favourable gas composition for maintaining the commercial and sanitary qualities of the fruits and vegetables concerned. This determination requires storage under controlled atmosphere and the results depend on the weighting of the different deterioration processes. Finally, a mathematical model is used to calculate the optimum permeabilities of the film to be used under the storage conditions entered in the model. Various software is used to simulate storage (the evolution of atmospheres) using the films available on the market and that display permeabilities similar to those previously calculated. At this stage, the functioning of the system can be verified by simulating the thermal profile of a realistic commercial channel.

Finally, it is essential to verify these theoretical results by experimental work as no model is yet capable of forecasting all the types of deterioration possible ■

New coating formulations for the conservation of tropical fruits

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Many storage techniques have been developed over the years to extend the storage life of fruits and vegetables. This helps to expand marketing distances from growing areas. Unfortunately, 25 to 80% of harvested fresh produce are lost due to spoilage each year, with losses being higher in tropical regions. One simple technology to extend the storage life of fruits and vegetables is through the use of edible coatings.

Tropical fruits and vegetables present a special problem in that they are chilling sensitive. Therefore, low temperature cannot be used effectively to extend storage life as, for example, can be done for apples. Often these commodities are shipped long distances to customers in temperate zones by air resulting in higher prices for consumers. Shipment by sea would be desirable, but not currently possible due to the rapid ripening and deterioration of these products

Fruits and vegetables can be classified as climacteric or non-climacteric. Climacteric fruit continue to ripen after harvest, whereas non-climacteric do not. Ripening is a process that includes development of color, flavor and texture (softening). Many important tropical fruits are climacteric, such as banana, mango, papaya, avocado, and guava. These fruit ripen rapidly during transit and storage, thus often requiring rapid shipment by air. There is an opportunity with climacteric fruit, however, to slow down ripening after harvest and, thus, extend the shelf life. This can be done with controlled atmosphere (CA) storage, modified atmosphere packaging (MAP), or with edible coatings. In all cases the atmosphere created is that of relatively low oxygen (O_2) and high carbon dioxide (CO_2) compared to standard atmosphere. The low O_2 and high CO_2 depress ethylene production which is required to turn on ripening genes that effect color changes, aroma and degredation of cell walls that results in softening.

Edible coatings can create a modified atmosphere, similar to that of MAP, which is a function of coating permeability and fruit respiration. In both cases, temperature control is very important since it can affect the rate of fruit respiration. Higher temperatures increase, and lower temperatures decrease fruit respiration rates. Coatings or MAP designed for ideal storage temperatures can cause anerobic respiration, subsequent off-flavor, and fruit deterioration at abusive storage temperatures. Nevertheless, if used properly, edible coatings can delay ripening of climacteric fruit, delay color changes in non-climacteric fruit, reduce water loss, reduce decay, and improve appearance.

Coatings can be formulated from different materials including lipid, resins, polysaccharides, proteins, and synthetic polymers. In fact, most coatings are a composite of more than one film-former with the addition of low molecular weight molecules such as polyols, that serve as plastisizers. These compounds become interspersed among the polymer chains, spreading them apart which imparts more flexibility to the coating. Otherwise, coatings can be too brittle and will flake or crack on the coated product. Surfactants, antifoaming agents, and emulsifiers are also often used in coatings.

Lipid materials used in coatings are generally incorporated as waxes or oils. For waxes: carnauba, candelilla, and rice bran waxes are natural plant waxes; beeswax is also a natural product; and paraffin and polyethylene wax are petroleum-based products. For resins: shellac is a natural product from tree resin, wood rosin is a waste product of the lumber industry, and coumarone indene resin is a petroleum-based product. The latter two resins are only approved for citrus in the U.S., where the peel is not eaten. Lipids are excellent water barriers, but are relatively permeable to gases, and thus, not as useful to create a modified atmosphere to delay ripening. The resins are relatively good water vapor barriers, very shiny, but exhibit relatively low permeability to gases and, thus, can cause anerobic conditions in fruit if there is temperature abuse. Other resins include copal, damar and elimi which are only used in pharmaceuticals.

Carbohydrate materials include cellulose, starch, and pectin which come from plants; alginate, carrageenan, and furcellaran, which come from seaweed; and chitosan which is made from the exoskeleton of crustaceans. Gums including gum arabic, gum ghatti, gum karaya, and gum tragacanth are plant exudates; guar and locust bean gum are from seeds; and xanthan and gellan gum are products of microbial fermentation. Polysaccharides are not good barriers to water vapor, but exhibit moderately low permeability to gases and are useful to delay ripening of climacteric fruit.

Protein materials used in coatings include soy protein, corn protein (zein), casein and whey proteins from milk, wheat gluten and peanut protein. The wheat, milk and peanut proteins are potential allergens to a small portion of the population, which should be taken into consideration when formulating coatings. Zein can be used where high gloss is desired instead of shellac, and as a group, protein materials are similar to carbohydrates in their permeability to water and gases.

Some advantages to using coatings include reduction of water loss, retardation of ripening, reduction of chilling and mechanical injury, reduced decay, and added shine or gloss to the coated commodity. Coatings can also be used as carriers of useful ingredients such as antimicrobial compounds, color or aroma additives, anti-oxidants, or anti-ripening compounds.

Disadvantages to using coatings include creation of anaerobic conditions under abusive temperature conditions, alteration of flavor, undesirable texture (tackiness, slipperiness), discoloration of coating (problem with shellac and zein which whiten when in contact with water), and flaking or peeling.

Some coatings used on tropical fruits include mineral oil for limes, shellac on oranges, paraffin wax on yams and coconut, vegetable oil on papaya, carnauba (with or without added shellac) wax on various fruits, carbohydrate coatings (with or without sucrose esters) on various fruits, and shellac or zein protein on oranges. These coating are usually applied by dip, spray or saturated brushes.

Some examples for using coatings on tropical fruits include the delay of yellowing in lemons with a polysaccharide coating; delay of ripening in guava, mango and papaya with carnauba/shellac, zein, or polysaccharide coatings; addition of gloss and prevention of water loss for citrus with shellac or zein coatings.

In conclusion, coatings are a simple, environmentally friendly, and relatively inexpensive technology that can extend the shelf life of tropical fruits and vegetables provided there is good storage and shipping temperature controls. For best results, coating materials need to be tested and tailored for each commodity ■

New litchi conservation techniques

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France is the leading destination and consumer country for litchi with nearly 80% of the total for Europe. Madagascar is the leading world exporter with 16 000 tonnes, mainly exported by sea except at the beginning of the season when the fruits travel by air. Air freight is used for high quality fresh litchi (treated or untreated) from other origins (Réunion, Mauritius, etc.).

The poor keeping qualities of litchi handicap the development of exports. At ambient temperature, litchi loses its pink-red colour and browns very rapidly. This enzymatic browning is shown by cell disorganisation. The drying of the area close to the peduncle causes cracking resulting in cell degradation and the coming into contact of polyphenoloxydase (PPO) and phenolic compounds. Browning may also be related to non-enzymatic phenomena (Maillard reaction) enhanced by bacterial attacks or lesions caused by insects, heat, physiological stress and the presence of ethylene.

The control methods that can be envisaged are the maintaining of the moisture content of the fruit shell, the blocking of the enzymatic systems responsible for browning (by using an inhibitor) and the limiting of fungal and bacterial attacks. The method most widely used is the fumigation of fruits using sulphur dioxide (either SO_2 in gas form or produced by burning sulphur) a few hours after harvesting, prior to sea transport. SO_2 treatment of litchi is sometimes followed by soaking in an acid bath to restore the red colour of the fruits after the bleaching caused by sulphur treatment; this results in commercially attractive fruits. However, it should not be forgotten that the use of SO_2 is a risk to health, especially for people suffering from allergies. Today, SO_2 treatments have totally ceased in the United States, except for treating table grapes. French legislation authorises residue levels of 10 ppm in litchi pulp