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Research Article

Active Packaging Techniques to Reduce Post-Harvest Loss in Perishables with Special Reference to Mango (cv. *Dushari*)

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Abstract

All horticultural produce continue their metabolic activities soon after harvest and during storage period. Modified atmospheric packaging is a common practice to minimize postharvest losses and extend shelf life of the produce. Even under modified atmosphere the control of respiration rate of the produce is limited. Optimal packaging micro environment can be adversely affected by dynamic changes in temperature and relative humidity throughout the storage period and under transportation. As an alternative, active packaging technologies provide interactive controls between the produce, package and surrounding environment to achieve and retain optimal atmospheric conditions inside the packages. Various active packaging technologies have been developed and are commercially available for a range of food products including horticultural produce and the combination of these with other postharvest management strategies offers benefits to extend shelf life. This paper reviews the recent active packaging technologies and their applications focused on horticultural produce such as Mango.

Keywords: *Active Packaging, Respiration rate, Package design, Shelf life*

1. Introduction

[1]Traditional food packaging is meant for protection, communication, convenience and containment (Paine 1991; Robertson 2006). The package is used to protect the product from the deteriorative effects of external environmental conditionals like heat, light, presence or absence of moisture, pressure, microorganisms, gaseous emissions and so on. It also provides the consumer with the greater ease of use and time saving convenience and contain product of various size and shapes (Yam *et al.* 2005). The key safety objective for traditional packaging materials which comes in contact with food is to be inert as possible. While the smart packaging systems like active and intelligent packaging concepts are based on the useful interaction between packaging environment and the food to provide active protection to the food.

2. Active Packaging

Active packaging can be defined as a system in which the product, package and the environment interact in a positive way to extend the shelf life or to achieve some characteristics (Miltz *et al.* 1995). Packaging may be termed active when it performs some role other than providing an inert barrier to the external environment (Rooney 1995). Active packaging can also be defined as a packaging type that changes the condition of the packaging to extend the shelf life or to improve safety or sensory properties while maintaining the quality of the packaged food (Ahvenainen 2003). Active ingredients are intended to extend the shelf life or to maintain or improve the condition of packaged food.

They are designed to deliberately incorporate components that would play an important role such as to release or absorb substances into or from the packaged food or environment surrounding the food (Sivertsvik 2007).The main goal and objective of active packaging is to extend the preservation of food in the package and enhance shelf life by involving application of various strategies like temperature control, oxygen removal, moisture control, addition of chemicals such as salt, sugar, carbon dioxide or natural acids or a combination of these with effective packaging (Robertson 2006).

These developments in active packaging applications bring advances in many areas including delayed oxidation in foods, controlled respiration rate in horticultural products, microbial growth, ethylene and moisture migration in fresh fruits and vegetables. In addendum, active packaging precisely manipulates the selectivity to modify the atmospheric concentration of gaseous compounds inside the package by coating, micro perforation, lamination, co extrusion, or polymer blending. (Brody *et al.* 2008). The most widely used

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active packaging technology for foods today are oxygen scavengers. The presence of oxygen in a package accelerates the oxidative deterioration of food. Oxygen facilitates the growth of aerobic microbes, off flavor and odour development, colour changes and nutritional losses and overall shelf life stability of muscle foods (Hogan and Kerry 2008). Carbon dioxide can be added to the packaging environment to suppress the microbial growth in certain products such as fresh meat, poultry, fish, cheese, and backed goods (Lopez-Rubio *et al*. 2004) and to reduce the respiration rate of fresh produce (Labuza 1996). Antimicrobial packing is a form of active packaging in which the packaging acts to reduce, inhibit or retard the growth of microorganisms that may be present in the packaged food or packaging material itself (Appendini and Hotchkiss 2002). A major cause of food spoilage is the presence of moisture and the purpose of moisture regulator is to lower the water activity of the product to suppress the microbial growth (Vermeiren *et al*. 1999). In the case of fresh fruits and vegetables, respiration followed by condensation occurs when one part of the package is cooler than the other areas. Ethylene is a natural plant growth hormone which accelerates respiration of fruits and vegetables, induces fruit ripening, fruit softening and senescence even at low concentration (Abeles *et al*. 1992). It causes yellowing of vegetables, russet spotting on lettuce and has detrimental impact on shelf life of many fruits and vegetables (Zagory 1995). Potassium permanganate immobilized on inert minerals are available in sachets for packages and blankets that can be placed in product holding rooms without integrating into the food contact packaging material (Day 2003). Activated carbon base with various metal catalysts also removes ethylene effectively. Activated charcoal impregnated with palladium catalyst is also used to scavenge ethylene from fresh produce. SedoMate® (Japan), NeupalonTM (Japan), Hatofresh® (Japan) is some of the commercial sachets based on activated carbon capable of scavenging ethylene (Rooney 2005).

3. MAP Vs Active Packaging

Modified atmosphere packaging (MAP) and Controlled atmosphere (CA) storage are well established technologies effectively used for prolonging the shelf-life period of fresh or minimally processed foods. Two aspects involve in using these technologies/ process are the respiration of the products and the gas exchanges properties through the package materials, both lead to the increase of CO_2 and depletion of O_2 in MAP and control O_2 and CO_2 atmosphere in CA (Rai and Paul, 2007). The package should maintain an optimal atmosphere that will reduce respiration and slow down the physiological and microbiological changes that decrease shelf life. Most of the climacteric fruits such as Mango, Banana, Guava etc. are packed in modified atmospheric packages to control the respiration and ripening rates. For fresh produce, the use of passive MAP is limited mainly by the unavailability of appropriate film with desired thickness that provide both gases fluxes, selectivity, and temperature compensation to function effectively (Examaet *al*, 1993). Furthermore, these packaging technologies in combination with refrigeration can delay the deterioration of the fresh produce but, not always sufficient for maintaining the quality for the desirable marketing period.

4. Material and methods

4.1 Respiration rate study of mango

The respiration rate of mangoes was determined as per the method adopted by Singh (2014). An air tight glass container was developed for measurement of respiration rate of mango. A Headspace Analyzer (Fig. 1) was used to measure the level of O_2, CO_2 and N_2 inside the container at every 30 minute intervals until equilibrium was achieved. Respiration rates of the mature raw mangoes were measured at different storage temperatures (10, 15, 20, 25 ^oC and room temperature). The respiration rates in terms of CO_2 evolution (ml) per kg of fruits are given in Table 1.

Fig.1 O_2 and CO_2 measurement of mango fruits in closed system

4.2 Package Design

Active modified atmosphere packages were designed based on the respiration rates of the mangoes, film parameters and environment factors. Film parameters such as water vapour transmission rate (WVTR), oxygen transmission rate (O_2TR) and carbon dioxide transmission rate (CO_2TR) of the films were measured. Based on design calculations using PACK-in-MAP software perforated polypropylene (PP) film and Low density poly ethylene (LDPE) film was selected for study.

4.3 Active packaging study

Matured mango fruits (cv. *Dusheri*) were harvested from local farm, washed with citric acid solutions and given a brief exposure to hot air (50 °C) for surface disinfections. Initial TSS, TA, firmness and colour values of fresh mangoes were measured. The fresh fruits had a TSS value of 10.2 °Bx, TA of 0.62 %, and firmness (to compress 5 mm) value of 25.8 kgf. The fruits were packed in polymeric films (LDPE, 75 µm) packs with ethylene absorbent sachets.

No of Hole: 10/ side of film; Size of Hole: 0.5 mm

The MA packages inside 3 ply corrugated paper boxes were stored inside a environmental chamber at 14±1 °C (Fig.2). Control (un-packaged) samples were kept at 14±1 °C for comparison.

Fig.2 Active package of mangoes with absorbents

The study was carried out with following 3 treatments:

1) Control (refrigerated)
2) MAP with Potassium permanganate (PP) as ethylene absorbent (refrigerated)
3) MAP with Potassium permanganate + salicylic acid (PP+SA) @ 0.15g/lit, as ethylene absorbent (refrigerated).

4.4 Shelf life study

Based on in-pack gas compositions and quality parameters such as firmness, TSS, and PLW of fruits measured at regular intervals were used to assess their shelf-life.

5. Results and discussion

5.1 Respiration rate

Based on close system study the respiration rate of mangoes were 16.12, 25.08 and 32.13 ml CO_2/kg-hr at 10, 15 and 20°C temperature, respectively. At ambient condition, the respiration rate value was 54.22 ml CO_2/kg-hr.

It is also concluded that the respiration rate of mangoes were increasing with the increase in temperature from 10°C to ambient storage. The respiration rate was high due to high metabolic reaction with increase in temperature. The detail of the respiration rate of mangoes was given in Table 1.

Table 1 Respiration rate of mangoes at different temperatures

Storage temperature (°C)	Respiration rates (ml CO_2/kg-hr)
	mango (cv. Dusheri)
10	16.12
15	25.08
20	32.13
Ambient (40)	54.22

5.2 Package design

Using PACK-in-MAP software the package design was done for storage study of mangoes. The design parameters such as Produce parameters, Packaging film parameters and Storage condition parameters were detailed in Table 2 as under:

Table 2 Package design details

Package properties	Unit	Value
Weight of package	kg	10
Bulk Density	kg/m³	821
Respiration rate (RR)	ml-CO_2/kg-h	25.05
Type of film		LDPE
Thickness of film	µm	75
Area of packaging film	m²	0.52
Headspace	%	10
Desired oxygen (O_2)	%	3-7
Desired carbon-dioxide (CO_2) level	%	5-8
Required permeability of film OTR CTR	 cc/m²-day-atm cc/m²-day-atm	 92505.1 257160.2
O_2 permeance	cc/m²-h-kPa	31798.0
CO_2 permeance	cc/m²-h-kPa	42570.1
Number of holes per side	number	10
Hole diameter	mm	0.5
Storage temperature	°C	14
RH	%	90-95

5.3 Shelf life

The control mangoes fruits had a shelf-life of 12 days. However, MA packed (LDPE, 75µm) with ethylene absorbents samples was found to have a shelf-life of 42 days at refrigerated conditions plus 5 days at ambient after opening of MA packages (Table 3; Fig 3).

Table 3: Quality parameters for shelf life

Parameters (after 6 weeks of storage)	Refrigerated storage	
	with out MAP	MAP with ethylene absorbents (PP+SA)
Firmness, Kg	0.27	2.11
TSS, °Bx	1	15.2
PLW, %	22.4	3.7
Gas composition inside MA packs	-	O_2 – 6.2 % CO_2 -7.8%
Shelf life, weeks	3	6 (Plus 5 days)

Fig.3 MAP (PP+SA) packed fully ripe mango after 6 weeks in refrigerated MA storage and addition 5 days storage at room temperature.

Conclusions

1) The respiration rate was found to be temperature dependent and the rates were increased with temperature for mango. The reparation rate in terms of CO_2 (ml-CO_2/kg hr) evolution was 16.12 at 10°C temperature.
2) Based on design calculation, polymeric film LDPE (75 μm) thickness for bulk packaging of Mango with perforations were found suitable for MAP studies for shelf life enhancement. The number and diameter of perforations were optimized to match the required O_2 and CO_2 permeability.
3) The active packaging techniques had improved the shelf life of mango. Using ethylene absorbent, the shelf-life of MA packed mango was enhanced up-to 7 weeks.

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