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A Comprehensive Review of Modified Atmosphere Packaging for Poultry Meat: Effects on the Qualitative Characteristics and Shelf-Life Stability

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Abstract: The aim of this article is to review applications of modified atmosphere packaging (MAP) in poultry meat. As well as, its effects on the qualitative characteristics and shelf-life stability. Packaging is a harmonized rule of preparing the product for transportation, dissemination, retail, and end-use to ensure safe delivery. MAP is modern packaging that includes air removal (78% N_2, 21% O_2, and 3% CO_2 gas) from inside the casings and replacing them with a single gas or a mixture of gases. The atmosphere with a high concentration of O_2 by 80 % leads to off-oxygenating the dye and keeps it from deteriorating on the surface of the meat. O_2 causes oxidation of fat and protein, and decreases the quality of meat. The CO_2 gas concentration and the casings composition significantly affect the change in the meat pH value. The decrease in oxygen in the packaging alters the meat colour from red to purple to convert the Oxymyoglobin to Deoxymyoglobin. Moreover, the consumer rejects this type of meat with a myoglobin tint. The colour stability using MAP has improved, and the Metmyoglobin configuration rate has decreased. MAP gave less moisture loss. The total and psychrophile bacterial populations in the poultry meat treated with MAP decreased and increased with the progress of storage periods. The TBA value, the peroxide value, and the fatty acid percentage decreased by using the MAP. MAP can be a part of Hurdle's technique to prolong the chicken meat shelf life.

Keywords: Bacterial population, Gas composition, Qualitative characteristics, Shelf-life stability.

Introduction

Raw poultry meat is broadly consumed worldwide due to its high nutritional value and the meat's chemical composition. Its products, and the nutritional ingredients are damaged when stored (Soriano-Santos, 2010). This damage is whether microbial or chemical. These two parameters affect the stored meat quality. The preservation of the meat's nutritional value, and the prolongation of it is stimulated interest among producers and consumers. As well as, through the development and utilization of modern technologies in the area of food processing and to secure lateral health (Zouaghi & Cantalejo, 2016). Therefore, packaging was used, which is the effective containment, preservation, and protection of meat products, collecting the necessary information about the packaging, transportation, retail, and sale, considering all legal and environmental issues (Zakrys *et al*., 2008). The shelf life of perishable food like fish, poultry, meat, fruit, bakery products, and vegetables is identified when natural air is present using two major factors: the atmospheric oxygen (chemical impact) and the perishable aerobic microorganisms' growth. These factors affect individuals or in combination as changes in smell, flavor, colour, and texture lead to general quality degradation. Refrigerated storage decelerates these undesirable alterations, while it will not be important to increase the shelf life enough for dissemination and retail objects. MAP is a type of modern packaging that shares removing air from the inside of the casings and replaces it with one gas or gas mixture. The aim of food packaging for containing food in a low-cost way verifies the consumer's industrial necessities and desires. This is keeping the food safe, and reduces the environmental impact. Canned food quality is immediately linked to the properties of foodstuffs and packaging materials. As well as, packaging delays the development of both pathological and destructive bacteria and chemicals reactions. Also, maintains the ideal sensory properties and qualitative product attributes (Wang *et al*., 2022, Heir *et al*., 2022). MAP typically contains a mixture of two or more gases, namely O_2 gas. O_2 promotes colour stability, CO_2, which inhibits microbial growth, and N_2, which maintains the shape of the shells (Sørheim *et al*., 1999; Jakobsen & Bertelsen, 2000; Kerry *et al*., 2006, Kandeepan & Tahseen, 2022). Colour is a significant factor in the assessment of meat by consumers as it is seen as an indication of the quality and freshness of the product (Lynch *et al*., 1986). One of the key assumptions of advanced packaging ways is to maintain the desired colour for a long time. Colour plays an important role in appearance, acceptance or meat display, which is a significant property of the consumer (Karpinska-Tymoszczyk, 2014).

It should be clear between MAP and controlled atmosphere packaging (CAP), where the storage time controls the atmosphere composition. CAP is often utilized in transporting and storing perishable foodstuffs. For example, meat and fresh products are carried out in combination with good temperature control and product circulation processes (Sivertsvik *et al*., 2002). Vacuum packaging (VP) is also considered as some MAP, but this is generally not considered MAP. This is because the atmosphere in the casing does not change but is only removed from the packaging (Sivertsvik *et al*., 2002).

Han (2005) explained that packaging is a harmonized system of commodity numbers for transportation, distribution, retail, and end-use. The product is in sound condition upon delivery at the lowest costs, commercial, technical performance, and maximizing sales. It was also pointed out that packaging is the effective preservation, containment, and meat products protection. Also, it's collection of the necessary information regarding the packaging, transportation, sale, and use while providing comfort and considering all environmental and legal topics. MAP is the ideal way to protect food, utilized in numerous raw and dried foods (Embleni, 2013).

Lei *et al*. (2023) stated that the sensory properties were improved by using MAP for packaging chicken meat and increased shelf life. The importance of meat packaging includes improving meat colour, increasing storage time, reducing moisture loss, improving sensory qualities, preventing flavor loss, and providing information (production history, expiry, additives, and product information (Maheswarappa *et al*., 2016). The review aimed to investigate the application of MAP in poultry meat and its effect on qualitative qualities during freezing storage, analyzing colour compounds and comparing them with packaging under vacuum packaging.

A brief history of packaging

The primary purposes of food packaging are to preserve food, provide necessary food information, and facilitate easy food handling during consumer distribution. Food safety, shelf life, and quality are all greatly influenced by packaging. Food quality and safety are significantly impacted by potential interactions between food and packaging (Vasile & Baican, 2021). A common method in the packaging of meat and meat products is modified atmosphere packaging (MAP) (Sun, 2020). CO_2 has been used for preserving meat since 1882 and has been developing further for long-term meat. Meat is shipped from New Zealand and Australia to Britain in the thirties (Dixon & Kell, 1989). In the fifties of the last century, researchers studied the relationship between CO_2 concentration, the product's shelf life, and the product's quality. It was specified that the colour of raw meat is vulnerable to change at higher concentrations of CO_2, and the recommendations were a maximum limit range between 20-25 %. These are popular for types of red meat (beef, pork, lamb) (Ledward, 1970). N_2 is usually added to eliminate O_2 from the package environment, which has involved raised CO_2. Due to the reduced red meat colour, poultry's high concentration of CO_2 can be used with unchanged colour (Rao & Sachindra, 2002). In 1920, Jude Richish hired Waldo Semon to develop synthetic rubber, which resulted in the development of polyphenyl chloride (PVC) that was introduced into many commercial applications including fresh meat packaging. After the Second World War, modified packaging was first used in 1930 by Killefer to store lamb and pork by cooling. Over the same period began to utilize the atmosphere saturated with CO_2 gas. In the transport of chilled beef meat in New Zealand and Australia, in 1950 by PV (Maheswarappa *et al*., 2016). In the seventies and eighties of the last century, using O_2 in MAP was studied to accomplish a charming colour of meat. It has been proven that higher levels of O_2 (40% or more than that) help overcome the change in the colour at high concentrations of CO_2 (Bartkowski *et al*., 1982). Newly, attention to the use of CO_2 for MAP has grown. The food and drug administration (FDA) adopted home bag packaging containing 0.4% CO of raw meat in 2002. In 2004, expanded this adoption to ready-made retail packaging. However, approval for CO is very restricted worldwide. Only New Zealand, Australia, and the United States allowing it to be used. CO was applied in Norway for retail meat Packaging from 1985 to 2004 by Sørheim & Nesbakken (1997). While due to changes to the trade agreement with the EU, the approval of CO raw meat packaging in Norway was stopped in 2004.

Control atmosphere packaging (CAP)

Gill (1990) explained that the discrepancy between oxygen-containing MAP and oxygen-free CAP could increase the shelf life for a long time. As its environment provides inadequate for the development of food-damaging by aerobic microorganisms. CAP was utilized commercially to ship large chilled lamb carcasses to distant markets. The process of packaging meat using CAP by adding N_2 gas and CO_2 increases the shelf life of refrigerated meat. CAP packaging systems help develop myoglobin in meat, which leads to giving an unattractive colour to the consumer. When exposing the meat to air after opening the covers for 20-30 min, the meat will regain its attractive cherry red colour (Hunt *et al*., 1999). Another negative feature associated with the CAP is that it should be considered that utilization of high amounts of CO_2 in the casings will show the flavor of this gas in detectable meat when consumed (Nattress & Jeremiah, 2000). The absorption process of CO_2 gas is related to biological factors like pH, fat, and water (Jakobsen & Bertelsen, 2002).

O'Sullivan *et al*. (2010) studied the sensory assessment of sub atmosphere-packed steaks containing 50% O_2+50% CO_2, 70% O_2+30% CO_2, and 80% O_2+20% CO_2. The researchers compared these slices with packaged steaks with a concentration of 100% CO_2 to identify its effect on the development of flavors. The results illustrated that the slices packed with a MAP containing 50% O_2 and 50% CO_2 are the best and they also compared these slices with two types of steaks coated with a concentration of 100% CO. One of them was exposed to the air after removing the casings for 30 min to dissipate the gas, and the another cooking the samples directly. The latter gave a moral difference with the samples that were not exposed to air by the appearance of the gas flavor when consumed.

Modified atmosphere packaging (MAP)

MAP is defined as a type of modern packaging that involves removing air (the normal composition of the air (78%N_2, 21%O_2, and 3% CO_2) from within the casings and replacing them with one gas or combination of gases. MAP typically contains a mixture of two or more gases are O_2 gas, which promotes colour stability, gas CO_2 which inhibits microbial growth, and N_2 gas that maintains the shape of the shells (Sørheim *et al*., 1999). Kennedy *et al.* (2004) depicted that the fresh meat colour changes shortly after slaughter and that this change in the colour of the meat surface that occurs during frozen or refrigerated storage leads to the deterioration of some of the qualities of the meat produced. The primary objective of using MAP is to increase food shelf life, prevent unwanted changes, safety, organoleptic properties and nutritional value of foods, as this type of packaging reduces unwanted chemical, physical, biochemical and physiological changes in food, controls growth of microbial, and prevents contamination of product (Han, 2005).

Zakrys *et al.* (2008) illustrated that the addition of O_2 gas to beef steaks promoted the stability of the desired colour, with the consumer preferring the beef colour of bright cherry as a meat quality indicator. Packaging in the MAP is of two types, namely passive MAP, in which case the atmosphere inside the shell develops negatively due to the breathing of the product as it consumes oxygen and produces CO_2 as it produces biochemical reactions that occur inside the envelope. If the respiration properties of the product are proportional to the values of the permeability of the casing of gases and this is called the negative MAP. The second type is the packaging in an active MAP in it, the shell is emptied of gases and replaced by known gases of specific proportions (Rosa, 2019).

Advantages and disadvantages of MAP

MAP has benefits for the consumer and the producer. On the part of the consumer, it provides him with top-quality food products with a long shelf life. As well as, it reduces or prevents the addition of preservative chemicals. This makes the products more natural and healthier. On the part of producers, they benefit more because of the longevity of the products and the ease of transportation of products packaged with MAP. While in terms of the disadvantages of MAP, each product requires the presence of different gases and proportions. In addition, workers need special training to handle these machines. As well as, temperature control, and the safety factor must be available in the packaging of MAP in large quantities. This increases shipping costs (Han, 2005).

Gases used in MAP

Carbon dioxide (CO_2)

It is a colourless gas and tastes dexterous, and it is suffocating if added in high concentrations. it works to change the taste and dissolve in water and works to form carbonic acid leading to a rise in the acidity of the product and that in turn leads to a reduction in pH (Kuley *et al*., 2020). CO_2 gas dissolves in fat and some organic compounds and its solubility increases whenever the temperature is less than 10 °C. While its solubility decreases whenever the temperature is more than 10 °C (Coles *et al*., 2003). When CO_2 added to the meat, it will lead to shrinkage of the casings and this condition gets with the stored meat and thus leads to give improper shape to the casings. As it inactivates growth of microbial and increases the meat shelf life. This is because it penetrates the membrane of bacteria and causes changes in pH inside the cell significantly and raises the acidity in it and inhibits the growth of bacteria. Also, it affects the enzymatic systems (Kerry *et al*., 2006).

Oxygen (O_2)

O_2 is a colourless and odorless gas, low soluble in water, and works to oxidize fats and especially phospholipids of cell membrane. O_2 leads to the manifestation of unwanted flavor, as well as works to oxidize pigments to keep the muscular myoglobin dye in its oxidized from (Coles *et al*., 2003). Oxygen increases the growth and activity of aerobic bacteria causing damage. The lower concentration of oxygen, the more it works to stop the development of aerobic Bactria in food and improves quality (Kerry *et al*., 2006).

Effect of high oxygen on MAP

Gray *et al.* (1996) explained that the phospholipids of the cell membrane that are especially exposed to oxidate which causes the accelerate development of flavor. The characteristic of flavor develops rapidly in meat that is cooked, stored in refrigeration and then reheated. In addition, the flavors can be explored and has adopted the term flavor (WOF) which serves to identify these deteriorating flavors. The oxidation of polyunsaturated fatty acids not only causes the development of undesirable flavor but also affects the nutritional value, colour and quality of meat (Kanner, 1994). Jakobsen & Bertlsen (2000) reported that an O_2 gas level of more than 20% was important to enhance colour of meat. O_2 gas concentration of more than 55% did not lead to additional colour advantages. This leads to protein oxidation, which is associated with increased hardness or durability in meat stored in MAP, especially beef. Therefore, protein oxidation may reduce meat quality, Juice, freshness and deterioration of flavor. Carpenter *et al*. (2001) stated that the consumer prefers colour of beef was enough to affect the purchase but not enough to obtain tasting scores. This is possible for making the decision to buy meat from the market whether it is fresh cherry red or pink under the influence of packaging with a high concentration of oxygen or a purple colour under the influence of vacuum packaging. The consumer depends only on the colour and not on the juiciness and flavor of the meat. These high levels of oxygen adversely affect fats leading to their oxidation and evolution of unwanted flavors (Zakrys *et al.,* 2008). Most meat producers want to continue to offer the product in packaging with a high oxygen content of about 80% to maintain the meat colour, in addition to containing CO_2 gas at least 20% to prevent aerobic microbial growth (Eilert, 2005).

Consumers utilize colour as a pointer of meat fresh and quality and therefore recent developments have focused on finding gases mixture that leads to colour fastening, prolonging shelf life, preventing microbial growth and fat oxidation (Mancini & Hunt, 2005). The main O_2 gas function is to preserve the muscular myoglobin dye in its oxidizing form oxymyoglobin (Kerry *et al,* 2006).

McMillin (2008) Confirmed that the atmosphere with a high concentration of O_2 by 80% oxygenates the dye. Thus, leads to the prolongation of its preservation period without deterioration of the dye on the surface of the meat. The problems in an increasing the concentration of O_2 by a high percentage in MAP develops rancidity. Rancidity often develops in meat although the colour is still desired. Either when the proportion of O_2 in MAP increases from70 - 80% and CO_2 of 20-30% for fresh meat. This is making the meat colour bright red and desirable for the consumer. Zakrys *et al*. (2008) explained that beef chops are usually displayed under a high concentration of O_2 in MAP. This is in order to enhance colour fastness but lead to negative effects on the oxidability of muscle fat when oxygen is increased. Huff-Lonergan *et al.* (2010) explained that the high O_2 concentration in MAP led to an increase in meat hardness after the cooking process. In addition, it helps to the negative flavor development and a decrease in the nutritional value of meat (Lund *et al*., 2011). It also increases the hardness of meat (Bao & Ertberg, 2015). Wang *et al.* (2019) found that the oxidation of fats and protein increased with the concentration of oxygen up to 80%. Lonergan *et al.* (2019) stated that MAP with high concentration of O_2 (40-80%), and 25% CO_2 have preserved the colour of the meat. The researchers also pointed out that the CO_2 should not exceed 30%. This is because it causes a change in the colour of products stored in a MAP with a high content of O_2. O_2 produces a deeper layer of oxymyoglobin which is responsible for red cherry colour on the surface of the meat. Also, it is noted that increasing the content of O_2 in MAP leads to a decrease in the meat freshness and negatively affects the flavor by oxidizing it. Also, it reduces the effectiveness of the protein decomposition of enzymes.

The effect of low O_2 on the MAP

Low concentration of O_2 gas in MAP was present for use in the US. While not as widespread as their counterpart with a high concentration of O_2. Low oxygen gas is usually added in MAP with CO_2 gas (efficient to dissolution it in the product) and also with N_2 gas. CO_2 gas acts as an antimicrobial and N_2 gas works to preserve the form and structure of the casings (Sørheim *et al.,* 1997).

Nitrogen (N_2)

N_2 is a colourless inert gas, tasteless and odorless, and has a density less than air and does not ignite. Its solubility in water is low and an oxygen-repellent gas. One of its benefits is that it does not help in the growth of micro-organisms. So, it works to inhibit microbes, especially anaerobic bacteria and maintains the shape of the packages. In addition, it prevents can contraction caused by CO_2 which is low soluble in food (Coles *et al*., 2003).

Carbon Monoxide (CO)

CO gas is colourless, tasteless and odorless and mainly produced from not complete combustion of carbon-containing substances. The food and drug administration noted that the colour has not decomposed in the packaging contained CO gas. Odors can constitute in the product naturally in the existence of CO. In the past, the United States was concerned about this packaging system that would conceal the damage that could be done in fresh meat products (Eilert, 2005).

Synthetically carbon monoxide was added to the packaging groups to eliminate oxygen drop defects in MAP casings. This is because carbon monoxide gas has a great affinity with myoglobin and forms a bright cherry red on the surface of the beef (Sørheim, 2006).

Wilkinson *et al.* (2006) explained that carboxymyoglobin more oxidation resistant than oxymyoglobin. This is due to the strong linking of CO gas to iron and porphyrin on the myoglobin molecule. For the addition of low-concentration O_2 gas in MAP in the US, CO can be utilized as a gas to improve colour of meat among the European Union. Norday has relied only 0.3-0.5% of CO gas in initial packaging in the mid-eighties. However, this practice was discontinued after a decision by the European Parliament Committee in 2004 does not permit the utilization of carbon monoxide gas in application of meat packaging. Nevertheless, one of the major consumer concerns related to use CO is quality loss of meat. This is because of the interruption of cooling and leads to its deterioration despite its attractive appearance (Sørheim *et al.,* 2006).

Using 0.4% CO gas in MAP during storage, improves the beef colour regardless of other qualities. When the packaging is removed from the product the meat colour which is likely to be a mixture of carboxymyoglobin and oxymyoglobin. It can be classified, and the meat coated by CO gas can be classified in a way that is no different from the product displayed in the air. Therefore, the addition of 0.4% of CO compared to the O_2, it will not affect colour stability. Reduce methemoglobin or consumption of O_2, this is most likely resulting the oxymyglobin formation in the atmosphere significantly, which contains 20-80% O_2. This dominates the capacity of carboxymyoglobin and limits its capabilities (Seyfert *et al*., 2007).

Vacuum Packaging

Vacuum packaging (VP) provides anaerobic conditions which extend both the microbiological and the oxidative shelf life of meat. VP prolongs the shelf life of chilled meat by removing oxygen from packages environment inside the packaging. The method of vacuum packaging is an excellent method to secure the product from the combustion of freezing during long-term storage. It is used extensively all over the world in meat storage under reduced temperature. In spite of chemical reactions happen way too slow, the oxidation of vitamins and pigment continues to advance. Technically, VP can be considered a kind of MAP and occasionally it's not a part of the MAP family. Owing to MAP include changing the atmosphere inside the packaging and replacement with a mixture of gases.

While in the VP, the air is removed from package only (Abdullah & Buchtova., 2020). As for retail markets, the VP is not suitable for packaging meat due to the depletion of oxygen gas. Besides, the decrease in oxygen gas in the packaging leads to alter meat colour from red to purple to convert it is Oxymyoglobin to Deoxymyoglobin. The consumer rejects this type of meat with a myoglobin dye because the change in the colour of the meat is unacceptable from their point of view (Bell *et al*., 1995). Garcıa-Esteban *et al.* (2003) depicted that consumers are reluctant to buy beef packaged under the influence of VP and displayed in purple colour resulting from the dye of Deoxymyoglobin. This dye increased meat storage time in VP and leads to an increased drip, which is also unattractive to the consumer. VP continues to be used in many effective packaging methods and remains the most cost-effective packaging for meat packaging. One of the recent innovations is VP which is the development of shrinkable packaging or films to facilitate their use in horizontal machines for packaging products. PV with impermeable wrappers is not recommended due to lack of oxygen and therefore the colour is negatively affected. This method benefits retail markets as the meat are red-pink as soon as the cover is opened. Moreover, meat is exposed to atmospheric oxygen and the vacuum wrappers made of bags or leather that were discharged. They are wrappers with little gas permeability. These vacuum wrappers improve the preservation process by providing an anaerobic environment inside the packaging. However, O_2 must be very little in the packaging during closure to effectively maintain the product. This is because the ability of muscle tissue to remove oxygen gas is limited (Gill & Gill, 2005). The O_2 content is in general decreased to lower than 1% under conditions of excellent vacuum. This is because the property of the barrier casings used and through which the Oxygen entry from outside is restricted (Robertson, 2005). The solution may be attributed to remove the ambient the casings by vacuum and replace it with a mixture of balanced gas from CO_2 and N_2 until CO gas for the purpose of getting rid of microorganisms (Sakowska *et al*., 2016). There are many factors related to O_2 depletion and conversion to CO_2 including metabolism, rapid growth of microbes, enzymatic efficacy of muscles and amine decarboxylation. The oxygen content in MAP-O_2 can be reduced as of the seventh day of storage. This is associated with the massive development of microorganisms visible on the skin of the chest and groin (Hulankova *et al.*, 2018). Any small amount of oxygen that remains after the can is closed is metabolized and converted into CO_2. This helps to enhance the meat shelf life because the meat is also metabolically active (Lonergan *et al*., 2019).

Impact of MAP on casings

The surface characteristics of food packaging polymers are of great significance to polymer designers and engineers in terms of the susceptibility of polymers to judgment, wetting and adhesion of food to the surface of the casing or other. These environmentally friendly polymers or films must be characterized by a number of specific sub-needs. For instance, their reservation of moisture and gas and not to transfer the components of the casing to the food and the mechanical, phenotypic and toxic properties (Guilbert, 2000). Sørheim *et al*. (2006) illustrated that the Packaging process is one of the most significant processes to keep the food products quality through containment and preservation during the process of transportation and storage until final use. When choosing packaging materials in the MAP method, several things must be taken into account. Namely that they are resistant to puncture, hermetically sealed, CO_2 and O_2 permeability and water transfer rate. So, different types of ready-made meat packaging polymers have been developed with a focus on the consumer's desire (Kerry & Ogan, 2006). It has been a well-known fact that MAP in food products during storage can prolong the duration of storage (Abdullah & Buchtova, 2020).

Packaging Materials

Especially in the situation of packaging meat, the plastic film properties are important such as thickness, shrinkage, clarity, resistance, O_2 transport, moisture and fogging resistance (McMillin, 2008). Plastics are increasingly being used in packaging processes due to their high readiness, proportionally low costs, and large mechanical properties such as tensile and resistance, their large O_2 restriction. They are insoluble in water and organic compounds and the mechanics of their sealing tightly by heat

(Siracusa, 2012). For MAP, packaging requires moisture and gas retention in order to remain a good environment within the packaging during storage (Rosa, 2019).

The types of plastics used in MAP

Common types of plastics used in MAP (Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), EVOH (Ethylene Vinyl Alcohol), PET (Polyethylene Terephthalate), Nylon (Polyamide), Multi-Layer Films and Plastic Trays and Containers)

Poly Ethylene

Polyethylene (PE) is one of the easiest types of industrial polymers and plastics utilized for packaging applications. Its density is either high or low. Polyethylene has low density (0.91-0.925 g/cm³). This type of polyethylene is used in the form of a film because of the thinness of this kind of casing. Either high density polyethylene (0.940 g/cm³) is solid or semi-solid (Kuley *et al*., 2020).

Poly Amides

Polyamide (PA) contains a gathering of plastics usually alluded to as nylon which is widely used in food packaging. This type has high resistance to tensile and corrosion, has a good barrier to gas but is sensitive to moisture and absorbs water from its environment. The humidity in the nylon environment disrupts holding and adversely influences the conditions of high humidity. There is a commercial nylon that is less affected by moisture and that its strength and relatively high hardness make it ideal (Alavi *et al*., 2014).

Poly Ethylene Terephthalate

Poly Ethylene Terephthalate (PET) is one of the most utilized in packaging applications. It is a good barrier for gas and water vapour. As well as, resistance to high temperatures and makes it ideal for microwave and cooking. The mechanical, optical and heat properties of the casing barrier can vary which relies upon the size or thickness of the casing. The type of packaging, type of additives, and plasticizers can be added to lubricate the casing and make it more adaptable and reasonable for cold environments or frozen food sources (Alavi *et al*., 2014).

Poly Propylene

Poly Propylene (PP) is a type of polymer that is versatile and has different applications or specifications including hardness and elasticity, as well as it is a good casing of gas and water vapor. It used in MAP system (Stoian *et al*., 2019).

Poly Styrene

These wrappers made from Poly Styrene (PS) are either fragile or hard and have limited uses due to their low density, and have been utilized for a long time as essential trays for fresh meat, fish and poultry products (Alavi *et al*., 2014).

Poly Vinylidene Chloride

Poly Vinyldene Chloride (PVC) is good casings that are an ideal material for the creation of designs. Despite the fact that there is a poor obstruction to gas in its plastic form. This plastic has properties for trapping gas and water fume and is impervious to oils and grease (Alavi *et al*., 2014). Table (1) indicates the characteristics of different films, as well as the reservation characteristics. Films require the properties of formability and / or sealing capacity, depending on their functionality. One of the requirements inherent to all MAP bundles is the capacity to hold the ideal atmosphere to the extent that this would be possible. This is accomplished first by selecting a film or films to give the necessary gas and vapor permeability properties and secondly the sealing efficiency of the envelope (Greengrass, 1998).

Table (1): Basic film for poultry meat using modified atmospheric packaging (MAP).

Film	WVTR ($g\ m^{-2}\ 24\ h^{-1}$)	GTR ($cm^3\ m^{-2}\ atm^{-1}$ per 24 h for 1 film at 25 °C)			Tensile strength, MPa	Tear strength, g/mL
		O_2	N_2	CO_2		
LDPE	18	>800	2800	42000	11.6	100-200
PVC	1.5-5	8-25	2-2.6	59-150	9.0-54	400-700
PS	100-125	5000	800	18000	45.1	39493
PP	10-12	3700	680	10000	35.8	340
PET	25-30	50-110	15-18	180-390	159	20-100
PA	400‒300g m^{-2}day atm	75‒50mL m^{-2} day atm	14 mL m^{-2} day atm	190‒150 mL m^{-2} day atm	81	15-30

WVTR: water vapor transmission rate, GTR: gas transmission rate, LDPE: low density polyethylene, PVC: Poly Vinylidene Chloride, PS: Poly Styrene, PP: Poly Propylene, PET: Polyethylene Terephthalate, and PA: Polyamide.

The effect of MAP on meat.

Since old human found horticulture, it became fundamental for him to look for a method for safeguarding the food that was typically delivered at a specific season. The underlying practices toward this path were the drying of products by the sun in tropical or mild regions or freezing in chilled spokes. The start of the food industry and packaging dates all the way back to 1810. The shelf life of food in MAP alters according to product attributes. The mechanism of corruption likewise shifts by product. So, the preservation methodology prescribed to broaden the shelf life of food in the Mediterranean Activity Plan additionally changes among numerous products (Abdullah & Buchtova, 2020).

Meats

Discolouration and growth of microbes are essential for damage that affects the duration and shelf life of meat, oxidizing oxymyoglobin pigment (red) to metmyoglobin (brown) (Gill, 1996). Oxygen represses the development of anaerobic microorganisms, so an elevated degree of O^2 gas is important to keep up with the existence of shelf life of meat and increase the storage period of meat. A gas mixture comprising (70%-80%) of O_2 gas and (20-30%) of CO_2 gas is prescribed to stabilize red colour, forestall microbial development and prolong of the shelf life (Sørheim *et al.*, 1997).

MAP has been step by step utilized in the storage of cooked meat products as of late, and an effective storage method has also been proven that can extend the storage life of products (Karpinska-Tymoszczyk, 2010). MAP was found to contain a high content of O_2 (70%-80%) and (20%-30%) of CO_2 gas. It is increasingly used in fresh meat products as high O_2 is utilized to keep the cherry red colour through which it attracts the consumer (McMillin, 2008). However, it might antagonistically influence the oxidative soundness of muscle fats and proteins (Xiong & Decker. 1995). It adds to the advancement of flavor (Grobbel *et al.*, 2006). Increased hardness (Bao Ertbjerg, 2015; Lund *et al.*, 2007). The Food Summit declined (Lund *et al.*, 2011). The Mediterranean Action Plan can also identify and adjust the amount of gas required to achieve desired results during the storage period (Cooksey, 2014).

Poultry

The skin makes up about 15% of the broiler carcass. The size of the skin in the wings is approximately 10% (Kokoszynski *et al*., 2013). The fat in the skin of broilers is about (20-30%) and broiler fat is featured by its high percentage of unsaturated fatty acids (Sheu & Chen, 2002). The skin ratio in the wings is higher than all parts of the broiler's body and includes 22%, which is double the quantity found in the thighs (Abdullah & Buchtova, 2016).

One of the most important pathogens, for example, is *Salmonella spp*. which poses a threat in the poultry processing in many areas of the world (Rossler *et al*., 2019). Some products that contain huge quantities of unsaturated fats are more defenseless to oxidative rancidity and microbial development and hence have a restricted shelf life. So, O_2 should be eliminated totally with the expansion of a combination of CO_2 and N_2. pH is a significant factor in poultry meat as it invigorates microbial harm and low pH leads to a prolongation of storage life (Church & Parsons, 1995).

Effect of MAP on Physical Qualities

The influence of MAP on the meat colour and freshness

Efforts are being made by meat makers to minimize losses by preserving colour. This has been done by improving the packaging, storage, distribution processes, methods of presentation and especially retailed meat to prevent chemical losses of meat products. It was stated that the O_2 consumption rate in beef muscles stored in low oxygen atmosphere with increase of storage time decreases oxygen consumption. It was found that the Optical Character Recognition (OCR) of meat decreases rapidly (O'Keeffe & Hood, 1982). The rate of oxygen consumption in meat leads to a decrease in the penetration of oxymyoglobin dye during blooming. Fresh meat usually contains two or more types of tinctures, namely Myoglobin, Oxymyoglobin and Metmyoglobin. Although there is a Metmyoglobin dye in the meat, some meats have a red colour resulting the supremacy of the Oxymyoglobin dye (Mancini & Hunt, 2005). Gill & Gill (2005) indicated that muscles that have a high oxygen consumption rate will have a brighter red colour more stable. If the meat exposed to a low concentration of O_2, it will have a purple colour, Deoxymayoglobin and this will sprout to dazzling red (oxymyoglobin) when presented to air (Mancini & Hunt, 2005). One of the primary objectives in the meat processing is to maintain the desired colour, as most consumers evaluate or prefer colour-related meat fresh (Jeyamkondan *et al*., 2000). Consumers realize that an altering meat colour is evidence of meat corruption or microbial contamination which is a rare condition (Zakrys *et al*., 2008). Hohikel (2009) mentioned that the oxygen consumption rate of OCR is important when thinking about the flowering of red meat. When competing for oxygen with dark myoglobin, the colour of dark non-oxidized meat will prevail.

Petracci *et al*. (2004) illustrated the poultry meat colour is influenced by several factors, the generally significant of which are age, gender, breed, nutrition and fat between the muscles, the conditions to which the bird is exposed before slaughter, manufacturing conditions and chemicals.

Several methods have been proposed to improve colour such as combining appropriate packaging techniques and introducing appropriate antioxidant agents (Fratianni *et al*., 2010). One of the generally significant key assumptions in modern packaging is to preserve the desired colour as long as possible

(Gazalii *et al*., 2013). The product packed in a film or VP has the penetration of O_2 from the outside to the inside is restricted. Fresh meat inhales the remaining O_2 in the meat, which leads to an increase in CO_2 gas from 10-20% within the packaging. Meat stored under the influence of the VP is not suitable in retail markets because the decrease in O_2 in the packaging works to convert the meat colour from red to purple by converting Myoglobin to Deoxy myoglobin. This converting undesirable for the consumer and is reversible. Either if the dye is converted to brown metmyoglobin it is difficult to reverse. These changes occur significantly for minced meat wrapped in VP with a long storage period and a limited capacity of the packaging. This effect is less on pork. It's through L*, a*, and b* values, it can evaluate if it is red, dark or light or it is greenish or yellowish. The value of L* is low if it is a colour of dark meat either if it is a colour of light flesh then the value of L* is high. The terms of yellowish colour depends on the value of b*. When the b* value is positive (+), the colour is yellowish and in the case of a negative value (-), the colour of the meat is bluish (Gulrajani, 2010; Pathare *et al*., 2013). The b* value ranges from -120 to 120, in the case of a b* value equal to (0) this means that the colour is neutral or gray (Segnini *et al*., 1999; Yam & Papadakis, 2004). The a* value refers to the red colour. Whenever the value of a* is positive, the colour is red either in the case of the value of a* negative, it means that the meat colour is greenish (Gulrajani, 2010; Pathare *et al*., 2013). The value of a* ranges between -120 to 120 (Leon *et al*., 2006). Table (2) summarized the effect of MAP on the meat colour. Łopacka *et al*. (2016) clarified that the L* value was not significantly impacted by the storage time of closed breed steaks treated by VP. They explained that the value of a* significantly impacted the packaging way by giving MAP and MAP –VP a higher a* value contrasted with VP for beef steaks. Also, they showed that the changes in red (a*) are related with the conversion of myoglobin shapes in the surface of the meat, and the value of a* decreases because of the oxygen leads to myoglobin oxidation to metmyoglobin with increase of storage time.

Colour considers a significant part in the appearance, acceptance, exhibit of rabbit meat, and it's an important characteristic of the consumer (Lan *et al*., 2016). Lan *et al*. (2016) stated the L* and a* values are impacted by the storage temperature and storage time. The oxidation of dye, fats and butene is a common phenomenon in meat and it is products at conventional conditions of storage (Lorenzo *et al.* 2018).

Table (2): A summary of the effect of MAP on the meat colour.

Important results	References
The MAP has significantly affected on the L* value. L* value inclined significantly ($p<0.05$) when using 50% N_2+50% O_2 and oil of clove compared to the standard treatment as the colour became darker than the standard treatment. This may be due to the presence of oxygen in the treatments led to the darkening of the colour through increasing dye. There is no significant variations were shown between70%CO_2+30%N_2 and 70%CO_2+ 30% O_2. In the L* value, also no significant variations were shown between the standard treatment and 70%CO_2 +30%N_2, 70%CO_2+ 30% O_2, and the VP treatment.	(Khalaf *et al*., 2019)
L* increases as the storage time increased under high oxidation conditions. This is due to changes in the meat protein shape and these changes may produce a significant dispersion of light and give a great value of L*. The colour is one of the most quality qualities used in food products and that has a significant effect on the consumer's desire and final product acceptance.	MacDougal (1982)
Storing the meat of the breast of poultry under 100% CO_2 in the presence of O_2 sweepers and VP gave the best results for the colour. The stability of colour was enhanced and formation rate of Metmyoglobin decreased in both ways. They also noted that the value of b* was higher at utilizing MAP and MAP-VP compared to VP at the beginning of the fourth day of storage. This is due to the beginning of the formation of Metmyoglobin. An increase in the value of h indicates a change in colour towards a decrease in redness and increased tanning. This is indicating an oxidation of Myoglobin	Sante *et al*. (1994), Yancey *et al*. (2001).
The value of L* raised with the storage period and improved in samples packaged by VP, but samples packaged with MAP, while the value of L* was constant.	Garcıa-Esteban *et al*. (2003)
The hue angle portrays the general measures of redness and yellowness where 50/360 represents red/purple. Values of yellow, green, and blue are 90, 180, and 270, respectively. Purple or middle colours between pairs close to those of the primary colours. The researchers also showed that the lowest value of the hue angle shows that the product colour is red. The hue angle depends on the colour compounds a* and b*, and represents a hue angle is between pure red (colour angle equal 0 degrees) and pure yellow (colour angle equal 90 degrees). When the hue angle value is high, it indicates the brownness of the flesh or a rise in yellowness over redness inside the colour range of the meat. This is because of the Metmyoglobin formation.	Pedisic *et al*. (2009)

Dies are formed when there is no binding at the location of the sixth coordinates and iron heme ferrous (Fe^{+2}). Deoxy myoglobin binds to the red-purple vacuum-packed product colour or the newly cut product after time has passed on the muscles to open (exposed to oxygen). Then myoglobin turns from Deoxy myoglobin to Oxymyoglobin. Usually, the muscles take 10 min to foster a brilliant cherry red colour. No adjustment of iron valence happens during oxidation albeit the 6th coordination site is busy with diatomic oxygen. The more drawn out the product is presented to oxygen, and the more profoundly the Oxymyoglobin enters the muscles. At that point, Oxymyoglobin is changed over completely to Metmyoglobin by long haul openness to oxygen. Metmyoglobin ties to brown colour that frequently shows up with surface staining. It is advantageous Carboxymyoglobin is shaped by restricting carbon dioxide to Myoglobin that prompts Myoglobin binding and carbon oxide to the very bright cherry red colour	Kerry *et al.* (2006).
The primary capability of oxygen is that Myoglobin stays on account of Oxymyoglobin in cherry red. Oxygen inside MAP fundamentally affects the value of a*.	Leon *et al.* (2006)
The Pork sauces and VP gave a high value to a*. The availability of O_2 in MAP plays a role in raising the b* value. An increase in the colour angle of 0-90 degrees indicates yellowish colour mixing or redness loss. This is likely due to the metmyoglobin formation in fresh meat.	Martínez *et al.* (2006)
The colour is better when the lower hue angle value. When the hue angle increases, it indicates an increase in the ratio of Metmyoglobin	Ghris (2007).
The b* value had expanded at the third day of storage for the meat packaged by VP and afterward diminished until the end of the storage time.	Rubio *et al.* (2008)
The L* value was not impacted by the MAP. The treatments of the MAP did not significantly affect the value of redness a* at the storage periods of 0 and 3 days. After six days of storage, the value of a* increased when using 30%O_2+20%CO_2+50%N_2 and 70%O_2+20%CO_2+10%N_2 compared to VP. They noticed after 9 and 12 days of storage that 70%O_2+20%CO_2+10%N_2 surpassed.	Soldatou *et al.* (2009)
L* values show whether the colour is dark (low L* value) or light (high L* value). It shows the clarity range of the product, the L* value is useful for determining how bright the colour of the product is (increase L*) or to darken its colour (decrease L*).	Esmer *et al.* (2011)

The L* value was higher when using MAP than the VP.	Li *et al.* (2012)
The value of b* increased when using O_2: CO2: N_2/15:30:50.	Cachaldora *et al*. (2013)
There was a slight expansion in the L* value using MAP for meat during the storage period and they did not notice significant differences between MAP and VP.	Murphy *et al*. (2013)
A rise in the value of a* during the seven days of storage in MAP coated meat and then decreased after the seventh days of storage.	Kameník *et al*. (2014)
Myoglobin is a protein that forms the pigments accountable for the red meat colour. It was fabricated of four pyrrole groups that combine to form the Porphyrin ring. The meat colour relies upon the condition of the iron in the center of the porphyrin ring as shown in Fig. (1). Oxymyoglobin has a red colour and is formed when iron is reduced to a low state and not oxidized, unlike oxymyoglobin and metmyoglobin have a brown-to-brown red colour with iron in the oxidized state.	Cooksey (2014)
Both myoglobin and metmyoglobin are considered undesirable for most consumers. With red meat seen as the newest and safest to buy	(Karpinska-Tymoszczyk, 2014).
Meat in the form of myoglobin actually has a longer shelf life according to the perspective of quality and safety. muscle and meat from poultry and fish contain low concentrations of myoglobin. So, the packaging is not designed to control the colour of these products.	Cooksy (2014)
The incline in the L* value of broiler chest skin in MAP may be due to the negative effect of CO_2 that acts on the formation of myoglobin	Hur (2013)
MAP of $0\%O_2+20\%CO_2+80\%N_2$ gave a lower value of L* and raised the shelf life of beef meat compared to VP.	Kim *et al*. (2014)

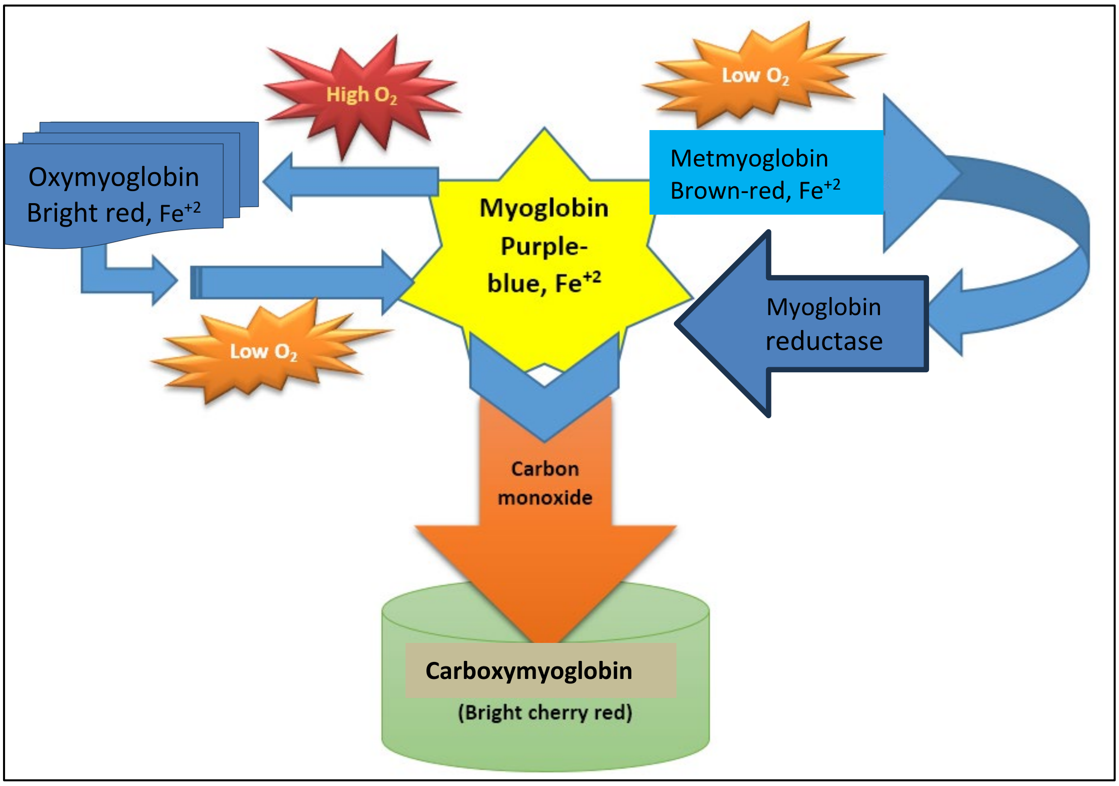

Fig. (1): Various cases of dye in fresh red meat.

Influence of MAP on meat pH

The pH value was declined after storing meat for a period of time in commercial MAP with 60% CO_2 and 40% N_2 compared to VP. The results achieved in another study are the storage of meat in MAP with 30 % CO_2 and 70% N_2 affirmed these results. The concentration of CO_2 in MAP has a significant effect on the value of meat pH. So, the gas concentration and the composition of the casings have a significant impact on a change in the value of meat pH. Also, the process of depletion of glycogen as a result of the animal's exposure to various stresses and stressors before slaughter causes a decrease in the value of pH (Ali, 2008).

The process of applying varied kinds of packaging and the length of time of meat storage may have a significant impact on chemical and physical of pigments. The results achieved in studies have shown a significant impact on the meat pH in the case of prolonging the storage period for meat packaging by MAP or VP. The value of pH increases with the increase in the storage period (Zakrys--Waliwander *et al*., 2012). There is an increase in the stored meat pH in refrigeration under the MAP, and the reason for this increase is due to the rapid diffusion of microorganisms. However, some researchers do not agree with those findings due to them believe that the high amounts of CO_2 in the MAP is rapidly soluble in water. This leads to the carbonic acid (HCO_3^-) formation which in turn causes a slight acidity in meat (Fraqueza & Barreto, 2009; Abdalhai & Sun, 2014).

Effect of MAP on moisture loss during storage

When investigating the chemical and physical attributes properties of beef treated by the VP, and MAP, the results observed significant loss of moisture in the MAP. This study was applied with different types of gases (80% O_2 and 20% CO_2). MAP with a high oxygen content in the shells can be of importance key to enhance the oxidation process of both fats and proteins. The protein oxidation process leads to a change in protein structure (Traore *et al*., 2012).

Zakrys--Waliwander *et al.* (2012) confirmed the oxidation process of proteins has a direct impact on the physical and chemical qualities of meat. This may lead to increase moisture loss and affect the juice. It was also found that the greatest moisture loss during storage was in the meat packaged by VP. Poławska *et al*. (2014) showed that the packaging system in MAP for high-fat poultry meat gave a moisture loss during 5 days of storage, and 1.5 days in the VP. As well as, the results confirmed that the storage time makes a negative influence on moisture loss during storage.

Abdalhaie *et al*. (2014) explained that the stored chest muscles in VP have a forfeiture of moisture during storage higher than the muscles stored in MAP. The reason for the loss of moisture during storage of meat in VP is due to the reducing pressure of meat that exposed in the VP. Liquids lost during storage by the MAP occurs with a high concentration of oxygen (Delles & Xiong, 2014).

Effect of the MAP on moisture loss during cooking

The higher loss of moisture during cooking for fresh meat after 24 hours of the slaughter process in contrast to the storage of meat in the packaging. the forfeiture of moisture during cooking decreased in the term of 10 days of the storage process in VP and MAP. In this period, no difference was observed between the treatments so it relied on applied packaging. either period on the day 15, the analyses have shown an important raise in moisture loss during cooking in the muscles stored in all kinds of casings (Jama *et al*., 2008). Increased loss of moisture during cooking with increased storage life is normal resulting from raised exogenous enzymes (Jama *et al*., 2008).

Effect of the MAP on fat rancidity

The process of fat oxidation occurs by the action of hydrogen peroxide produced by bacteria during the process of fermentation of meat. Thus, forms free radicals and this consists of three steps which are starting, sedimentation and termination. Hydrogen peroxide is a primary oxidation product, but somewhat precarious and scentless. While it is the oxidation of by-product that led to the inducing of unwanted flavors as well as deterioration of the colour and likelihood of formation of toxic compounds (Kanner, 1994).

Fernandez-Lopez *et al.* (2005) stated that process of fat oxidation and degradation of meat leads to damage of proteins and fats. This is lead to the damage of the colour, flavor and meat taste. Also, the available of free radicals or peroxide which contribute to the process of oxidation of fats. Moreover, fat oxidation able to form peroxide which reacts with the dye of Oxymyoglobin and turns the dye into Metmyoglobin. In addition, one of the most vulnerable fatty acids for oxidation is unsaturated fatty acid because they contain double bonds (Kmiecik & Korczak, 2006). The process of oxidation of cholesterol is formed at the point when cooked meat is warmed or during the storage of frozen meat. Either in the case of heating pork sausages, it has been observed that oxidation of cholesterol has not been detected (Baggio & Bragagholo, 2006). So, the oxidation of endogenous fats works to affect the organoleptic qualities of meat products, especially taste and smell (Kmiecik & Korczak, 2006). Kerry *et al.* (2006) depicted that the main job of O_2 is to preserve the muscular myoglobin pigment in its oxidized oxymyoglobin form.

Jayathilakan *et al.* (2007) illustrated that low temperatures through the storing process are slow down the decomposition and formation of free radicals. Although it is possible to cause changes in fat. Fat oxidation is a reason significant deterioration in meat and it is products such as triglycerides, phospholipids, lipoproteins, cholesterol. The phosphatides of the cell membrane are more vulnerable to oxidation because of their high quantity of unsaturated fats containing double bonds. Oxidation is caused by metal ions like iron and cobalt. Copper and manganese.... etc or enzymes such as Lipoxygenase and this enzyme needs to be activated by hydrogen peroxide (Hohikel, 2009).

The smell and taste of spoiled fat in light of unsteady substances with low sub-atomic weight like ketones, dehydes or free unsaturated fats and the idiosyncrasy of fat oxidation prompts undesirable changes that impact its sensory attributes. For instance, colour, texture, flavor and aroma advancement. Additionally, meat loses its nutritional and healthy quality (Gomez & Lorenzo, 2012). Antioxidant supplements improvements can additionally foster meat quality by modifying metabolic cycles in muscles, including the adequacy of enzymes. This movement might be affected by encapsulation (Kang *et al.*, 2014). One of the primary drivers of meat harm is the course of oxidation that happen after the muscles are switched over completely to meat or during the dealing with and storage of meat. In any case, the synthetic changes responsible for changing the muscles into meat lead to a stop in the body's antioxidant balance and thus facilitate the oxidation reactions of meat after animal slaughter (Kumar *et al.*, 2015). The primary support in the process of fat oxidation is unsaturated fatty acids (Kumar *et al.,* 2015). Although packaging in conditions with a high concentration of oxygen is suitable only for meat rich in myoglobin to give it an attractive colour, it can be used by the Bipark Farm field curve fed organic matter (without chemical additives) and when comparing the high-oxygen packaging with samples free of it, the latter has the ability to maintain the freshness standards of poultry meat and has a greater positive on the content of ammonia and TBA. Antioxidant susceptibility, and one of the most commonly used criteria for estimating fat oxidation is thioperic acid, free fatty acids and peroxide value (Chen *et al.,* 2018).

Influence of MAP on Bactria

Traditional organic acids are used as antimicrobials in food (Simon *et al*., 2010). Elevated degrees of organic acids are expected to include the number of bacteria and that these high concentrates can have detrimental impacts on quality of product (Samant *et al*., 2015).

MAP is one of the packaging strategies that was created around 90 years ago (Zhang *et al.,* 2015). It is found to be noted that the MAP with cooling temperatures is a good technique preserving vegetables and fruits. The impact of the MAP on microorganisms fluctuates depending upon storage conditions and the packaged product type (Oliveira *et al*., 2015). The effect of gases in VP or casings is significant on the number of microbes prevalent in meat. Various studies have reported that Psychrophiles bacteria are prevalent under aerobic conditions Pseudomonas. So, the main goal of having a low oxygen atmosphere is for the purpose of reducing agrobacteria, especially *Pseudomonas*. (Viana *et al*., 2005; Nychas *et al.,* 2008). Kennedy *et al*. (2004) stated that lamb muscles packed in carbon dioxide concentration between 80 -100 and stored for a one week gave an inclined in the number of microorganisms. The meat exposed to the longest duration in the gas had positive results on reducing lymphatic germs. In addition, it is important to consider that CO_2 is more efficient when microbial growth is in the late stage (Viana *et al*., 2005). Meat damage is caused by changes in meat quality like flavor, appearance, changes in colour or gas advancement (Borch *et al.*, 1996; Nychas *et al*., 2008). Meat is a protein-rich supplement that is distractable. In addition, it has a short shelf life at room temperature and is impacted by storage period (Olaoye & Onilude, 2010).

Damage to raw poultry products addresses an economic weight on the product (Petrou *et al*., 2012). Poultry meat is generally consumed as raw. Meat and poultry meat are profoundly short-lived. Their contents, high water activity and high pH facilitate the growth of bacteria (Zouaghi & Cantalejo, 2016). As well as, research results have shown that the rise of CO_2 gas in special stores for storing meat (poultry) works to prolong the storage life of these meats without leading to corruption. This is because CO_2 gas has a significant effect in thwarting the growth of microbiology responsible for the synthesis and change of texture of these meats. Usually for products where no breathing occurs where microbial development is the fundamental consider harm 30 to 60% of the gas utilized is CO_2 and the rest is either pure N_2 or a mix of N_2 and O_2 for products. It generally happens levels of around 5% of CO_2 and O_2 are normally utilized. The rest is N_2 to diminish the respiratory rate (Robertson, 2005). The Mediterranean action plan for food packaging as well as refrigerated temperatures is a minimally processed fruit and vegetable safety preservation technology. Anyway, the effect of MAP on microorganisms can be different depending upon storage conditions and the kind of product packaged (Oliveira *et al*., 2015). MAP with high concentration of CO_2 really repress the development of microorganisms including microbes transmitted by *Salmonella*, *Campylo Bacter* (Djordjević *et al*., 2018). Table (3) illustrates an outline of the impact of MAP on the qualitative characteristics of poultry meat.

Influence of MAP in the poultry meat shelf life

The shelf life for chicken meat coated with MAP increased from 0-5 days and decreased lipid oxidation (Lei *et al.,* 2023). Abdullah & Buchtová (2020) found that there was a strongly increase in TBARS from one week after storage to the end of the storage period. Hotchkiss *et al*. (1985) clarified there is a 2.5-fold increase in the shelf life of MAP-packed chicken quarters in comparison to air-cooled storage. Moreover, sensory studies of raw and cooked chicken have indicated that it is not only an improvement in microbial traits but also in sensory traits. Anderson *et al*. (1985) found that dump-packed broiler chicken thighs, CO_2 and N_2 have concluded that MAP may help increased the shelf life. Gill *et al*. (1990) confirmed that carbon dioxide prolongs the storage life of poultry. Using MAP (70%CO_2+15% O_2+15%N_2) of chicken meat led to an increase in its shelf life. Also, it decreased the microbes except *E. coli* which did not have a significant decrease (Thomas *et al*., 2020). The use of 70% N_2 +30%CO_2 has prolonged the shelf life of grilled duck meat by 7 days (Chen *et al*., 2020). Table (4) shows summary of the impact of gas mixtures used in MAP on the poultry meat shelf life.

Table (3): Summary of the impact of gases mixtures used in modified atmosphere packaging (MAP) on quality of poultry meat.

Samples	Mixture of gases	MAP effect	References
Coated turkey meat	50% CO_2+50% N_2	There is no significant influence of TVB-N between colour totals plus storage durations	Fraqueza & Barreto (2009)
Turkey meat	20% CO_2+80% N_2	Residual and aerobic microbiology was lower in MAP coated samples compared to sub-vacuum as well as antenna	Rajkumar *et al.* (2007)
Chicken thigh meat	T_1=70% CO_2+15%N_2+15%O_2, T_2=70% CO_2+30%N_2, T_3=70% CO_2+30%O_2,T_4=50% O_2+50%N_2	they have significant effect on the lightness, redness/greenness, and h, but chroma change, colour diference, and yelo did not affected by MAP. The duration of the storage had a significant impact on lightness, redness/greenness, yellowness/blueness, hue angle, chroma change, colour difference pH =5.84 for MAP compared to control (5.95). A decrease in the amount of liquid lost during storage and cooking was observed, and the values of peroxide value,free fatty acids, and TBA were decreased at utilizing 70% CO_2+15%N_2+15%O_2	Khalaf *et al.* (2019)
Cooked chicken	70% $C0_2$+30% N_2	Total bacterial counting was acceptable in unpacked and MAP (under 10^5 CFU /g for 15 days at a temperature of zero Celsius).	Young *et al.* (1987)
Cooked chicken pancakes (breasts and pancakes of the thigh muscles)	70% N_2 + 30% CO_2 or vacuum	The thigh muscles are more oxidized than chicken breast pancakes	Smiddy *et al.* (2002)
Fowl	Increasing concentrations of CO^2 from 0% to 80%.	The shelf life of chicken quarters stored at 2 ° C.	Hotchkiss *et al.* (1985)
Chicken breasts or thighs	100% CO_2 100% N_2 20% CO_2 :80% N_2	More effective than vacuum packaging in terms of: delay the development of microbes and the happen of physical and chemical alters. Less effective. The effect was less than using 100% N_2	Kakouri & Nychas, (1994)

Chicken carcasses	70% CO_2 + 30% N_2 at 2, 4,7 and 9°C.	The storage life of carcasses is three times longer comparing specimens stored in the air.	Sawaya *et al*. (1995a)
Breasts of chicken	70% CO_2 + 30% N_2 at 4ºC	Extend the chicken breasts shelf life up to 3 weeks compared to five days for samples stored in compressed air	Jiménez *et al*. (1997)
breast fillets	30% CO_2 + 70% N_2 at 4ºC.	The shelf life increased by up to seven to eight days compared to 4-5 days for pneumatic storage.	Balamatsia *et al.* (2006)
meat of fresh chicken	65%CO_2+30%N_2+5%N_2	The shelf life of fresh chicken meat samples was from nine to eleven days	Ntzimani *et al*. (2010)
Pre-cooked chicken meat	90% CO_2 + 10% N_2 30%CO_2+70%N_2 and 60%CO_2+40%N_2	The development of yeasts, mold, Br.Thermosphacta and pseudomonads were prevented by MAP for all tested gas mixtures	Patsias *et al*. (2006)
Sliced turkey	80%CO_2+20%N_2, 60%CO_2 +20%O_2 + 20% N_2 , 0.4 %CO + 80%CO_2+19.6% N_2 , 1%CO +80%CO_2+rest N_2 , 0.5% CO+24% O_2 +50%CO_2+ 25.5% N_2 and 100% N_2	There are no differences between VP and 80% CO_2+20%N_2, beyond 25 days at 4 °C. In other MAP processors, there were slight differences in lactic acid bacteria growth, but 60%O_2+20%CO_2+20%N_2 gave the speeder Lactic acid bacteria development rates.	Pexara *et al.* (2002)
Turkey meat	100%N_2, 20%CO_2+80%O_2, and 40%CO_2+60%O_2	A. hydrophila was able to grow on meat of turkey stored at 1 ° C, or 7 °C. There is no growth in a. hydrophile	Mano *et al.* (2000)
Turkey	100% N_2, 20%CO_2: 80 %O_2 and 40 %CO_2: 60% O_2 at 7°C.	The monocytogenes growth on turkeys stored in MAP and antenna at 7 °C, while at 1 °C, aerobic storage only and 100%N_2 permitted the development of pathogenic microbes.	Mano *et al.* (1995)

Fresh bird carcasses	air, 100%O_2, 100CO_2, 5%O_2+10%CO_2+85%N_2	All treatments inclined the bacterium Campylobacter, but 100% O_2 led to a strongest inclination in the incidence of Campylobacter comparing with other atmospheres. The atmosphere of carbon dioxide reduced by 100% the development of psychotropic substances, total aerops, and *E. Coli* more than the other atmosphere.	Byrd *et al*. (2011)
Turkey breast	40%CO_2+30%O_2+30%N_2	The age of the Khazni has increased	Meredith *et al*. (2014)
Chicken breast	CO_2/N_2 = 3:7	pH, liquid loss (%), lightness redness/greenness, and yellowness/blueness, cooking loss (%), shear power (J), and shear strength (N) of 5.79, 1.52, 85.53 d, 3.71, 9.84, 15.00, 0.03 and 9.26 using MAP Respectively compared to the vacuum packaging which amounted to 5.98, 2.01, 83.31, 3.26, 9.45, 16.67, 0.03 and 7.75 respectively.	MarcinkowskA-Lesiak *et al.* (2016)
Fresh poultry sauces	50%CO_2+50%N_2	Lactic acid bacteria numbered 8.83 log10 cfu/g using MAP compared to air 8.88 log10 cfu/g, and pH decreased from 4.70 using air to 4.82 using MAP after the 21-day storage period. thiobarbituric acid decreased from 2.21 mg/kg Monoaldehyde using air to 2.21 mg/kg Malondialdehyde using MAP.	Lerasle *et al*. (2014)
Poultry	CO_2	It prompts an expansion in the life of the reservoir due to its inhibition of bacteria. If the concentration of carbon dioxide decreases, it leads to a change in colour.	Priyadarshi *et al.* (2020)
Boiled chicken	100% N_2, and 30%CO_2+70%N_2	The total viable numbers were 15 and 2.5 cfu/g in MAP compared to pneumatic filling (AP) (4.9 CFU/g). The content of TVB-N in MAP was less than the content of the AP. Extend the product shelf life for two days using MAP with CO_2.	Deng *et al.* (2020)
Chicken legs	100%N_2 , 20%CO_2+80%N_2, and 40%CO_2+60%N_2	Numbers of C. jejuni have been larger in lactic acid-treated chicken legs packed in MAP than in manufactured and air-packed.	Gonzalez-Fandos *et al.* (2020)
Chicken skin and wings	80%O_2+20%CO_2 (MAP-O_2) and 70%N_2+30%CO_2 (MAP-N_2)	The illumination of the meat treated by the MAP and oxygen was higher than MAP+nitrogen and control. TBARS was increased by using MAP-O_2, and antioxidant activity using MAP-O_2 was lower than MAP-N_2. MAP-O_2 gave a positive effect to skin colour while MAP-N_2 increased the product shelf life.	Abdullah & Buchtová (2020)

Turkey meat and chicken	O_2	Oxygen is not necessary for chicken and turkey meat because it may cause a change in taste and smell. Inhibits anaerobic bacteria and increases fat oxidation.	D'Aoust (1991), Floros & Matsos (2005) and Balamatsia *et al.* (2007)
Turkey breast slices	70%+30% O2+CO2 MAP for 8 days at temperature of 4-5◦C	Isolated jejuni breeds of turkeys and C. jejuni NCTC 11168 isolated decreased to 2.0 and 2.6 record CFU /g	Boysen *et al*. (2007)
Thighs	Combination antimicrobial 24% W/V sodium lactate and low molecular weight potato protein parts) + 80%+20%, and MAP (80%N_2+20%CO_2 at 4 ◦C for one week)	*C. jejuni* ATCC 33560, *C. jejuni* reduced to 1.52 to 1.66 CFU /g.	Gonzalez & Hanninen (2011)
Grilled chicken	40%CO2+60%N2	The remaining microbiology in MAP is lower than traditional packaging and mab with storage of good quality and safety of grilled chicken meat	Huang *et al*. (2020)
Pre-cooked chicken fillets	high pressure, with/without soluble gas stabilization (100%CO_2)	More efficient in increasing the Khazni age	Dang *et al*. (2021)
chicken skin	70% N_2+30%CO_2	lightness value for chicken skin coated at 20% CO_2+80%O_2 It has expanded on day 7 and 10 of the storage period and was strongly higher than the samples treated with 70%N_2+30%CO_2 and the standard treatment.	Abdullah & Buchtová (2020)

Table (4): Summary of the impact of gas mixtures used in MAP on the poultry meat shelf life.

Samples	Mixture of gases	Storage temperature	Shelf life	MAP effect	References
Healing, cooked turkey slices	80%CO_2+20%N_2, 0.4%CO, 60% 60% CO_2+ 20%O_2+20%N_2, 0.4%CO+80%CO_2+19.6%N_2, 1%CO+80%CO_2+19%N_2, 0.5%CO+24%O_2+50%CO_2+15.5%N_2, and 100%N_2.	4°C	14 days	There is no significant effect for gas mixture on the development of Bactria at 10 min compared to 4 min. When using 100% N_2 gave the least total bacterial count and LAB	Pexara *et al.* (2002)
Chimney turkey slices	30%CO_2+70% N_2	4°C	27 to 30 days	*Pseudomonas spp. Enterobacteriaceae* didn't increment during the storage time frame and Mesophiles arrived at 7 log CFU/g	Ntzimani *et al.* (2008)
Turkey meat	100% N_2; 20% CO_2+80%O_2 40%O_2 +60% CO_2	1 and 7°C		development of A. *hydrophila* B. *thermosphacta* did not grow at 7°C	Mano *et al*. (2000)
Cooked turkey meat	80%+20% CO_2	4°C	14 days	The count of aerobic bacteria and TVC was lower.	Rajkumar *et al.* (2007)
uncured turkey	100% N_2 ; 30% CO_2+70% N_2	15°C	7 days	The appearance of Botulinal toxin on the seventh day of storage.	Lawlor *et al.* (2000)
	100% N_2	10°C			
	30% CO_2+70% N_2	10°C	14 days	The appearance of Botulinal toxin sold 14 days of storage.	
	100% N_2	4°C			

Chicken thigh	70%CO_2+30%O_2	-	1-90 days	The peroxide number increased from 0.31-0.6	Khalaf *et al*. (2019)
Chicken skin	20% CO_2+80%O_2	-	10 days	The value of L* increased on the seventh and tenth day	Abdulla & Buchtová (2020)
Chicken meat	30%CO_2+70%N_2, and 60%CO+40%N_2	4°C	20 days	pH ranged between 6.25–6.42, and TBA was reduced.	Patsias *et al*. (2006)
Chicken breast fillets	30%CO_2+65%N_2+5%O_2, and 65%CO_2+30%N_2, 5%O_2	4°C	20 days	The composition of volatile amines was less	Balamatsia *et al.* (2007)
Chicken meat	65%CO2+30%N2+5%O2+500IU /g Nisin–50mM EDTA	4°C	shelf life increased by 13-14 Days (totally 24 days)	The smell was acceptable.	Economou *et al.* (2009)

Table (5): Summary of Hurdle technology containing modified atmosphere packaging (MAP).

Sample	MAP included with hurdle concept	MAP effect	References
Ground chicken thigh meat	80%O_2+20%CO_2, rosemary oil	The addition of oil has a significant impact on the fresh meat appearance during the storage period and the flavor of cooked meat. It has no influence on the development of bacteria Oxidation was slow when adding oil. Decreased TBA and hexanal concentration	Keokamnerd *et al*. (2008)
Chicken breast + skin	70%CO_2+30%N_2+1% acetic acid solution	Remove contamination and prevent the development of odor and raised the shelf life to 21 days. Stop the growth of pseudomonads. Expand the deceleration phase to 7 days.	Jiménez *et al.* (1999)

Grilled chicken	40% CO_2+60%N_2+ grape seed extract.	Reduce *Pseudomonas* spp, wines, molds and lipid oxidation rate while maintaining colour stability	Guo *et al*. (2020)
Fresh turkey sausages	To add lactate with oxygen-rich MAP	Change the red colour to gray or dark brown.	Luong *et al*. (2020)
Meat of chicken	65%CO_2+30%N_2+5%O_2+1500IU/g NIS 50Mm EDTA	Expand the storage age from 9-10 days and the rest is acceptable till twenty days of storage.	Economou *et al.* (2009)
Chicken drumettes	Vacuum pressure+ disodium ethylenediaminetetra and NIS for 30 min at15 ^oC	The storage time was 9 days at 4 °C temperature.	Cosby *et al*. (1999)
Poultry sausages100	100% CO_2+high hydrostatic pressure	Inactivate of *L. carnosum, B. thermosphacta, L. innocua*	Al-Nehlawi *et al*. (2014)

EDTA: ethylenediaminetetraacetic acid, NIS: nisin.

Hurdle concept with MAP

Hurdle concept with MAP MAP causes potential inhibitory effects after the treatment and during storage. It is not difficult to incorporate MAP as an "extra" treatment to enhance additives, high-pressure treatment, radiation, and numerous other antimicrobial treatments. There have been a few reports of MAP, as a feature of the hurdle term, adding to increment generally hindrance of microorganisms or further developed item quality (Rao & Sachindra, 2002). Ie., the poultry meat treatment using solution of sorbate with MAP has further inhibited damage and pathogenic microorganisms respectively (Gray et al., 1984; Sawaya et al. 1995b). The combination of MAP and radiation for raw meat was clarified to be efficient in minimizing the number of primary microbes and inhibiting the growth of residual during storage (Zhao *et al*., 1996). Irradiation associated with MAP was widely studied, although in the state of irradiation, balances exist between raised mortality of microbes with radiation in the availability of oxygen (Avery *et al.,* 1995). In addition, the possible quality loss at exposing products to radiation in the air. Nevertheless, irradiation associated with MAP was presented to be efficient in accelerating the beef aging at increased temperature (Lee *et al.,* 1996).

Guo et al. (2020) studied the impact of adding a solution of grape seed extract with MAP (40%CO2+60%N2) on the phyco-chemical characteristics of grilled chicken meat stored at 4 ºC temperature. Researchers depicted that the addition of 0.5% of the solution of grape seed extract with 40%CO2+60%N2 resulted in a reduction in Pseudomonas spp, liquor, mold and fat oxidation rate while maintaining colour stability. Luong et al. (2020) found a significant effect of adding lactate with MAP to sausage of raw turkey and that the mixture of gas is rich in oxygen and the colour change from red to gray/dark brown. Table 5 shows many studies for Hurdle technology containing MAP.

Conclusions

MAP is the ideal way to protect food, a common method used in many fresh and dry foods. Increasing the gas level in MAP in a large form led to protein oxidation and decreased meat quality. Moreover, it improved meat colour. Also, significant improvement in the physical qualities of MAP meat. The total and Psychrophiles bacterial populations in MAP-treated meat decreased and increased with the progress of storage periods. There is a rise in the pH value of meat stored in refrigeration under the influence of MAP. The amount of fluid lost during storage by MAP with a high oxygen concentration were decreased. MAP had significantly impact on the fracture of muscle fibers index, and it increased with the increase of storage duration. The quality of chicken meat was improved by adding natural extracts. The utilization of MAP in chicken packaging raises the shelf life more than traditional packaging (without utilize of gases). Essential oils can be used in packaging to keep the product from damage and increase the shelf life. Future Visions for MAP, MAP is an important technique in meat preservation. To develop this technique, a mixture of gases with volatile essential oils can be utilized to prevent oxidation and enhance the quality of stored meat. Meat can also be treated ultrasonically and then gassed to prolong the storage life and guarantee that it is not damaged. Smart packaging can also be combined with MAP to quickly indicate the consumer's knowledge of the state of damage and product quality. MAP can be included as an "extra" treatment to supplement preservatives, heat processes, high-pressure treatment, radiation, and numerous other antimicrobial treatments.

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Contributions of authors

A.R.A.: Methodology, data curation, writing—original draft, software, formal analysis.

M.H.A.: Conceptualized, formal analysis, validation.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

All ethical guidelines related to meat and care issued by national and international organizations were implemented in this report.

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راجعة شاملة لتقنية التعبئة والتغليف بالغلاف الجوي المعدل للحوم الدواجن: تأثيراتها على الخصائص النوعية وثباتية العمر الخزني

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المستخلص: الهدف من هذه المراجعة هو دراسة تطبيقات التغليف الجوي المعدل (MAP) في لحوم الدواجن، فضلا عن آثاره على الخصائص النوعية واستقرار العمر الافتراضي. تُعد التعبئة والتغليف قاعدة موحدة لتحضير المنتج للنقل والتوزيع والبيع بالتجزئة والاستخدام النهائي لضمان التسليم الآمن. التعبئة والتغليف في الجو المعدل (MAP) هي تقنية تعبئة حديثة تتضمن إزالة الهواء (78% نيتروجين، 21% أوكسجين، و3% ثاني أكسيد الكربون) من داخل الغلاف واستبداله بغاز واحد أو مزيج من الغازات. ان الغلاف الجوي ذو تركيز عالٍ من الأوكسجين بنسبة 80% يساعد على تأكسد الصبغة ويحافظ عليها من التدهور على سطح اللحم، ولكنه يؤدي إلى أكسدة الدهون والبروتين ويقلل من جودة اللحم. ان تركيز غاز ثاني أوكسيد الكربون وتكوين الغلاف يؤثران بشكل كبير على تغير قيمة درجة الحموضة في اللحم. يعمل انخفاض غاز الأوكسجين في التعبئة والتغليف على تغيير لون اللحم من الأحمر إلى الأرجواني، بتحول الأوكسيميوجلوبين إلى ديوكسيميوجلوبين. يرفض المستهلك هذا النوع من اللحم ذو اللون الأحمر البنفسجي. ان استقرار اللون باستخدام التعبئة والتغليف في الجو المعدل يؤدي الى تحسنه، وانخفاض معدل تكوين الميتميوجلوبين. أدى استخدام التعبئة والتغليف المعدل إلى فقدان أقل للرطوبة فضلا عن خفض إجمالي الاعداد البكتيرية والبكتيريا المحبة للبرودة في لحم الدجاج المعالج بتقنية التعبئة والتغليف في الجو المعدل وزادت مع تقدم فترات التخزين. قيمة TBA وقيمة رقم البيروكسيد ونسبة الأحماض الدهنية انخفضت باستخدام التعبئة والتغليف المعدل. يمكن أن تكون التعبئة والتغليف المعدلة جزءًا من تقنية العوائق لتمديد مدة صلاحية لحم الدجاج.

الكلمات مفتاحية: التجمعات البكتيرية تركيب الغاز، الخصائص النوعية، ثبات العمرالخزني