Proceedings from Conference '97: Searching for Quality. Joint Meeting of the Australian Avocado Grower's Federation, Inc. and NZ Avocado Growers Association, Inc., 23-26 September 1997. J. G. Cutting (Ed.). Pages 46-54.

COATING TO ENHANCE FRUIT LIFE

Nigel H. Banks, Jason W. Johnston, Rosemary A. Watson, Anna M. Kingsley and Bruce R. MacKay
Department of Plant Science and Centre for Postharvest and Refrigeration Research, Massey University, Private Bag 11 222, Palmerston North, New Zealand

Keywords: avocado; carbon dioxide; gas exchange; internal atmosphere; optimisation; oxygen; permeance; *Persea americana,* polyethylene wax; respiration; surface coating; water loss; wax; weight loss

Abstract

Surface coatings can reduce weight loss and retard ripening and could therefore be valuable in developing more distant export markets for the New Zealand avocado industry. This programme is evaluating benefits and risks of waxing avocados.

Waxing reduced weight loss by up to 50%, depending upon coating type and concentration. Waxing depressed fruit internal oxygen and increased internal carbon dioxide, modestly with dilute coatings at 15°C but more dramatically with higher wax concentrations and storage temperatures. Coating could cause fermentation if transit, ripening or shelf-life temperatures were too high.

At 20°C, a good balance between reduced weight loss (benefit) and reduced internal O_2 (risk) was achieved by coating with 11% 'Avocado wax', relative to other concentrations investigated. At 10%, it slightly extended marketable life, an effect linked to lower incidence of anthracnose. However, even with this substantially diluted wax, there was an increased incidence of incomplete ripening (hard, unripe tissue within the flesh of the ripened fruit), particularly in fruit ripening at higher temperatures. Severity was linked to excessive internal atmosphere modification in coated fruit at high temperatures.

Overall, it appears that commercial wax formulations must be diluted substantially to avoid risks of excessive internal atmosphere modification in the coated fruit. Nevertheless, we believe that this simple technology could enhance market returns provided that its application and subsequent handling of the fruit are appropriately managed. Further characterisation of the interaction of initial fruit attributes, coating treatment and ripening environment should be used to optimise waxing for the New Zealand industry.

Introduction

Most of the New Zealand avocado *(Persea americana* Mill.) export crop is currently marketed in Australia. If the industry is to develop new markets to spread marketing risk, low cost technologies are required to transport fruit further while maintaining high quality. Sea-freight is likely to be used but may result in fruit having very limited residual storage and shelf-life once they reach their destination market.

Weight loss is one of the critical causes of loss of value in avocados. The fruit can lose 1% of its weight each day at 20°C, 60 % relative humidity, mostly through water loss. To compensate for weight loss associated with extended transportation and storage periods, packhouses would need to over-pack export trays, directly adding to costs of production. In addition, weight loss can hasten ripening (Joyce *et al.* 1995) and increase incidence of physiological disorders and disease (Bower *et al.* 1989; Cutting & Wolstenholme 1992). Surface coatings provide one way in which water loss can be reduced (Joyce *et al.* 1995; Banks, Cutting *et al.* 1997), along with other standard postharvest technologies (refrigeration, high relative humidity storage and tray liners).

Many observers have noted that surface coatings can slow down some of the processes associated with ripening. This happens because some coatings behave at the fruit surface like the plastic film of a modified atmosphere package, excluding oxygen necessary for deterioration and causing accumulation of carbon dioxide. In short, such films act as a barrier to oxygen and carbon dioxide transfer. This has led to some extravagant claims that such coatings could replace much more sophisticated techniques such as controlled atmosphere storage and the more widely used refrigerated storage in maintaining quality of harvested horticultural produce.

In this paper, we explore the potential to use surface coatings to reduce weight loss and slow ripening of avocados without adversely affecting other aspects of fruit quality. We outline the components of the balance that must be struck to achieve low rates of water loss without excessive risk of fermentation and adverse effects on fruit quality. We outline experimental approaches used to achieve this optimisation and review progress that has been made towards this goal in avocados.

Benefits

Reduced water loss

Some surface coatings are like the waxy natural fruit surface in that they are good barriers to water vapour. This reduces the rate at which water evaporates from the fruit surface and thereby slows loss of saleable weight. In many fruits, it can also delay loss of juiciness and the onset of visible shrivel, protecting produce from loss of value because of decline in quality. Tendency to lose water can be characterised by loss of fresh weight under standardised conditions.

Slowed ripening

In addition to being good barriers to water diffusion, surface coatings hinder exchange of other gases between the fruit and its environment (Banks, Cutting *et al.* 1997). This results in a reduction in permeance, a measure of how easily gases move through the fruit surface. The natural process of respiration in avocados is very rapid during ripening. Coupled with reduced skin permeance caused by coating, this modifies the atmosphere inside the fruit, lowering internal O_2 and increasing internal CO_2. Such modified internal atmospheres can slow ripening by direct effects on processes such as colour and textural change. Alternatively they may inhibit respiration, limiting availability of energy for deteriorative processes and conserving energy reserves of the tissue (Kader *et al.* 1989).

Benefits, in terms of reduced rate of ripening, are often achieved by the combined effects of both low O_2 and high CO_2. This concept is illustrated in Figure 1 which shows how colour change can be affected by levels of the two gases in apples. Similar relationships are likely to apply for other processes associated with ripening such as respiration and softening. Such studies have yet to be conducted with avocados but suppression of ripening by surface coatings would be achieved in a similar way by the modified atmospheres that develop within the coated fruit.

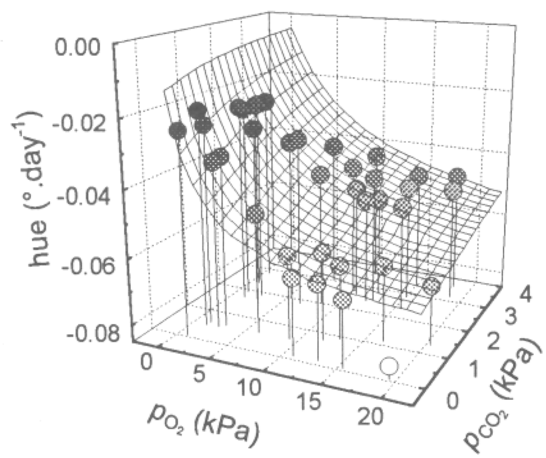

Figure 1 Variation in rate of loss of green colour (measured as change in 'hue angle') in 'Braeburn' apples stored at 0°C associated with storage in different levels of O_2 (p_{O_2}) and CO_2 (p_{CO_2})

Risks

Whilst slowing ripening may appear to be an attractive possibility, using coatings for this purpose is a high risk strategy. Unfortunately, when respiratory gas exchange through fruit skins is excessively impaired, off-odours and off-flavours may develop as fruit ferment (Hagenmaier & Shaw 1992; Banks, Cutting *et al.* 1997) and they may ripen unevenly (Meheriuk & Lau 1988; McGuire & Hallman 1995). This risk can be minimised through selection of coatings with appropriate permeability characteristics and careful management of storage and ripening temperatures.

Aside from the issue of avoiding physiological disorders, if different ripening processes differ in their dependency on levels of O_2 or CO_2 then the modified atmosphere developed within the fruit can differentially affect these processes. This can readily be seen when pears are overwaxed; the fruit may become soft whilst remaining green as colour change can be much more dramatically retarded than softening (Amarante *et al.* 1997). Such 'abnormal' ripening could be a serious consideration in the marketing of fruit in which ripening had been slowed by modified atmosphere techniques.

Optimisation

If final marketability of the fruit were solely dependent upon one process such as softening, deterioration in fruit quality would be minimised by eliminating O_2 from the fruit's internal atmosphere and by increasing CO_2 to high levels. However, as outlined above, such a strategy would have adverse effects on other aspects of fruit quality. Figure 2 shows a conceptual approach to optimising internal atmosphere composition analogous to a recently developed scheme for 'Braeburn' apples (Banks, Jeffery *et al.* 1997). In this case, the extent to which rates of softening and colour change can be minimised by low O_2 and high CO_2 must be tempered by the potential for generating disorders within the fruit when the internal atmosphere is excessively modified.

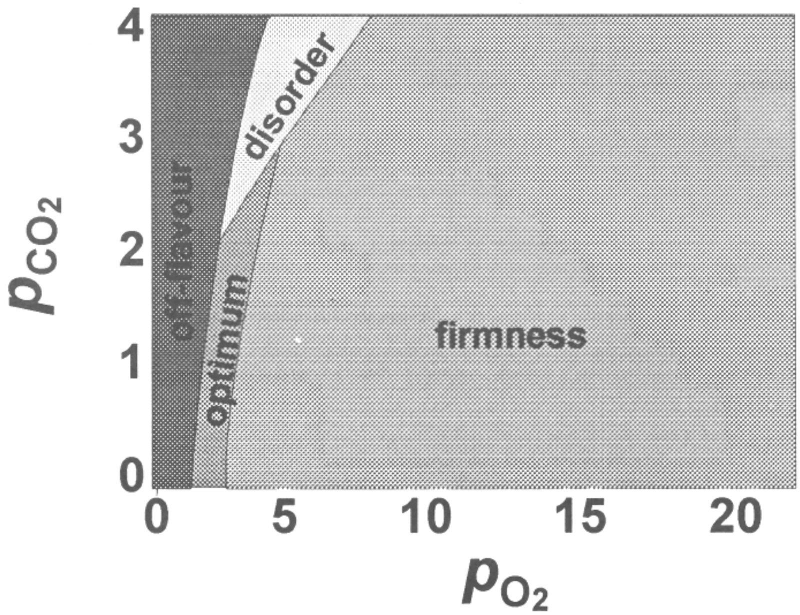

Figure 2 **Diagram to illustrate the concept of optimisation of controlled atmo phere composition with respect to O_2 (p_{O_2}) and CO_2 (p_{CO_2}) levels**

To achieve the maximum MA benefit from a surface coating treatment, modification of the internal atmosphere becomes close to that at which the fruit begins to ferment. In the case of MA benefits, there is no clear separation of benefits and risks as they are dependent upon the same mechanism: depression of O_2 and increase in CO_2 levels. At the current time, we believe that these problems make use of surface coatings to achieve MA benefits too risk-laden for deliberate commercial application. Thus, optimisation of waxing for avocados will involve achieving a safe balance between reduced water loss and avoidance of disorders associated with excessive internal atmosphere modification.

Tendency to lose water can be measured by loss of fresh weight under standardised conditions. The oxygen status of a fruit can be monitored by sampling internal gases through an insertion into the fruit tissues. With these data, a plot of reduction in water loss (desired benefit) against reduction in internal oxygen level (major risk) can be used to select and optimise coatings which achieve desired benefits with acceptable levels of risk (Banks, Cutting *et al.* 1997a).

Choice of coating material

Many different types of materials have been developed as surface coatings. Contemporary coatings include a collection of wax-type products which are generally good water vapour barriers and which add gloss to produce an attractive sheen or, when they do this to excess, shine. Growing consumer resistance to the idea of waxing has led to exploration of a wide range of alternatives which are viewed as being more natural. Polysaccharides such as the cellulose derivative carboxymethyl-cellulose (CMC; extracted from plant tissues) and chitosan (extracted from shells of some types of seafood) add gloss but provide little protection against water loss. Likewise, protein-based coatings such as the milk-protein casein and the wheat protein gluten have been widely experimented with in recent years. They form strong films but are also generally poor barriers to water loss. In this work, we have focused mainly on wax coatings.

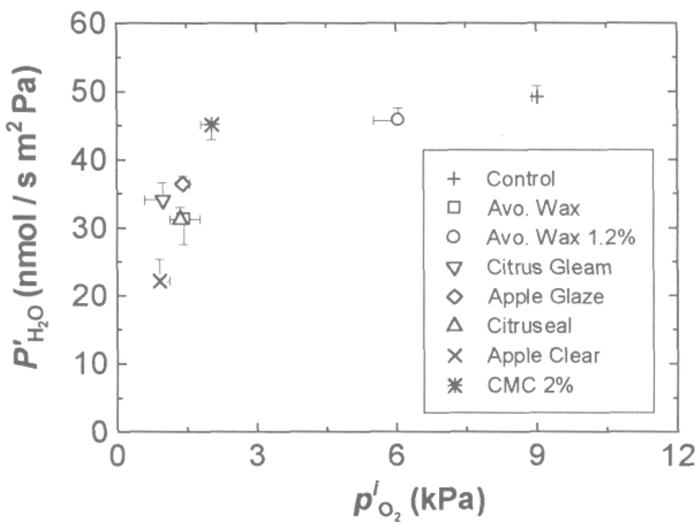

Figure 3 Effects of different surface coatings on skin permeance to water (P'_{H_2O} ; SED = 3.4 nmol / s • m^2 Pa) and internal O_2 level ($p^i_{O_2}$; SED = 0.4 kPa) of 'Hass' avocados at 20°C, 60% relative humidity

In 1996, use of full strength commercial formulations of wax coatings achieved between 30% and 50% reduction in rate of water loss on avocados from a single orchard (Figure 3). 'Apple Clear' coating had the greatest benefit but was cosmetically unacceptable and, in common with 'Citrus Gleam', resulted in very low internal O_2 (high risk). CMC and very dilute 'Avocado Wax' (in use in one commercial avocado packhouse) were rejected because they provided little benefit. The two materials that provided a large reduction in rate of water loss for a given reduction in internal O_2 were full strength Avocado Wax and 'Citruseal', both containing polyethylene-type waxes. This was consistent with work by Hagenmaier and Shaw (1992) which showed that the relative permeance of polyethylene-type waxes to O_2 and water made them more effective barriers to water loss of fruits than other fruit coating waxes. Avocado Wax (Castle Chemicals, Australia) was selected as the material for further work for its relatively good performance and because we knew it was already being used on avocados in New Zealand.

Optimization of wax concentration

With full strength Avocado wax, the absolute level of internal atmosphere modification in avocados at 20°C was too great to be considered optimal. Experiments with a dilution series of this material indicated that about 11% provided a good balance of reduced rate of water loss without excessive depression of internal CO_2 (Figure 4).

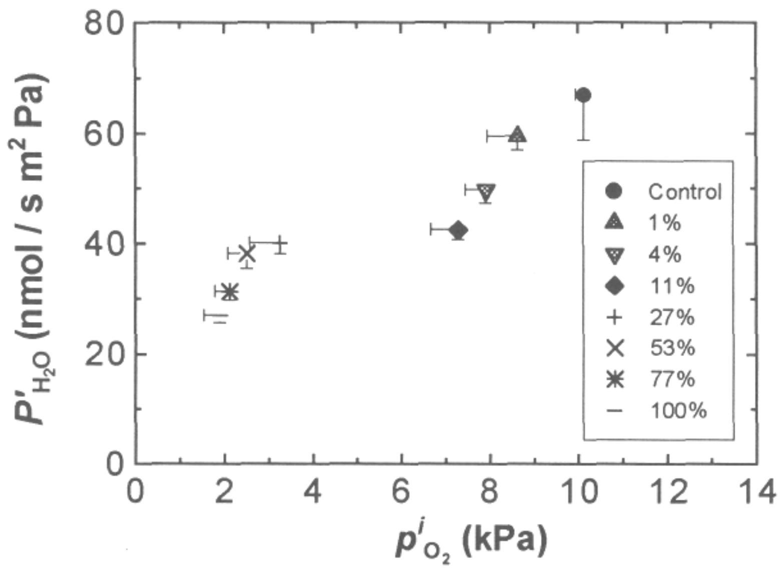

Figure 4 Effects of different 'Avocado Wax' concentrations on skin permeance to water (P'_{H_2O} ; SED = 3.4 nmol / s m^2 Pa) and internal O_2 level ($p^i_{O_2}$; SED = 0.7 kPa) of 'Hass' avocados at 20°C, 60% relative humidity

Verification of suitability of wax treatment

Disorder development is much more likely to occur in coated fruits kept at high than at low temperatures. In 1997, we have experimented with avocados from a greater range of sources using 10% Avocado wax and a more diverse range of ripening temperatures (15°C, 20°C and 25°C). Marketable life (time from receipt of fruit until they developed an unacceptable, externally-visible defect) declined at higher ripening temperatures but was slightly enhanced by coating (data not shown). This was associated with delayed onset of anthracnose rots in coated fruit (Figure 5), probably as a result of a slight delay in ripening (data not shown). These positive effects were countered by exacerbation of a ripening disorder in which a proportion of the flesh remained hard whilst the remainder of the flesh softened normally (Figure 6). The disorder was only present in control fruit at high ripening temperature. In waxed fruit, the disorder was present at all 3 temperatures but it was most severe at 25°C. We believe that this was the result of excessive internal atmosphere modification in the coated fruit at the high temperature; an effect linked to elevated respiration rate of fruit at high temperatures and, particularly, to high internal CO_2 levels (data not shown). We have recently characterised and explained similar effects on gas exchange in apples in which O_2 is reduced and CO_2 is increased more by waxing in fruit kept at high rather than low temperatures (Banks, Cheng *et al.* 1997). For waxing to be used with confidence on avocados, excessively high temperatures would need to be avoided during ripening of the fruit. This would presumably be easier to achieve at some times of year, and in some destination markets, than in others.

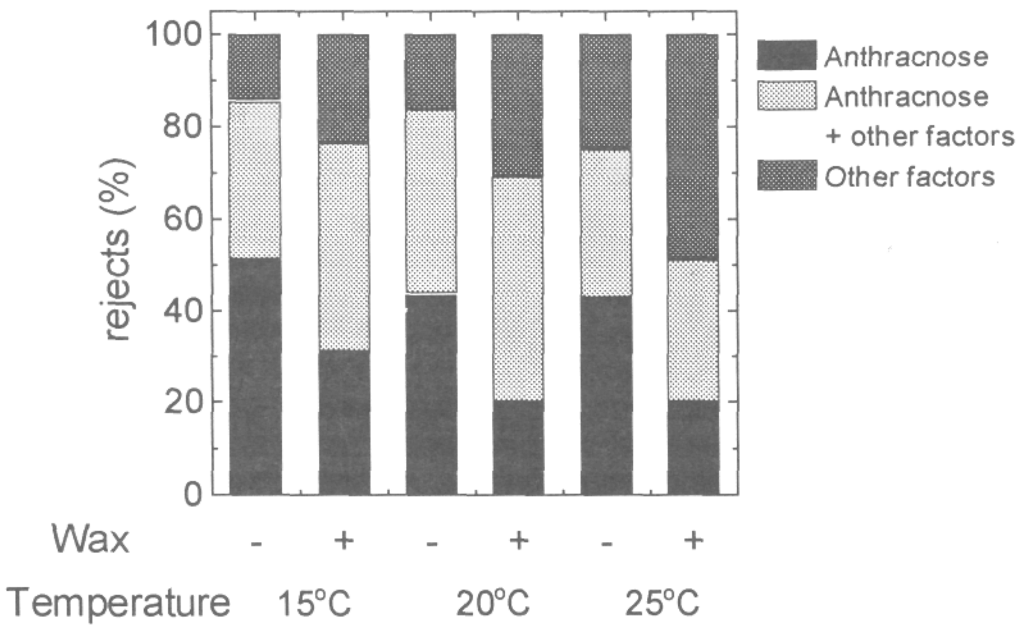

Figure 5 Reasons for fruit for becoming unmarketable (rejects) based upon external appearance (anthracnose rot, other factors (stem end rot, brown rot, soft patches) or a combination of both categories)

Recommendations

Based on the above information, we make the following recommendations:

- Technological development should run hand in hand with, and preferably ahead of, commercial applications of the technology to prevent occasional mis-matches of coating and produce, and the negative reaction in consumers that this would cause
- Only low concentrations of wax should be applied to avocados (e.g. 10% of commercial formulation)

• Ripening temperatures should be managed even more carefully for waxed avocados than for non-waxed controls

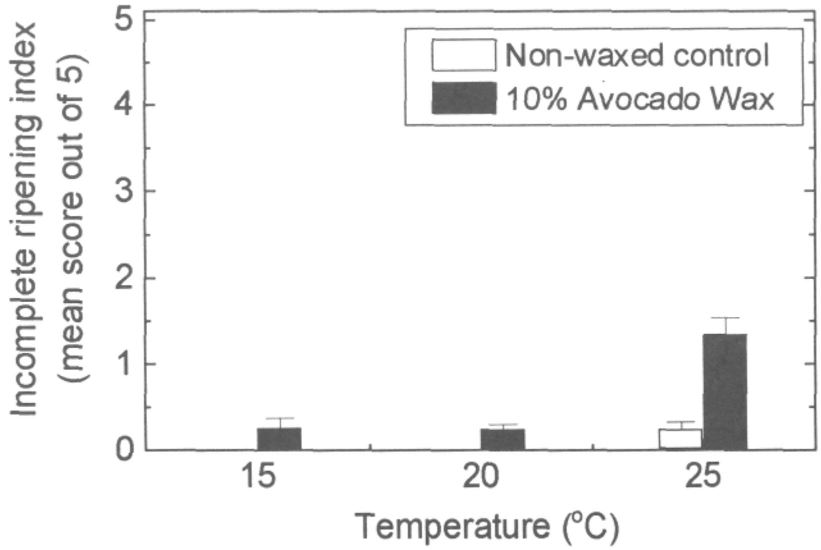

Figure 6 **Increase in incomplete ripening index associated with elevated ripening temperatures and waxing**

Concluding comments

Surface coatings can have marked effects upon the quality of avocados. Potential to reduce weight loss is associated with some level of risk (fermentation and disorder development associated with excessive internal atmosphere modificiation). The immediate challenge for scientists working in this area is to achieve high levels of benefit without serious risk to quality. In avocado, this seems likely to be quite feasible provided optimised levels of coating are applied to fruit which are then ripened at carefully managed temperatures.

Acknowledgements

This work was supported by the Avocado Industry Council.

References

Amarante, C.; Banks, N.H. 1997. Permeance to gases, internal atmosphere modification and ripening of coated pears. *Proceedings of the 7th International Controlled Atmosphere Research Conference,* 13-17 July, 1997, University of California, Davis, USA. In press.

Banks, N.H.; Cheng, Q.; Nicholson, S.E.; Kingsley, A.M.; Jeffery, P.B. 1997. Variation with temperature in effects of surface coatings on gas exchange of apples. *Proceedings of the International Congress for Plastics in Agriculture,* Tel Aviv, Israel, 9-15 March 1997. In press.

Banks, N.H.; Cutting, J.G.M.; Nicholson, S.E. 1997: Approaches to optimising surface coatings for fruits. *New Zealand Journal of Crop and Horticultural Science.* In press.

Banks, N.H.; Jeffery, P.B.; MacKay, B.R. 1997. Response surfaces of colour change and softening to O_2 and CO_2 partial pressures in 'Braeburn' apples. *Proceedings of the 7th International Controlled Atmosphere Research Conference,* 13-17 July, 1997, University of California, Davis, USA. In press.

Bower, J.P.; Cutting, J.G.M.; Wolstenholme, B.N. 1989: Effect of pre and post-harvest water stress on the potential for fruit quality defects in avocado *(Persea americana). South African Journal of Plant and Soil 6: 2*19-222.

Cutting, J.G.M.; Wolstenholme, B.N. 1992: Maturity and water loss effects on avocado *(Persea americana* Mill.) postharvest physiology in cool environments. *Journal of Horticultural Science 67:* 569-575.

Hagenmaier, R.D.; Shaw, P.E. 1992: Gas permeability of fruit coating waxes. *Journal of the American Society for Horticultural Science 117:* 105-109.

Joyce, D.C.; Shorter, A.J.; Jones, P.N. 1995: Effect of delayed film wrapping and waxing on the shelf life of avocado fruit. *Australian Journal of Experimental Agriculture 35:* 657 659.

Kader, A. A.; Zagory, D.; Kerbel, E.L. 1989: Modified atmosphere packaging of fruits and vegetables. *Critical Reviews in Food Science and Nutrition 28:* 1-30.

McGuire, R.G.; Hallman, G.J. 1995: Coating guavas with cellulose or carnauba-based emulsions interferes with postharvest ripening. *HortScience 30:* 294-295.

Meheriuk, M.; Lau, O.L. 1988: Effect of two polymeric coatings on fruit quality of'Bartlett' and 'd'Anjou' pears. *Journal of the American Society for Horticultural Science 113:* 222-226.