The Pharma Innovation Journal 2022; SP-11(6): 40-47

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(6): 40-47

www.thepharmajournal.com
Received: 18-04-2022
Accepted: 23-05-2022

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Postharvest life of fruits as influenced by modified atmosphere packaging (MAP): A mini review

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Abstract

The postharvest loss of fruits has been in its soaring high ever since the pandemic hit, among the plethora of management practices, modified atmosphere packaging (MAP), is a technique to enhance the shelf life and maintain the quality of products through the alterations in gases concentration by encompassing them (product packaging). The fruits are a highly respiring commodity, so for the selection of films/packaging material for this purpose, the permeability to carbon dioxide and oxygen gases is of utmost consideration. The gases that play a key role in MAP such as O_2, CO_2, and nitrogen, sometimes Argon (Ar), and the individual composition of gases varies depending on crop and the storage method. For MAP, the choice of gas composition inside the package depends on the type of fruits (based on sensitivity), etc. that are being packed. The MAP enhances the shelf life of fruits by altering the microenvironment, thereby reducing respiration and increasing shelf life. The fruits either fresh or minimally processed are packed using active MAP and passive MAP for better quality and shelf-life enhancement. The present review reveals the effect of MAP on the shelf-life of fruits through the use of various packaging materials and summarizes recent advances/developments in the same field.

Keywords: Modified atmosphere packaging, transpiration, respiration, shelf life

Introduction

Consumers are looking for convenient food products due to their busy lifestyles. The health problems have led to a greater interest in quality of food than in quantity of food. The demand for "fresh" and "natural" products without the addition of "hazordous" chemicals spiked dramatically over the decade. MAP seem to be the ideal storage method for most foods, as it can significantly extend its shelf life without affecting the "freshness" or freshness like characters of the product. Nowadays, MAP has become an integral part of the food industry particularly the fresh produce industry, and it is more important than freezing and canning combined surgery is required (Kumar and Amresh, 1996) [6].

34 The World Health Organization (WHO) recommends consuming at least 400 grams of fresh fruits and vegetables per day to obtain the nutritional benefits and for a balanced diet. In 2018, the world has produced a total of 868 million tons of fruit and 1,089 million tons of vegetables (FAOSTAT).

Between 2000 and 2018, global fruit and vegetable production fell by more than half. In 2017, the production increased to 390 grams (FAO, 2020), but it still contains food parts such as pellets and skin, as well as damage and debris that is usually too much. Most products are lost or discarded before they reach the customer's plate. However, the postharvest losses of fruits and vegetables are still considerably high and it is considered the foremost reason for low per capita availability. The enormous losses of fruits and vegetables which are estimated to be 15 to 50% occur at different stages of handling, transport, storage, processing, and distribution. According to the various reports. The postharvest losses in India account for 20-25% of fruits and about 20% of vegetables.

Loss means any change in the accessibility, palatability, or quality of the food which makes the consumers prevent it from being consumed (Fallik and Aharoni 2004). Losses could be caused by biological, microbiological, chemical, biochemical, mechanical, physical, and psychological reactions. Many microbiological, mechanical, and physical factors contribute to perishable crop loss. Protection of fruits and vegetables from mechanical damage and microbial infection keeps the fruits in sound condition; however, it does not increase the shelf-life of the commodities beyond their normal season. This is because fresh fruits and vegetables are living commodities and their metabolic process continues even after harvest.

However, their metabolism is not similar to the metabolic process of the mother plant, which grows in its natural environment (Giusti *et al*. 2008; Martins *et al*. 2008). Horticultural crops undergo a catabolic process causing degradation in quality and quantity during the post-harvest stages. Quality is generally defined as all those characteristics of food that lead a consumer to be satisfied with the product (Echeverria *et al*. 2008). Quality optimization and loss reduction in the postharvest chain of fresh fruits and vegetables are the main objectives of postharvest technology. Generally maintenance of quality depends on diverse conditions in terms of the appropriate temperature, gaseous composition, and relative humidity during storage and transportation. Temperature control and modified atmosphere (MA) are the two important factors in prolonging the shelf-life. The primary factors in maintaining quality and extending the postharvest life of fresh fruits and vegetables are harvesting at optimum maturity, minimizing mechanical injuries using proper sanitation practices, and seeing the perfect temperature and humidity of the relationship at all stages of marketing. Secondary factors include modification of oxygen (O_2), carbon dioxide (CO_2), and/or ethylene (C2H4) concentrations in the atmosphere surrounding the commodity to levels different from those in the air. The application of commodity-specific packaging plays an important role in the maintaining quality and shelf-life enhancement of the perishable horticultural commodities (fruits) (Jayarajan & Sharma, 2021) [10]. Modified atmosphere packaging (MAP) is the alternation of in-pack air with desired gases and their concentration. The gaseous composition inside the packaging during the storage is changed due to the diffusion of gases into and out of the packaged film and also due to the physiological metabolism of the packaged product. The permeability of the film for gases, the respiration rate of the horticultural produce, and biochemical reactions inside the package, are greatly influenced by the temperature. So, temperature control is important for the MAP technique to get effective results. With an increase in temperature, the permeability of the packing film is increased (Scetar *et al*.,2010) [28]. In the early 1920s, the first application of MAP in extending the shelf life of apples was reported. For MAP, the basic idea is altering the air inside the packaging with a desirable, predetermined ratio and concentration of gases (Soltani *et al*., 2015) [31]. MAP is of two types i.e., active and passive MAP. The respiration rate of the horticulture produces (packed one) i.e., the expenditure of O_2 is proportional to the production of CO_2 inside the packing, so the respiration rate of the crop and the permeability of packaging film are important conditions that are taken into consideration in passive MAP. After a certain time, the ratio and concentration of gases inside the film reach a steady state, the total amount of O_2 absorbed in respiration and the CO_2 produced are the same diffused through the packaging film. As for the active MAP, the desired gas mixture is injected for accelerating modification in gas composition following the evacuation of air inside the packaging to avoid exposure of the packed product to high concentrations of undesirable gases (Zhang *et al*.,2015) [40]. History of MAP

MAP was first recorded in 1927 as an extension of the shelf-life of apples by storing them in atmospheres with reduced O_2 and increased CO_2 concentrations. In the 1930's it was used as MA storage to transport fruit and beef carcasses in the holds of ships by increasing the CO_2 concentrations for long distance transport and it was observed to increase the shelf-life by up to 100%. However, this method was not commercially introduced for retail packaging until the early 1970s in Europe. The main limitation of the application of MAP in the initial study was its technical nature; In particular, O_2 levels in the package were not continuously monitored. Since then, the types and properties of polymers have been characterized by high gas densities; harvestability; flexible, developed for printability and transparency. Therefore, the best packaging systems have been made for many products. In the U.K. Marks and Spenser introduced MAP for meat in 1979; the success of this product lead to years later to the introduction of MAP for bacon, fish, sliced cooked meats and cooked shellfish. Other food manufacturers and super market chain followed the same, resulting in a sharply increased availability of MAP food product reflecting to the increase in consumer demand for food with longer shelf-life and less use of preservatives. This technology is now available in a variety of fresh or cold dishes, such as raw and cooked fish, chicken, fresh pasta, fresh and sliced fruit. More recently vegetables and coffee, tea and baked goods.

Packaging materials in MAP

The technique of MAP involves packing of actively respiring horticultural products in polymeric films like LDPE (low-density polyethylene), LLDPE (linear low-density polyethylene), PP (polypropylene), PVC (polyvinyl chloride), PVDC (polyvinylidene chloride), PET (polyesters polyethylene terephthalate), HDPE (high-density polyethylene), EVA (ethylene vinyl acetate). EVOH (ethylene vinyl alcohol), PVOH (polyvinyl alcohol), polystyrene having flexible package structures for balancing their shelf life and maintaining good quality by altering the O_2 and CO_2 concentrations inside the package (Soltani *et al*.,2015) [31].

Principles of MAP

The MAP of products is based on the modification of the atmosphere in the packaging attributing to the natural interaction between the two processes of respiration and deportation of O_2 and CO_2, through packaging, leading to an atmosphere with a high CO_2 content and a low O_2 content (Fonseca *et al*. 2002; Mahajan *et al*. 2007) [17]. This atmosphere can potentially reduce respiration rate, C2H4 sensitivity and production, ripening, softening and compositional changes, decay and physiological changes, namely, oxidation depending on the characteristics of the goods and the packaging film. MAP involves the exposure of produce to the atmosphere generated in a package by the interaction of the produce, the package and the external atmosphere. The initial atmosphere can be air or a mixture of gases. Various additives that can act on the atmosphere may be included in the package before sealing. When fresh products are packaged in plastic films, MA is resulted from commodity. The change in the atmosphere inside the bag depends on the film permeability, product respiration rate, gas diffusion properties of the product, weight, surface area and initial free volume of the commodity and atmospheric composition within the package. Temperature, relative humidity and movement of air around the package can affect the permeability of the film. Temperature also affects the metabolic activity of the com- modity and consequently the rate of attaining the desired MA. All of these factors must be taken into account when developing a mathematical model for selecting the best film for each product.MA are be of 2 types: MA in polymer film packaging can be produced passively by the goods, or intentionally by active packaging, or by a combination of both.

In the case of active MAP an atmosphere is established by pulling a slight vacuum and replacing the atmosphere of the package with the desired gas mixture of O_2, CO_2 and N2. The advantage here is that the beneficial equilibrium atmos- phere may be established more quickly in the package con- taining commodity. In addition, a reducer or adsorber can be included in the package to capture O_2, CO_2 or C2H4 to control the concentration of the gas.

In case of passive MA, the atmosphere in the package is modified by the natural interaction of two processes, the respiration of the products and the transfer of the gases from the packaging leads to a high CO_2 atmosphere and low O_2 and depends on the properties of the packaging film and the product.

Mechanism of modified atmosphere packaging

In modified atmosphere packaging, any kind of product is sealed in polythene packing. This packing has controlled gaseous mixture like CO_2, O_2 and others. This mixture slows down the rate of respiration, oxidative changes and multiplication rate of decay microorganism. Ultimate objective of this system is to enhance the life of perishable commodities like fruits by slowing down the various catabolic changes associated with ripening. Gaseous mixture which is used in this technique, is driven by particular nature of product (passive MAP) and further control over the system by incorporating various absorbents (active MAP). In passive MAP, the product respiratory changes will help in maintaining the storage environment, whereas in active MAP, the absorbents like KMnO4 and carbon dioxide and oxygen scrubbers and antioxidants are incorporated into the packaging system for improving the efficacy of MAP (Fig 1). When amount of oxygen is reduced, there will be deferment of deteriorative reactions (which may occur in the product) such as browning reaction and lipid oxidation including growth rate of spoilage organisms (Wilson *et al*., 2019) [17]. If the levels of carbon dioxide are more than10%, it will be phytotoxic for vegetables and fruit and due to this reason, the concentration of CO_2 is kept below this detrimental level. To prevent collapsing of product packing nitrogen gas is used as a filler gas (Floros and Matsos, 2005) [6]. Besides this some noble gases like Argon (Ar), Helium (He), Xenon (Xe) etc. are also used as an alternative of N2 as a balancing gas in this technique. Above all, most of advantageous impacts are due to diffusivity in water and higher solubility, resulting them further effective in shifting O_2 from enzymatic O_2 receptors and cellular locations. MAP of multi-component foods, is still a challenging task. Packaging material is prime concern while adopting this technique. It includes the rate at which water vapor is transpiration occurs, how sealing of system is done and what is permeability of the packing material. The mechanism of the MAP is given in the figure which is adapted from Barrios *et al*. (2014) [2].

Role of MAP in increasing shelf life of fruits

Delay in Ripening and Senescence

Fruit ripening is a complex physiological and biochemical process by which unpalatable fruits become palatable. The key physiological and biochemical changes associated with ripening in fruits are tissue softening, change in peel colour, increase in respiration and ethylene evolution rates, sugar, organic acid metabolism etc (Sharma *et al*., 2011; Valero & Serrano 2005) [10]. When fruits are packed in desired packaging film in MAP, then the ripening of fruits is delayed. For some products ethylene absorbers are also added within the package. The atmosphere generated by modified atmosphere packaging (MAP) delays ripening of certain subtropical-tropical fruits, including mango (Kader, 1994). The main factors that maintain quality of fruits in various film packaging are increased CO_2 and decreased O_2 levels, which reduce respiration rate and prevent water loss and increase fruit firmness in strawbwerry, (Magazin, N *et al*., 2015). MAP slowdown the ripening process by reducing respiration which results in reduction in production of ethylene, litchi (Kudachikar *et al*., 2007) [13].

Ethylene production and respiration rate processes accelerate senescence in the harvested fruits which decrease the marketability of fruits. Several techniques are in vogue for increasing the shelf life of fruits but the recent literatures reveal that modified atmosphere packaging also plays a significant role in improving the shelf life of fruits without compromising the organoleptic properties. When fruits are packed in MAP, they show delay in senescence due to reduced respiration rate and production of ethylene. Application of MAP for different fruits resulted in delayed senescence in Banganapalli mangoes (Erkan M, Wang CY, 2006) [9], banana (Julianti, E., & Yusraini, E., 2012) [11] etc.

Modified atmosphere packaging (MAP) technology offers the possibility to retard the respiration rate and extend the shelf life of fresh produce. Increase respiration rate reduces the shelf-life of the fruits. By using MAP, we can reduce the respiration rate of the commodity as there is reduction in transpiration rate of gases through the packaging film. There is reduced respiration rate of some fruits when packed with MAP in guava (Dhillon *et al*., 2007) [4], strawberry (Rahman and Ahmad, 2012) [25], banana (Kudachikar *et al*., 2011) [12].

Reduction in weight loss

MA packaging significantly reduced the PLW (%) at various storage temperatures irrespective of the film used. The effect of MAP in reducing PLW is due to the restriction of water vapor diffusion by the semi permeable films and in turn, generating a water vapour pressure and higher RH inside the package. This effectively reduced the transpiration rate of fruits like pomegranate (Sudhakar Rao, D. V., & Shivashankara, K. S., 2018) [32] thereby significantly reducing the PLW. Samar *et al*., (2017) explained that the reduction of physiological loss in weight in pomegranate fruits packed in high density polyethylene (HDPE) which was attributed to retardation in transpiration and respiration rate. Similar results were observed by Nanda *et al*., (2001), Laribi *et al*., (2012) and Selcuk and Erkan (2014) in pomegranate and lemon (Jawandha *et al*., 2014).

Effect of MAP on the Shelf-life of fruits

The shelf life of perishable commodities like fruits and vegetables are so lean that it requires special attention and management practices for extending the shelf life without compromising the quality of fruits (Jayarajan & Sharma, 2021) [10]. MAP advocates the use of suitable packaging material along with some absorbers to achieve the goal of shelf-life extension. Kudachikar *et al*. (2007) [13] studied the physio-chemical changes in litchi fruit cv. China by treating them with various post-harvest treatments, packed in LDPE films at 2 °C and claimed increased shelf life up to 21 days when treated with SO_2 fumigation and 4% HCl dip. They explained that it happened due to retardation of physiological metabolism and increased CO_2 and decreased O_2 concentrations, reduced rate of ethylene production, reduced microbial contamination and increased humidity resulting in less PLW and more quality retention.

The guava fruits when treated with SO_2 fumigation + acid, showed an overall reduction in the physiological loss in weight up to day 21. Guavas packed in LDPE 100 microns (perforated) films increased shelf life up to 36-42 days as the packaging seizures the moisture loss which resulted in a reduction in transpirational losses, thereby minimizing desiccation of fruits and checking microbial development and it also alters the CO_2 and O_2 levels inside the package resulted in sustainment of the fruit weight and quality by retarding the enzymatic activities, respiration and transpiration processes and production of ethylene (Dhillon *et al*., 2007) [4].

The ideal atmospheric composition created by MAP in different packaging is attributed to ripening inhibition which in turn retards deteriorative changes by slowing down the rate of production of ethylene. Mahendran *et al*. (2008) [18] conducted a study on MAP of matured pre-climacteric avocados in Sri Lanka (tropical climate) and revealed that shelf life of fruits was extended up to 6 weeks when packed in microporous polypropylene film (MY-15, 4.8% O_2 + 8.4% CO_2) at 7 °C, due to combined effect of MAP and refrigeration. An experiment for altering the shelf life of pear fruit (cv. Lagoon) was conducted using different films for packaging by Nath *et al*. (2012) and revealed that when fruits when packed in non-perforated (0.025mm) film, increased shelf life up to 15 days at ambient condition. The extension in shelf life is attributed due to retardation of respiration rate and less moisture loss due to transpiration and limited permeability of gases (CO_2 and O_2) and water vapor. Kudachikar *et al*., (2011) [12] revealed that banana cv. Robusta had exhibited increased shelf life and maintained good quality up to 5-7 weeks when packed in LDPE under MAP + ethylene absorbent at 12 °C by reducing PLW, transpiration rate, and respiratory rate. Ma *et al*. (2019) reported that fig fruit when packed in multifunctional packages like TMAP and DMAP, the change in the content of fig's TSS of TMAP and DMAP was smaller than that of the control group. TMAP had the best preservation effect on figs. Alturki (2013) conducted the experiment in Southern Arabia (semi-arid climate) and revealed that fig (*Ficus carica*) exhibited increased shelf life (28 days) due to reduced transpiration and respiration rate when stored under MAP in a tray sealed with (20% CO_2; 70% N2; 10% O_2) at 0 °C. The shelf life was increased due to reduction in water loss as the films act as barriers for the diffusion of water vapor. Above all, figs are not sensitive to chilling injury. Similarly, guava (Lucknow - 49) showed increased shelf life up to 42 days when packed in LDPE bags of 50 microns with 9% O_2 and 5% CO_2 due to decreased O_2 concentration and reduced transpiration and respiration rates (Antala *et al*., 2015) [1] revealed that sapota cv. Kalipatti increased its shelf life up to 49 days when packed in LDPE bags of 50 microns with 5% O_2 and 10% CO_2 and stored at low temperature (6 °C) due to reduced respiration rate, lessens moisture loss and high CO_2 concentration. Passion fruits harvested and packed in Activebag®, increases shelf life up to 23 days due to the presence of ethylene absorbents in the lining of the film and reduced weight loss due to reduced respiration and reduced transpiration rate, fruit metabolism (Yumbiyo *et al*., 2014). Mahajan *et al*., (2015) [17] revealed that when peach (Shan-i-Punjab) packed in cryovac heat-shrinkable RD-106 film, showed increased shelf life up to 9 and 4 days under supermarket (18-20 °C, 90-95%RH) and ordinary market conditions (28-30 °C, 60-65%RH), respectively. Singh *et al*., (2018) revealed that kinnow fruits showed increased shelf life up to 20 days with minimum spoilage when tray packed in shrink film (125 microns and 25 microns) at 21- 22ºC and 45-48% RH due to reduced respiration rate. Similarly, Venkateshwarlu *et al*., (2016) [36] revealed that the sapota cv. Pala showed increased shelf life up to 21 days when packed in LDPE bags and stored at 10 ºC due to a gradual decrease in oxygen concentration from 5% to steady-state concentration of 3.5%. Venkatram *et al*. (2016) [37] revealed that custard apple cv. Balanagar, when packed in polypropylene bags with 3% O_2+5% CO_2 and stored at 15±1ºC, showed increased shelf life up to 12 days resulting from restricted availability of CO_2 and O_2 accumulation and consequently reduction in respiration leading to less moisture loss.

Kumar *et al*., (2017) [14] revealed that guava cv. Allahabad Safeda when packed in polypropylene bags and stored at 6±1ºC, increased shelf life up to 25.63 days and recorded the lowest chilling injury due to the low rate of respiration and transpiration rate, reduction in PLW and high humidity in the packs. Nagaraju *et al*., (2018) [19] revealed that the guava cv. Khaja showed increased shelf life (12 days) when packed in LDPE bags with 2% perforation. Rajitha (2018) [25] revealed that guava cv. Allahabad Safeda exhibited an increased shelf life of 30 days when stored in MAP with 5% O_2 and CO_2 at low temperature and maintained good post-harvest quality for 12 days at ambient condition. Rana *et al*., (2018) [26] revealed that guava cv. Hisar Safeda when individually packed through MAP and vacuum in LDPE bags displayed a significant increase in shelf life because the films adhered to the surface of the fruit and thereby reduced transpirational losses and prevented evapo- transpirational losses. Individual wrapping led to improved concentration of CO_2 inside the packaging that resulted in reduced ethylene production, slowed down degradation of chlorophyll and ripening of fruits. Singh *et al*., (2018) revealed that guava variety Allahabad Safeda, when stored in LDPE of 50 microns with gaseous concentration (5% O_2 and 8% CO_2) and stored at low temperature, exhibited good maintenance of quality attributes and increased shelf life up to 32 days. When this technique of preservation combined with other preservation procedures such as edible coatings etc., yielded more optimistic and potential results.

In the table 2, the optimal conditions for packaging different types of fruits under modified atmosphere conditions for increasing shelf life are mentioned. Apple fruits when packaged in MAP (O_2 and CO_2, 3% each) and stored at 0-3ºC showed increased firmness and improved shelf life to 300 days. Some fruits like apple, apricot, fig, grapes, kiwi fruit, plum and strawberry require low temperature from 0-5ºC for successful storage in case of modified atmosphere package system (Irtwange 2006) [9]. But these fruits have different requirements for O_2% and CO_2%. As like in the case of apple and apricot this concentration is 3% each for O_2% and CO_2% for both cases. At the end we got Excellent market condition of the product in the case of apple while it is fair in the case of apricot. The case is totally reversed in the case of plum and strawberry where the concentration is comparatively high i.e.,5-10% (O_2%) and 15-20% (CO_2%) (Rahman and Ahmad 2012) [25]. In some other fruits like Banana, Guava, Lemon & Lime, Mango, and pineapple some higher temperature (10-15 ºC) is considered optimum conditions for MA/CA (Mahajan

2001 and Irtwange 2006) [17, 9]. It is interesting to see that less comparatively concentration is required for successful storage. But in the case of lime and lemons, the range of O_2% (5-10) and CO_2% (0-10), is very variable (Rahman and Ahmad 2012) [25].

Tinebra *et al*., (2021) [34] concluded from their studies that mulberry fruit (*Morus alba* L. cv Kokuso) showed increase shelf life up to 12 days when treated with (10% O_2+5% CO_2+85% Ar) by reducing weight loss as MAP reduces water loss by maintaining a relatively high humidity in the headspace atmosphere and the fact that when argon combines with water at an appropriate pressure which results in the formation of clathrate hydrate, which limits the liquidity of the water and thus reduces PLW in fruits. Tinebra *et al*., (2021) [34] also studied argon-based MAP treatments (MAPAr) on arils of pomegranate cv. Wonderful and concluded that fruits showed an increased shelf life upto 16 days assuring a limited loss of weight and juice content as the use of noble gas allowed to maintain the characteristics of both the arils and their juice when stored at cold storage (0, 4, 8, 12, and 16 days at 4 ± 1 ◦C and 90 ± 5% RH). Perumal *et al*., (2021) [22] from their studies showed the results that mango fruits cv. Banganapalli and cv. Totapuri increased their shelf life up to 26 ± 2 days and 23 ± 2 days respectively when treated with MAP+ thyme oil vapour (TO) as MAP reduces transpiration and TO vapours effectively prevent the incidence of postharvest diseases in mango fruits.

Impact of MAP on senescence

Temperature prevailing during post-harvest, storage and levels of O_2, ethylene, CO_2, and water vapor strongly influences shelf life of the product. Hence by regulating product surrounding environment along with temperature we can alter various processes of development and ultimately increase in shelf life (Caleb *et al*., 2013) [3]. Senescence process and colour changes in product are highly influenced by prevailing storage atmosphere conditions., particularly the change from green to yellow colour. When MAP with low temperature is combined, lead to deferment of senescence. This technique is highly useful during storage of fruits and vegetables like fresh-cut watercress, lettuce and broccoli (Guo *et al*., 2019 and Pinela *et al*, 2016) [7, 23]. Poonsri (2020) [24] experiment with dendrobium orchids and proved that controlled atmosphere significantly depressed the rate of ACC (1-aminocyclopropane-1-carboxylic acid) synthase and action of ACC oxidase and was effective in deferring senescence process. Adaptation of this technique creates such type of atmosphere where there is high CO_2 with low O_2. Such atmosphere leads to reduction in rate of respiration and causes suspension senescence of fruits and vegetables (Ozturk *et al*., 2021) [21]. Earlier many workers also revealed that when there is high CO_2 and/or low O_2 during storage, leads in reduction in chlorophyll loss along with reduction in accretion of various pigments such as anthocyanin, carotenoids, xanthophyll and lycopene (Barth and Hong, 1996; Salunkhe and Wu, 1973; Zhuang *et al*., 1994). Saltveit 2003 [27] and Tijskens *et al*., (2003) [23] submitted that speed of enzymatic degradation of substrates and respiration is lowered when stored under MA and there is also decline in compassion to synthesis of ethylene and senescence of product is prevented. Guo *et al*, (2019) [7] and He *et al*., (2019) also supported the fact that quality of product and respiration rate is greatly influenced by MAP. It has been established (Elwan *et al*.,2015) [5] that anaerobic type of respiration which yields less energy comparative to aerobic respiration and devours lot of materials during life processes, also inclines process of senescence. Lin *et al*., (2019) also submitted the analogous results that ascorbic acid content is also get effected when storage is prolonged. A decline in ascorbic content of product is recorded.

Future challenges for MAP

MAP undoubtedly helps in increasing the shelf life of horticulture produce and presents the consumer with distinct advantages of high-quality products. Moreover, there is very little use of chemical natured preservatives in MAP. There is a feasible and viable cost that has to be borne by the consumer. It is important to learn that all the benefits of MAP (reduced respiration and transpiration rate, increase in CO_2, decrease in O_2) will be lost once the packaging (MAP) is opened. The future thrust should be in the area of devising films that are cost-effective and able to maintain the quality of the packaged products with less strict temperature control or films that can change their gas permeability characteristics in response to temperature changes, thus compensating for subsequent changes due to respiration of the packed product.

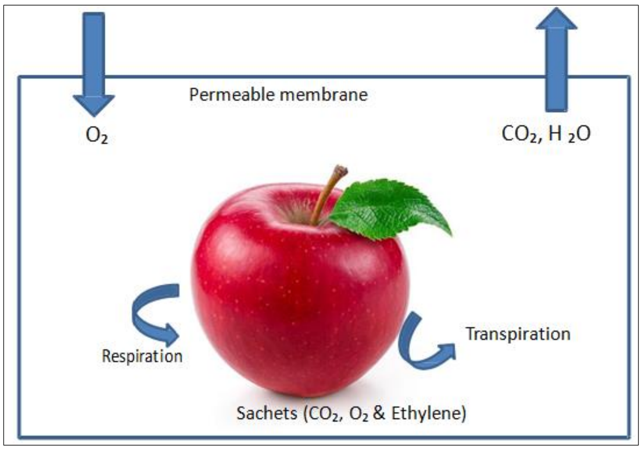

Fig1: Mechanism of MAP in fruits

Table 1: Ideal conditions for some tropical, sub-tropical and temperate fruits stored in MAP

Tropical	fruits	Temperature	Required Oxygen	Required CO_2	Reference
1.	Mango	10°-15 °C	3-5%	5-10%	Kader, 1997
2.	Banana	12°-15 °C	2-5%	2-5%	Kader, 1997
3.	Guava	10°-15 °C	2-5%	2-5%	Kader, 1997
4.	Papaya	10°-15 °C	3-5%	5-10%	Kader, 1997
5.	Pineapple	7 °C	50%	50%	Zhang *et al*., 2013 [40]
6.	Dragon fruit	6 ±0.5 °C 2-5 °C	- 5-21%	- 0%	Ho *et al*., 2021, Ho *et al*., 2020
Sub-tropical fruits					
1.	Grape	4 °C	6%	10%	Shahkoomahally *et al*., 2021
2.	Grape	4±1 °C	Air	20%	Wang *et al*.,2021 [9]

3.	Grape	0±0.5	2%	5%	Admane *et al.*, 2018
4.	Grape	5 °C	1%	>20%	Cefola *et al.*, 2018
5.	Lemon	10°-15 °C	5-10%	0-10%	Kader, 1997
6.	Lime	10-15 °C	5-10%	0-10%	Kader, 1997
7.	Litchi	0°-2 °C	2-3%	2-5%	Kader, 1997
8.	Orange	4 °C	-	-	Wu *et al.*, 2021
9.	*Citrus unshiu* Marc	4 °C	9.9 ±0.2%	2.1 ±0.1%	Bang *et al.*, 2021 [22]
Temperate fruits					
1.	Apple	0±0.1 °C	2-3%	1%	Du *et al.*, 2021
2.	Apple	1.5 ± 0.1 °C	-	-	Anese *et al.*, 2020
3.	Apple	1 °C	-	-	Elias *et al.*, 2018
4.	Apple	1.5–2.0 °C	<2%	<1%	Bílková *et al.*, 2020
5.	Apple	4 ± 2 °C	7%	2.5%	Bílková *et al.*, 2017
6.	Apricot	4 °C	5%	10%	Muftuo *et al.*, 2012
7.	Avocado	5-13 °C	2-5%	3-10%	Irtwange, 2006 [9]
8.	Olive	5-10 °C	2-3%	0-1%	Kader, 1997
9.	Raspberry	0-3 °C	5-10%	15-20%	Kader, 1997
10.	Strawberry	5 °C	Air	5%	Matar *et al.*, 2021
11.	Strawberry	0 ±0.5	20%	20%	Yang *et al.*, 2020 [16]
12.	Strawberry	4.0 ±1.0	5-10	10-15	Kahramano *et al.*, 2019
13.	Strawberry	10 °C	10%	0%	Kahramano *et al.*, 2019
14.	Blueberry	4 °C	-	-	Pinto *et al.*, 2020
15.	Cherries	5 °C	16%	20%	Cozzolino *et al.*, 2019
16.	Cherries	0 ±1	5%	10%	Yang *et al.*, 2019 [16]
17.	Pear	1.1 °C	1–2%	<1	Guo *et al.*, 2020 [7]
18.	Pear	5 °C	6-16%	10%	Du *et al.*, 2021
19.	Pear	0 °C	20%	0%	Feng *et al.*, 2018
20.	Nuts& dried fruits	0-25 °C	0-1	0-100	Kader, 1997
21.	Plum	0 °C	10%	4%	Wang *et al.*, 2021 [9]
22.	Peach	4 °C	-	-	Oliveira *et al.*, 2015 [23]
23.	Peach	0 °C	-	-	Ortiz *et al.*, 2010
24.	Persimmon	5 °C	-	-	Liamnimitr *et al.*, 2018
25.	Nectarine	0-5 °C	1-2%	3-5%	Kader, 1997

Table 2: Optimum conditions for MA/CA for some fruits and their shelf life

Commodity	Storage temperature (°C)	Optimum MA/CA		Commercial potential
		O_2%	CO_2%	
Apple	0-5	3	3	Excellent
Apricot	0-5	2-3	2-3	Fair
Avocado	5-13	2-5	2-5	Good
Banana	12-15	2-5	2-5	Excellent
Fig	0-5	3-10	10-15	Good
Grapes	0-5	3-5	1-3	Fair
Guava	12-15	2-5	2-5	Good
Kiwi fruit	0-5	1-2	3-5	Excellent
Lemon & Lime	10-15	5-10	0-10	Good
Orange	5-10	10	5	Fair
Mango	13	3-5	5-8	Good
Pears	0-1	2-3	0-1	Excellent
Papaya	13	3-5	5-8	Fair
Pineapple	10-15	2-5	10	Fair
Plum	0-5	1-2	0-5	Good

Conclusion

Modified atmosphere packaging leads to an extension of shelf life and maintaining the good quality of fruits and vegetables. According to this concept, the packaging of food in an atmosphere the composition of which is continuously modified, according to the desired profile. The shelf life of the product is extended due to the reduced respiration, transpiration rate, increased CO_2, and decreased O_2 concentration inside the packing of the product. The decrease in transpiration rate resulted in reduced ethylene synthesis which delays ripening. Moreover, microbial contamination is also decreased due to low moisture content inside the package. Among various package films, Low- Density Polyethylene films are considered as one of the best low-cost and effective packaging films in increasing shelf life. There is utmost need to generate awareness about this concept and to make this technique more feasible and viable under the conditions of our country.

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