Relative Humidity Influences Postharvest Browning in Rambutan (*Nephelium lappaceum* L.)

M. Landrigan¹

Northern Territory Department of Primary Industry and Fisheries, P.O. Box 79, Berrimah, NT 0828, Australia

S.C. Morris

Commonwealth Scientific and Research Organization, Division of Horticulture, Sydney, Australia

K.S. Gibb

Northern Territory University, Science Faculty, Darwin, Australia

Additional index words. polyphenol oxidase, peroxidase, storage, mechanical damage

Abstract. The effect of enzymic action, mechanical damage, and relative humidity (RH), on browning of stored rambutan was investigated. Mature rambutan fruit ('R 134') were infiltrated with known enzyme inhibitors, then either mechanically damaged or left undamaged, before storage at 20 °C with 95% or 65% RH. Fruit were visually scored for browning and weight loss was measured. All fruit at low RH browned severely. At high RH, infiltration with water, but not with the enzyme inhibitors, salicylhydroxamic acid and catalase, led to a large increase in browning. We infer that enzymes were involved in browning in damaged tissue under high RH. At low RH, inhibitors were ineffective as desiccation was the dominant causative factor of browning.

In northern Australia, the commercial importance of rambutan is increasing. Total production is ≈ 400 t·year⁻¹, but there is considerable potential for expansion. When mature, rambutans are bright red or yellow and characterized by distinctive spinterns (or hairs). However, the market life of rambutans is limited by skin susceptibility to desiccation and browning. Browning is initially primarily located in the epidermis of rambutan (Landrigan et al., 1994) and its development depends, at least in part, on the amount of water lost from the skin (Lam et al., 1987; Pantastico et al., 1975). To our knowledge, nothing has been published, however, about the mechanisms responsible for browning in rambutan.

Browning occurs in many fruit species and the mechanisms underlying the process may be either enzymic or nonenzymic. For enzymic browning to occur, the appropriate enzyme, substrate, and oxygen must be present. Either polyphenol oxidase (PPO; EC 1.14.18.1) or peroxidase (POD; EC 1.11.1.7) or both have been implicated in browning (Kahn, 1975; Lagrimini, 1991; Vámos-Vigyazo, 1981; Whitehead and De Swardt, 1982). PPO is widely distributed in fruit and catalyzes the

oxidation of phenols to quinones that in turn polymerize to form brown pigments (Mayer and Harel, 1979). Normally, PPO is separated from vascular phenolic substrates; thus, browning occurs when cells are damaged and compartmentation is lost. Peroxidase is also capable of oxidizing phenolics to quinones and requires the presence of hydrogen peroxide (Bucheli and Robinson, 1994). POD has been implicated in cell wall biosynthesis, response to injury, disease resistance, and wound repair (Préstamo and Manzano, 1993). Non-enzymic browning in a product is very complex and numerous hypotheses have been advanced for the mechanism of these reactions (Lee, 1983).

The dearth of published information on PPO and POD in rambutan browning led to this preliminary investigation into their role in browning. Extensive analysis for PPO and POD activity in rambutan pericarp revealed the presence of a very high level of endogenous oxygen consumption. Such high levels of auto-oxidation are able to mask the activity of PPO and POD, requiring a more indirect assessment of the role of these enzymes (Landrigan, 1995). Hence, enzyme inhibitor infiltration was used to elucidate the potential role of these enzymes in browning of rambutan in response to desiccation and mechanical damage.

Materials and Methods

Fruit ('R 134') were harvested at the red-mature stage from a commercial orchard south of Darwin, Australia (long. 12°S, lat. 130°E). Fruit were randomly divided into four groups of 12 fruit of uniform size and appearance.

Three of the groups were vacuum-infiltrated (65 kPa, for 3 min, plus 3 min after release of pressure) with one of the following treatments: 1) water; 2) 0.26 mM salicylhydroxamic acid (SHAM, a powerful noncompetitive inhibitor of PPO) (Bucheli and Robinson, 1994); or 3) catalase (POD inhibitor) at 2.7 mg·mL⁻¹ (Bostock et al., 1987). The fourth group (control) received no treatment. Fruit were weighed before and after (blotted dry) infiltration to determine solution uptake during infiltration. The surface area of the fruit was then divided in half and 10 spinterns on one-half were bent (not broken), by applying pressure with a glass rod, to simulate mechanical damage occurring during harvest and packaging. Six fruit from each treatment were then stored at 20 °C, at either high (95%) or low (65%) relative humidity (RH) (equivalent to 0.25 kPa and 0.85 kPa vapor pressure deficit, respectively). Browning of the spinterns was scored on a scale of 1 to 5 (1 = no browning; 5 = fully browned) and fresh fruit mass was recorded every second day.

Data were subjected to analyses of variance for a split-plot design, and, where appropriate, means were compared using Waller-Duncan's Bayesian *k* ratio LSD at *k* = 100 (Steel and Torrie, 1980). The level of *k* = 100 used here is about equal to the *P* < 0.05 in conventional LSD.

Results and Discussion

The vacuum-infiltrated fruit increased in mass 0.8%, 1.0%, and 1.3% for water, SHAM, and catalase, respectively. Furthermore, all vacuum-treated rambutans lost significantly less weight during storage than noninfiltrated fruit (Fig. 1A). Infiltration with water significantly increased browning, relative to noninfiltrated fruit (Fig. 1B). This increase in browning was due to the act of infiltration alone. However, when inhibitors of PPO or POD were present in the infiltration solution, browning was significantly less (Fig. 1B), although the differences were minor.

Mechanical damage significantly increased browning in all samples, whether infiltrated or not (Fig. 1C). Browning from mechanical damage was worst in fruit that were infiltrated with water. Infiltration of mechanically damaged fruit, with either of the two enzyme inhibitors, significantly reduced browning compared to mechanically damaged fruit infiltrated with water. Mechanical damage may have aided in the penetration of enzyme inhibitors into the tissue.

Storage at low RH significantly increased browning in all treatments compared to fruit stored at high RH (Fig. 1D). There was no effect of infiltration with either enzyme inhibitor on browning when fruit were stored at low RH (Fig. 1D). In contrast, infiltration with the enzyme inhibitors significantly reduced browning, compared to fruit infiltrated with water, when stored at high RH (Fig. 1D). Browning increased with duration of storage for damaged and nondamaged fruit stored at low RH (Fig. 1E). At low RH, mechanical damage increased the browning score com-

Received for publication 24 July 1995. Accepted for publication 24 Feb. 1996. We wish to thank T.K. Lim and W.B. McGlasson for technical advice. The manuscript has been much improved by comments from Rik Buckworth and Neil Smit. The financial support from the Rural Industries Research and Development Corp. is gratefully acknowledged. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.
¹To whom reprint requests should be addressed.

Fig. 1. Effects of inhibitors, bending of spinterns, and relative humidity (RH) on weight loss and browning of rambutan during storage for 10 days at 20 °C. (A) Weight loss; (B) browning score as affected by noninfiltration or infiltration, regardless of injury; (C) browning score of unbent and bent spinterns, as affected by noninfiltration or infiltration; (D) browning score at low and high RH, as affected by noninfiltration or infiltration; (E) browning score of treatments over time; and (F) browning score as affected by injury, storage humidity, and noninfiltration or infiltration. Mean separation within each square at the $k = 100$ level.

pared to nondamaged fruit for the first 8 days during 10 days of storage. High humidity storage, in the absence of mechanical damage, prevented any significant increase in browning over the 10 days of storage. In contrast, mechanically damaged fruit stored at high RH yielded the same browning score after 10 days as the fruit stored at low RH.

When considering the interaction among

the three factors, inhibitor, RH, and bending, the treatments effects were small for unbent spinterns (with a considerable differential due to RH) and greater for the bent spinterns (Fig. 1F). Browning was less severe in bent spinterns kept at low RH when infiltrated with water, compared to noninfiltrated bent spinterns kept at low RH. However, for high RH and bent spinterns, the water infiltration led to more

browning. In contrast, the enzyme inhibitors showed significantly less browning, which suggests that browning in rambutan results largely from nonenzymic changes associated with desiccation and a small amount mediated by enzyme activity in mechanically damaged tissue.

These results have implications for developing practical methods for controlling browning in that care must be employed when harvesting and packaging rambutans to avoid mechanical injury browning under low RH. High RH storage is essential to maintain quality. Further work is required to fully understand browning rambutan under conditions of high water loss.

Literature Cited

- Bostock, R.M., C.S. Thomas, J.M. Ogawa, R.E. Rice, and J.K. Uycemoto. 1987. Relationship of wound-induced peroxidase activity to epicarp lesion development in maturing pistachio fruit. *Physiol. & Biochem.* 77:275-282.
- Bucheli, C.S. and S.P. Robinson. 1994. Contribution of enzymic browning to colour in sugarcane juice. *J. Agr. & Food Chem.* 42:257-261.
- Kahn, V. 1975. Polyphenol oxidase activity and browning of three avocado varieties. *J. Sci. Food & Agr.* 26:1319-1324.
- Lagrimini, L.M. 1991. Wound-induced deposition of polyphenols in transgenic plants over-expressing peroxidase. *Plant Physiol.* 96:577-583.
- Lam, P.F., S. Kosiyachinda, M.C.C. Lizada, D.B. Mendoza, Jr., S. Prabawati, and S.K. Lee. 1987. Postharvest physiology and storage of rambutan, p. 39-50. In: P.F. Lam and S. Kosiyachinda (eds.). *Rambutan: Fruit development, postharvest physiology and marketing in ASEAN*. ASEAN Food Handling Bureau, Malaysia.
- Landrigan, M. 1995. Postharvest browning of rambutan (*Nephelium lappaceum*). PhD Diss., Univ. of Western Sydney, Hawkesbury, Richmond, N.S.W.
- Landrigan, M., V. Sarafis, S.C. Morris, and W.B. McGlasson. 1994. Structural aspects of rambutan (*Nephelium lappaceum*) fruits and their relation to postharvest browning. *J. Hort. Sci.* 69:571-579.
- Lee, F.A. 1983. Browning reactions, p. 283-306. In: *Basic food chemistry*. AVI, Westport, Conn.
- Mayer, A.M. and E. Harel. 1979. Polyphenol oxidases in plants. *Phytochemistry* 18:193-215.
- Pantastico, E.B., J.B. Pantastico, and V.B. Cosico. 1975. Some forms and functions of the fruit and vegetable epidermis. *Philippine J. Biol.* 4:175-197.
- Préstamo, G. and P. Manzano. 1993. Peroxidases of selected fruits and vegetables and the possible use of ascorbic acid as an antioxidant. *HortScience* 28:48-50.
- Steel, R.G.D. and J.H. Torrie. 1980. Multiple comparisons, p. 172-191. In: *Principles and procedures of statistics*. McGraw-Hill, New York.
- Vámos-Vigyazo, L. 1981. Polyphenol oxidase and peroxidase in fruits and vegetables. *Critical Rev. Food Sci. & Nutr.* 15:49-127.
- Whitehead, C.S. and G.H. De Swardt. 1982. Extraction and activity of polyphenoloxidase and peroxidase from senescing leaves of *Protea neriifolia*. *South African J. Bot.* 1:127-130.