is slowly opened and monitoring changing the weight until it reaches the required limit, and after that, the valve is immediately closed. This process is done with rest gases. Every experiment is repeated for three times and then it is stored (Fig. 2).

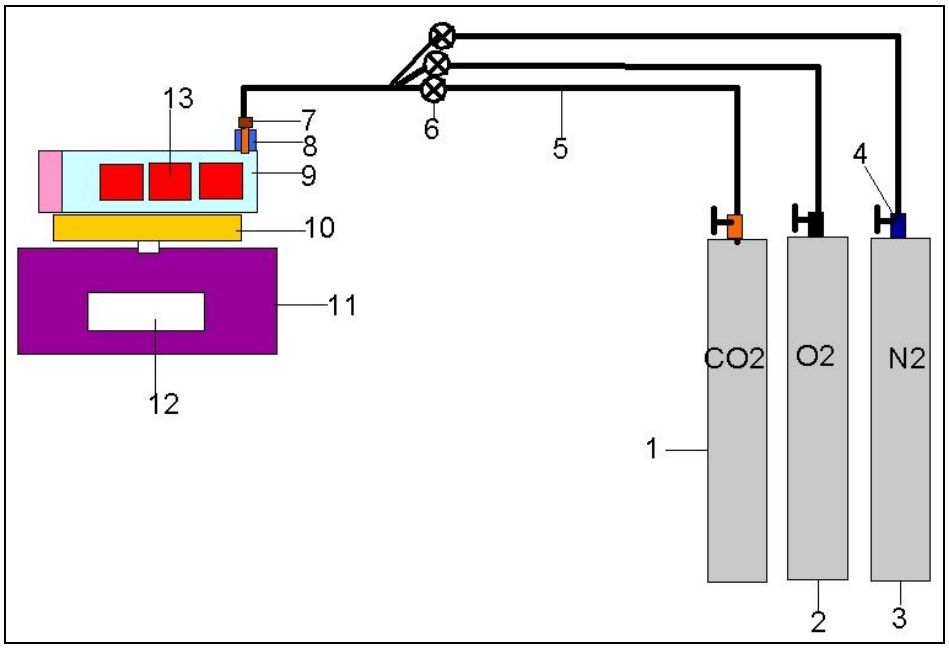

Fig. (1): Scheme of the gas pumping system in the meat package.

Abbrev.: 1.CO_2 gas cylinder, 2.O_2 gas cylinder, 3. N_2 gas cylinder, 4.valve, 5.pipe, 6.valve, 7. filled gas point, 8.delevery valve, 9.meat bag, 10. cuff digital scale, 11. scale, 12. Scale screen, 13. Meat.

Colour measurement

The image processing method is used to analyze the colour characteristics of part of thigh. Images have taken to all treatments by a high-resolution digital camera (8 megapixels) in suitable light, image program is used instead of Photoshop program to analyze the image and to find the values of corrected standard values within the following equations (Yam & Papadakis, 2004).

$$L^* = \frac{L}{255} \times 100 \quad (1)$$

$$a^* = \frac{240a}{255} - 120 \quad (2)$$

L*a*and b*according to Yam & Papadakis (2004).

Where: L is the white\ lightness, is the redness\ greenness and bis the yellowness\ blueness. The mean of L, a, & b*consider non-standard in this case, so it should transform to

Fig. (2): Photo of the gas pumping system in meat bags.

$$b^* = \frac{240b}{255} - 120 \quad (3)$$

The change in colour was calculated from the following equation (Wrolstatad & Smith, 2017):

$$\Delta E = \sqrt{(L_o{}^* - L^*)^2 + (a_o{}^* - a^*)^2 + (b_o{}^* - b^*)^2} \quad (4)$$

Where:ΔE is the total change in colour, $L_o{}^*$is the lightness, $a_o{}^*$is the redness,$b_o{}^*$ is the yellowness for untreated meat.

The colour density (chroma) is calculated from the following equation (Robertson,1977;Wrolstad & Smith, 2017):

$$\Delta C = \sqrt{(a_o{}^* - a^*)^2 + (b_o{}^* - b^*)^2} \quad (5)$$

Hue angle is calculated as follows(Wrolstad & Smith, 2017):

$$h = tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (6)$$

Statistical analysis

Factorial experiment in full random design (4×7) has used seven factors , Control, 70% CO_2 + 15% N_2 + 15% O_2,70% CO_2 + 30% N_2,70% CO_2 + 30% O_2,50% N_2 + 50% O_2, vacuum and clove oil at four storage periods which are 1, 30, 60 and 90 days. Every factor is repeated three times. LSD test is used to compare the averages of the factors is at level 0.05. SPSS ver. 21 program is used in analysis.

Results & Discussion

Lightness (L*)

Table (1) exhibited the effect of modified atmosphere packaging and frozen storage time in the value of L*. the modified atmosphere packaging significantly (P<0.05) affects the value of L* which decreased at using atmosphere of 50% N_2+50% O_2 and clove oil comparative with control. This indicated that the colour is darker than control. This may attributed to presence of oxygen which led to the form the dark colour via increasing the dye.

There are no significant differences appear in the value of L* between70% CO_2+15% O_2+15% N_2,70% CO_2+30% N_2, 70% CO_2+30% O_2, control and vacuum. Also, there are no significant differences between 50%N_2+50%O_2 and clove oil. Treatment of clove oil was characterized that L* value was as close as control. It was 42.28 and 42.65 continuously and that because the oxygen was not in the bag and it did not change the dyes. The results refer that the lower value of L* was when clove oil used because of the light dye in it which led to meat dark.

Additionally, some of meat sides might stick on the bag making the reaching of essential oil in small quantities which led to decrease L*value and became dark, note that the oil density higher than water density. Martucci *et al.* (2015) and Adilah & Hanani. (2016) showed the meat packaging with natural antioxidants prevents the oxidation of

meat because the active packaging interacts with upper space of the can.

In the case of storage time effects in L*value, the L*value was changed through the Frozen storage periods. Increasing frozen storage period led to increase of L*value under high oxidation conditions. In addition, protein form in meat was changed and dispersed the light (Mac Dougal., 1982). Esmer *et al*. (2011) and Soldaton *et al*. (2009) proved that L*value did not affect by modified atmosphere packaging treatments. But L*value after 60 and 90 days of storage was significantly decreased (P<0.05) and was 31.75 and 27.33 respectively. This because of oxidation occurrence. L* value after 30 days of storage not significantly increased compared to control. This result agreed with Murphy *et al*. (2013) who clarified that a little increase has happened in the L*value of packaged meat with MAP during Frozen storage period. The results also showed the two times, 60 and 90 days, did not appear significant differences in L*value. The colour of meat was very dark during 90 days of storage period, it was 27.33 and that because of the high oxidation.

The results showed significant differences (P<0.05)in L* value because of interaction between the modified atmosphere packaging treatments and Frozen storage period. The highest L*value was at using the vacuum during a frozen storage period of 30 days, it was 54.12 because there was not oxygen that made the meat colour an attractive cherry red.

Table (1): Effect of modified atmosphere packaging and frozen storage period on L* value.

Treatments	Frozen storage period (day)				Treatment mean
	1	30	60	90	
Control	41.76±2.15	52.25±5.58	±2.15 48.14	26.96±1.56	42.28±5.54
70%CO_2+15%N_2 +15%O_2	32.25±5.58	37.84±0.19	± 2.7441.37	38.43±1.37	37.45±1.90
70%CO_2+30%N_2	47.55±3.82	49.41± 4.31	±1.6633.82	29.41±0.2	40.05±4.96
70%CO_2+30%O_2	50.49±6.56	40.98±2.45	±1,.8632.25	35.39±2.35	39.78±4.00
50%N_2+50%O_2	37.06±7.25	±7.4934.71	27.06±3.92	28.04±0.88	31.71±2.46
Vacuum	44.41± 0.68	± 0.5854.12	±0.68 30.69	41.37±4.31	42.65±4.82
Clove oil	33.04 ± 0.88	± 2.0537.35	38.73±2.84	16.08±1.27	31.30±5.00
Frozen storage periodmean	35.82±3.54	38.4575±3.96	31.7575±4.15	27.335±5.99	37.88±3.52

RLSD for treatments = 4.16, RLSD for frozen storage period= 3.14, RLSD for treatments × frozen storage period= 8.32, ±: standard error

Redness\ Greenness (a*)

Table (2) showed the effect of modified atmosphere packaging treatments and frozen

storage period in tjhe a* value. The results disclosed the modified atmosphere packaging

treatments has significantly affected (P<0.05) in a* value and modified atmosphere packaging including 70%CO_2+ 30 %N_2 has given the highest a* value, it was 16.12, this was higher than control, (9.53), 70%CO_2+30%O_2(14.29),70%CO_2+15%N_2+15%O_2 (11.65), clove oil (13.64),15% N_2+15%O_2 (13.17) and vacuum(12.58),and that because the oxidation of oxymyglobin into metomyglobin. Topacka *et al*. (2016) mentioned the packaging method affected in a*value, then modified atmosphere packaging treatments gave the highest a*value in comparative with packaging under the vacuum of slices beef. The changes of red colour (a*) depends on transforming myoglobin on meat surface. The results did not display significant differences between 15%N_2+15% O_2, clove oil, vacuum, 70% CO_2+15% N_2+15% O_2 and 70%CO_2+30% O_2 in a*value.

The results of the effect of frozen storage period in a*value revealed a significant difference (P<0.05) in the frozen storage periods of a* value. The highest a*value was 15.59 at the period of one day and that it might happen because of myoglobin oxidation. a* value has decreased with the increase of Frozen storage period. When the frozen storage period increased from 1 to 90 days the a*value decreased from 15.56 to 11.90 and that because the transforming oxymyglobin to metmyglobin. According to Topack *et al*. (2016) the reason of the decrease of a*value was the oxidation of myoglobin to metmyglobin during the increase of frozen storage period and it did not spectacle significant difference between frozen storage periods 30,60 and 90 days, in a*value.

The interaction between modified atmosphere packaging treatments and frozen storage periods did not affect in a*value. Although, the highest a* value was 17.41 at control during one day, and it decreased to the lowest value at the same treatment during 90

Table (2): Effect of the modified gas atmosphere and frozen storage period on value a* for meat chicken thighs.

Treatments	Frozen storage period(day)				Treatment mean
	1	30	60	90	
Control	17.41±1.41	6.59±1.64	8.24±1.88	5.88±1.88	9.53±1.70
70%CO_2+15%N_2+ 15%O_2	15.53±0.47	8.24±0.70	12.00±0.11	10.82±1.35	11.65±1.40
70%CO_2+30%N_2	15.76±1.64	16.24±2.11	16.71±1.41	15.76±1.17	16.12±0.58
70%CO_2+30%O_2	15.29±0.47	13.88±1.88	12.24±0.47	15.76±0.23	14.29±0.76
50%N_2+50%O_2	14.82±1.88	12.71±0.58	11.29±0.88	13.88±1.17	13.17±1.87
Vacuum	16.24±0.23	11.76±0.00	10.59±0.24	11.76±0.70	12.58±0.29
Clove oil	13.88±0.00	15.53±2.80	12.24±0.23	12.94±2.82	13.64±1.46

Frozen storage period mean	15.56±0.87	12.13±1.67	11.90±1.75	12.40±1.47	12.99±1.43

$RLSD_{0.05}$ for treatments = 2.19, $RLSD_{0.05}$ for frozen storage period= 1.65, $RLSD_{0.05}$ for treatments × frozen storage period= ns, ±: standard error

days which was 5.88. According to modified atmosphere packaging treatments, a*value was between 16.71 at 70% CO_2+30% N_2 during frozen storage period of 60 days to 8.24 at 70% CO_2 +15% N_2+15% O_2 during frozen storage period of 30 days.

Yellowness\greenness (b*)

Table (3) demonstrated the effect of modified atmosphere packaging treatments and frozen storage period in b* value. The results exhibited that treatments did not significant affect b*value despite the differences between them. b* values were from 10.70 in control to 16.65 in using modified atmosphere packaging 70% CO_2+15% N_2+15% O_2. According to the effect of frozen storage periods in b*value, the results of b* value ($P<0.05$) has significantly increased with the increase of frozen storage period because the forming of deoxymyglobin during the increase of frozen storage period. Amsa (2012) mentioned the reason for decrease in b*value was because of partial decrease of metmyglobin and its transforming into deoxymyglobin. Not significant increase in b* value happened after 30 storage days, but this increase became significant with the progress of frozen storage period.

The differences between 60 and 90 days were not significant. According to interaction between the modified atmosphere packaging treatments and frozen storage period, the results bared differences were significant ($P<0.05$) in the b* value. The lowest b*value was at control for 90 days, it was 3.29. The highest b*value was at using modified atmosphere packaging 70% CO_2+15% N_2+15% O_2, it was 27.76 during the frozen storage period of 90 days.

Table (3):Effect of modified atmosphere packaging and frozen storage period on b* value of meat chicken thighs.

Treatments	Storage time (day)				Treatment mean
	1	30	60	90	
Control	12.71±2.35	15.06±0.94	11.76±1.94	3.29±0.47	10.70±1.43
70%CO_2+15%N_2+ 15%O_2	13.18±1.41	8.71±0.70	16.94±1.41	27.76±1.58	16.65±2.52
70%CO_2+30%N_2	12.71±0.35	10.82±1.25	12.24±0.47	13.88±1.64	12.41±1.78
70%CO_2+30%O_2	11.53±0.70	12.71±2.11	17.65±0.70	18.35±0.24	15.06±0.94
50%N_2+50%O_2	16.47±0.24	19.06±1.88	14.82±1.88	10.12±0.00	15.11±1.00
Vacuum	13.29±1.94	16.71±1.52	18.35±0.23	16.47±0.47	16.20±1.79
Clove oil	10.12±0.70	14.59±0.24	18.35±0.24	15.52 ±1.88	14.64±0.76

Time mean	12.86±1.52	13.95±1.66	15.73±0.98	15.05±2.18	14.39±1.60

$LSD_{0.05}$ for modified atmosphere packaging treatments = ns, $RLSD_{0.05}$ forfrozen storage period= 1.92, $RLSD_{0.05}$ formodified atmosphere packaging ×frozen storage period= 5.09, ±: standard error.

Colour total differences

The results of interaction between modified atmosphere packaging treatments and frozen storage period in b*value was varied, for example b*value reached 13.8, 19.06 and 18.35 at using modified atmosphere packaging 70% CO_2 +15% N_2 +15% O_2 at one day of frozen storage period, 50% N_2+50% O_2 at 30 days of frozen storage period and Vacuumed packaging at 90 days of Frozen storage period respectively, and it reached 27.76 and 8.71 during storage periods of 90 and 30 days respectively by using 70% CO_2+15% N_2+15% O_2. In the case of using clove oil, the b* value was increased significantly ($p<0.05$) as frozen storage period increased from 1 to 60 days, but it decreased to 15.52 at 90 days of frozen storage period. Cachaldora *et al*. (2013) found out increase in b*value at using modified atmosphere packaging included 15:30: CO_2:N_2:O_2 50. Rubio *et al.* (2008) mentioned that b*value increased after 30 days of storage, then it decreased.

Table (4) showed the effect of modified atmosphere packaging and frozen storage period in the value of the colour total difference (ΔE). The results presented that modified atmosphere packaging treatments did not significantly affect ΔE value despite little differences. The lowest ΔE value was at using modified atmosphere packaging included 70%CO_2+30%O_2,it was 9.12.The highest ΔE value was 13.95 at using modified atmosphere packaging included 50% N2+50%O_2.

According to the effect of frozen storage period in ΔE value, the results clarified significant differences between frozen storage periods in ΔE value.

Table (4): Effect of modified atmosphere packaging and frozen storage period on ΔE value of chicken meat carcasses.

Treatments	Storage time (day)				Treatment mean
	1	30	60	90	
Control	------	10.24±1.93	12.07±0.70	8.15±1.80	7.61±1.36
70%CO_2+15%N_2+ 15%O_2	14.84±0.93	8.42±0.92	9.49±0.25	11.05±8.10	10.95±3.55
70%CO_2+30%N_2	12.87±0.49	4.96±1.22	14.24±1.30	13.57±2.43	11.41±0.11
70%CO_2+30%O_2	11.40±1.62	6.42±1.50	10.06±1.05	8.63±0.15	9.12±1.08
50%N_2+50%O_2	25.30±1.07	8.03±0.35	13.89±1.36	8.59±1.68	13.95±1.29
Vacuum	12.28±0.65	12.18±1.20	11.21±0.05	10.26±0.56	11.48±1.36

Clove oil	10.82±1.78	16.91±1.30	12.48±0.30	15.36±1.72	13.89±1.77
Time mean	12.50±1.09	9.59±1.20	11.92±1.71	10.80±0.77	11.20±1.06

$RLSD_{0.05}$ for modified atmosphere packaging treatments = ns, $RLSD_{0.05}$ for frozen storage period= 2.70, $RLSD_{0.05}$ for modified atmosphere packaging treatments × frozen storage period= ns, ±: standard error.

ΔE value significantly (P<0.05) decreased from 12.50 to 9.59 during the increase frozen storage period from 1 to 30 days respectively. The decrease of ΔE at two frozen storage periods, 60 and 90 days compare of one day, was not significant. No significant differences appear between frozen storage periods 30, 60 and 90 days.

The interaction between modified atmosphere packaging treatments and frozen storage periods was not significant although presence differences in ΔE values. ΔE values were from 4.96 at using modified atmosphere packaging included 70% CO_2+30% O_2 during frozen storage period of 30 days, to 25.3at using modified atmosphere packaging included 15%N_2 +15% O_2 during frozen storage period of one day. The decrease of ΔE values considers positive where the differences are little between treated meat colour compounds and fresh meat.

Chroma (ΔC)

Table (5) demonstrations the effect of modified atmosphere packaging and frozen storage time in ΔC value. The results clarified that the differences between the modified atmosphere packaging treatments in ΔC value were not significant. ΔC value ranged from 4.99 at using the modified atmosphere packaging70% CO_2+30%N_2 and 8.65 at using modified atmosphere packaging included 70%CO_2+15%N_2 + 15%O_2. According to the effect of frozen storage period in ΔC value, the results displayed the ΔC value has significantly (P<0.05) increased with the

Table (5): Effect of modified atmosphere packaging and frozen storage period on ΔC value of chicken thighs meat.

Treatments	Frozen storage period (day)				Treatment mean
	1	30	60	90	
Control	--------	7.41±0.35	11.62±0.17	6.40±3.07	6.35±1.28
70%CO_2+15%N_2+ 15%O_2	2.70±1.64	11.20±0.17	6.37±2.57	14.32±7.57	8.65±2.98
70%CO_2+30%N_2	3.40±0.51	5.55±1.54	7.39± 0.83	3.62±0.64	4.99±1.38
70%CO_2+30%O_2	7.54±1.79	5.55±0.54	7.70±1.14	8.07±0.41	7.21±1.47
50%N_2+50%O_2	3.50±0.16	8.15±1.14	7.63±0.26	9.98±1.25	7.31±2.45
Vacuum	3.38±1.11	7.00±0.30	6.92±1.19	9.93±0.79	6.80±1.09
Clove oil	4.69±0.81	8.96±0.46	6.91±0.88	6.54±0.38	6.77±2.13

Frozen storage period mean	3.60±1.43	7.68±1.78	7.79±1.29	8.40±2.58	6.86±1.82

$RLSD_{0.05}$ for modified atmosphere packaging treatments= ns, $RLSD_{0.05}$ for frozen storage period= 2.09, $RLSD_{0.05}$ for modified atmosphere packaging treatments × frozen storage period= ns, ±: standard error

increase of frozen storage period on one day, and that because the increase of oxidation at the increase of frozen storage period which led to increasing of colour density. However, no significant differences appear between the frozen storage periods 30, 60 and 90 days in ΔC value which was 7.68, 7.79 and 8.40 respectively. According to the effect of the interaction between modified atmosphere packaging treatment and Frozen storage period, the result indicated the interaction effect was not significant in ΔC value despite the differences in ΔC value. For example, ΔC value was 2.70 at using the modified atmosphere packaging 70% CO_2 +15%N_2+15%O_2 during frozen storage period of one day. ΔC value increased to 14.32 at frozen storage period of 90 days which is the highest ΔC value. The differences in ΔC value was largely decreased compare to the rest interactions. For example, at using the modified atmosphere packaging 70% CO_2+15%N_2 +15% O_2 during frozen storage period of 60 days. ΔC value were 7.70 and 7.63 respectively and were 11.2 and 14.32 at using the modified atmosphere packaging of7% CO_2+15% N_2+15% O_2 during 30 and 90 days respectively. The differences were very little between modified atmosphere packaging15%N_2+15%O_2 and under vacuum which was 9.98 and 9.93 respectively.

Hue Angle (h)

Table (6) exhibited the effect of modified atmosphere packaging and frozen storage time in the value of the hue angle (h).The results indicated the modified atmosphere packaging treatments has a significant effect ($P<0.05$) in h value and 70% CO_2+30% N_2 gave the lowest h value which was 0.65.

Table (6): Effect of modified atmosphere packaging and frozen storage period on the h value for chicken carcasses meat.

Treatments	Frozen storage period (day)				Treatment mean
	1	30	60	90	
Control	0.75±0.00	0.95 ±0.04	1.24±0.05	0.64±0.13	0.89±0.05
70%CO_2+15%N_2+ 15%O_2	0.70±0.06	0.81±0.00	0.95±0.04	1.17±0.15	0.91±0.06
70%CO_2+30%N_2	0.67±0.14	0.58±0.04	0.66±0.14	0.72±0.09	0.65±0.10
70%CO_2+30%O_2	0.66±0.02	0.57±0.03	0.85±0.05	1.00±0.01	0.77±0.03
50%N_2+50%O_2	0.76±0.07	1.04±0.06	1.01±0.02	0.87±0.06	0.92±0.05
Vacuum	0.67±0.10	0.94±0.10	0.91±0.02	1.10±0.02	0.90±0.06

Clove oil	0.53±0.02	0.79±0.12	1.01±0.01	0.94±0.05	0.82±0.05
Frozen storage period mean	0.67±0.05	0.81±0.05	0.94±0.05	0.92±0.07	0.83±0.05

$RLSD_{0.05}$ for atmosphere packaging treatments = 0.15 $RLSD_{0.05}$ for frozen storage period= ns, $RLSD_{0.05}$ for modified atmosphere packaging treatments × frozen storage period= ns, ±: standard error.

This value was significantly different (P<0.05) with all treatments excluding 70% CO_2+30% O_2.where the differences between them were not significant. Hence, h value was 0.77 which referred to redness of meat colour. Yancey *et al*. (2001) reported that the increase of h-value means increase of brown colour and reduce of redness of meat. This referred to oxidation of myoglobin. Ghris (2007) clarified that colour is better when h value decreases and its decrease refers to increase of metmyglobin concentration. Also, the results did not show a significant difference between control, 70% CO_2+15% N_2+15% O_2, vacuum, and clove oil. According to the effect of frozen storage period in h value, the results clarified the frozen storage period did not significantly affect in h value although, there were simple differences between the treatments, h value was between 0.67 during the Frozen storage period on one day and 0.94 during frozen storage period of 60 days. Additionally, there was no significant effect of interaction between modified atmosphere packaging treatments and frozen storage period despite some differences between them. The lowest h value was 0.53 at using clove oil during frozen storage period of one day and the highest h value was 1.24 at using the control during frozen storage period of 60 days, and that because of oxidation of myoglobin to metmyglobin.

Conclusions

The modified atmosphere packaging significantly (P<0.05) affected the value of L* and a*. Modified atmosphere packaging included 70% CO_2+ 30 % N_2 has given the highest a* value. Modified atmosphere packaging had no significant effect in b*value, ΔE value and ΔC. Modified atmosphere packaging treatments have a significant effect (P<0.05) in h value, and 70% CO_2+30% N_2 gave the lowest h value. Frozen storage time had a significant effect on the colour parameters.

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Conflicts of interest

The authors declare that they have no conflict of interests.

Ethical approval

All applicable national and international guidelines for the care and use of animals were followed

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