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 and 250 ppm in shells. Alternatives to sulphur have been examined by various research teams, in particular in Israel and South Africa. The treatments proposed are based on various chemical or heat techniques:

- application of calcium nitrate to increase cell wall strength; this has does not significantly slow pericarp browning;
- steam treatment;
- soaking in hot benomyl.

None of these investigations has yet led to the devising of a treatment method that is acceptable or developed commercially.

As the trend is for the precautionary principle, it is very probable that these levels will be lowered or even that the use of SO_2 will no longer be permitted. In this context, it is particularly important to provide sector trade operators with a technique to replace fumigation. This is why we addressed the development of a conservation technique that would maintain litchi colour.

Litchi shipped by air

The creation of a modified atmosphere (MA) requires the use of a packaging film with the following purposes:

- creation of a packing volume of MA favourable for product conservation;
- limiting dehydration;
- preventing contamination;
- defining the sales unit;
- forming a support for communication.

The results expected are:

- prevention of fruit browning;
- reduction of mould growth;
- prevention of fermentation;
- ensuring that the produce is free of sulphur derivatives that are harmful for health.

The post-harvest physiology of litchi has been mastered and we can propose to sector operators packaging and conservation methods that make possible the sale in Europe of high-quality litchis—with regard to both the visual and organoleptic aspects—corresponding to specifications and times compatible with those of marketing.

The system functions as follows: plant respiration releases CO_2 into the dead space of the packaging and uses the oxygen in this volume. This modification of the atmosphere creates a difference in partial pressure between the inside and the outside of the system. This causes gas diffusion phenomena between the inside and outside of the packaging. Atmospheric oxygen tends to enter and CO_2 tends to be released. This is a dynamic system that can stabilise at a recommended gas balance.

This balance depends in particular on:

- the respiratory intensity of the produce, the quantity packaged and the storage temperature;
- the film permeability and the exchange surface.

Mastery of an MA involves the control of these parameters.

Some results demonstrate the influence of storage temperature on litchi respiration and hence on the maintaining of the gas balance under modified atmosphere. Apart from these considerations, the results also show that it is important to maintain the cold chain during conservation, even without using MA. Indeed, it is seen that the respiratory intensity of the fruits can increase five-fold when the temperature is raised from 2 to 22°C. Our first trials consisted of defining the best atmosphere that can be used to lengthen colour maintenance in litchi while conserving the organoleptic qualities and, of course, preventing any fermentation. The trials concerned five known atmospheres maintained in equilibrium by a sophisticated electronic system (at the INRA research station at Montfavet). In the light of the results, we tested plastic films that can recreate this atmosphere in a pack of litchis at a given temperature (after prior modelling of the system to refine the results). The films used were supplied by companies such as Atofina Bolloré or Danisco. The most convincing results to date were obtained with a micro-perforated film supplied by the Danisco company (material now known as Amcor Flexible Europe P+).

Litchi shipped by sea

We then addressed the development of treatments making it possible to avoid using sulphur. In the light of the literature and the research performed at the CIRAD-FLHOR technology laboratory, our research was directed towards treatments consisting of soaking the fruits in hot or cold acid baths.

Our first conclusions led us to favouring a cold treatment that would have the advantage of reducing handling risks if it were used at production. Finalisation of the trials is in progress because they must be transposed to real conditions. The tests show that the soaking and the procedure that we have developed maintain the red colour of the fruits without causing negative secondary effects and results in less marked drying of the fruits treated.

We are now studying the mechanism involved during this blocking of fruit colour. The tests are being continued until the coming litchi season (2001/2002) and will be the subject of a publication.

Conclusion

We have acquired substantial knowledge of the physiology and metabolism of litchi. The limits of the atmosphere that enables the length of the life of fruits have been determined.

A phase of transposition and validation of the techniques that we wish to develop is to be started for both 'air' and 'sea' litchi ■