PROPERTIES OF MODIFIED ATMOSPHERE PACKAGING FILMS AND APPLICATION ON FRUITS AND VEGETABLES

MEYVE VE SEBZELERİN PAKETLENMESİNDE KULLANILAN PLASTİK FİLMLERİN ÖZELLİKLERİ VE KULLANIMI

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SUMMARY: This paper reviews the importance of the permeability characteristic of packaging materials to some gases for modified atmosphere packaging (MAP) and its application to fruit and vegetables storage. The respiration rates of the some fruits and vegetables are reviewed in relation to MAP.

MAP has been developed and used commercially throughout the world to extend shelf life and reduce shrinkage, weight loss and the development of various blemishes of fruit and vegetables. The choice of films used in this technique is extensive but polyethylene of various densities and thicknesses is the main one used. The permeability of a particular film depends on the nature of the gas, the polymeric structure and thickness of the film, storage temperature and relative humidity. During the packaging these factors should be considered.

Selection of film is also very important in terms of equilibrium rate of respiration inside the package. There is a danger that CO_2 will increase and O_2 decrease to levels which will damage the produce within the package. An ideal film must let more CO_2 exit that O_2 enter. CO_2 permeability of film should be 3-5 times greater than the O_2 permeability.

ÖZET: Bu derlemede, meyve ve sebzelerin paketlenmesinde kullanılan (Modifiye atmosfer) paketleme maddelerinin gaz geçirgenlikleri ile meyve ve sebzeler üzerine uygulanışları ve ayrıca bazı meyve ve sebzelerin solunumları üzerinde durulmuştur.

Çeşitli plastikler ile meyve ve sebzelerin paketlenmesi, raf ömürlerinin uzatılması ve bu ürünlerin bozulma ve kayıplarının azaltılması amacı ile geliştirilmiş ve Dünyada bir çok ülke tarafından kullanılmaktadır. Paketlemede farklı maddelerin kullanılmasına karşın farklı yoğunluk ve kalınlıkları ile polietilen ilk sırayı almaktadır. Paketleme maddesinin gaz geçirgenlikleri çok önemli olup bu maddenin polimerik yapısına, kalınlığına, depolama sıcaklık ve oransal nemine bağlıdır.

Paketleme filminin seçimi paketin içinde ve dışındaki ortam arasında dengenin sağlanabilmesi açısından önemlidir. Paket içerisinde oksijen oranının çok düşmesi ve karbondioksit oranının çok artması istenmez. Paketleme açısından ideal bir film oksijenden 3-5 kat daha fazla karbondioksit geçirgenliğine sahip olmalıdır.

INTRODUCTION

Fruit and vegetables are living and respiring tissue. After harvesting, ripening continues and commodities may become over ripe very rapidly at the ambient temperature. This result in loss of quality, restricted self life and, in some instances, wastage of fruit during marketing (GEESON at al, 1985). The quality of fresh fruit and vegetables is determined by appearance, colour, firmness and flavour (RISSE et al,1985). Extending the shelf life of produce is very important for both domestic and export marketing. Several techniques are used to preserve of postharvest quality and extension of shelf life of fruit and vegetables. One of the ways extending of shelf life is achieved by retarding the rate of physiological processes (SHEWFELT, 1986). A vegetable store will be successful only if it will keep the produce in good condition with minimum deterioration (LINDSAY and NEALE, 1981).

One of the way to extend shelf life is to optimise the environmental conditions (RISSE et al, 1985) which are temperature, humidity and atmospheric composition (HATTON and CUBBEDGE, 1982). Manipulation of the environmental conditions is usually performed to lower respiration and growth of decay organism without inducing physiological injury (SHEWFELT, 1986). The rates of growth of fungi and bacteria are markedly influenced by the storage environment (SNOWDON, 1990).

Temperature is major factor in control of postharvest injuries and decay organism. In general the lower storage temperatures (above the chilling temperatures and freezing point) the slower the growth of micro-organism and the longer will be the shelf life of produce (SHEWFELT, 1986) and the higher the temperature the higher the rate of respiration and the more quickly the produce approaches the end of its life.

Relative humidity is another important environmental factor in shelf life of fruit and vegetables (KADER, 1987) and decease (SOMMER et al, 1992). Low relative humidity can increase transpirational damage and lead to desiccation, increase respiration, and an unmarketable product (KADER, 1992).

Another important factor for storage is gas environment. The composition of gases in the storage atmosphere can effect the storage life of produce. When O_2 levels in plant cells fall the rate of chemical reaction decrease and metabolism is reduced. If the O_2 level in the cells is low there may be undesirable changes in the chemical which contribute to the flavour and aroma of the crop. Physiological disorders in the fruits associated with excess CO_2 levels may be associated with this disruption of the respiratory pathway leading to an accumulation in the crop cells of alcohol and acetaldehyde (ZAGORY and KADER, 1988). When after eating quality of ripeness the respiration rate declines, a process of senescence sets in, off-flavour develop and dying tissues become increasingly susceptible to attack by decay organism. (SNOWDON, 1990).

Controlling Deterioration

Chemical control is an obvious measure to prevent the development of disorders but it is not necessarily the sole method possible (WILLS et al, 1989). Cooling is most probably the oldest and most widely utilised technique to prolong the life of perishable produce but MAP is more sophisticated and very important technique in maintaining quality and extending the post harvest life of fresh fruit and vegetable more than does cooling alone (BEN-YEHOSHUA et al, 1981), which mean is modification of O_2, CO_2 and/or C_2H_4 concentration in the atmosphere surrounding the commodity to levels different from those in air (KADER et al, 1989). MAP of fruit and vegetables also involves the protection of a very complex, biologically active materials. This protection involves ensuring unchanged micro climatic conditions to maintain the sensory and the nutritive values of food from production to consumption (DAY, 1993).

USE OF PLASTICS FOR MAP

The increasing consumer demand for fresh fruits and vegetables has led to the growth of the MAP. It is a process by which the self life of a fresh product is increased significantly by enclosing it in an atmosphere which slow down degradative processes. (PAINE and PAINE, 1992b). Modified atmosphere mean removal or addition of gases resulting in an atmospheric composition surrounding the commodity that is different from that of air. Usually this involves reduction of oxygen and/or elevation of CO_2 concentration (KADER, 1985). Modification of atmosphere depends on many factors-primarily respiration rate of the plant tissue, the permeability of packaging films (ROBERTS,1990) and surface area of the packaging material (GEESON, 1989).

The tissues of fresh fruit and vegetable are living and continue to respire, consuming oxygen and the producing carbon dioxide. For MAP, the packaging material therefore allow some exchange of respiratory gases in order to maintain the quality of the product (GOODBORN and HALLIGAN, 1988). Because the package atmosphere is maintained by utilising a packaging material by having a specific O_2 transmission rate that allows a specific CO_2/O_2 ratio to develop for a given product (BARMORE, 1987).

Over the last few years the development and commercialisation of MAP for fresh food has been most rapid in the Western European countries. The MAP market has demonstrated significant growth in fresh fruit and vegetables were sold in Europe in 1990 (BRODY, 1993).

Beneficial and Detrimental Effects of MAP

Preventation of ripening in fruit is one of the main benefit of MAP (KADER et al, 1989). Delays maturation of vegetable and retards of ripening due to a suppression of production and action of ethylene. Increased CO_2 and reduced O_2 levels will also inhibit the growth of aerobic spoilage microorganisms, especially those responsible for fungal rotting (DAY, 1988).

MAP conditions reduce respiration rates as long as the levels of O_2 and CO_2 with in those tolerated by commodity.This, combined with the decreased C_2H_4 production and reduced sensitivity to C_2H_4 action, result in delayed senescence and sensory quality of non fruit vegetables (KADER et al, 1989).

BEN-YEHOSHUA (1985) reported that individual seal packaging extend shelf life and reduce weight loss, severity of surface blemishes and chilling injury symptoms on some commodities, especially citrus fruits, provided they are pre-treated against decay. Disadvantages of packaging plastic films influence the rates of cooling and warming of the commodity. Film wrapped produce usually requires longer cooling time than unwrapped produce. Another potential disadvantage of film wrapping is the possible water condensation within the package, which may encourage fungal growth and increase decay problems (KADER et al, 1989). EL-GOORANI and SOMMER (1981) also pointed out that decreasing of O_2 levels below 1 % and/or CO_2 levels above 10 % are needed to significantly suppress fungal growth.

Plastic Films Commonly Used in MAP

Thermoplastics are very common films used for packaging which have the ability to soften repeatedly when heated, and harden when cooled (ROUFFIGNAC, 1990). Packaging materials commonly used in MAP are polyethylenes (PE), polivinylcholorides (PVC), polypropylene (PP) and polybutylene as well as their components (KADER et al, 1989). Lowdensity Polyetylene (LDPE) is the most widely used film made, and its used for all forms of consumer packaging. PVC is used for wrapping in the pre-packaging industry. PP is heat shrinkable and it is good moisture barrier (SALUNKHE et al, 1991 and ZAGORY; KADER, 1988). Film permeability is the critical and choice will depend on the respiration rate of the produce. The greatest problems occur in matching respiration rates to film permeability (PAINE and PAINE, 1992c).

General Characteristics of Films

Depending on the morphological properties, polymers have different mechanical,physiological and chemical characteristics. Nitrogen, oxygen, carbon dioxide and water vapour permeabilities of polymers important from the point of view food packaging (VARSANYL, 1986) properties such as heat sealability, light transmission, thermoformability and resistance to damage (ROBERTS, 1990).

High Density Polyethylene (HDPE) has a higher softening point than LDPE and it is harder (PAINE and PAINE, 1992a). HDPE is generally much more crystalline than LDPE. They are more resistant to chemicals and water (ROUFFIGNAC, 1990). The result is HDPE a much stiffer, higher strength material than LDPE (LEVY and DUBOIS, 1977). It is not suitable as a sealing elements (GREENGRASS, 1993).

Low density Polyethylene (LDPE) is widely used for the manufacture of carrier and wrapping bags (ROUFFIGNAC, 1990) and it is relatively inert chemically and almost insoluble in all solvents at the room temperature. Permeability is low for vapour but many organic vapour and essential oils pass rapidly through LDPE. Its permeability to oxygen is fairly high so where oxidation is likely to be problem, LDPE is not suitable. Its permeability low for vapour higher heat and puncher resistance and impact strength are better (GREENGRASS, 1993).

Polypropylene (PP) is similar chemically to LDPE . Its softening points higher than LDPE, but it is steal easily able to with stand steam sterilisation. PP has low impact strength at low temperatures, but copolymers are available in which low temperature impact strength is improved (PAINE and PAINE, 1992a). PP provides a much greater barrier to gasses, seven to ten times that of PE. In addition it has excellent grease resistance (GREENGRASS, 1993).

PVC has good gas barrier properties and is moderate barrier to moisture vapour. Chemically, it is resistant to weak or strong acids and alkalis. It is soluble in esters and ketoses and is attacked by aromatic hydrocarbons (PAINE and PAINE, 1992a). PVC main properties , hard and brittle, but can be softened. PVC and its derivatives are widely used in many forms of packaging. Its permeability varies, but it is generally resistant to chemicals and solvents. A PVC copolymer variable PVDC film, is widely used in the home and in stores for wrapping foods such as cheeses, as its permeability to water and gases is comparatively low (ROUFFIGNAC, 1990).

Ethylene Vinyl Acetate Copolymer (EVA) is a polymer with the flexibility of PVC. It has a greater flexible than LDPE. Permeability to water vapour and to gases is higher than LDPE and the solvent resistance is lower (PAINE and PAINE, 1992a; GREENGRASS, 1993).

Table 1. Some permeability Characteristics of polymers from point of view of food packaging (GREENGRASS, 1993; PAINE and PAINE, 1992a; ZAGORY and KADER, 1988).

Film type	Gas Permeabilities (cc/m²/mil/day at 1 atm for 25 m film at 25 °C)						
	O_2	CO_2	N_2	CO_2/O_2	WVTR*	TRS**	OGR***
Polyethylene (Low Dens)	7800	42000	2800	5,4	18	G	P
Polyethylene (High Dens)	2600	7600	650	2,9	7--10	G	G to E
Polypropylene, cast	3700	10000	680	2,7	10--12	G	G
Polypropylene, oriented	2000	8000	400	4,0	6--7	G	G to E
Polyvinyl chloride, rigid	150-350	450-1000	60-150	2,9-3,0	30-40	E	E
Polyvinyl chloride, plastised	500-30000	1500-46000	15-40	1,5-3,0	15-40	E	G
Polyvinylidene chloride, saran	8--25	50-150	2--2,6	6-6,3	1,5-5,0	G	E
Polyester, oriented	5000	18000	800	3,6	100-125	E	G
Polystyrene, oriented	50-130	180-390	15-18	3,0-3,6	25-30		E
Ethylene-vinyl-acetate (EVA)	12500	50000	4900	4,0	40-60	...	P

* Water Vapour Transmission Rate g/m² .day at 38 °C and 90 % RH.
** Transparency *** OGR: Oil and Grease Resistance
E,Exellent; G, Good; P, Poor ; RH, Relative Humidity.

Permeability of the MAP films

Some permeability charecteristics of polymers are given in Table 1. One of the very important factor of films to be considered from the point of food packaging is its gas permeabilities. The permeability of a particular film depends on several factors such as the nature of the gas, the polymeric structure and thickness of the film, storage temperature and the relative humidity (DAY, 1988). The relative humidity inside the package is dependent on the water vapour and permeability of the film. The final composition of the gasses in side the package depends on the rate of respiration of the produce in the pack and the gas permeability of the film and its surface area (FRITH, 1991).

The normal (aerobic) respiration of the fruit involves the uptake of oxygen and the production of carbon dioxide. If the permeability of the pack allows less oxygen to diffuse in to the pack than is consumed by the respiration of the pack atmosphere will decline and similarly if the permeability of the pack allows less CO_2 to escape than is produced by the respiring fruit, than CO_2 accumulates within the package. As the concentration of O_2 decreases and that of CO_2 increases, the rate of diffusion of these gases through the packaging material will also continue to increase (GEESON et al, 1981; GORRIS and DEPPELENBOS, 1992). The rate at which O_2 diffuses into the pack increase until it is equal to the rate at the which O_2 taken up by the respiring fruit, and similarly the rate of CO_2 out of the pack increases until is equal to the rate of CO_2 production by the fruit, when this point is reached, little or further change in the concentration of O_2 and CO_2 within the pack occur, and a state of equilibrium is reached. The time taken to reach this position is known as the '*equilibrium time*' (GEESON et al, 1981 and GEESON et al, 1985).

When the oxygen supplies are low, or carbon dioxide levels are high, anaerobic respiration becomes important. Anaerobic respiration involves the reaction of plant material components which carbon dioxide to produce a variety of partially oxidised products such as alcohols, aldehides etc. Most of these components affected quality adversely (GOODBORN and HALLIGAN, 1988). Exposure of fresh fruits and vegetables to O_2 levels below and/or to CO_2 levels above their tolerance limits (Table 2) increase anaerobic respiration and the consequent accumulation of ethanol and acetaldehyde causing off-flavours (KADER, 1987).

Low density polyethylene, polyoropylene and plestised polyvinil chloride which have higher permeability rate could be useful for some produce such asparagus, broccoli, green onions leeks, sweet corn, etc. which have very high respiration rates and Saran and polyester have such low gas permeabilities that they would be suitable only for those commodities with very low respiration rates (ZAGORY and KADER, 1988).

Vegetables vary greatly in their respiration rate (Table 2). Root, tuber, and bulb vegetables have a low respiration rate. Fruit and vegetables that are picked mature, such as tomato and melons, respire at lower rate than thos picked immature, such as green beans, peas, sweet corn, and okra (KADER, 1987;PAINE and PAINE, 1992c). Plant parts with vegetative or floral meristematic tissues, such as asparagus, broccoli, and green onions, have very high respiration rates. In generally, the degree of perishability of fresh vegetables is parallel to their respiration rates (KADER, 1987).

Table 2. A Summary of Modified Atmosphere Requirements and Recommendations for Selected Harvested Fruit and vegetables (KADER, 1985; GOODBURN and HALLIGAN, 1988)

		Temperature range		Atmosphere (%)					
Fruits	Vegetables	°C		O_2		CO_2		PFB*	
		Fruits	Vegs.	Fruits	Vegs.	Fruits	Vegs.	Fruits	Vegs.
Apple	Asparagus	0--5	0--5	2–3	Air	1--2	10--14	A	B
Apricot	Beans	0--5	5--10	2–3	2–3	2–3	4–7	C	C
Cherry	Brocoli	0--5	0--5	3--10	1–2	10--12	5--10	B	B
Fig	Cabbage	0--5	0--5	5	2–3	15	3–6	B	B
Grape	Cantaloupes	0--5	3–7	none	3–5	none	10–20	D	B
Kiwifruit	Cauliflower	0--5	0--5	2	2–5	5	3–4	A	C
Nectarine	Celery	0--5	0--5	1–2	1–4	5	3–5	B	C
Peach	Chinese	0--5	0--5	1–2	1–2	5	0--5	B	?
Pear	Cucumbers	0--5	8--12	2–3	1–4	0--1	0	A	C
Plum	Leeks	0--5	0--5	1--2	1–6	0--5	5--10	B	B
Strawberry	Mushroom	0--5	0--5	10	Air	15–20	10--15	A	C
Banana	Okra	12--15	8--12	2--5	Air	2–5	4--10	A	C
Grapefruit	Onions	10--15	0--5	3--10	0--1	5--10	0--5	C	B
Lemon	Pepper	10--15	8--12	5	3–5	0--5	0--5	B	C
Olive	radish	8--12	0--5	2--5	1--2	5--10	2--3	C	D
Orange	Sugar peas	5--10	0--10	10	2--3	5	2--3	C	?
	Sweet Corn		0--5		2–4		5--10		B
	Tomato		12--20		3–4		2--3		B

*Potential For Benefit: A,excellent: B,good: C.Fair: D,Slight or none

SELECTION OF FILMS

Although many plastic films are available for packaging purposes, relatively few have been used to wrap fresh produce. Even fewer gas permeability's that make them suitable to use for MAP. Because O_2 content in a MA package is typically being reduced from an ambient 21 % to 2-5 % within the package. There is a danger that CO_2 will increase from ambient 0.03 % to 16-19 % in the package. An ideal film must let more CO_2 exit than O_2 enter. CO_2 permeability should be somewhere in the range 3-5 times greater than the O_2 permeability, depending upon the desired atmosphere (ZAGORY and KADER, 1988).

Hence one reason for choosing a particular film gauge could be to ensure that an adequate barrier is provided overall by the thinner sections of pack walls. In less permeable films, equilibrated atmospheres containing higher CO_2 and lower levels completely inhibit ripening, which does not resume when packs are opened. Packaging film with lower WVTR result in excessively high internal RH and encourage rotting (GEESON, 1989).

The depletion of oxygen and accumulation of carbon dioxide are natural consequences of the progress of respiration when fruit or vegetables are stored in sealed package. If produce sealed in impermeable film, internal O_2 levels will fall to very low concentrations where anaerobic respiration will be initiated. So the packaging materiel selected is crucial to the success of MAP. That is why films of correct intermediary permeability should be chosen for the MAP of respiring fruit and vegetables (DAY, 1988).If the permeability of the film is too high a limited atmosphere modification takes place and the produce continues to respire almost unchecked, and if the permeability is too low, too little O_2 can pass into the pack and anaerobic conditions will occur with the subsequent rotting of the produce (ROBERTS, 1990).

CONCLUSION

In developing a MA package, the objective is to match the respiration rate of the commodity to the gas permeability of the packaging material. Optimum concentration of O_2 and CO_2 should minimise respiration rate without danger of metabolic damage to the commodity. Using a high barrier packaging film O_2 will be fully depleted, the product will switch to anaerobic respiration, and quality will be lost.

An adequate O_2 concentration must be available to maintain aerobic respiration. This should be considered in selecting the various films for wrapping or/and packaging. Respiring products, therefore need to use semi-permeable or low barrier films.

Major influences on the ripening, senescence and determination of fruit and vegetables are exogenous factors which consist of environmental parameters such as microbial growth, temperature, relative humidity and atmospheric composition. A better and more effective utilisation of fruit and vegetables crops can be achieved by careful manipulation of these factors.

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