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Application of modified atmosphere packaging for fruits and vegetables

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Abstract

Fresh produce is more susceptible to disease organisms because of increase in the respiration rate after harvesting. The respiration of fresh fruits and vegetables can be reduced by many preservation techniques. Modified atmosphere packaging (MAP) technology is largely used for minimally processed fruits and vegetables including fresh, "ready-to-use" vegetables. Extensive research has been done in this research area for many decades. Oxygen, CO_2, and N_2, are most often used in MAP. The recommended percentage of O_2 in a modified atmosphere for fruits and vegetables for both safety and quality falls between 1 and 5%. Although other gases such as nitrous and nitric oxides, sulphur dioxide, ethylene, chlorine, as well as ozone and propylene oxide have also been investigated, they have not been applied commercially due to safety, regulatory, and cost considerations. Successful control of both product respiration and ethylene production and perception by MAP can result in a fruit or vegetable product of high organoleptic quality; however, control of these processes is dependent on temperature control.

Keywords: MAP, CAP, Ethylene, Packaging, Respiration, Preservation

Introduction

Postharvest begins at the moment of separation of the edible commodity from the plant that produced it by a deliberate human act with intention of starting it on its way to the table. The postharvest period ends when the food comes into the possession of the final consumer. Plants or plant parts continue to function metabolically after harvest. However, their metabolism is not identical with that of the parent plant growing in its original environment and therefore, they are subjected to physiological and pathological deterioration and losses. "Loss" means any change in the availability, edibility, wholesomeness or quality of the food that prevents it from being consumed by people (Fallik and Aharoni, 2004) [2]. Causes of losses could be biological, microbiological, chemical, biochemical reactions, mechanical, physical, physiological and psychological. Microbiological, mechanical and physiological factors cause most of the losses in perishable crops (Kader, 1992). Other causes of losses, according to Fallik and Aharoni (2004) [2], may be related to: (1) Inadequate harvesting, packaging and handling skills. (2) Lack of adequate containers for the transport and handling of perishables. (3) Storage facilities inadequate to protect the food. (4) Transportation inadequate to move the food to market before it spoils. (5) Inadequate refrigerated storage. (6) Inadequate drying equipment or poor drying season. (7) Traditional processing and marketing systems can be responsible for high losses. (8) Legal standards can affect the retention or rejection of food for human use being lax or unduly strict. Losses may occur anywhere from the point where the food has been harvested or gathered up to the point of consumption, that is, harvest, preparation, preservation, processing, storage and transportation.

Fruits and vegetables are living, respiring and perishable products with active metabolism even after harvest from the parent plant. The storage life and quality of fruits and vegetables can be extended by modifying the atmosphere surrounding products. A modified atmosphere can be defined as one that is created by altering the normal composition of air (21% oxygen and 0.03% carbon dioxide) to provide an optimum atmosphere for increasing the storage length and quality of produce. Modified atmospheres can be achieved by using controlled atmosphere (CA) storage or modified atmosphere packaging (MAP).

Modified atmosphere packaging (MAP) has been applied in the food industry for about 90 years to extend shelf life and maintain quality of fresh and fresh-cut foods. Recently, MAP has experienced a rapid development in both scientific and industrial communities, which was one of the most appropriate and practical technologies for packaging fresh and fresh-cut produce.

Unlike most food products, fresh fruits and vegetables continue to respire after they have been harvested. This process consumes oxygen and produces carbon dioxide and water vapour. The key to keeping these packaged products fresh for as long as possible is to reduce the respiration rate without harming the quality of the product – its taste, texture and appearance. In general, the rate of respiration can be reduced by keeping the temperature low, having lower levels of oxygen in the packaging atmosphere and increased levels of carbon dioxide. However, things are not straightforward. For example if there is too little oxygen in the packaging atmosphere, a process called anaerobic respiration will kick in. This produces unwanted tastes and odours in the product and will cause the food to deteriorate. Furthermore, excessively high carbon dioxide can damage some varieties of product.

As well as these considerations, the high water content of this class of food, plus the fact that fruit are intrinsically acidic, can lead to spoilage from yeasts and mould. Also, the flesh can become soft because of attack by enzymes from microbes, eventually resulting in rotting.

The packaging material used for fruit and vegetables is especially crucial and in particular how permeable or breathable the material is. If the products are sealed in an airtight package, oxygen will soon become depleted and undesirable anaerobic conditions could develop. On the other hand if the material is too porous, the modified atmosphere will escape and no benefit will be derived.

CA requires precise control of O_2 and CO_2 concentration around fresh produce and involves large specialised storage buildings and sophisticated operation equipment. CA is more appropriate for long term storage, while MAP is used on smaller quantities of produce and the atmosphere is only initially modified. MAP techniques involves either actively or passively controlling or modifying the atmosphere surrounding the product within a package made of various types of films. Active modification occurs by the displacement of gases in the package, which are then replaced by a desired mixture of gases, while passive modification occurs when the product is packaged using a selected film type, and a desired atmosphere develops naturally as a consequence of the products' respiration and the diffusion of gases through the film.

Passive MAP is extensively used now a days to extend the shelf life of many fresh commodities and fresh cut fruits and vegetables because passive MAP presents a much more economical alternative approach to controlled atmosphere (CA) to extend storage life.

Modified Atmosphere Packaging and Related Technology

Most perishable commodities require a R.H. of 90% to 95% in order to avoid excessive moisture loss during storage. Refrigeration equipment should be designed to maintain the required R.H. Removal of field heat by some cooling methods is the first step in temperature management. Cooling produce slows down the changes during ripening and subsequent deterioration, reduces water loss, and slows or stops the growth and spread of rots. Produce should be cooled as soon as possible after harvest. The various ways of cooling methods include room cooling, forced-air cooling, hydrocooling, vacuum cooling and top or package icing (Fallik, 2004) [1]. Wilting, re-growth, ripening, senescence and decay can be postponed through good temperature and relative humidity management. The benefits of film packaging include easy to handle (consumer package); protection from injuries; reduction of water loss, shrinkage, wilting; reduction of decay by modified atmosphere (MA); reduction of physiological disorders (chilling injury); retardation of ripening and senescence processes; retardation of regrowth and sprouting (green-onion radishes) and control of insect in some commodities. Harmful effects of film packaging include enhancement of decay due to excess humidity; initiation and/or aggravation of physiological disorders; internal browning in potatoes, apples, pears; brown stain in lettuce; irregular ripening in improper concentrations of CO_2/O_2; off-flavors and off-odors and increased susceptibility to decay. Modified atmosphere is created as a result of the produce respiratory activity; consumption of oxygen (O_2) and emanation of carbon dioxide (CO_2), occurring within a sealed plastic package.

Modified Atmosphere Packaging (MAP): MAP is the replacement of air (N2 content 78%, O2 content 21%, CO2 content 0.035%, together with water vapour and traces of inert gases) in a pack with a single gas or mixture of gases; the proportion of each component is fixed when the mixture is introduced. No further control is exerted over the initial composition, and the gas composition is likely to change with time owing to the diffusion of gases into and out of the product, the permeation of gases into and out of the pack, and the effects of product and microbial metabolism. Storage in plastic films in all kinds of combinations (different materials, perforation, inclusions, individual seal packing - shrunken and non-shrunken) are additional types of MA storage.

Controlled Atmosphere (CA) Storage: The proportion of each gas is maintained (controlled) at the original level introduced throughout the distribution cycle, regardless of the temperature or other environmental variations. CA technique is used primarily for the bulk storage and transport of products and requires constant monitoring and control of the gas composition within the package or storage facilities.

Equilibrium Modified Atmosphere (EMA) Packaging: This technique is used primarily for the packaging of fresh fruit and vegetables. Either the pack is flushed with the required gas mix or the produce is sealed within the pack with no modification to the atmosphere. Subsequent respiration of the produce and the gas permeability of the packaging allow an equilibrium-modified atmosphere to be reached. EMA is also called passive atmosphere modification (PAM).

Vacuum Packing (VP): The product is placed in a pack of low oxygen permeability, air is evacuated and the package sealed. Since it is not currently possible to evacuate all the air (0.3-3% may remain after sealing), the gaseous atmosphere of the vacuum package is likely to change during storage (owing to microbial and product metabolism, and gas permeation) and therefore the atmosphere becomes modified.

Gas Exchange Preservation (GEP): Gas-exchange preservation involves pumping air out of the pack and replacing it with a series of gases, each with a different role. CO is added first to inhibit enzymes, followed by SO2 or ethylene oxide to kill microorganisms, and finally N2 to flush out the pack. GEP should be approved by regulatory agencies.

Extending shelf life of fruits and vegetables by map

MAP utilises polymeric films with selective permeability for O_2, CO_2, and H_2O vapor to create an MA around the packaged product due to the respiration of the product and the selective permeability of the packaging material (Guevara *et al*. 2003) [3]. Horticultural products are a main application for MAP, and reduced levels of O_2 and increased levels of CO_2 in the atmosphere surrounding fresh produce seem to have several positive effects: MA reduces respiration rate, ethylene production and sensitivity and texture losses, improves chlorophyll and other pigment retention, delays ripening and senescence and reduces the rate of microbial growth and spoilage (Rodriguez-Aguilera and Oliveira, 2009).

Fresh fruit and vegetables: MAP is most commonly used for highly perishable commodities and effectively retards deterioration of fresh fruits and vegetables. MAP can prolong the shelf life of mushrooms *Pleurotus nebrodensis* to 90 days, inhibit the respiration and weight loss, and retard soluble sugars, titratable acidity and anthocyanin decrease of strawberries (Zhang *et al*. 2003) [9]. MAP significantly inhibits the lignification and delay of the ripeness of bamboo shoots. MAP using 0.03 mm PE film could inhibit weight loss and decrease TSS, firmness of fruits and keep an acceptable appearance of mini tomatoes compared with control fruit.

Fresh-cut fruit and vegetables: Modified atmosphere packaging (MAP) is extensively used to extend the shelf life of many fresh cut (minimally processed) fruits and vegetables products. The most suitable packaging material to prolong the shelf life of fresh cut lotus roots has been reported to be 0.04 mm low density polyethylene (LDPE). Fresh cut lotus roots treated by MAP with 100% O_2 could maintain better quality of appearance. Fresh cut celery packaged in MA with three different atmospheres found that 10% O_2, 10% CO_2 and 80% N_2 was the best combination to keep cut celery fresh.

Factors determining the effectiveness of map

Film type and thickness used in MAP: MAP involves the use of plastic film, with known permeability to gases, for the packaging of products. There is no doubt that MAP materials should be selected appropriately according to their gas permeation properties. Many factors influence film permeability, among which polymer type and film thickness are most important. Many plastic films have been in use for MAP of a variety of produce. Packaging film of correct permeability can create desirable MA of fresh fruit and vegetables. Due to differences in the respiration rates of individual fruits or vegetables, the type of plastic film required to achieve any special equilibrium MA must be defined for each commodity. The MAP industry has an increasing choice of packaging films, yet most packs are still constructed from four basic polymers: polyvinyl chloride (PVC), polyethylene terephthalate (PET), polypropylene (PP) and LDPE for packaging of fresh produce (Mangaraj *et al*., 2009).

Plastic film*:* LDPE films are among those most commonly used in packaging of fresh produce. that The best packaging material for MAP storage of pioneer cherry has been reported as 0.02 mm LDPE film. Nectarines packed in 0.03 mm LDPE showed significantly less polygalacturonase and cellulase activities, decreased respiration rate and ethylene production, and a slower decrease in flesh firmness and increase in relative membrane permeability than the control.

PP and PVC films are often used to pack fruit and vegetables such as waxberry (0.025mm PVC). Zhang *et al*. (2003) [9] reported that the composite membrane containing LDPE and PVC was superior to single LDPE and PVC membranes to obtain the optimum gas composition of 2.5% O_2 +16% CO_2 in MAP for strawberry; MAP could inhibit the respiration and weight loss of strawberries and retard soluble sugars, titrable acidity and anthocyanin decrease. The packaging material containing biaxially oriented polypropylene (BOPP): PET: LDPE was reported to be the best choice for keeping bamboo shoots fresh. Fuji apples packed in five types of plastic film bags for seven months showed that apples in MAP film of PVC or LDPE had a fresh-like quality.

Silicon gum film*:* The effect of silicon gum films as windows for gas exchange on the respiration and quality change of stored edible mushroom *Agrocybe chaxingu* was evaluated, and showed that silicon gum film windows could extend the shelf life by more than 8 days compared to the control. Packages with the silicon gum film window with initial gas concentrations of 5% O_2 and 10% CO_2 were the most effective for maintaining mushroom quality (Li *et al*., 2007). Li and Zhang (2008) reported that different sizes of silicon gum film windows had a significant effect on quality of *Agrocybe chaxingu*.

Initial gas composition before packaging: Zhang *et al*. (2003) [9] reported that the optimum gas composition for MAP of strawberry was 2.5% O_2 and 16% CO_2. The initial gas proportion of 10% O_2 and 10% CO_2 at 5oC was effective in maintaining the quality of spinach. The quality of fresh cut onion could be maintained for 17 days at 4oC in a package atmosphere of 80%O_2 and 20% N_2 combined with 1.5% citric acid. The optimum initial gas composition for MAP of peas was determined by a comprehensive evaluation model to be 9% O2, 7% CO_2 and 84% N_2.

Conclusion

Current knowledge and use of MAP are mainly empirical, but a systematic approach to designing optimal MAP is being developed. Despite many advantages of MAP, adoption of this technique has been rather slow in countries dependent on machinery to apply it, and the technique has not yet reached its full potential. Possibly, non-availability of fast and reasonably priced equipment and the cost of the film are the main reasons limiting the commercial adoption of MAP. The plastic films used for MAP must be flexible and easy to use, but sufficiently strong to survive normal handling operations. The use of MAP for fresh produce is quite restricted for a number of reasons and no single polymer offers all the properties required for MAP.

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