Application of Modified Atmosphere Packaging and Related Technology in Postharvest Handling of Fresh Fruits and Vegetables

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ABSTRACT

Fruits and vegetables are important source of carbohydrates, proteins, organic acids, vitamins and minerals for human nutrition. When plants or plant parts are used by humans, whether for food, or for aesthetic purpose, there is always a postharvest component. Postharvest losses in fresh fruits and vegetables may occur anywhere from the point where the food has been harvested or gathered up to the point of consumption. Appropriate postharvest handling can minimize moisture loss, slow down respiration rate and inhibit the development of decay causing pathogens. Temperature is the most important determinant of fresh produce deterioration rate. An important supplement to proper temperature and relative humidity management is the use of controlled (CA) or modified (MA) atmosphere. This paper reviews the physiological factors affecting shelf life and applications of modified atmosphere packaging (MAP) and related technology in prolonging shelf life of fresh fruits and vegetables. The paper further provides tables of values for permeabilities of films available for packaging fresh produce, classification of horticultural commodities according to respiration and ethylene production rates and MAP potential for benefit for whole and fresh-cut fruits and vegetables. The paper encourages commercial application of MAP by processors and retailers in addition to further research efforts for local crops under local conditions.

Keywords: Modified Atmosphere Packaging, postharvest, fruits, vegetables.

1. 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). 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), 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.

2. PHYSIOLOGICAL FACTORS AFFECTING SHELF LIFE OF FRESH FRUITS AND VEGETABLES

Shelf life may be defined as the period of time from harvest to manufacture to consumption that a food product remains safe and wholesome recommended production and storage conditions. Shelf life is affected by intrinsic factors such as respiration, biological structure, ethylene production and sensitivity, transpiration, compositional changes, developmental processes and physiological breakdown.

2.1 Respiration Rate

Respiration is a process by which stored organic materials (carbohydrates, proteins, and fats) are broken down into simple end products with a release of energy. Oxygen (O_2) is used in this process and carbon dioxide (CO_2) is produced. Under normal atmospheric conditions, aerobic respiration takes place, whereby metabolic oxidation of glucose for example, leads all the way to CO_2 as described by the simplified equation: $C_6H_{12}O_6 + 6O_2 \text{ ----> } 6CO_2 + 6H_2O$ + Energy (heat). During the respiration process there is a loss of stored food reserves in the commodity. This leads to hastening of senescence because the reserves that provide energy are exhausted. Also, there is loss of flavor quality, especially sweetness. The energy released as heat, affect postharvest technology considerations, such as estimations of refrigeration and ventilation requirements. The rate of deterioration of harvested commodities is generally, proportional to the respiration rate (Fallik and Aharoni, 2004). The commodities are classified according to their respiration rates in Table 1. Table 2 shows a list of climacteric and non-climacteric fruits. Respiratory activity is markedly affected by temperature and modified atmosphere. Respiration rates alter during a commodity’s natural process of ripening, maturity and senescence. Certain climacteric fruits, e.g. apples, avocados pears and tomatoes, experience a marked and transient increase in respiration during their ripening which is associated with increased production of and sensitivity to ethylene (Pesis, 2004a). The ratio of CO_2 produced to O_2 consumed, known as the respiratory quotient (RQ), is normally assumed to be one, but can range from 0.7 to 1.3 depending on the metabolic substrate utilized.

2.2 Biological Structure

The resistance of plant tissue to diffusion of O_2, CO_2, ethylene and water vapour is dependent on the biological structure of individual fruit or vegetables. Resistance to gas diffusion influences a commodity’s tolerance to depleted levels of O_2 and elevated levels of CO_2 (Pesis, 2004b). Resistance to gas diffusion varies depending on the type of commodity, cultivar, part of the plant, severity of preparation and stage of maturity, but appears to be little affected by temperature (Fallik and Aharoni, 2004).

Table 1: Classification of Horticultural Commodities according to Respiration and Ethylene Production Rates

Class	Respiration Rates*		Ethylene Production Rates**	
	Range at 15°C (mg CO_2/Kg-hr)	**Commodities**	**Range at 20°C (68°F) (µl C_2H_4/Kg-hr)**	**Commodities**
Very low	< 5	Dates, Nuts	Less than 0.1	Artichoke, Asparagus, Cauliflower, Cherry, Citrus, Grape, Jujube, Strawberry, Pomegranate, Leafy vegetables, Root vegetables, Potato, Most cut flowers
Low	5-10	Apple, Celery, Citrus fruits, Garlic, Grape, Kiwifruit, Onion, Persimmon, Pineapple, Potato, Sweet potato, Watermelon	0.1-1.0	Blueberry, Cranberry, Cucumber, Eggplant, Okra, Olive, Pepper, Persimmon, pineapple, Pumpkin, Raspberry, Tamarillo, Watermelon
Moderate	10-20	Apricot, Cabbage, Cantaloupe, Carrot, Cherry, Cucumber, Pig, Gooseberry, Lettuce, Nectarine, Olive, Peach, Pear, Pepper, Plum, Tomato	1.0-10.00	Banana, Fig, Guava, Honeydew, Melon, Mango, Plantain, Tomato
High	20-40	Avocado, Cauliflower, Lima bean, Raspberry	10.0-100.00	Apple, Apricot, Avocado, Cantaloupe, Feijoa, Kiwifruit (ripe), Nectarine, Papaya, Peach, Pear, Plum
Very high	40-60	Artichoke, Bean sprouts, Broccoli, Green onion, Snap beans	More than 100.00	Cherimoya, Mammee apple, Passion fruit, Sapote
Extremely high	> 60	Asparagus, Mushroom, Parsley, Peas, Sweet corn		

Sources: *Fallik and Aharoni (2004); **Pesis (2004a)

Table 2: Fruits classified according to respiratory behavior during ripening

Climacteric fruits		**Non climacteric fruits**	
Apple	Nectarine	Blackberry	Lychee
Apricot	Papaya	Cacao	Okra
Avocado	Passion fruit	Carambola	Olive
Banana	Peach	Cashew apple	Orange
Blueberry	Pear	Cherry	Peas
Breadfruit	Persimmon	Cucumber	Pepper
Cherimoya	Plantain	Date	Pineapple
Feijoa	Plum	Eggplant	Pomegranate
Fig	Quince	Grape	Prickly pear
Guava	Rambutan	Grapefruit	Raspberry
Jackfruit	Sapodilla	Jujube	Strawberry
Kiwifruit	Sapote	Lemon	Summer squash
Mango	Soursop	Lime	Tamarillo
Muskmelon	Tomato	Longan	Tangerine
		Loquat	Watermelon

Source: Fallik and Aharoni (2004)

2.3 Ethylene Production and Sensitivity

Ethylene (C_2H_4), the simplest of the organic compounds affecting the physiological processes of plants, is a natural product of plant metabolism and is produced by all tissues of higher plants and by some micro-organisms. As a plant hormone, ethylene regulates many aspects of growth, development, and senescence and is physiologically active in trace amounts (less than 0.1 ppm). It also plays a major role in the abscission of plant organs. Ethylene production rates increase with maturity at harvest, physical injuries, disease incidence, increased temperatures up to 30^{o}C and water stress (Pesis, 2004a). On the other hand, ethylene production rates by fresh horticultural commodities are reduced by storage at low temperature, by reduced O_2 levels, and elevated CO_2 levels around the commodity (Aharoni, 2004a). Exposure of climacteric fruits to ethylene advanced the onset of an irreversible rise in respiration rate and rapid ripening. Various packages can delay the onset of climacteric and prolong shelf-life of fruits by reducing ethylene production and sensitivity (Peleg, 1985). Even non-climacteric fruits and vegetables can benefit from reduced ethylene sensitivity and lower respiration rate under various conditions.

2.4 Transpiration

Transpiration is the evaporation of water from plant tissues. Water loss is a very important cause of produce deterioration, with severe consequences. Elazar (2004) states that water loss is, first, a loss of marketable weight and then adversely affects appearance (wilting and shriveling). Also, the textural quality is reduced by enhanced softening, loss of crispness and juiciness, and reduction in nutritional quality. The nature of the epidermal system of the commodity governs the regulation of water loss that is affected as well by environmental factors. Eventually, transpiration is a result of morphological and anatomical characteristics, surface-to-volume ratio, surface injuries and maturity stage on the one hand, and relative humidity (R.H.), air movement and atmospheric pressure on the other. As a physical process, it can be controlled by applying waxes and plastic films as barriers between the produce and the environment, as well as by manipulating R.H., temperature and air circulation (Aharoni, 2004b).

2.5 Compositional Changes

Many changes in pigments may occur during development, maturation and ripening on the plant. Some may continue after, or start only at harvest. These changes, which may be either desirable or undesirable, can occur as loss of chlorophyll; development of carotenoids (yellow orange and red colors); and development of anthocyanins and other phenolic compounds (Fallik and Aharoni, 2004). All processes involving color are of particularly importance in ornamentals. Changes in carbohydrates are generally desirable in fruits but are quite important in all commodities. Starch is converted to sugars - a process desirable in banana and apple but not in potato. In sweet corn, sugars are converted back to starch - which is undesirable. In most commodities starch is used as a substrate for respiration. During ripening, softening occurs and polysaccharides such as pectins, cellulose and hemicellulose are degraded. Increase in lignin is undesirable in asparagus spears and root vegetables, but lignification sometimes prevents the invasion of microorganisms. There are changes in proteins, amino acids and lipids which may affect the flavor of the commodity. Development of flavor and aroma volatiles is very important for the eating quality. Loss of vitamins, especially ascorbic acid (vitamin C), takes place during storage and thus adversely affects nutritional quality.

2.6 Developmental Processes

Sprouting, elongation and seed germination in storage are undesirable processes. Sprouting or rooting occurs in potatoes, onions, garlic and other root crops and greatly reduces their commercial value (Elazar, 2004). Asparagus spears and gladiolus flowers continue to elongate during storage and bend when held horizontally during transportation (geotropic response). Seed germination occurring inside fruit during storage is undesirable in tomato, pepper, avocado and lemon (Pesis, 2004b).

2.7 Physiological Breakdown

Exposure to undesirable conditions such as freezing either before or after harvest results in the collapse of tissues (Fallik, 2004). Chilling injury occurs in some commodities (mainly tropical and subtropical) which are held at temperatures above their freezing point but which still cause injury (below 15^{o}C or lower, depending on the commodity). Chilling injuries are expressed as internal discoloration (browning), pitting, water-soaked areas, uneven ripening or failure to ripen, off-flavor development and accelerated incidence of decay. Certain types of physiological disorders originate from preharvest factors such as heat or chilling injuries in the field, which appear as bleaching, surface burning or scalding or nutritional imbalances. Very low oxygen or too-high CO_2, and the presence of excessive ethylene concentrations, may exacerbate the severity of physiological disorders related to storage conditions.

3. 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) and hydorvac (Aharoni, 2004). Wilting, re-growth, ripening, senescence and decay can be postponed through good temperature and relative humidity management. Aharoni (2004b) has given the benefits of film packaging and also its harmful effects. 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. Special film packages, with suitable permeability to CO_2 and O_2 are used to ensure an optimal equilibrium of these gases during storage and shipment (see Figure 1, 2 and Table 3). MA = changes of the respiratory gases (CO_2 and O_2) in the package/container. Steady state level depends on rate of produce respiration (temperature dependent), produce weight and package permeability. Ethylene might accumulate in the package/container. Fallik and Aharoni (2004) presented five related types of packaging, storage and preservation technologies:

3.1 Modified Atmosphere Packaging (MAP)

MAP is the replacement of air (N_2 content 78%, O_2 content 21%, CO_2 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.

3.2 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.

3.3 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).

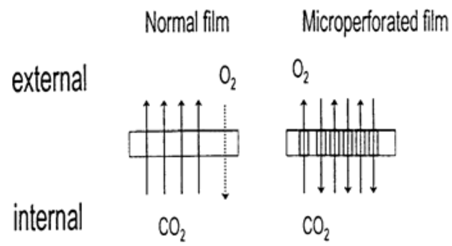
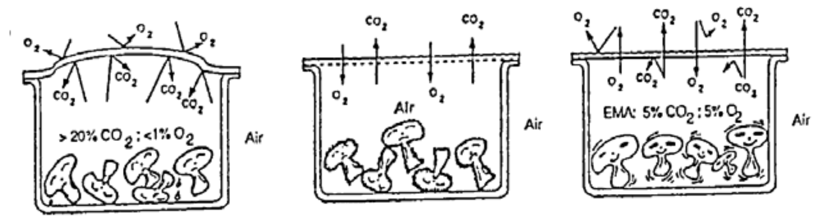


Figure 1: Permeability "selective" and "non selective"
Source: Aharoni (2004a)



(a) (b) (c)

Figure 2: (a) Barrier film: undesirable anaerobic conditions; (b) Fully permeable film: no desirable atmospheric modification; (c) Intermediate permeable film: desirable EMA
Source: Aharoni (2004a)

Table 3: Permeabilities of films available for packaging fresh produce

Film type	Permeabilities ($cc/m^2/mil/day$ at 1 atm)		CO_2:O_2 Ratio
	CO_2	O_2	
Polyethylene: low density	7,700-77,000	3,900-13,000	2.0-5.9
Polyvinylchloride	4,263-8,138	620-2,248	3.6-6.9
Polypropylene	7,700-21,000	1,300-6,400	3.3-5.9
Polystrene	10,000-26,000	2,600-7,700	3.4-3.8
Saran	52-150	8-26	5.8-6.5
Polyester	180-390	52-130	3.0-3.5

Source: Aharoni (2004a)

3.4 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.

3.5 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 SO_2 or ethylene oxide to kill microorganisms, and finally N_2 to flush out the pack. GEP should be approved by regulatory agencies.

Aharoni (2004a,b) has presented the MA/CA potential benefit for fruits and vegetables at various temperatures (Tables 4 and 5) while Rodov (2004) has presented the MA/CA efficacy for fresh-cut fruits and vegetables (Tables 6 and 7).

4. HEALTH, SAFETY AND ENVIRONMENT (HSE) CONSIDERATIONS

Fallik and Aharoni (2004) inform that the atmosphere in a CA room is dangerous for humans. Many people lost their lives working in CA rooms without proper breathing equipment. A danger sign should be posted on the door. When entering the room, at least two people with breathing equipment should work together at all times. Ethylene removal is partially by water scrubbers used for CO_2, potassium permanganate, oxidation of ethylene and the use of UV light to decompose (oxidize) ethylene present in air.

5. CONTROLLED AND MODIFIED ATMOSPHERE IN POSTHARVEST PATHOLOGY

Fungi and bacteria are the two main sources of infection that may occur during the growing season, at harvest time, during handling, storage transport and marketing, or even after purchasing by the consumer. Plants and plant parts by virtue of their particular genetic make-up, are resistant to attack by the majority of microorganisms; disease is the exception rather that the rule, and occurs only when a number of conditions are fulfilled (Fallik and Aharoni, 2004). Bacteria gain entry through wounds or natural opening (such as stomata, lenticels, or hydathodes) and multiply in the spaces between plant cells. Entry via wounds or natural openings is also characteristic of many fungi. Certain species of fungi, however, are capable of direct penetration of intact cuticle, the waxy outermost layer possessed by leaves, stems, and fruits. Many fruits are resistant to fungal attack when unripe; the infection process is halted almost as soon as it has begun, but the fungus remains alive, entering a `quiescent' or `latent' phase. The process of ripening is accompanied by weakening of cell walls and a decline in ability to synthesize anti-fungal substances, until eventually the fruit is no longer able to resist the advance of the fungus (Elazar, 2004). Decay reduction and disease control is through sanitation, careful handling, cooling of produce, use of approved chemicals (fungicides which prevent or delay the appearance of rots and molds in the products, chemicals that delay ripening or senescence, growth retardants that inhibit sprouting and growth, chemicals that hasten ripening and senescence, metabolic inhibitors that block certain biochemical reactions that normally occur, ethylene absorbents and fumigants to control insects or sometimes molds), physical treatments (such as heat treatments, irradiation with gamma-ray, UV irradiation), biological control and controlled and modified atmosphere (Fallik and Aharoni, 2004).

Modifications of the storage atmosphere, along with their effects on the physiological life of the host, can also be advantageous in retarding postharvest disease development. The effect of atmosphere modification on postharvest disease development can be direct-by suppressing various stages of the pathogen growth and its enzymatic activity, or indirect-by maintaining the resistance of the host to infection as a result of keeping it in a superior physiological condition.

Table 4: MA/CA potential for benefit for fresh fruits

Commodity	Temperature range (°C)	MA/CA %O_2	MA/CA %CO_2	Potential for benefit (*)
Deciduous tree fruits				
Apple	0-5	1-3	1-5	A
Apricot	0-5	2-3	2-3	C
Cherry, sweet	0-5	3-10	10-15	B
Fig	0-5	5-10	15-20	B
Grape	0-5	2-5	1-3	C
Kiwifruit	0-5	1-2	3-5	A
Nectarine	0-5	1-2	3-5	B
Peach	0-5	1-2	3-5	B
Pear, Asian	0-5	2-4	0-1	B
Pear, European	0-5	1-3	0-3	A
Persimmon	0-5	3-5	5-8	B
Plum and prune	0-5	1-2	0-5	B
Raspberry and other cane berries	0-5	5-10	15-20	A
Strawberry	0-5	5-10	15-20	A
Nuts and dried fruits	0-25	0-1	0-100	A
Subtropical and tropical fruits				
Avocado	5-13	2-5	3-10	B
Banana	12-15	2-5	2-5	A
Grapefruit	10-15	3-10	5-10	C
Lemon	10-15	5-10	0-10	B
Lime	10-15	5-10	0-10	B
Olive	5-10	2-3	0-1	C
Orange	5-10	5-10	0-5	C
Mango	10-15	3-5	5-10	C
Papaya	10-15	3-5	5-10	C
Pinneaple	8-13	2-5	5-10	C

*A=Excellent; B=Good; C=Fair; D=Without benefit
Source: Aharoni (2004a)

Table 5: MA/CA potential for benefit for fresh vegetables

Commodity	Temperature range (°C)	MA/CA		Potential for benefit
		$\%O_2$	$\%CO_2$	(*)
Artichokes	0-5	2-3	2-3	B
Asparagus	0-5	Air	5-10	A
Beans, snap	5-10	2-3	4-7	C
Beets	0-5	None	None	D
Broccoli	0-5	1-2	5-10	A
Brussels sprouts	0-5	1-2	5-7	B
Cabbage	0-5	2-3	3-6	A
Cantaloupes	3-7	3-5	10-15	B
Carrots	0-5	None	None	D
Cauliflower	0-5	2-3	2-5	C
Celery	0-5	1-1	0-5	B
Corn, sweet	0-5	2-4	5-10	B
Cucumbers	8-12	3-5	0	C
Honeydews	10-12	3-5	0	C
Leeks	0-5	1-2	3-5	B
Lettuce	0-5	1-3	0	B
Mushrooms	0-5	Air	10-15	C
Okra	8-12	3-5	0	C
Onions, dry	0-5	1-2	0-5	B
Onions, green	0-5	1-2	10-20	C
Peppers, bell	8-12	3-5	0	C
Peppers, chili	8-12	3-5	0	C
Potatoes	4-12	None	None	D
Radish	0-5	None	None	D
Spinach	0-5	Air	10-20	B
Tomatoes:				
Mature-green	12-20	3-5	0-3	B
Partially ripe	8-12	3-5	0-5	B

*A=Excellent; B=Good; C=Fair; D=Without benefit

Source: Aharoni (2004a)

Table 6: Atmosphere efficacy for fresh-cut vegetables

Fresh-cut Product	Temperature (^oC)	Atmosphere %O_2	Atmosphere %CO_2	Efficacy
Beets (Red), Grated, Cubed, or Peeled	0-5	5	5	Moderate
Broccoli, Florets	0-5	2-3	6-7	Good
Cabbage, Shredded	0-5	5-7.5	15	Good
Cabbage (Chinese), Shredded	0-5	5	5	Moderate
Carrots, Shredded, Sticks, or Sliced	0-5	2-5	15-20	Good
Leek, Sliced	0-5	5	5	Moderate
Lettuce (Butterhead), Chopped	0-5	1-3	5-10	Moderate
Lettuce (Green Leaf), Chopped	0-5	0.5-3	5-10	Good
Lettuce (Iceberg), Chopped or Shredded	0-5	0.5-3	10-15	Good
Lettuce (Red Leaf), Chopped	0-5	0.5-3	5-10	Good
Lettuce (Romaine), Chopped	0-5	0.5-3	5-10	Good
Mushrooms, Sliced	0-5	3	10	Not Recommended
Onion, Sliced or Diced	0-5	2-5	10-15	Good
Peppers, Diced	0-5	3	5-10	Moderate
Potato, Sliced or Whole-Peeled	0-5	1-3	6-9	Good
Rutabaga, Sliced	0-5	5	5	Moderate
Spinach, Cleaned	0-5	0.8-3	8-10	Moderate
Tomato, Sliced	0-5	3	3	Moderate
Zucchini, Sliced	0-5	0.25-1	-	Moderate

Source: Rodov (2004)

Table 7: Atmosphere efficacy for fresh-cut fruits

Fresh-cut Product	Temperature (^oC)	Atmosphere %O_2	Atmosphere %CO_2	Efficacy
Apple, Sliced	0-5	<1	-	Moderate
Cantaloupe, Cubed	0-5	3-5	6-15	Good
Honeydew, Cubed	0-5	2	10	Good
Kiwifruit, Sliced	0-5	2-4	5-10	Good
Orange, Sliced	0-5	14-21	7-10	Moderate
Peach, Sliced	0	1-2	5-12	Poor
Pear, Sliced	0-5	0.5	<10	Poor
Persimmon, Sliced	0-5	2	12	Poor
Pomegranate, Arils	0-5	-	15-20	Good
Strawberry, Sliced	0-5	1-2	5-10	Good

Source: Rodov (2004)

6. CONCLUSIONS

The paper concludes as follows:

- MAP and related technology can be selectively used in postharvest handling of fresh fruits and vegetables with good results
- There is need for commercial application of the technology by processors and fresh produce retailers
- There is need for MAP and related technology research for local crops under local conditions in developing countries

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