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Pineapple: Postharvest Quality-Maintenance Guidelines

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Pineapple is a terrestrial member of the diverse family *Bromeliaceae*. The pineapple fruit has the distinction of having been selected, developed, and domesticated by peoples in tropical America in prehistoric times (Collins 1968). Of the many pineapple cultivars, 'Smooth Cayenne' is the major commercial cultivar. Other cultivars that are grown on a smaller scale include 'Red Spanish', 'Queen,' 'Pernambuco', 'Sugarloafs', and 'Cabaiani'. Low-acid 'Smooth Cayenne' varieties are also available (Paull and Duarte 2011).

Pineapple, *Ananas comosus* L. Merr.

Quality Characteristics and Criteria

Pineapple fruit must have a desirable size and shape, with flat "eyes" (individual fruitlets) and crown leaves that look fresh and are deep green. High shell color is not always a good measure of sweetness. Negative characteristics include dry, brown crown leaves; dull, yellow skin appearance; presence of mold on the surface or cut stem; and fruit having an unfirm feel.

Horticultural Maturity Indices

Pineapple fruit maturity is evaluated on the extent of fruit "eye" flatness and skin yellowing. Consumers similarly judge fruit quality by skin color and aroma. A minimum of 12% SSC is required for fresh fruit in Hawai'i (Anon. 1968). A sugar-to-acid ratio of 0.9 to 1.3 is recommended (Soler 1992a). Fruit do not continue to ripen or sweeten after harvest. Fully ripe, yellow fruit are unsuitable for transporting to distant markets, so slightly less mature fruit are selected for this purpose (Akamine 1963, Cancel 1974). Immature fruit should not be shipped, since they do not develop good flavor, have low brix, and are more prone to chilling injury (Rohrbach and Paull 1982 ; Paull and Chen 2003).

Grades, Sizes, and Packaging

Pineapples are graded by degree of skin coloration, size (weight), absence of defects and disease, and uniformity of these characteristics before packing. Other characteristics include maturity, firmness, nice shape, flat eyes, well-cured broken stem (peduncle), and, in Hawai'i, a minimum SSC of 12% (Anon. 1968). Crown size is a crucial grade component, with a minimum size, and ratio of crown : fruit length (0.33 to 1.5) for higher grades. Crowns developed during the summer in Hawai'i tend to be larger and may require gouging (removal of the crown center) at harvest

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to meet the standard.

Pineapples are normally packed into cartons of two different sizes and on the basis of color and size: 1) a large telescoping fiberboard carton holding 18 kg (40 lb) and containing 8 to 10 fruit in two layers, flat or upright, for surface and air shipment; and 2) a smaller container of 9 kg (20 lb) with five to six fruit in a single layer laid flat for air shipping. Tourist packs of two to four fruit are also prepared. Absorbent pads are used at the bottom of the carton and between layers, if fruit are placed horizontally within the carton. In other packs, fruit are placed vertically (Paull and Chen 2003).

Pre-Cooling Conditions

Room-cooling or forced-air cooling should be used.

Optimum Storage Conditions

Temperatures of 7 to 12°C (45 to 55°F) are recommended for storage of pineapples for 14 to 20 days, provided fruit are at the color break stage (Paull 1993). A relative humidity of 85 to 95% is recommended; a high relative humidity significantly reduces water loss. Ripe fruit can be held at 7.2°C (45°F) for about 7 to 10 days. Pineapple may be stored at 0 to 4°C (32 to 39°F) for weeks, but upon removal, fruit fail to continue ripening and show severe chilling injury. Quarter-yellow fruit at harvest gain about one additional week of storage for every 6°C (11°F) decrease in storage temperature (Dull 1971). The maximum storage-life at 7°C (45°F) is about 4 weeks (Paull and Rohrbach 1985). However, when removed, chilling injury-induced internal browning develops within 2 to 3 days.

Controlled Atmospheres (CA) Consideration

Modified O_2 levels have shown only minimal effectiveness at extending pineapple shelf-life (Akamine and Goo 1971, Dull et al. 1967). Some beneficial effect is gained from CA (4% O_2) treatments in reducing chilling injury development (Paull and Rohrbach 1982). The fruit waxes currently used generate high internal concentrations of CO_2 (up to 5%) and reduced O_2 (Paull and Rohrbach 1982). Low O_2 has no effect on crown condition or decay but does delay shell color development and reduce superficial mold growth (Akamine and Goo 1971). Subjecting fruit to 1 to 2% O_2 + 0 to 10% CO_2 after shipment from Mexico to England at 8 °C did delay chilling injury (Haruenkit and Thompson 1994). Polyethylene bagging, though difficult to perform commercially on individual fruit, results in atmospheres of 8 to 10% O_2 + 7% CO_2, and fruit waxing delays appearance of chilling-induced internal browning (Abdullah et al. 1985, Paull and Rohrbach 1982, Rohrbach and Paull 1982). The tentative recommendation is 2 to 5% + 5 to 10% CO_2 (Yahia 1998).

Retail Outlet Display Considerations

Whole fruit should be displayed refrigerated at 10 to 13°C (50 to 55°F). Do not mist or ice.

Chilling Sensitivity

Symptoms of chilling injury include wilting, drying, and discoloration of crown leaves; failure of green-shelled fruit to yellow; browning and dulling of yellow fruit; and internal flesh browning (Lim 1985, Paull and Rohrbach 1985). Pre-harvest shading, as well as pre-harvest and postharvest low temperature, are the major factors increasing symptom intensity (Akamine et al. 1975, Akamine 1976, Keetch and Balldorf 1979, Smith 1983). Chilling injury symptoms include endogenous brown spot, physiological breakdown, blackheart, and internal browning, and they develop after fruit are returned to physiological temperatures of 15 to 30°C (59 to 86°F) (Paull and Rohrbach 1985). Susceptible fruit are generally lower in ascorbic acid and sugar content and are opaque (Abdullah and Rohaya 1983, Abdullah et al. 1985, Paull and Rohrbach 1985, Swete Kelly and Bragshaw 1993).

Ethylene Production and Sensitivity

The ethylene production rate of this non-climacteric fruit is low at 0.1 to 1.0 µL kg-1 h-1. Postharvest use of ethephon to degreen the shell has been tested in the Ivory Coast (Crochon et al. 1981, Poignant 1971), Hawai‘i (Paull 1985, unpublished data), and Australia (Smith 1991).

Treated fruit show more rapid and uniform skin degreening and little change in quality. However, shelf-life is slightly shortened (Paull 1985, unpublished; Smith 1991; Soler 1992b). There is no recommendation for use of ethephon; it is not approved for postharvest use.

Respiration Rates

Respiration rates for various temperatures are shown in Table 1. To get $mLkg^{-1}\ h^{-1}$, divide the $mg\ kg^{-1}\ h^{-1}$ rate by 2.0 at 0°C (32°F), 1.9 at 10°C (50°F), and 1.8 at 20°C

Table 1. Respiration Rates for Pineapple

Respiration Rate	
Temperature	mg CO_2/$kg^{-1}h^{-1}$
5°C	2
10°C	4 to 7
15°C	10 to 16
20°C	19 to 29

(68°F). To calculate heat production, multiply mg kg^{-1} h^{-1} by 220 to get BTU per ton per day or by 61 to get kcal per metric ton per day.

Physiological Disorders

Flesh translucency, also called porosity, is associated with greater fruit sensitivity to mechanical injury, indicated by leakage and oozing of cellular fluids. This condition begins before harvest and continues after harvest (Bowden 1969, Rohrbach and Paull 1982, Paull and Reyes 1996). Fruit with increased translucency also have increased pH, a higher SSC/acid ratio, higher fruit weight, higher total esters, and lower acidity. SSC, flesh pigments, and palatability increase to a maximum at about 60% translucency, then decline in fruit with higher translucency (Bowden 1969). A related disorder leads to green-shelled ripe fruit having full translucency.

Bruising, due to impact damage, is a major problem during harvesting, packing, and shipping of pineapple (Singleton 1958). This injury is normally confined to the impact side of the fruit, and the damaged flesh appears slightly straw-colored (Keetch 1978). Mechanical injury of translucent fruit can lead to leakage of cell contents and loss of marketability. Injury can be avoided by careful handling and avoiding impacts and bruising.

Sunburned or sun-scorched pineapples show a bleached, yellow-white skin that turns pale gray/brown with damage to the flesh underneath. Damaged areas are more susceptible to disease. Sunburn is common during hot periods, ie., > 35°C (95°F), of the year (Keetch and Balldorf 1979).

Malformations, or pineapple fruit with pronounced eyes or fruitlets, are normally not acceptable in Fancy grades of fruit, and the thicker skin results in lower flesh recovery. This condition is common in fruit that flower during cool weather. Some Spanish varieties are susceptible to broken core, in which the central core has a transverse break leading to the upper part of the fruit ripening ahead of the bottom (Lim 1985).

Black rot (top), pineapple translucency (bottom).

Postharvest Pathology

Black rot, also called Thielaviopsis fruit rot, water blister, soft rot, or water rot, is a universal fresh pineapple problem characterized by a soft watery rot (Rohrbach 1983). Diseased tissue turns dark in the later stages of the disease because of the dark mycelium and spores. Black rot is caused by the fungus *Chalara paradoxa* (De Seynes) Sacc. 'Red Spanish' types are more resistant than 'Smooth Cayenne'. Infection occurs within 8 to 12 hours following harvest and enters through the point of detachment or wounds. The severity of the problem is dependent on the degree of bruising or wounding during harvesting and packing, the level of inoculum on the fruit, and storage temperature during transportation and marketing (Rohrbach and Schmitt 1994). The rot is commercially controlled by minimizing bruising of fruit during harvest and handling, refrigeration, and postharvest fungicides (Rohrbach and Phillips 1990).

Fruitlet core rot, black spot, fruitlet brown rot, and eye rot all refer to the brown to black color of the central part of an individual fruitlet. Epidemic levels are rare in the major commercial pineapple-producing areas of the world (Rohrbach and Schmitt 1994). Low-acid cultivars being grown commercially are most susceptible (Rohrbach and Schmitt 1994). This disease is caused by a complex of fungi (Rohrbach and Schmitt 1994). Infection frequently can lead to misshapen fruit that are culled before packing and shipping.

Yeasty fermentation arises due to the fact that fruit are not sterile inside, containing many non-growing but viable yeasts and bacteria. In damaged, overripe fruit and fruit with inter-fruitlet cracking, resident yeasts begin to grow, or new yeasts invade. This growth leads to fermentation and bubbles of gas and juice through cracks in the skin. The skin turns brown and leathery, and fruit become spongy with bright yellow flesh.

Saprophytes growing on the broken end of the peduncle (*Penicillium* sp.) and fruit surface are nonpathogenic but are unsightly, and therefore a marketing problem (Rohrbach 1989). The condition is more common on highly translucent fruit.

Quarantine Issues

Pineapple fruit that are more than 50% ‘Smooth Cayenne’ are not regarded a host for tephritid fruit flies. Thus, insect disinfestation is not required for import into fly-free countries (Armstrong 1994).

Pineapple caterpillars (*Thecla basilides* Geyer, *Metamasius ritchiei* Marchall, *Batrachedre methesoni* Busch, *Paradiophorus crenatus* Billbarg) are exotic and limited to Central America, South America, and the Caribbean (Harris 1927, Rohrbach 1983). The adult oviposits on the inflorescence prior to anthesis. Larvae then infest fleshy parts of the bracts and feed inside the developing inflorescence, exuding gum from the feeding chambers. Control with insecticides is relatively easy if flowering is induced uniformly with forcing agents. *T. basilides* is a tropical species that could cause problems if imported into Southern states such as Florida, as it can feed on corn, cacao, Heliconia, and several other bromeliads (Rohrbach 1983).

The pineapple scale, *Diaspis bromeliea* Kerner, occurs wherever pineapple is grown. Normally in Hawai‘i, pineapple scale is not a major problem in fields, probably because of scale parasites and predators. However, because of the quarantine requirement that fruit be insect free, even low levels of pineapple scale at harvest present quarantine problems. Scale are controlled by pre-harvest insecticide applications, taking into account “last-application-to-harvest” time.

The pineapple fruit mite, *Steneotarsonemus ananas* Tryon, occurs universally on the growing plant, developing inflorescence, fruit, and crown. Fruit mites feed on developing trichomes on the white basal leaf tissue and flower bracts and sepals, causing light brown necrotic areas. The pineapple red mite, *Dolichotetranychus floridanus* Banks, feeds on the white basal leaf tissue, particularly of the crown. Severe damage occurs when the fruit mature under drought conditions. Red mites may cause death of basal crown leaves, affecting quality (Rohrbach and Schmitt 1994).

Mealy bugs are removed from the surface by brushing. Pre-harvest insecticide and ant control almost eliminate mealy bugs (Soler 1992a). Crickets/locusts may feed on bracts before harvest.

Suitability as Fresh-Cut Product

Fresh-cut pineapple is readily prepared at a central plant or in-store as a ready-to-use consumer pack. Packs contain fresh-cut cylinders with the core removed, spears, chunks, or wedges. The product has a shelf-life of at least 7 days at proper temperature. A patent has been issued for the use of pouches flushed with 15 to 20% O_2 + 3% argon and held at 1°C (34°F) for 10 weeks (Powrie et al. 1990) for fresh-cut pineapple pieces.

Special Considerations

Ease of removal of crown leaves, full skin yellowing, or the sound produced by tapping the fruit are not signs of ripeness or quality. Fruit are picked at the ripe stage and are ready to eat, even if there is a little skin yellowing.

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