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Comparison of the effect of modified atmospheric and aerobic packaging on quality attributes of chicken meat during refrigeration storage

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Abstract
Modified atmospheric packaging (MAP) is commonly used in the food industry to maintain the quality and extend the shelf life of meat and meat products. Therefore, research was carried out to compare the effect of aerobic and MAP on the quality and shelf of chicken meat. The chicken leg and breast meat were separately aerobic packaged as well as modified atmosphere packaged (MAP20 = 20% O_2 + 30% CO_2 + 50% N_2; MAP 10 = 10% O_2 + 40% CO_2 + 50% N_2; MAP 0 = 0% O_2 + 20% CO_2 + 80% N_2) and stored at refrigeration temperature (4±1 °C) to study the changing quality attributes. By considering all the meat quality parameters, it is concluded that the shelf life of both chicken leg and breast meat under aerobic packaging was 6 days. Irrespective of different gaseous concentrations (0-20% O_2 + 20-40% CO_2 + 50-80% N_2), the MAP showed a shelf life of 15 days for chicken leg meat and 12 days for chicken breast meat.

Keywords: Modified atmospheric packaging, aerobic packaging, chicken breast meat, chicken leg meat, shelf-life, quality

Introduction
Modified atmospheric packaging (MAP) is the replacement and/or removal of the atmospheric gases surrounding the food product before sealing the package with vapor-barrier packaging materials (Mc Millin *et al.*, 2008) [16]. Currently, this significant inventive system turned out to be popular in retail food packaging (Sezer *et al.*, 2022) [22]. MAP may be defined as a packaging in which air is replaced by a simple gas or mixture of gases depending on the type of meat being packed (Wu *et al.*, 2022) [28].
Three gases are mainly used in MAP namely carbon dioxide, oxygen, and nitrogen. Oxygen preserves the bright red color of meat but causes oxidative rancidity, growth of aerobic spoilage organisms, premature browning during cooking. The efficacy of MAP in prolonging the shelf life of packed meat relies on the antimicrobial properties of CO_2 present inside the package (Arvanitoyannis *et al.*, 2012) [3]. Nitrogen is used as filler gas as well as to prevent pack collapse caused by carbon dioxide. Nitrogen has no antimicrobial properties and does not affect the meat color. (Narasimha Rao and Sachindra, 2002, Kandeepan and Tahseen, 2022) [20, 12]. This research was undertaken to study the comparative effects of MAP and aerobic packaging on the quality attributes of chicken meat.

Materials and Methods
A. Meat sample
For modified atmospheric packaging, the gas mixture (O_2, CO_2, N_2) was blended in a Gas mixing machine (Elixir technologies, GAS MIXER - E2M316, Bangalore) attached to oxygen, carbon dioxide, nitrogen cylinders. The concentrations used in modified atmospheric packaging were MAP-20 (20% O_2 + 30% CO_2 + 50% N_2), MAP-10 (10% O_2 + 40% CO_2 + 50% N_2), and MAP-0 (0% O_2 + 20% CO_2 + 80% N_2). In aerobic packaging, the trays were sealed using a tray sealing machine without flushing any gas. The packed meat was then stored under refrigeration storage at 4±1 °C. The aerobically packaged meats were analyzed on 0, 3, 6, and 9 days of storage. Modified atmosphere packaged samples were studied at 0, 3, 6, 9, 12, 15, 18, and 21 days of storage.

B. Physico-chemical parameters

i. pH

The pH of the chicken meat sample was estimated using the portable handheld pH meter (Hannah Instruments, H198163, Romania).

ii. Thiobarbituric acid reactive substance (TBARS)

Thiobarbituric acid reactive substance method by Zhang *et al*. (2019) [31] was used to determine the lipid oxidation in chicken meat. Results were interpreted as TBARS in mg malondialdehyde (MDA)/ kg chicken meat.

iii. Myoglobin content

To extract the myoglobin from the chicken meat sample Krzywicki (1982) [14] and Shang *et al*. (2020) [23] method was used.

vi. Measurement of concentration of gases

The concentrations of O_2, CO_2, and N_2 were measured by inserting the needle probe at five different places inside the packaging through the Gas analyzer Checkmate 3, (Dansensor -L.E 316/2015, a Mocon company, Denmark).

C. Microbiological analysis

All the microbiological parameters of the meat sample were determined as per the methods described by APHA (2001) [2].

D. Sensory analysis

The sensory quality of the chicken meat samples was judged based on appearance, color, odor, and sliminess characteristics. The samples were subjected to sensory evaluation by a panel consisting of a minimum of seven members. The sensory evaluation was repeated thrice.

E. Statistical analysis

The experiment has been repeated a minimum of three times in duplicate and the data obtained for different meat quality parameters were compiled and analyzed using SPSS (version 16.0 for Windows, SPSS, Chicago, USA). The smallest difference (D_5%) for the two means was reported as significantly different (p<0.05).

Results and Discussion

i. pH

The pH of all the groups was significantly (p<0.05) decreasing, with storage time (Fig. 1). The pH of the aerobic and modified atmosphere packaged chicken meat differed significantly (p<0.05) on days 6 and 9 of the refrigerated storage period. Rapid pH decline in muscle may be related to the denaturation of myofibrillar and sarcoplasmic proteins, accumulation of lactic acid and the formation of carbonic acid through carbon dioxide dissolution in the aqueous portion of chicken meat (Milijasevic *et al*. 2019). A significant (p<0.05) reduction in the pH values of fresh CBM MAP-1 (30:70 = CO_2:N_2) and MAP-2 (70:30=CO_2:N_2), respectively during the 25 days of storage time at 4 °C (Chouliara *et al*. 2007) [5]. The current results with broiler chicken meat collaborated with the findings of Vaithiyanathan *et al*. (2008) [27] indicating that the pH value of aerobic packaged spent hen breast meat at 4 °C gradually decreased from 5.73 on day 0 to 5.30 on the 28th day of postmortem.

The results indicated in Fig.1 showed that the pH of MAP-CLM groups did not differ significantly (p>0.05) compared to MAP-CBM groups during the whole storage period.

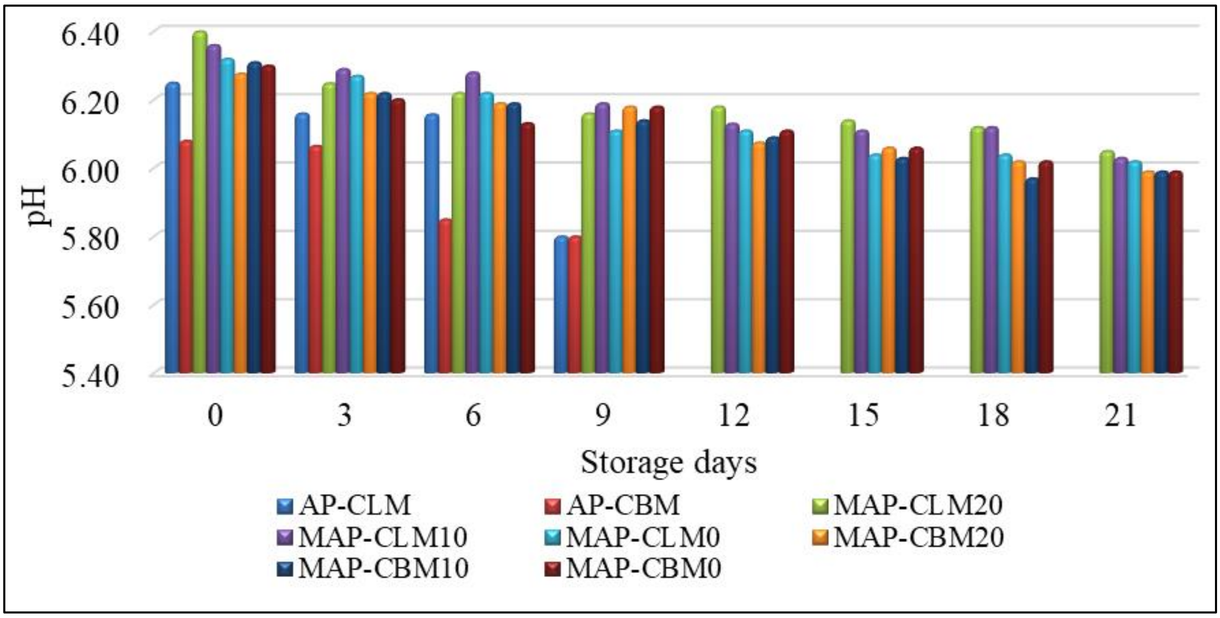

Fig 1: Change in the pH values of chicken leg and breast meat with aerobic and modified atmospheric packaging during refrigeration storage (Mean ± SE)

ii. Thiobarbituric acid reactive substance (TBARS)

The TBARS values of all the groups were significantly (p<0.05) increasing with storage time (Fig.2). The TBARS values of the aerobic and modified atmosphere packaged chicken meat differed significantly (p<0.05) during the whole refrigerated storage period. The highest value of TBARS was recorded in AP-CBM on day 9. The increasing trend of TBARS value is due to increased oxidation of unsaturated fatty acids during storage which is accelerated in the presence of oxygen (Mendes *et al*., 2008) [17].

Similar results were obtained by Abdullah *et al*. (2017) [1] who determined an increase in thiobarbituric acid reactive substance value in all analyzed samples (MAP1-80% O_2 + 20% CO_2 and MAP2-70% N_2 + 30% CO_2) of organic chicken breast and thigh during 14 days of storage at 2±2 °C. Chicken breast fillets to which Rosemary essential oil was added had significantly lower TBARS values than did the untreated fillets, and the TBARS value increased in all the groups (air packaging, air packaging + 0.2% REO, MAP- 30% CO_2 + 70% N_2 and MAP + 0.2%) during the storage period (Kahraman *et al*., 2015) [11].

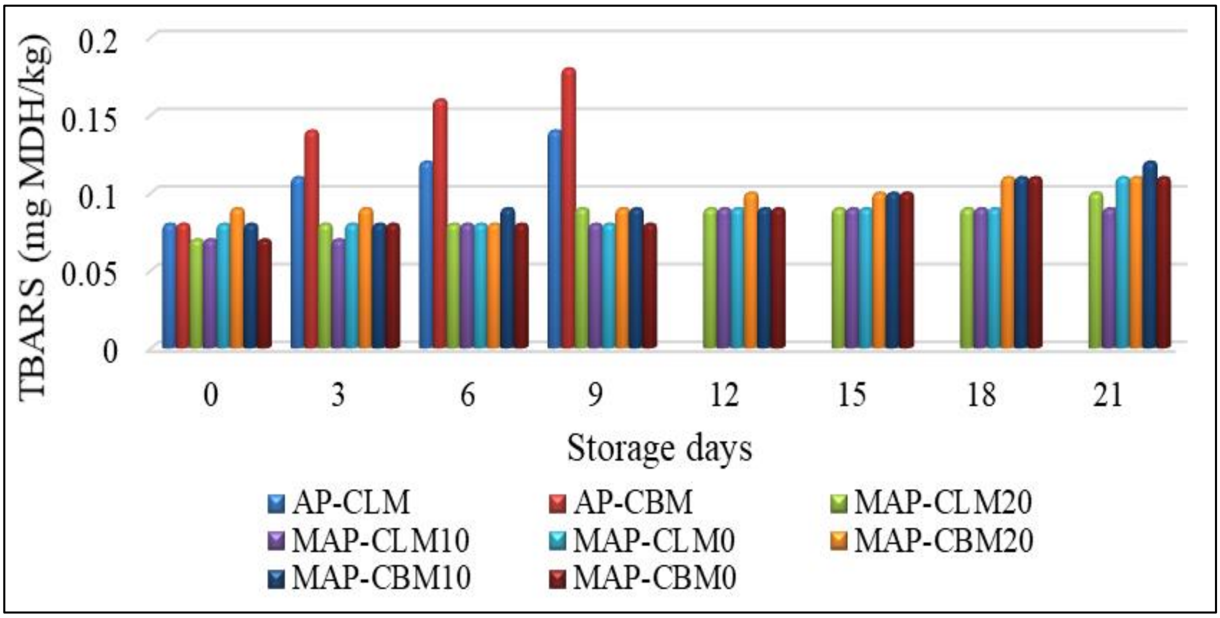

Fig 2: Change in the TBARS values of chicken leg and breast meat with aerobic and modified atmospheric packaging during refrigeration storage (Mean ± SE)

iii. Myoglobin content

The deoxymyoglobin (Dmb) content of all the groups was found to be significantly (p<0.05) increasing with storage time (Table.1) except MAP-CBM0, where no significant difference was noticed (p>0.05), which may be due to the absence of oxygen. The deoxymyoglobin content of the aerobic and modified atmosphere packaged chicken meat differed significantly (p<0.05) on days 0, 3, and 9 of the refrigerated storage period. The highest value of deoxymyoglobin content was recorded in MAP-CLM20 on day 21 and the lowest in MAP-CBM10 on day 0. Myoglobin is a water-soluble sarcoplasmic protein. Its function and structure in the muscle depend on temperature, oxygen partial pressure, pH, microbial growth, and muscles reducing capacity (Grujic *et al*., 2010) [8].

The metmyoglobin content of the AP meats was significantly (p<0.05) increased with storage time (Table.1). The metmyoglobin content of the aerobic and modified atmosphere packaged chicken meat differed significantly (p<0.05) on days 0 and 3 of the refrigerated storage period.

The oxymyoglobin content of all the groups was significantly (p<0.05) decreased with storage time except in MAP-CBM20, where no significant difference (p>0.05) was noticed (Table.1) which may be due to a decrease in oxygen% with storage time. Oxymyglobin content in *triceps* and *longissimus dorsi* muscles in pigs reached the maximum (51.61-51.75%) at 35 d slaughter and they achieved minimum levels (41.06-33.82%) at 161 d slaughter (Yu *et al*., 2017) [29].

The results indicated in Table.1 showed oxymyoglobin content was significantly (p<0.05) higher on day 0 and significantly (p<0.05) lower on day 9 in MAP-CBM groups compared to AP-CBM. Oxymyoglobin content of the MAP-CLM groups differed significantly (p<0.05) compared to MAP-CBM groups on days 12 and 18.

vi. Measurement of the concentration of gases

The oxygen% of all the groups was significantly (p<0.05) decreasing, with storage time (Table.2). The oxygen% of the aerobic and MAP chicken meat differed significantly (p<0.05) during the refrigerated storage period, which might be because of consumption of oxygen by putrefactive bacteria and permeability of packaging material (Jeremiah, 2001) [9].

The results were similar to Chemiel *et al*. (2018) [4] who noticed that the content of oxygen decreased with storage time in CBM packages stored in the cooling room (2±0.5 °C) as well as refrigerated display case (<4 °C). The lowest O_2 content was observed in MAP (75% O_2 + 25% CO_2) packages stored for 9 days in the display case. The results indicated in Table.2 showed that oxygen% of the MAP-CLM groups differed significantly (p<0.05) compared to MAP-CBM groups on days 0, 15, 18, and 21.

The carbon dioxide% of all the groups was significantly (p<0.05) decreasing, with storage time except MAP-CBM10, where no significant difference (p>0.05) was noticed (Table.2). The carbon dioxide% of the aerobic and MAP chicken meat differed significantly (p<0.05) during the refrigerated storage period. The results were similar with Jinemez *et al*. (1997) [10] who noticed that the concentration of the CO_2 decreased with increasing storage time (21 days) at 4 °C in both MAP's (70% N_2 + 30% CO_2 and 30% N_2 + 70% CO_2) packaged CBM. Both AP-CBM and AP-CLM showed a significantly (p<0.05) lower carbon dioxide% compared to MAP-CLM and MAP-CBM during the whole storage period. The results indicated in Table.2 showed that carbon dioxide% of the MAP-CLM groups differed significantly (p<0.05) compared to MAP-CBM groups during the storage period of 21 days.

The nitrogen% of all the groups was significantly (p<0.05) increasing, with storage time (Table.2). The nitrogen% of the aerobic and MAP chicken meat differed significantly (p<0.05) during the refrigerated storage period. The results indicated in Table. 2 showed that the nitrogen% of the MAP-CLM groups differed significantly (p<0.05) compared to MAP-CBM groups from day 3 to 21. Kot Vel Lawecka *et al*. (2019) [13]

observed similar results in MAP (80% O_2 + 13% CO_2 + 7% N_2) packaged CBM, the percent of O_2 decreased by nearly 10%, CO_2 increased by more than 2.5%, the concentration of N_2 increased more than twice after 7 days of storage at 2 °C.

B. Microbiological analysis

i. Standard plate count (SPC)

The standard plate count of all the groups was significantly ($p<0.05$) increasing, with storage time (Table.3). The SPC of the aerobic and MAP chicken meat differed significantly ($p<0.05$) during the refrigerated storage period. The mutual effects of high pH and high microbial numbers will restrict the shelf life of the meat (Rodriguez-Calleja *et al*., 2010) [21].

Studies on skinless chicken meat at 3 °C for 7 days showed that the growth of the microbes depends on the packaging atmosphere, with the MAP (70% CO_2 + 15%O_2 + 15%N_2) development of inhibitory effect was highest (Thomas *et al*., 2020) [24]. The results indicated in Table.3 showed that the SPC of the MAP-CLM groups were significantly ($p<0.05$) higher compared to MAP-CBM groups on day 18. Zhang *et al*. (2012) [30] reported an increasing trend in TPC for aerobically packaged poultry from 4.60 to 5.38 CFU/g at 0-4 °C during 4 days storage time.

As per FSSAI (2011) [6], a chilled meat sample should be rejected when the SPC is above 7.70 cfu/g. In the current study, SPC was above 7.70 cfu/g from day 18 in MAP-CLM groups and on day 21 in MAP-CBM groups.

ii. Yeast and mold count (YMC)

The yeast and mold count of all the groups was significantly ($p<0.05$) increasing, with storage time except MAP-CLM groups, which had no significant ($p>0.05$) difference (Table.3). Chicken samples contaminated by fungi are due to environmental contamination, since fungi are ubiquitous in water, air, soil, feeds and processing materials (Greco *et al*., 2014) [7].

Freshly cut meat stored in a refrigerator with high humidity consistently undergoes microbial spoilage preferably mold spoilage. Yeast and mold count vary between 1.87-2.52 log CFU/g in the fresh chicken meat sample (Kumar *et al*., 2011) [15]. The results indicated in Table.3 showed that the MAP-CLM groups had significantly ($p<0.05$) lower YMC compared to MAP-CBM groups on days 18 and 21. Tuncer and Sireli (2008) [26] reported yeast and mold count was 4.70 log CFU/g for the chicken meat packaged in a synthetic plate for 8 days and 6.07 log CFU/g for meat packaged in polythene for 10 days under refrigerated storage.

Between the MAP-CLM groups, no significant ($p>0.05$) difference in YMC was found. No significant ($p>0.05$) difference in YMC was found between the MAP-CBM groups, during the whole storage period. As per FSSAI (2011) [6], a chilled meat sample should be rejected when the YMC is above 5 cfu/g. In the current study, YMC was above 5 cfu/g from day 18 in MAP-CBM groups.

C. Sensory analysis

All the sensory attributes showed a significantly ($p<0.05$) decreasing trend with storage time (Fig. 3-6). The appearance score of all the modified atmosphere groups was significantly ($p<0.05$) decreasing, with storage time may be due to oxidation of myoglobin to metmyoglobin.

Morales-Delanuez *et al*. (2011) [19] studied the effects of different packaging (air, vacuum, and MAP-30% O_2 + 40% CO_2 + 30% N_2) for 9 days at 4 °C and determined that MAP packaged goat kid ribs had better values for color and odor than air and vacuum packaging.

In another study, the beginning of surface slime on chicken meat was recorded from day 12 of the storage in the oxygen-modified atmosphere, whereas in the argon-modified atmosphere group, it showed from day 16 of storage (Tomankova *et al*. 2012) [25].

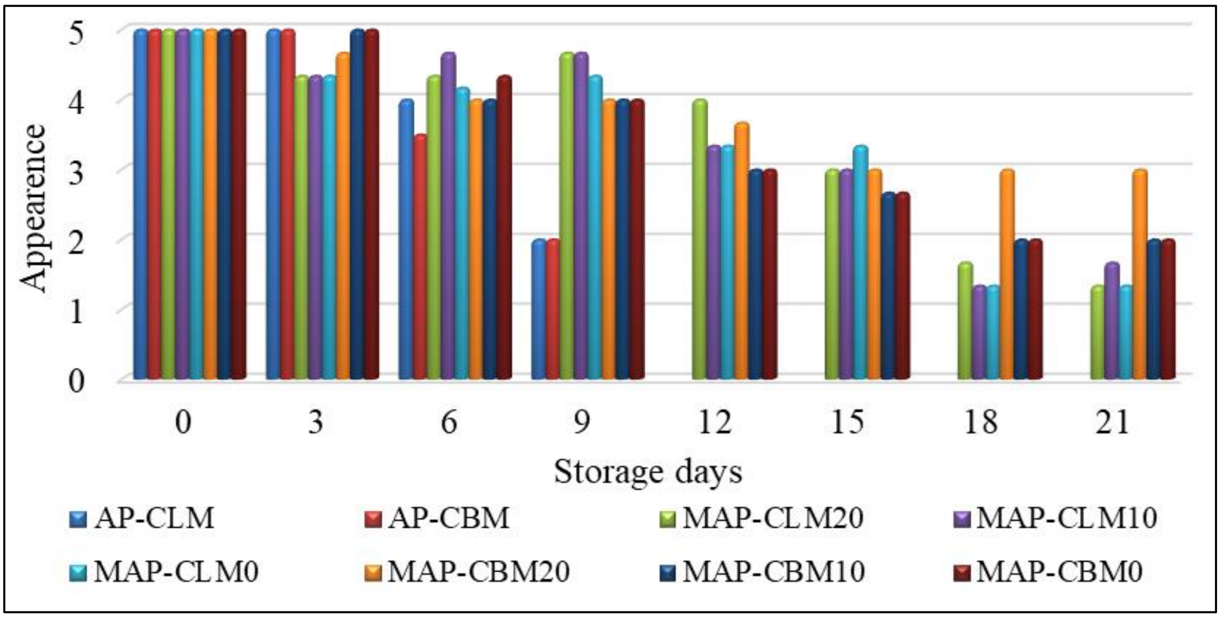

Fig 3: Change in the Appearance values of chicken leg and breast meat with aerobic and modified atmospheric packaging during refrigeration storage (Mean ± SE)

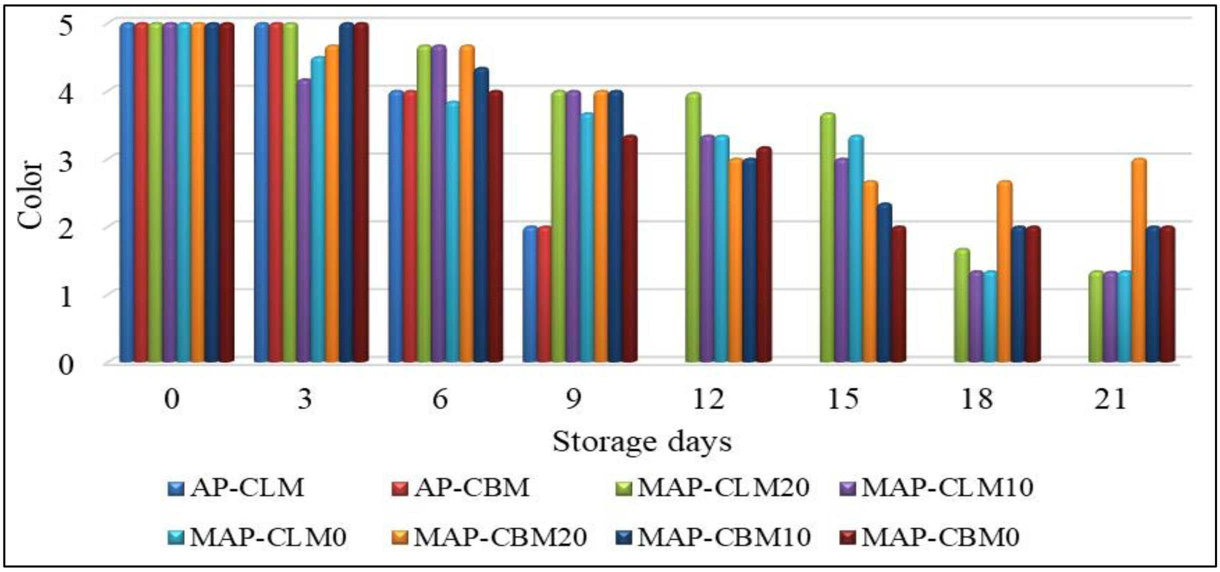

Fig 4: Change in the Color values of chicken leg and breast meat with aerobic and modified atmospheric packaging during refrigeration storage (Mean ± SE)

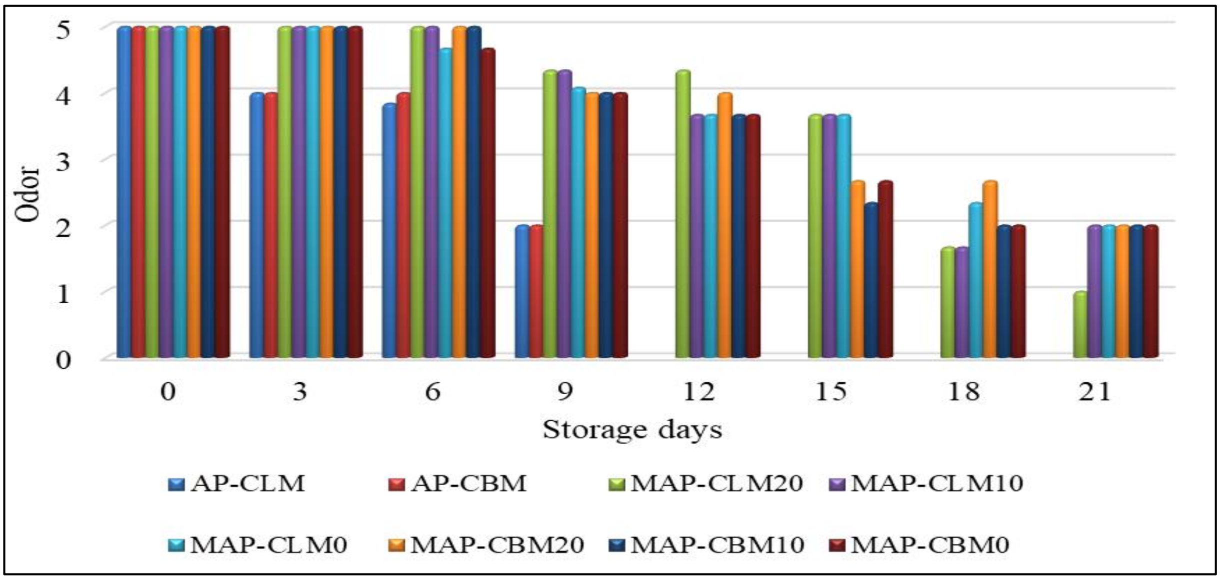

Fig 5: Change in the Odor values of chicken leg and breast meat with aerobic and modified atmospheric packaging during refrigeration storage (Mean ± SE)

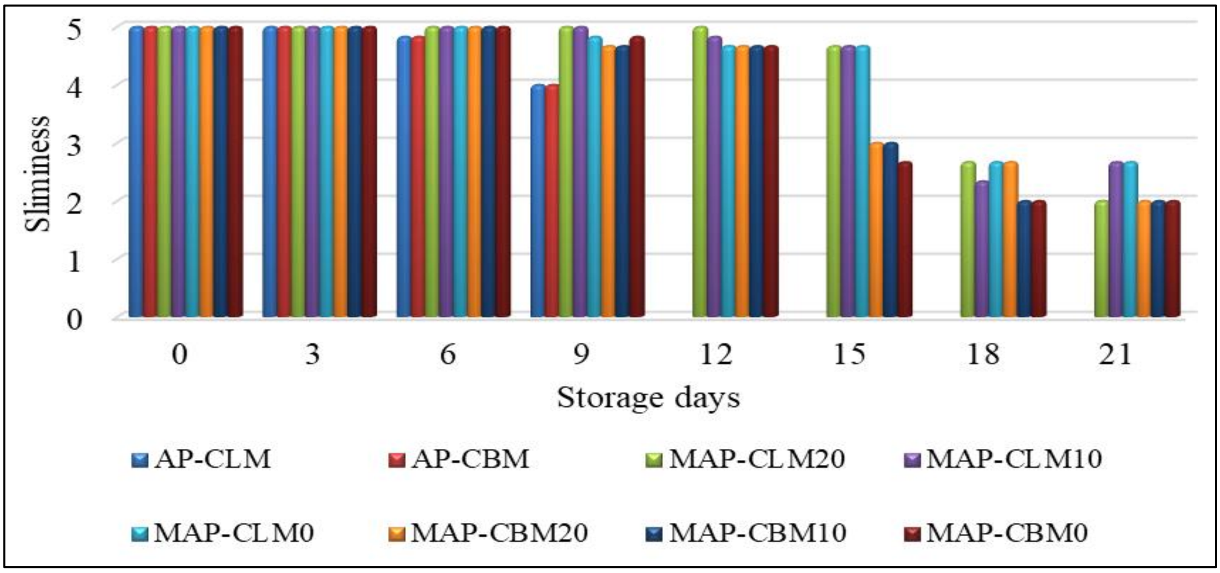

Fig 6: Change in the Sliminess values of chicken leg and breast meat with aerobic and modified atmospheric packaging during refrigeration storage (Mean ± SE)

Table 1: Myoglobin content changes in aerobic and modified atmospheric packaged chicken leg and breast meat during refrigeration storage (4±1 °C)

Groups	Days							
Deoxymyoglobin (%)	**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**
AP-CLM	26.45±0.73^{aAB}	25.69±0.58^{aB}	25.40±0.26^{abB}	27.25±0.31^{aA}	ND	ND	ND	ND
AP-CBM	23.52±0.69^{abC}	25.42±0.25^{aB}	25.59±0.22^{aB}	27.02±0.01^{aA}	ND	ND	ND	ND
MAP-CLM20	22.02±1.44^{bcB}	23.44±0.54^{bAB}	23.74±1.08^{bAB}	25.14±0.71^{bAB}	24.54±1.37^{aAB}	24.44±1.00^{aAB}	25.50±0.48^{abA}	26.00±1.26^{aA}
MAP-CLM10	22.19±0.29^{bcC}	24.47±0.64^{abBC}	23.77±0.89^{bBC}	24.82±0.54^{bBC}	24.40±0.52^{aBC}	25.20±0.33^{aBC}	26.72±1.58^{abAB}	28.75±2.35^{aA}
MAP-CLM0	21.19±1.68^{bcC}	23.50±0.69^{bBC}	24.27±0.46^{abBC}	24.04±0.76^{bBC}	23.67±1.11^{aBC}	25.07±0.42^{aAB}	25.67±0.82^{aAB}	28.32±1.98^{aA}
MAP-CBM20	20.40±0.90^{bcD}	21.97±0.59^{cCD}	24.74±0.15^{abAB}	24.54±0.67^{bAB}	24.34±0.98^{aAB}	24.30±0.70^{aAB}	23.07±0.50^{cBC}	26.17±0.26^{aA}
MAP-CBM10	19.84±1.00^{cB}	24.67±0.21^{abA}	25.84±0.20^{aA}	24.60±0.73^{bA}	24.24±0.82^{aA}	25.77±0.44^{aA}	24.14±0.52^{bcA}	25.07±0.17^{aA}
MAP-CBM0	25.37±0.15^{aA}	25.50±0.26^{aA}	24.60±0.29^{abA}	24.77±0.61^{bA}	25.30±0.35^{aA}	24.97±0.04^{aA}	24.84±0.49^{abcA}	25.00±0.20^{aA}
Metmyoglobin (%)								
AP-CLM	55.99±1.33^{cdB}	56.60±0.52^{cB}	59.97±0.24^{aA}	59.77±0.11^{bA}	ND	ND	ND	ND
AP-CBM	54.07±0.85^{dC}	58.00±0.20^{bcB}	61.85±0.60^{aA}	62.00±0.37^{aA}	ND	ND	ND	ND
MAP-CLM20	58.67±1.20^{bcA}	60.65±1.27^{aA}	59.89±2.26^{aA}	60.17±0.41^{abA}	59.70±0.66^{bcA}	60.51±0.79^{aA}	60.51±1.97^{bA}	59.27±1.59^{bA}
MAP-CLM10	59.62±0.36^{bC}	58.90±0.83^{abC}	60.77±0.65^{aBC}	60.80±1.24^{abBC}	61.48±1.35^{abcBC}	62.30±0.71^{aABC}	64.30±0.51^{aAB}	65.70±2.51^{aA}
MAP-CLM0	59.79±1.18^{abA}	60.02±0.97^{abA}	60.19±0.67^{aA}	60.90±0.62^{abA}	62.17±1.05^{abA}	61.71±1.10^{aA}	62.04±0.89^{abA}	62.50±0.64^{abA}
MAP-CBM20	62.44±1.16^{aA}	60.93±0.50^{aAB}	59.95±1.09^{aAB}	60.45±0.40^{abAB}	59.49±0.62^{cB}	58.53±0.17^{bB}	59.61±0.96^{bB}	59.20±1.10^{bB}
MAP-CBM10	57.10±0.45^{bcC}	59.74±0.67^{abB}	59.82±0.68^{aB}	58.92±0.74^{bBC}	58.90±1.11^{cBC}	60.84±0.61^{aB}	61.00±0.79^{bB}	63.85±0.76^{aA}
MAP-CBM0	58.60±0.81^{bcD}	60.68±0.17^{aBCD}	59.72±0.69^{aCD}	60.89±0.67^{abBC}	62.36±0.90^{aAB}	62.38±0.93^{aAB}	62.16±0.59^{abAB}	64.21±0.59^{aA}
Oxymyoglobin (%)								
AP-CLM	17.79±0.99^{abcA}	16.40±0.75^{aB}	14.79±0.41^{abC}	14.54±0.33^{abcC}	ND	ND	ND	ND
AP-CBM	22.20±2.65^{aA}	16.14±1.56^{aB}	13.44±0.55^{bBC}	12.73±0.52^{cC}	ND	ND	ND	ND
MAP-CLM20	19.55±2.00^{abcA}	17.75±0.72^{aAB}	16.64±2.00^{aABC}	14.75±0.82^{abcBC}	14.18±0.23^{bcBC}	14.87±0.67^{abBC}	13.64±1.40^{bcBC}	13.47±1.28^{abC}
MAP-CLM10	17.72±1.86^{abcA}	15.09±0.77^{aAB}	14.43±0.64^{abAB}	14.65±0.92^{abcAB}	14.37±1.49^{bcAB}	14.47±2.10^{abAB}	10.67±0.46^{cBC}	6.50±4.25^{cC}
MAP-CLM0	18.87±0.72^{abcA}	16.67±0.63^{aAB}	16.84±1.53^{aAB}	14.43±0.61^{bcBC}	12.60±0.75^{cCD}	11.37±0.36^{cCD}	11.77±1.91^{bcCD}	10.94±1.06^{bcD}
MAP-CBM20	15.30±1.17^{cA}	17.77±0.72^{aA}	15.94±0.40^{abA}	16.50±0.19^{aA}	16.53±0.57^{aA}	15.77±0.09^{aA}	18.67±1.77^{aA}	16.64±1.82^{aA}
MAP-CBM10	20.97±1.95^{abA}	17.44±0.63^{aB}	16.17±0.08^{abBC}	15.54±0.73^{abBC}	15.54±0.37^{abBC}	14.80±0.79^{abBC}	14.30±0.81^{bC}	11.67±0.49^{abcD}
MAP-CBM0	16.47±1.03^{bcA}	15.60±0.73^{aAB}	14.87±0.40^{abABC}	13.64±0.69^{bcBC}	13.60±0.20^{bcBC}	12.94±0.88^{bcC}	12.70±0.62^{acC}	8.74±0.93^{bcD}

Table 2: Head space gaseous changes in aerobic and modified atmospheric packaged chicken leg and breast meat during refrigeration storage (4±1 °C)

Groups	Days							
Oxygen (%)	**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**
AP-CLM	21.44±0.06^{aA}	19.97±0.30^{aB}	18.84±0.46^{aC}	17.37±0.66^{aD}	ND	ND	ND	ND
AP-CBM	21.09±0.03^{aA}	19.49±0.06^{abB}	19.72±0.21^{aB}	18.47±0.41^{abC}	ND	ND	ND	ND
MAP-CLM20	19.19±1.14^{bA}	17.87±1.25^{bcAB}	16.05±1.32^{bABC}	15.55±0.94^{cCD}	15.29±1.79^{aCD}	14.3±0.59^{bCD}	13.55±0.81^{bD}	12.72±0.84^{bD}
MAP-CLM10	9.16±0.57^{cA}	7.98 ±1.03^{dAB}	6.63±0.33^{cB}	6.78±0.96^{dB}	6.8±0.32^{bB}	6.8±0.39^{cB}	6.84±0.66^{cB}	6.17±0.92^{cB}
MAP-CLM0	1.79±0.16^{dA}	1.53±0.30^{eA}	1.33±0.44^{dAB}	1.54±0.35^{eA}	1.95±0.58^{cA}	1.33±0.36^{dA}	0.38±0.15^{dBC}	0.03±0.01^{dC}
MAP-CBM20	19.70±0.04^{bA}	17.24±0.04^{cB}	17.14±0.04^{bBC}	16.67±0.26^{bcBCD}	16.14±0.75^{aCD}	15.80±0.41^{aDE}	15.67±0.28^{aDE}	14.97±0.09^{aE}
MAP-CBM10	9.83±0.10^{cA}	7.49±0.26^{dB}	7.33±0.09^{cBC}	6.64±0.09^{dCD}	6.27±0.42^{bD}	6.01±0.33^{cDE}	5.92±0.28^{cDE}	5.37±0.15^{cE}
MAP-CBM0	0.38±0.23^{eA}	0.01±0.01^{eB}	0.04±0.02^{dB}	0.01±0.01^{eB}	0.02±0.01^{cB}	0.01±0.01^{eB}	0.01±0.01^{dB}	0.01±0.01^{dB}
Carbondioxide (%)								
AP-CLM	1.90±0.13^{eA}	1.60±0.27^{eB}	1.50±0.13^{eB}	0.27±0.02^{eC}	ND	ND	ND	ND
AP-CBM	1.75±0.12^{eA}	1.52±0.10^{eB}	0.93±0.06^{eC}	0.47±0.08^{eD}	ND	ND	ND	ND
MAP-CLM20	31.32±0.66^{cA}	30.87±1.14^{cA}	29.82±1.38^{cAB}	29.39±1.67^{cAB}	28.44±2.29^{bABC}	26.82±1.93^{cABC}	19.47±6.11^{cBC}	18.49±5.81^{cC}
MAP-CLM10	38.9±0.86^{bA}	33.32±1.65^{bB}	33.24±1.54^{bB}	31.72±0.61^{bB}	31.77±3.05^{bB}	31.25±0.89^{bB}	30.85±1.52^{abB}	30.70±0.82^{abB}
MAP-CLM0	20.54±0.21^{dA}	20.54±0.09^{dA}	20.37±0.08^{dA}	19.67±0.06^{dB}	19.24±0.15^{cC}	19.00±0.22^{dCD}	18.70±0.73^{cDE}	18.33±0.20^{cE}
MAP-CBM20	30.63±0.22^{cA}	30.53±0.15^{cA}	30.50±0.31^{cA}	29.90±0.10^{bcB}	29.27±0.09^{bC}	28.97±0.06^{bcC}	28.00±0.07^{bD}	27.57±0.30^{bD}
MAP-CBM10	40.70±0.26^{aA}	40.60±0.91^{aA}	40.80±1.29^{aA}	38.83±0.28^{aA}	38.50±1.02^{aA}	38.44±2.30^{aA}	37.17±2.49^{aA}	35.77±2.71^{aA}
MAP-CBM0	21.97±0.81^{dA}	21.04±0.17^{dAB}	20.47±0.28^{dB}	20.30±0.23^{dB}	19.94±0.07^{cB}	19.64±0.75^{dBC}	19.50±0.67^{cBC}	18.34±0.06^{cC}
Nitrogen (%)								
AP-CLM	76.67±0.18^{aD}	78.43±0.36^{aC}	79.67±0.37^{aB}	82.37±0.67^{aA}	ND	ND	ND	ND
AP-CBM	77.18±0.16^{aC}	79.00±0.15^{aB}	79.35±0.18^{aB}	81.07±0.45^{abA}	ND	ND	ND	ND
MAP-CLM20	49.7±1.70^{bC}	51.27±0.67^{cC}	54.13±0.31^{cC}	55.07±2.60^{dC}	56.61±1.08^{cBC}	58.88±1.92^{bcABC}	66.98±6.80^{bAB}	68.80±6.33^{bA}
MAP-CLM10	51.94±1.35^{bB}	58.71±1.82^{bA}	60.14±1.60^{bA}	61.51±0.57^{cA}	61.44±2.77^{bA}	61.96±0.54^{bA}	62.32±0.91^{bcA}	63.13±0.78^{bcA}
MAP-CLM0	77.68±0.28^{aD}	77.94±0.32^{aCD}	78.30±0.37^{aCD}	78.80±0.30^{bBC}	78.83±0.69^{aBC}	79.67±0.33^{aB}	80.92±0.14^{aA}	81.64±0.30^{aA}
MAP-CBM20	49.67±0.20^{bF}	52.23±0.10^{cE}	52.37±0.34^{cDE}	53.43±0.30^{dD}	54.60±0.83^{cC}	55.23±0.37^{dBC}	56.33±0.22^{cB}	57.47±0.37^{cA}
MAP-CBM10	49.52±0.32^{bC}	51.91±0.95^{cBC}	51.88±1.36^{cBC}	54.53±0.23^{dABC}	55.23±0.73^{cAB}	55.56±2.50^{cdAB}	56.92±2.51^{cAB}	58.87±2.57^{cA}
MAP-CBM0	77.66±0.75^{aD}	78.97±0.17^{aCD}	79.49±0.26^{aBC}	79.69±0.23^{abBC}	80.05±0.59^{aBC}	80.37±0.75^{aABC}	80.50±0.67^{aAB}	81.67±0.06^{aA}

n=6; Means with different superscripts in the same column (small letters) and same row (capital letters) differ significantly ($p<0.05$).

Table 3: Microbial changes in aerobic and modified atmospheric packaged chicken leg and breast meat during refrigeration storage (4±1 °C)

Groups	Days							
SPC (Log cfu/g)	**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**
AP-CLM	4.18±0.08^{cD}	5.02±0.02^{cC}	5.25±0.02^{cB}	7.41±0.01^{aA}	ND	ND	ND	ND
AP-CBM	5.03±0.02^{bD}	5.31±0.02^{bcC}	5.73±0.08^{bcB}	6.30±0.01^{cA}	ND	ND	ND	ND
MAP-CLM20	5.71±0.20^{aC}	6.24±0.35^{aBC}	6.50±0.23^{aBC}	6.90±0.17^{bB}	6.97±0.41^{aB}	6.90±0.20^{abB}	8.41±0.31^{aA}	8.43±0.32^{aA}
MAP-CLM10	5.76±0.22^{aC}	6.18±0.39^{aBC}	6.32±0.37^{abBC}	6.54±0.15^{bcBC}	6.22±0.33^{bBC}	6.89±0.19^{bB}	8.13±0.37^{aA}	8.42±0.32^{aA}
MAP-CLM0	5.77±0.17^{aC}	6.23±0.36^{aBC}	6.43±0.31^{aBC}	6.62±0.18^{bcBC}	6.90±0.44^{abB}	6.90±0.17^{abB}	8.16±0.38^{aA}	8.43±0.32^{aA}
MAP-CBM20	5.65±0.19^{aE}	5.88±0.09^{abE}	6.80±0.15^{aD}	6.82±0.17^{bD}	6.94±0.17^{abCD}	7.27±0.01^{aBC}	7.44±0.05^{bB}	7.83±0.14^{aA}
MAP-CBM10	5.58±0.17^{aE}	5.74±0.15^{abE}	6.65±0.23^{aD}	6.92±0.17^{bCD}	6.83±0.14^{abCD}	7.24±0.01^{abBC}	7.48±0.06^{bAB}	7.84±0.14^{aA}
MAP-CBM0	5.63±0.18^{aD}	5.85±0.08^{abD}	6.94±0.19^{aC}	6.82±0.14^{bC}	6.99±0.13^{aBC}	7.20±0.06^{abBC}	7.38±0.06^{bB}	7.84±0.15^{aA}
YMC (Log cfu/g)								
AP-CLM	1.11±0.71^{aB}	1.31±0.83^{aB}	1.46±0.92^{aB}	3.57±1.17^{aA}	ND	ND	ND	ND
AP-CBM	1.03±0.66^{aB}	1.19±0.76^{aB}	1.56±0.99^{aB}	3.36±1.08^{aA}	ND	ND	ND	ND
MAP-CLM20	1.43±0.91^{aA}	1.56±0.99^{aA}	1.49±0.94^{aA}	1.53±0.97^{aA}	1.90±1.20^{aA}	1.90±1.20^{aA}	3.36±1.08^{bA}	4.17±0.14^{bA}
MAP-CLM10	1.43±0.91^{aA}	1.43±0.91^{aA}	1.43±0.91^{aA}	1.43±0.91^{aA}	1.92±1.22^{aA}	1.82±1.15^{aA}	3.31±1.06^{bA}	3.39±1.09^{bA}
MAP-CLM0	1.49±0.94^{aA}	1.62±1.02^{aA}	1.61±1.02^{aA}	1.49±0.94^{aA}	1.82±1.15^{aA}	1.82±1.15^{aA}	3.26±1.04^{bA}	3.46±1.12^{bA}
MAP-CBM20	1.43±0.91^{aC}	1.53±0.97^{aC}	1.90±1.20^{aC}	1.92±1.12^{aC}	1.95±1.23^{aC}	3.96±1.25^{aBC}	6.45±0.24^{aAB}	7.07±0.04^{aA}
MAP-CBM10	1.49±0.94^{aB}	1.43±0.90^{aB}	1.82±1.15^{aB}	1.87±1.18^{aB}	1.98±1.25^{aB}	3.9±1.24^{aAB}	6.61±0.29^{aA}	6.83±0.18^{aA}
MAP-CBM0	1.49±0.94^{aB}	1.49±0.94^{aB}	1.82±1.15^{aB}	1.82±1.15^{aB}	1.92±1.22^{aB}	3.90±1.24^{aAB}	6.59±0.28^{aA}	6.79±0.18^{aA}

n=6; Means with different superscripts in the same column (small letters) and same row (capital letters) differ significantly (p<0.05). SPC= Standard plate count; YMC=Yeast and mold count; AP-CLM= Aerobic packaged leg meat; AP-CBM= Aerobic packaged breast meat; MAP-CLM20= Modified atmosphere packaged leg meat (20% O_2 + 30% CO_2 + 50% N_2); MAP-CLM10= MAP leg meat (10% O_2 + 40% CO_2 + 50% N_2); MAP-CLM0= MAP leg meat (0% O_2 + 20% CO_2 + 80% N_2); MAP-CBM20= MAP breast meat (20% O_2 + 30% CO_2 + 50% N_2); MAP-CBM10= MAP breast meat (10% O_2 + 40% CO_2 + 50% N_2) and MAP-CBM0= MAP breast meat (0% O_2 + 20% CO_2 + 80% N_2) packaged at 4±1 °C.

Conclusion

The shelf life of both chicken leg and breast meat analyzed in aerobic packaging under refrigerated conditions (4±1 °C) was 6 days. Modified atmospheric packaging of chicken leg meat had a shelf life of 15 days irrespective of different gaseous concentrations. Modified atmospheric packaging of chicken breast meat had a shelf life of 12 days irrespective of different gaseous concentrations. Modified atmosphere packaging allows the extension of the shelf life of chicken meat in comparison to aerobic packaging by at least 9 days for leg meat and 6 days for breast meat under refrigeration storage. For chicken leg and breast meats, oxygen at the rate of 0-20% and carbon dioxide at the rate of 20-40% along with nitrogen gas at the rate of 50-80% are recommended in MAP for improving the shelf-life in refrigerated storage.

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