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Modified Atmosphere Packaging and Its Application:-A Review

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Abstract
Packaging in a modified environment is a popular preservation technique. Modified environment packaging (MAP) is becoming more and more popular as a way to preserve freshness and extend the shelf life and storage of fresh fruits and vegetables. Food items having a changed gaseous environment that are encased in gas-barrier materials could be classified as such. MAP-fresh food success depends on a number of factors, including the types of fresh foods, storage temperature and humidity, gas composition, and packing material qualities. Therefore, developments in food packaging technology will continue to support the production of new MAPs. This review study emphasizes how new developments in gas and film have affected the quality of MAP.

Keywords: Modified Atmosphere Packaging (MAP), Gas barrier attributes, Plastic films, Gas composition, Food packaging technologies

1. Introduction

Due to its different climate, India has the ability to obtain a wide range of fresh produce.Following China, it is the world's second-largest producer of fruits and vegetables. As per the National Horticulture Database (2nda Advance Estimates) published by the National Horticulture Board, during 2023-24, India produced 112.62 million metric tonnes of fruits and 204.96 million metric tonnes of vegetables "(APEDA 2023-24)". There were 7.04 million hectares dedicated to fruit cultivation as well as 11.11 million hectares to vegetable cultivation. In impact to the growing c fresh produce over processed foods, there is a rise in the global production processing of fresh produce. To achieve this, fresh produce has to be minimally processed to maintain its freshness, organoleptic properties, nutritional value, and textural properties.

Fresh produce, however, is extremely perishable and vulnerable to significant spoiling mechanisms as a result of storage. In ambient atmosphere conditions, which cause microbial growth, moisture loss, enzymatic browning, and oxidation. So keeping the produce in this condition may cause the produce to go unpalatable and unsafe for human consumption. To overcome this problem, a packaging technique called MAP (Modified Atmosphere Packaging) is employed to increase the shelf life of fresh and minimally processed produce. Modified atmosphere packaging (MAP) is defined as 'the packaging of a perishable product in an atmosphere that has been modified so that its composition is other than that of air' (Hintlian& Hotchkiss, 1986).

1.1 History

In 1927, Kidd and West studied the effect of atmosphere modification on fruits. Then later, in 1929, the first commercial use of CAS was for apples in England. The first known commercialuse of MAP was the exporting of fresh meat carcasses in CAS in the early 1930s. In the 1930s there were scientific studies to extend the shelf life using modified atmospheres on fresh meat & poultry. Some studies showed that storage of fresh meat and poultry in 100% CO_2 extended the shelf life nearly double (Killefer et al. 1930). In 1969, two Unilever employees, Georgala and Davidson, received the first patent for MAP of red meat in France. An atmosphere with at least 70% O2 and 10% CO2—the remainder being an inert gas—was described. After 15 days at 4°C under such an MA, the beef remained fresh in a gas-impermeable container.

Since the 1970s, MAP has been widely employed as a preservation technique due to its versatility and efficiency in preserving various food products. To attain the current level of commercial success, it necessitated the convergence of scientific knowledge, cold distribution networks, gas flusing and vacuum packaging equipment, and polymeric films.

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2. Principle

MAP is used to delay the degradation of foods that are not aseptic and whose enzymatic systems may still be in function. As long as the overall pressure within and outside the packaging is equal, the gas combination inside a fresh produce package aside from baked goods can differ from that in the ambient atmosphere outside the package. The term "MAP" is always used in reference to cold temperatures. When addressing cold temperatures, MAP is always employed. Generally understood to be between -1°C and +7°C, chill temperatures are those that are near but above the freezing point of fresh foods. The following events are delayed when food is kept at cold temperatures, which is a popular and efficient short-term preservation technique:

1. Microorganism growth
2. The metabolic processes of intact plant tissues after harvest and the metabolic processes of animal tissues after slaughter
3. Deteriorative chemical reactions, such as oxidative browning caused by enzymes, lipid oxidation, color degradation-related chemical changes, fish autolysis, and overall food nutritional value loss
4. Loss of moisture

When paired with gas environment modification, chilling can significantly increase its preservation effect. This is because aerobic respiration, in which the food or microbe consumes oxygen and generates CO2 and water, is a component of many deteriorative events. It is possible to slow aerobic respiration by lowering the O2 concentration. It is possible to delay or stop microbial development by raising the CO2 concentration.

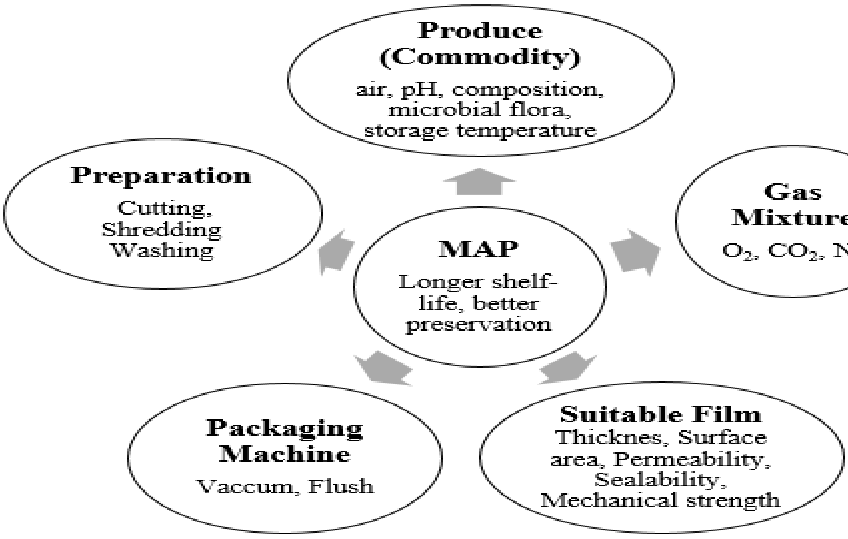

Figure.1 Parameters to be considered for designing MAP of fresh produce.

Modified atmosphere can be created in two ways:

1. **Passive MAP:** This is created when fresh produce breathes through the gas permeability of packaging films. Over time, the CO2 level rises as the O2 level falls. through the process of breathing. In order to prevent damage from excessive CO2, excess CO2 in some produce must be released from the package. To get the desired atmosphere in the package, gas permeation and respiration must be properly balanced.

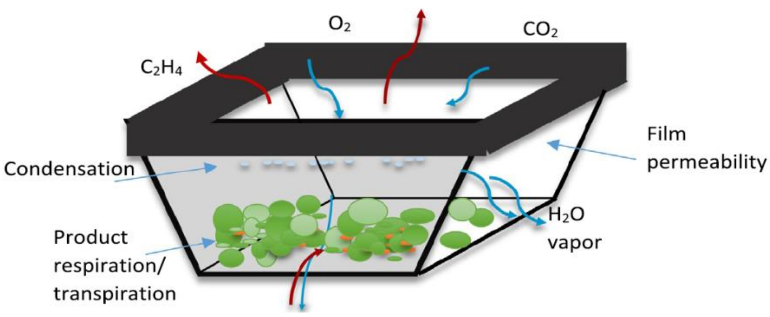

Figure.2 Schematic representation of passive MAP

2. Active MAP: It can be produced by two different methods.

I. Excluding all the air inside the package and then replacing it with a desirable gas mixture.
II. Replacing the existing gas composition by flushing the package with the desired gas composition and use absorbers/scavengers to further extend the shelf life.

Mostly fresh respiring commodities are packed using passive MAP, and non-respiring commodities are packed using active MAP.

2.1 Gases used in MAP

Table 1:- Properties of gases and water vapour with respect to their use in MAP

Gas	Properties	Use in MAP
Argon	●Inert ●Heavier and more soluble than N_2	●Replaces O_2 to prevent oxidation and aerobic microflora ●Inhibits browning in fruits
Carbon Dioxide	●Highly soluble ●Suppress microorganisms and respiration of fresh produce ●High concentration may cause discoloration and acid taste	●Delays microbial growth of mainly gram –Ve bacteria and molds ●Reduces physiological metabolism of fresh produce
Helium	●Inert ●Least soluble and very light	●Used as an inert filler gas and as a tracker gas for leak detection
Hydrogen	●Very light and low solubility ●Flammable and high permeability	●Used for O_2 removal with help of palladium based oxygen scavenger
Nitrogen	●Inert ●Low solubility and least permeable	●Replaces O_2 to prevent oxidation and aerobic microflora ●Used as an inert filler gas to prevent package collapse and also as a diluting gas
Oxygen	●Moderately soluble and permeable ●Lead to formation of oxymyoglobin ●Suppress microbes at a higher concentration ●Maintains and accelerates respiration of fresh produce	●Usually excluded from package ●Avoids anaerobic condition ●Blooms the meat ●At high concentrations, may inhibit microbial growth and browning

Lee *et al.* 2008

3. Applications:

Table 2:-Recent MAP applications in fruits

Fruits	Gases Mixture			Temperature (^{0}C)	Shelf-life (Days)	Refrences
	O_2(%)	CO_2(%)	N_2(%)			
Strawberry	2.5	15	82.5	4±0.5	8-10	Zhang *et al.*, 2006
Fresh-cut apple	5	15	80	5-6	7	Torrieri *et al.*, 2009
Fresh-cut	2.5	7	90.5	4	14	Oms-Oliu *et*

pear						*al.*,2008
Sliced carrot	5	5	90	5±2	13	Alasalvar *et al.*, 2005
Blueberry	100	0	0	5	35	Zheng *et al.*, 2008
Raspberry	3	5	92	7	7	Siro *et al.*, 2006
Papaya	3-5	6-9	86-91	10	25	González-Aguilar *et al.*, 2003
Fresh-cut melon	70	0	30	5	10-14	Oms-Oliu *et al.*,2008
Fresh-cut jackfruit	3	5	92	6	35	Saxena *et al.*, 2008

Zhang *et al.* 2015

Table 3:-Recent MAP applications in vegetables and mushrooms

Sample	**Gases Mixture**			**Temperature (^{0}C)**	**Shelf-life (Days)**	**Reference**
	O_2(%)	**CO_2(%)**	**N_2(%)**			
Broccoli	3	8	89	3	35	Tano *et al.*, 2007
Green Asparagus	10	5	85	2	16-20	An *et al.*, 2006
Sea Asparagus	4	5	91	2	28-32	Lu *et al.*, 2010
Celery sticks	6 kPa	7kPa	5/35 kPa	5	15	Gómez and Artés,2005
Fresh-cut peppers	80/50 kPa	15 kPa	80/85 kPa	5	9-10	Conesa *et al.*, 2007
Kohlrabi	5 kPa	10/15 kPa	79	5	14	Escalona *et al.*, 2007
Summer truffles	21	0	85	4	8-12	Rivera *et al.*,2011
Shiitake mushroom	5	10	91	3±1	20	Jiang *et al.*,2010
Agrocybechaxingu whiteMashroom	5	4	-	4±1	15	Li *et al.*, 2008
Mashroom	21	0	79	4	21	Tao *et al.*,2006

Zhang *et al.* 2015

Table 4:-Recent MAP applications in meat products

Meat	Gases Mixture			Temperature (^0C)	Shelf-life (Days)	Reference
	O_2(%)	CO_2(%)	N_2(%)			
Fresh pork	45	20	35	4	8	Zhang and Sundar, 2005
Beef muscle	50	20	30	4	15	Zakrys *et al.*,2008
Ground beef	70	20	0	4±1	14	Jayasingh *et al.*, 2001
Buffalo meat	80	20	0	4±1	15	Sekar *et al.*, 2006
Chicken breast	0	30	70	4	15	Shin *et al.*, 2010
Ground ostrich meat	0	20	80	4±1	9	Seydim *et al.*,2006
Ostrich sticks	0	80	20	2	12	Fernández-López *et al.*, 2008
Sheep meat	80	20	0	4	12	Kennedy *et al.*, 2004
Lamb meat	0	80	20	4±0.5	13-14	Karabagias *et al.*, 2011

Zhang *et al.* 2015

Table 5:- MAP gas mixture for Bakery products

Food	Gas mixture		Storage temperature (^0C)	Shelf life	
	CO_2 (%)	N_2(%)		MAP	In Air
Pasta	100	-	-	-	-
Fresh pasta	50	50	0 to 5	3-4 weeks	1-2 weeks
Bakery products	50	50	0 to 5	4-12 weeks	4-14 days
Baked food	20-70	20-80	-	-	-
	-	100	-	-	-
	100	-	-	-	-
Pies	50-70	30-50	4 to 6	2-3 weeks	3-5 days
Cakes	20-40	60-80	20 to 25	Even 1 year	Max some weeks
Rye wheat bread	20-40	60-80	20 to 25	2 weeks	Max some days
Pre-baked bread	80-100	0-20	20 to 25	20 days	5 days

Galic *et al.*, 2009

Table 6:-MAP gas mixture for Milk and Milk products

Type of food	Gas mixture CO_2(%)	O_2(%)	N_2(%)	Storage temperature (^{0}C)	Shelf life	Reference
Whey cheese	30	-	70	4 or 12	37 or 17 days respectively	Vieira et al., 2019
	70	-	30			
Channa jalebi	100	-	-	28 ± 2	-	Geetha et al., 2017
	-	-	100			
	50	-	50		40 days	
Fresh mozzarella cheese	40	-	60	4	6 weeks	Felfoul et al., 2017
Soft Surface mould ripened Cheese	17-21	1-3	-	12	17 days	Rodriguez-Aguilera et al., 2011
Fresh Stracciatella cheese	50	-	50	8	8 days	Gammariello et al., 2009
	95	-	5			
	75	-	25			
	30	5	65			
Whey cheese; Lor cheeses	60	-	40	4	45 days	Temiz et al., 2009
	70	-	30			

Shah *et al.*, 2024

4. RECENT TREND IN MA PACKAGING FILM AND MATERIALS

Each commodity of food has a variable respiration rate, and the type of film and food respiration rate determine the particular equilibrium environment.

Table 7:- Basic components of plastic film and its permeability and water vapor transmission rate. (Sandhya, 2010)

Film	Permeability (cm3 m−2 day−1 atm−1 for 25 mm film at 25°C)			Water Vapor Transmission (g m−2 day−1 atm−1; 38°C and 90% RH)
	O_2(%)	CO_2(%)	N_2(%)	
Ethylene vinyl alcohol (EVOH)	3-5	-	-	16-18
Polyvinylidene chloride coated (PVDC)	9-15	-	20-30	-
Polyethylene,	7800	2800	42000	18

lowdensity				
Polyethylene, high density	2600	650	7600	7-10
Polypropylene, cast	3700	680	10000	10-12
Polypropylene, oriented	2000	400	8000	6-7
Polypropylene, oriented, PVDC coated	10-20	8-13	35-50	4-5
Rigid PVC	150-350	60-150	450-1000	30-40
Plasticized PVC	500-30000	300-10000	1500-46000	15-40
Ethylene vinyl acetate (EVA)	12500	4900	50000	40-60
Polystyrene, oriented	5000	800	18000	100-125
Polyurethane (polyester)	800-1500	600-1200	7000-25000	400-600
PVDC–PVC copolymer (Saran)	8-25	2-2.6	50-150	1.5-5
Polyamide (Nylon 6)	40	14	150-190	84-3100

Bodbodak & Moshfeghifar 2016.

5. Future Trends in MAP

Antioxidant active films, nanoactive films, biodegradable films, and microperforated films are just a few of the new film types that have been created by recent research and have garnered a lot of interest in the MA packaging sector.

5.1 Micro perforated films:

The permeability of the packaging film is crucial for balancing the product's respiration rate and achieving a desired equilibrium atmospheric state. Microperforated films create the right atmospheric conditions to prolong the product's shelf life. The gas barrier base, which includes the quantity and size of the perforations, regulates the pace at which the gas exchange takes place through the microholes in the film. The dimensions, density, quantity, and size of microholes all influence permeability. In these films, gas permeability varies with temperature. (M Singh *et al.*, 2019)

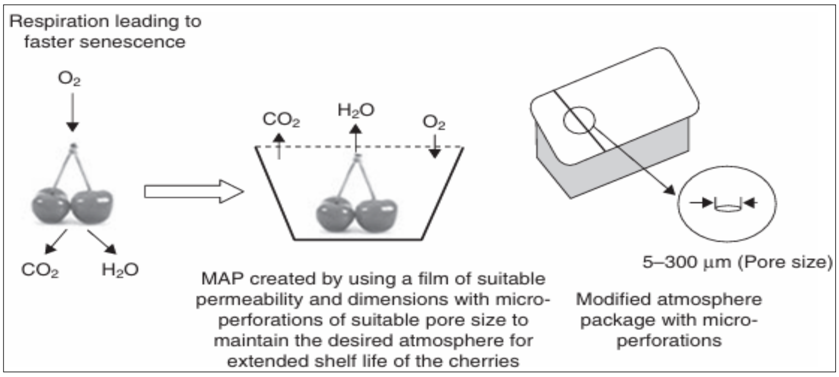

Figure.3 MAP with microperforations for fresh produce. (Vakkalanka *et al.*, 2012)

5.2 Biodegradable films:

There is much ongoing research and also future prospects in the production of biodegradable films. Biodegradable films can be degraded into simpler compounds like carbon dioxide, water, and inorganic products in aerobic conditions by the microorganisms present in nature, and these can also degrade them in anaerobic conditions to produce compounds like methane, carbon dioxide, and inorganic products. The primary categorization of polymeric films is based on the synthesis process: polymers derived from microorganisms, agro-resources, chemical synthesis, and biotechnology techniques. Among these sources, cellulose-based polymers and starch are the most often utilized in food packaging. The most common cellulose-based polymer is cellophane, which is composed of cellulose. Polylactides (PLA), polyhydroxyalkanoate (PHA), hydroxylpropylated starch, and a copolymer of polyhydroxybutyrate and valeric acids (PHB/V) are examples of starch-based polymers.Edible coatings/films, a branch of biodegradable films, have garnered a lot of popularity because of their good barrier properties for gas and moisture. These are made with starch, cellulose, chitosan, pectin, wax, and others.(M Singh *et al.*, 2019)

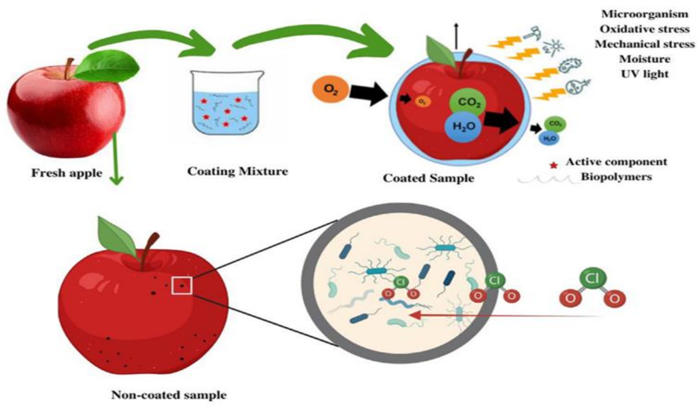

Figure.4 Schematic representation of active and barrier function of edible films/coating (Gupta*et al.*, 2022)

5.3 Nano active films:

The field of nanotechnology is the study of extremely tiny materials. Many nanomaterials are used as functional additives in food packaging; some of them are silver nanoparticles, nano-zinc oxide, nanoclay, and many others. To improve the barrier qualities and other characteristics, nanoparticles are combined with a polymer matrix. Many nanoparticles, including carbon nanotubes, nano-copper oxide, nano-silver, and nano-magnesium oxide, have antimicrobial qualities. Nano-sensors embedded in packaging film can be used as tracing devices.(M Singh *et al.*, 2019)

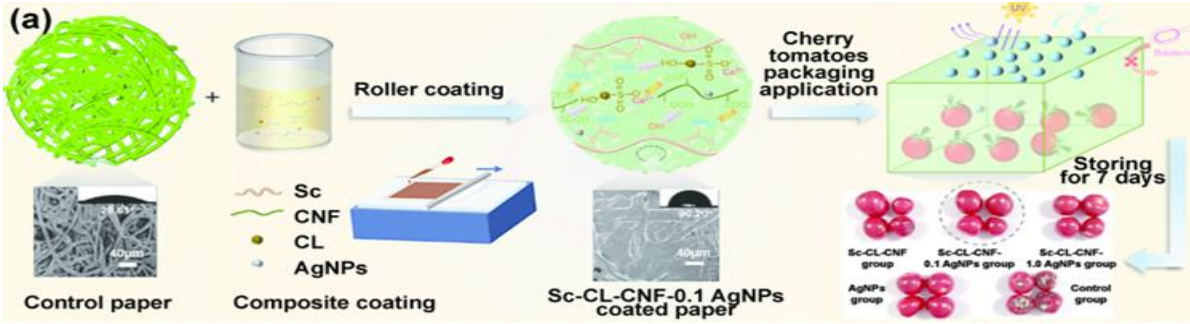

Figure.5 Schematic diagram of the preparation process for the coated paper prepared using Sc-CL-CNF-AgNPs coatings for cherry tomatoes packaging(Wang*et al.*, 2024)

5.4 Antioxidant active films:

Nanoparticles are mixed with a polymer matrix to enhance their barrier properties and other attributes. Numerous nanoparticles possess antibacterial properties, such as carbon nanotubes, nano-copper oxide, nano-silver, and nano-magnesium oxide. (M Singh *et al.*, 2019)

6. CONCLUSION

By suppressing pathogenic and spoilage-causing bacteria, MAP is an efficient method of maintaining the nutritional and organoleptic qualities of food while also guaranteeing safety and extending its shelf life. The effect of MAP is further increased by incorporating antimicrobial or antioxidative agents. Each food's ideal gas composition and packing material must be known in order to get the optimum outcomes. MAP is one of the most innovative areas of the current food packaging industry. It is also very important to maintain strict hygienic conditions throughout the production to ensure the best results for MAP. Nowadays in MAP there are many new gases and their different compositions. The creation of novel and sophisticated polymers and their various compositions is the subject of extensive continuing research, and packaging materials also play a significant part in MAP. But there are some challenges, such as high equipment cost and precise control of parameters.

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