EFFECTS OF ETHYLENE ON HORTICULTURAL COMMODITIES DURING POSTHARVEST HANDLING

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Ethylene gas is a natural senescence hormone which is produced by horticultural commodities at varying rates. A classification of fruits and vegetables according to their ethylene production rates is shown in Table 1. Most ornamental commodities produce ethylene at very low rates. Generally, ethylene production rates increase with maturity at harvest, physical injuries (cutting, scratching, bruising, etc.), disease incidence, increased temperatures up to about 86°F (30°C), and water stress (resulting from low relative humidity). On the other hand, ethylene production rates by fresh produce are reduced by storage at the lowest safe temperature and by low oxygen (less than 8%) and/or elevated carbon dioxide (more than 2%) levels around the commodity.

Another important source of ethylene is from air pollution due to burning of coal, oil, or natural gas in industrial uses; refuse burning; operation of internal combustion engines (motor vehicles, fork lifts, etc.); decomposing plant materials; cigarette smoke; fluorescent lamp ballasts; etc.

Ethylene is physiologically active at extremely low concentrations, e.g., 0.1 ppm, and its effects on horticultural commodities can be desirable or undesirable. Thus, handlers of fresh fruits, vegetables, and ornamentals should be aware of ethylene effects on these commodities in order to minimize its potential harmful effects and to utilize its potential benefits.

Beneficial Effects of Ethylene

Ethylene can be used to promote faster and more uniform ripening of fruits picked at the mature-green stage. Faster ripening can mean reduced time between harvest and consumption of fruits resulting in better flavor and nutritional quality for the consumer. Commodities which can benefit from ethylene application, in terms of faster and more uniform ripening, include avocado, banana, mango, nectarine, papaya, peach, pear, persimmon, plum, tomato, casaba melon, crenshaw melon, honeydew melon, and orange-flesh honeydew melon. Ethylene is effective only if applied before the fruits have begun to ripen and produce enough ethylene of their own to initiate the ripening processes.

Ethylene can also be utilized to degreen mature citrus fruits (grapefruit, lemon, lime, orange, tangerine). Degreening means loss of green color as a result of accelerated chlorophyll degradation without the other changes associated with ripening such as softening, increased sweetness, decreased acidity, formation of aroma volatiles, etc. Exposure of seed potato tubers and some flowering bulbs to ethylene at 2 to 10 ppm stimulates their sprouting before planting to ensure faster emergence and a more uniform stand in the field.

Commercial Application of Ethylene

Ethylene treatments can be applied at shipping point, at destination markets or distribution centers,

or even at retail stores. When applied at origin or at destination markets, ethylene treatments are generally done in large temperature-controlled rooms equipped with a system for ethylene addition and circulation. At the retail markets, ethylene treatment can be applied in special temperature-controlled cabinets or by placing the fruits under a plastic tarp or in a covered pallet bin kept in a room maintained at temperatures between 59 and 77°F (15 and 25°C).

Ethylene concentrations recommended for degreening citrus fruits are 1 to 10 parts per million (ppm) while 10 to 100 ppm are needed for ripening. The duration of exposure to ethylene ranges between 1 and 5 days, depending upon fruit maturity at harvest; more mature fruits require shorter durations. A 2-day ethylene treatment is adequate for most fruits. The optimum temperature range for ripening is 59 to 77°F (15 to 25°C) and within this range, the higher the temperature the faster the ripening. Relative humidity should be maintained between 90 and 95%. Adequate air circulation within the room is important to ensure uniform distribution of ethylene. One method to achieve this is by forcing the ethylene-containing air through the fruit boxes. It is also important to avoid accumulation of carbon dioxide (produced by the commodity through respiration) in the ripening room since carbon dioxide counteracts ethylene effects. This can be done by periodic air exchange, i.e., introduction of fresh air into the ripening or degreening rooms. Also, hydrated lime can be used to absorb carbon dioxide.

Methods of ethylene application include the following:

1. Addition of measured quantities of ethylene from gas cylinders as daily short applications or in a continuous flow system. Since *ethylene gas is flammable and explosive at concentrations above 3.1% (31,000 ppm)*, it is safer to use ethylene diluted with an inert gas such as nitrogen. An example of diluted ethylene is the "Banana gas" available commercially.
2. Use of catalytic ethylene generators which involve heating a liquid to produce about 10 to 100 ppm ethylene continuously for up to 24 hours. The number and location of these generators within a ripening room depend upon room size and desired treatment duration.
3. Use of ethephon solution which releases ethylene upon changing the pH to the alkaline side and circulating the produced ethylene within the ripening room.
4. Direct application of ethephon to the commodity by spraying or dipping. This treatment is not yet

TABLE 1

Classification of fruits and vegetables according to their sensitivity to chilling injury and ethylene production rates[1] at optimum handling temperatures

Relative ethylene production rate (microliters per kilogram per hr.)	Commodities	
	Non-chilling sensitive	Chilling-sensitive
Very low (less than 0.1)	Artichoke, asparagus, beets, cabbage, carrot, cauliflower, celery, cherry, garlic, grape, leeks, lettuce, onion, parsley, parsnip, peas, radish, spinach, strawberry, sweet corn, turnip	Ginger, grapefruit, lemon, lime, melons (casaba, Juan canary), orange, pomegranate, potato, snap beans, sweet potato, tangerine, taro (dasheen)
Low (0.1 to 1.0)	Blackberry, blueberry, broccoli, Brussels sprouts, endive, escarole, green onions, kiwifruits (unripe), mushrooms, persimmon (Hachiya), raspberry, tamarillo	Cranberry, cucumber, eggplant, okra, olive, peppers (sweet and chili), persimmon (Fuyu, pineapple, pumpkins, summer squash, watermelon
Moderate (1.0 to 10)	Figs	Banana, guava, lychee, mango, melons (cantaloupe, crenshaw, honey dew, Persian), plantain, tomato
High (10 to 100)	Apples, apricot, kiwifruit (ripe), nectarine, peach, pear, plum	Avocado, feijoa, papaya
Very High (above 100)		Cherimoya, mammee apple, passion fruit, sapote

[1]Ethylene production rate by fruits and fruit-vegetables is greatest as they approach the eating-ripe stage.

approved for postharvest application but it can be used as a preharvest spray on tomatoes.

5. Use of ripening fruits which are high to very high ethylene producers (Table 1) as a source of ethylene. This method is practical only for small-scale ripening such as at retail markets and at home where the consumer can ripen mature-green fruits by placing them with ripe fruits into a paper bag or a ripening bowl.

Harmful Effects of Ethylene

Accelerated softening and ripening of fruits during transport and storage when not desired result in shorter postharvest life and faster deterioration. For example, the presence of ethylene in cold storage facilities of apples, kiwifruits, and avocados kept in air or in controlled atmospheres can significantly hasten softening and reduce storage-life of these fruits.

There are many examples of the detrimental effects of ethylene on vegetables (Table 2) and ornamentals (Table 3). The incidence and severity of ethylene damage depend upon its concentration, duration of exposure, and storage temperature.

TABLE 2

Examples of detrimental effects of ethylene on postharvest quality of vegetables

Commodity	Symptoms of Ethylene Injury
Asparagus	Increase toughness of spears
Beans, Snap	Loss of green color (yellowing)
Broccoli	Yellowing, abscission of florets, development of off-flavors
Cabbage and Chinese Cabbage	Yellowing and abscission of leaves
Carrots	Development of bitter flavor
Cauliflower	Leaf abscission and yellowing, brown discoloration of remaining portions of leaves
Cucumber and Summer Squash	Accelerated softening, yellowing
Eggplant	Calyx abscission, browning of pulp and seeds, accelerated decay
Lettuce	Russet spotting
Potato	Sprouting
Sweet Potato	Brown discoloration and off-flavor detectable upon cooking
Turnip	Increased toughness
Watermelon	Reduced firmness, flesh tissue maceration resulting in thinner rind, poor flavor

Procedures for Reducing Ethylene Damage

Ethylene damage can be greatly reduced by holding the commodity at its lowest safe temperature and by keeping it under modified or controlled atmospheres (reduced oxygen and/or elevated carbon dioxide). Under such conditions, both ethylene production by the commodity and ethylene action on the commodity are significantly reduced.

Avoiding exposure of the commodity to ethylene can be accomplished by one or more of the following procedures:

1. Exclusion of ethylene from storage rooms and transport vehicles:

a. Use of electric fork-lifts.

b. Avoiding mixing ethylene-producing commodities (those listed in classes moderate to very high in Table 1) with those which are sensitive to ethylene.

2. Removal of ethylene from storage rooms and transport vehicles:

a. Use of adequate air exchange (ventilation), e.g., one air change per hour provided that outside air is not polluted with ethylene.

b. Use of ethylene absorbers such as potassium permanganate. It is essential for the air within the room or transit vehicle to be circulated past the absorber for effective ethylene removal. It is also very important to replace the used absorbing material with a fresh supply as needed.

TABLE 3

Examples of detrimental effects of ethylene on ornamentals and nursery stock

Commodity	Symptoms of ethylene injury
Cut Flowers[1]	Failure to open of flowers cut at the bud stage, closure of open flowers ("sleepiness")
Flowering Plants	Flower abscission, flower closure (wilting)
Foliage Plants	Abscission of leaves, leaf chlorosis, epinastic responses (downward curvature of leaves)
Flowering Bulbs	Inhibition of shoot and root elongation, formation of abnormal flowers, induction of gummosis in tulips, flower-bud abscission in lily.
Geranium seedlings	Development of chlorosis on leaves, poor growth after planting
Dormant nursery stock	Reduced budbreak, greater mortality after planting

[1] Sensitivity of cut flowers to ethylene varies greatly with carnation being one of the most sensitive.