Appendix 1: Summary of Treatments for control of enzymic browning in fresh-cut fruit

Treatment	Description	**Example:** Compound/Method	Issue
Physical			
Heat treatment	Denatures the enzyme and prevents the formation of *o*-quinones.	Blanching – water, steam, microwave	The use of heat in the production of fresh-cut fruit is avoided to prevent cooking of the product and consequent loss of fresh-like characteristics.
Reduction of Temperature	Lowered temperature reduces enzymic activity. Freezing induces a decrease of available water for the enzymic reactions leading to less activity of PPO (Lavelli 2010).	Low temperature (refrigeration) Freezing	Freezing leads to irreversible changes in the food product such as firmness loss during thawing (Lavelli 2010)
Oxygen reduction	Oxygen is essential for the oxidation reaction and a reduction in the available oxygen slows the enzymic browning reaction.	Modified atmosphere packaging (MAP) – used to change the oxygen content of the storage atmosphere.	Modified/controlled atmosphere packaging is an expensive option.
Edible coatings	Application of a layer of edible material on the surface of the fruit producing a modified atmosphere on the coated fruit.	Chitosan, alginate, carrageenan, polysaccharides, resins, waxes for example create a semipermeable barrier.	Appropriate selection of edible coatings is important to achieve the required end result – may require a combination of coatings. No studies reported on banana or avocado.
High hydrostatic pressure (HHP)	Application of pressure to inactivate PPO.		High pressure processing used in combination with an acid will also control enzymatic browning but is generally reserved for purees and juices. The high capital cost limits its wide spread use.
Gamma irradiation			The high capital cost limits its wide spread use. Not permitted in ANZ for avocado and banana.
Chemical			
Antioxidants (reducing agents)	Prevent the initiation of browning by reacting with oxygen. These compounds reduce *o*-quinones back to diphenols before they form brown pigments. They are oxidised to a non-participating compound when	**Ascorbic acid** is commonly used in the food industry for this purpose. Other agents include: erythorbic acid, citric acid and glutathione, The traditional approach to overcome enzymatic browning for many fruits and vegetables is to immerse the cut product in an ascorbic acid dip for	Tests have shown that this method is not successful in preventing browning in sliced bananas. The use of acids to lower the pH to effectively control enzymatic browning makes the product unpalatable. The amount of ascorbic acid required to prevent pigmentation in bananas for even a few hours is so

Treatment	Description	**Example:** Compound/Method	Issue
	reducing *o*-quinones back to diphenols.	a short period. In time, the ascorbic acid is completely used up in reducing quinones to diphenols. The enzyme PPO is then free to catalyse the oxidation of diphenols to quinones which build up and react to form complex brown pigments. An excess of ascorbic acid is required so that a reasonable delay in browning can be achieved before the supply of ascorbic acid is exhausted. When the system is depleted of antioxidant the enzymatic browning process can proceed without hindrance.	great that the bananas taste unacceptably acid. The amount of ascorbic acid required to prevent pigmentation in bananas for even a few hours is so great that the bananas taste unacceptably acid.
Acidifying agents	The optimum pH for PPO reactions is between 6 and 7, pH environments outside this range result in much slower reactions and at a pH below 4 the enzyme becomes inactivated.	Ascorbic acid; citric acid	**Ascorbic acid** – as above for antioxidants
Chelating agents	The active site on the PPO enzyme requires copper, chelating agents bind to copper atoms preventing the enzyme functioning properly.	Citric acid and kojic acid	Kojic acid is not permitted for use in Australia. The use of acids to effectively control enzymatic browning makes the product unpalatable.
Firming agents	Strengthen the cell walls to prevent the destruction of cell wall components and contact of PPO with polyphenols	Calcium lactate, calcium propionate, calcium chloride, calcium ascorbate and sodium chloride	Calcium chloride is a component of the dip proposed to be used by the applicant together with L-cysteine.
Sulphur dioxide	Sulfhydryl compounds irreversibly react with *o*-quinones to form colourless addition compounds that despite having an *o*-phenolic structure are not substrates for PPO. The irreversible nature of the reaction means that, unlike antioxidants, excess sulfhydryl compounds are not necessary and do not participate in an	Sulphur dioxide	Sulphur dioxide is not permitted to be added to products under 4.3.1 – fruits and vegetables that are peeled, cut or both peeled and cut. Due to adverse health effects, the WHO has recommended limiting the use of sulphiting agents as much as possible in the treatment of foods (Queiroz et al 2008)

Treatment	Description	**Example:** Compound/Method	Issue
	ongoing struggle to prevent the buildup of *o*-quinone		