Modified atmosphere packaging of fresh produce

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During the past few years, there has been renewed interest in increasing the use of plastic films for the packaging of fresh fruits, vegetables or ornamentals in small quantities and the wrapping of individual commodity units. This has been stimulated by recent advances in the manufacturing of polymeric films with a wide range of gas diffusion characteristics. Film packaging influences the micro-environment around the commodity which, in turn, can affect quality maintenance in fresh horticultural crops during postharvest handling and marketing, as will be briefly discussed in this article.

Physical injuries

Many types of consumer packages provide some protection of the commodity against mechanical damage. Examples include cradles made of soft materials and placed around the commodity. However, there are examples of consumer packages, such as the strawberry plastic-mesh basket, which may cause surface abrasions and accelerate deterioration.

Improved sanitation

Consumer packaging can provide better sanitation by reducing contamination of the commodity by dirt, insects, consumer handling, etc.

Exclusion of light

By using consumer packages made of materials that exclude light, undesirable greening of certain commodities, such as potatoes and Belgian endive, can be minimized. Some types of polymeric films may also provide protection against ultra-violet (UV) light for commodities which are sensitive to UV radiation. The disadvantage of light-excluding films is that they impair the consumer's ability to clearly see the contents of the package.

Heat transfer

Plastic films influence the rate of cooling and warming of the commodity and must be considered in selecting the appropriate temperature management procedures for a packaged commodity. Generally, film-wrapped units require longer cooling time than unwrapped units of a given commodity. This difference can be reduced by perforating the film used to wrap the commodity.

High relative humidity

Consumer packages involving moisture-retentive films can reduce water loss and water stress, which can be a major advantage, especially for leafy vegetables, cool-season root vegetables, and some fruits. Maintenance of high relative humidity in the microenvironment surrounding the commodity can reduce development of chilling injury symptoms (particularly pitting), encourage wound healing, retard losses of textural quality, and help maintain skin resistance to pathogens.

Plastic films vary in their ability to transmit water vapor. In many cases, perforations that are adequate for diffusion of carbon dioxide and oxygen do not significantly increase the water vapor transmission rate because the perforated area is very small relative to the total film surface. Polymeric films are generally more effective than waxing in reducing water loss without resulting in an undesirable atmospheric modification.

Extension of postharvest life of individually-wrapped (seal-packaged, uni-packaged) citrus fruits is largely due to maintenance of a high relative humidity (water-saturated atmosphere) around the fruit. This alleviates water stress and slows down associated physiological and biochemical changes in the fruit resulting in delayed senescence of the rind. While very significant extension of postharvest life has been shown for seal-packaged citrus fruits, results with other commodities have been inconsistent and less impressive. Consequently, most of the current commercial developments of individual-fruit-wrapping technology is concentrated on citrus fruits.

Modifying atmosphere composition

Packaging in polymeric films can result in a commodity-generated modified atmosphere (reduced oxygen levels; elevated levels of carbon dioxide, ethylene and other volatiles). Atmospheric modification within polymeric film packages depends upon:

1. Film permeability which is related to type (e.g., polyethylene, polypropylene, PVC, etc.) thickness and surface area of the film as well as the effectiveness of the seal or closure of the package.
2. Respiration rate (i.e., the production of carbon dioxide and the consumption of oxygen) of the commodity which depends upon kind, maturity stage, and quantity in a package. Respiration rate increases 2-to 3-fold for a 10° C (18° F) increase in commodity temperature.

Maximum carbon dioxide concentration tolerated	Commodities
2%	Apples (Golden Delicious), pears, apricots, grapes, tomatoes, lettuce, endive, celery, artichokes, sweet potatoes
5%	Apples (most cultivars), peaches, nectarines, avocados, bananas, mangos, peppers, eggplant, cauliflower, cabbage, brussel sprouts
10%	Cucumbers, summer squash, cantaloupes, snap beans, asparagus, green onions, dry onions, garlic, potatoes
15%	Strawberries, raspberries, cherries, figs, sweet corn, mushrooms, spinach, broccoli.

Atmosphere

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3. Gas diffusion characteristics of the commodity which influence the gradient in concentrations of oxygen, carbon dioxide, ethylene and other volatiles, and water vapor between, inside and outside the commodity.

4. Initial free volume and atmospheric composition within the package.

5. External environmental factors such as temperature, relative humidity, and air velocity which can affect the film permeability.

Modified atmospheres (reduced oxygen and elevated carbon dioxide) may be beneficial or detrimental to the commodity. Most fresh horticultural commodities benefit from reduced oxygen levels in terms of lower respiration rate and senescence. However, if the oxygen concentration falls below 1% inside the tissue, anaerobic respiration will occur, resulting in off-odors and off-flavors due to the accumulation of ethanol and acetaldehyde. The degree of tolerance to elevated carbon dioxide varies greatly among fresh horticultural crops as shown in the classification information on page 9.

Physiological injury from elevated carbon dioxide can be manifested in external and/or internal brown discoloration, irregular ripening of fruits, development of off-flavor and off-odors. Beneficial effects of elevated carbon dioxide include retardation of senescence and associated compositional changes and decay control at 10 to 20% carbon dioxide.

Accumulation of ethylene within the package may enhance ripening of fruits unless the oxygen level is reduced below about 5% and/or the carbon dioxide level is increased above about 2%. If ethylene accumulation is a potential problem, absorbers containing potassium permanganate can be used to absorb it. Activated carbon and lime may be used to absorb volatiles and carbon dioxide, respectively.

Selection of a film that will result in a favorable modified atmosphere should be based on the expected respiration rate of the commodity at the transit and storage temperature to be used and on the known optimum oxygen and carbon dioxide concentrations for the commodity. For most commodities (except those which tolerate high CO_2 levels), a suitable film must be much more permeable to carbon dioxide than to oxygen.

It should be remembered that a film resulting in a favorable atmosphere at a low temperature may result in a harmful atmosphere at high temperatures because of changes in respiration rate of the commodity and permeability of the film. An ideal film is one that increases in its gas diffusion capabilities by 2- to 3-fold for each increase in temperature of 10° C (18° F).

Since passive modification of the atmosphere (through commodity respiration) takes a relatively long time, specially at lower temperatures, it may be necessary to modify the atmosphere immediately after packaging by pulling a slight vacuum and replacing the package's atmosphere with the desired gas mixture. In this case, the function of the film would be to maintain the desirable atmosphere during postharvest handling.

Consumer packaging in relatively gas-tight film may be used for the intentional modification of the atmosphere to benefit the commodity in terms of quality maintenance. For example, cut vegetables may be packaged in 4-mil polyethylene bags to which an atmosphere to 30 to 50% oxygen and about 5% carbon monoxide is added. The elevated oxygen ensures adequate oxygen supply to avoid anaerobic respiration during postharvest handling while the carbon monoxide inhibits tissue discoloration. Great caution is needed if carbon monoxide is used since it is extremely toxic to humans and is explosive at concentrations about 12.5%.

Decay

Packaging of individual commodity units can reduce the spread of decay from infected units to healthy ones. Another advantage of some films which maintain optimum relative humidity is preserving the skin's vitality and resistance to pathogens. However, if water condensation occurs within the package due to temperature fluctuations, decay problems may increase. Some commodities such as onions and sweetpotatoes do not tolerate high relative humidity without the potential for increased decay.

Conclusion

The advantages and disadvantages, i.e., the cost/benefit ratio of using a specific type of polymeric film for a given commodity will determine the extent of its use in modified atmosphere packaging. Continued advances in the technology of manufacturing polymeric films for specific uses and in automated packaging systems will increase the potential for expanded use of these films in the future. To attain maximum postharvest life (on the basis of appearance and flavor quality), modified atmosphere packaging should be used as a supplement to and not as a substitute for proper temperature management. □