Modified Atmospheres Packaging and the Fresh-cut Revolution

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In the last decade fresh-cut produce sales have skyrocketed and now account for almost 10% of all produce sales in the United States. This fresh-cut revolution in produce has been made possible by modified atmosphere packaging (MAP) innovations, as well as improvements in the chill chain and processing technology. How does MAP extend the shelf-life of fresh-cut produce and what are its limitations ?

MAP Effects

The basic premise of MAP technology is that once produce is placed in a package and hermetically sealed, an environment different from ambient conditions will be established. The key to successful use of MAP technology is knowing what type of environment will be most beneficial to the produce inside the package and then determining which packaging materials should be used to create such an environment. Critical environmental conditions for produce, that packaging materials can effect, are atmospheric oxygen (O_2), carbon dioxide (CO_2), ethylene (C_2H_4) and water vapor (relative humidity) concentrations. Correct application of MAP technology can significantly extend the shelf-life of fresh-cut products but, if incorrect packaging materials are chosen, atmospheric conditions which are injurious may be generated and this can actually result in shorter shelf-life.

Relative Humidity

One of the greatest benefits derived from the use of MAP is the maintenance of high relative humidity around the fresh-cut product. Many natural barriers to water loss are removed during fresh-cut processing, leaving fresh-cut products very susceptible to dehydration. Flexible film pouches and rigid trays overwrapped with flexible films, significantly reduce the rate of water loss from fresh-cut products by creating an environment inside the package that is near 100% relative humidity. However, water condensation on the inside of the package may promote the growth of spoilage microorganisms and obscure the consumers ability to examine the product prior to purchase. Appropriate selection of flexible film water vapor transmission rate and incorporation of antifog additives into a flexible film can eliminate both problems.

O_2 and CO_2 Levels

Generation of a low O_2 and/or elevated CO_2 environment within a fresh-cut MAP extend fresh-cut product shelf-life by:

- slowing browning reactions
- reducing the rate of product respiration and
- reducing C_2H_4 biosynthesis and action.

The low O_2 and/or elevated CO_2 atmosphere within a fresh-cut MAP is the result of the living fresh-cut product consuming O_2 and releasing CO_2 within a confined space. Flexible packaging films used in the fresh-cut industry allow O_2 to move into the package from the outside air and CO_2 to be released from the inside of the package. The equilibrium atmospheric composition within a MAP is determined by the O_2 consumption and CO_2 evolution rate of the product, film O_2 and CO_2 permeability, as well as film surface area and product mass within the package. The rapid establishment of a low O_2 and/or elevated CO_2 environment is critical for the prevention of cut surface browning on many fresh-cut products and equilibrium gas concentrations within a package can be attained quickly by evacuating the package and flushing it with the predicted O_2 and CO_2 equilibrium concentrations. This type of actively modified atmosphere is necessary for MAP fresh-cut lettuce products which commonly have less than 1% O_2 to slow the browning reaction caused by the enzyme polyphenol oxidase (PPO), and more than 10% CO_2 to inhibit biosynthesis of reaction substrates. Although the use of low O_2 and elevated CO_2 MAP is very effective for reducing cut surface browning of lettuce products it does not work well for other commodities such as fresh-cut fruit. This is due to the fact that phenolic compounds, which are substrates for the PPO mediated browning reaction, are very abundant in ripe fruit. Hence elevated CO_2 levels will not limit the amount of substrate available for the browning reaction and the reduction of O_2 levels to near 0% is necessary to completely inhibit the activity of PPO.

Respiration

Reduced O_2 and elevated CO_2 atmospheres within MAP also extend the shelf-life of fresh-cut products by reducing their respiration rates and slowing use of the finite energy supplies that are available in any living tissue. MAP is not a substitute, but merely a supplement to cold storage, since low temperatures have a much greater effect on produce respiration rates. MAP is designed to maintain optimal O_2 and CO_2 concentrations within a package and proper functioning is predicated upon storage temperatures being maintained within a specified range. Temperature throughout the chill chain must be carefully controlled because if a MAP of fresh-cut produce is exposed to temperatures above its expected storage temperature range, injuriously low O_2 or injuriously high CO_2 levels will be generated and significant shelf-life reduction will occur due to induction of fermentative metabolism and the enhanced growth of lactic acid bacteria, both of which cause objectionable off-flavors and odors.

Ethylene Biosynthesis and Action

Low O_2 (<5%) and elevated CO_2 (>5%) will also significantly inhibit of the effects of the plant hormone C_2H_4, which promotes tissue senescence. Wounding plant tissue by cutting, slicing or bruising will cause induction of C2H4 biosynthesis almost immediately and promote tissue breakdown. Therefore, rapid establishment of a low O_2 and elevated CO_2 environment within a MAP of fresh-cut produce will reduce the effects of wound induced C_2H_4 biosynthesis. Numerous industrial attempts have been made to incorporate C_2H_4 absorbing materials into flexible packaging films with the hope of significantly extending the shelf-life of fresh-cut fruits and vegetables. However, this strategy may be redundant, since low O_2 and elevated CO_2 environments within MAP already significantly diminish the production and effects of C_2H_4.

Successful MAP Application

Elevated CO_2 environments within MAP bring an additional benefit of being fungistatic and are commercially used in both the whole and fresh-cut strawberry industry to reduce the growth of *Botrytis cinerea*. A properly designed MAP, when used in combination with low temperature storage, delays spoilage of fresh-cut fruits and vegetables by slowing the natural processes that lead to tissue death and decay by food spoilage microorganisms. In general young vegetative fresh-cut tissues, because they are more physiologically active and vigorous, respond more favorably to the use of MAP than fresh-cut fruit products. Reducing the rapid senescence rate of fresh-cut fruit products via the use of MAP is not particularly effective, since many of the physiological changes associated with fruit ripening are not effected by reduced O_2 and/or elevated CO_2 atmospheres, once genetically regulated ripening events have been initiated.

Conclusion

MAP technology has, and will continue to be, an integral part of the food preservation strategy employed to extend the shelf-life of fresh-cut fruits and vegetables, and understanding its mode of action will help maximize its safe and effective use.