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# **FACTORS INFLUENCING THE SUSCEPTIBILITY OF APPLES TO BRUISING**

This thesis is presented in partial fulfilment of  
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## ABSTRACT

Financial returns to New Zealand orchardists could be increased if bruise damage to apples and its visual consequences were reduced. Comprehension of the variability of susceptibility to the bruising of apples associated with either preharvest, harvest or postharvest influences is fundamental to reducing bruise damage. Standard impacts to apples have been generated in many ways and bruise severity has generally been represented as bruise volume per unit energy. In this study bruise severity was represented by a) the diameter of a bruise generated by a sphere of mass and radius of curvature similar to that of apples and whose impact energy (0.32 J) was similar to apple-apple collisions that occurred during grading or b) the damage that apples incurred by grading in a standard manner. Bruise colour was also measured and visual differences between dark and light brown 'Granny Smith' bruised tissue were associated with a 5° difference in hue angle, as measured by a Minolta chromameter.

In 1990 from a survey of 'Granny Smith' orchards it was determined that the range in bruise diameter of individual fruit was 17% (fruit mass range; 0.157-0.207 kg) and in 1991 was 63% (fruit mass range; 0.098-0.278 kg). The between-season difference in mean bruise diameter was 2.8%. Over the two years it was found that bruise diameter of fruit from orchards producing either the most or least bruise susceptible fruit differed by an average of 6.5%. In 1991 bruise diameter generated from a standard impact was related to grader damage ( $R^2 = 0.49$ ) and the slope of this relationship indicated that small increases in bruise diameter equated to large increases in grader damage. In both years the most bruise susceptible fruit had higher levels of tissue phosphorus, calcium and nitrogen than least susceptible fruit. In one year of the survey bruise diameter was positively related to apple calcium content and apple mass with grader damage positively related to phosphorus content.

In a within-orchard study between-tree variation in bruise diameter of 'Royal Gala' (11%) exceeded that of 'Granny Smith' (4%). Bruise diameter of least bruise susceptible fruit was more consistently related to starch index, soluble solids, fruit mass and firmness than bruise diameter of the most susceptible fruit. Harvesting 'Granny Smith' and 'Royal Gala' early rather than later in the season

resulted in bruise diameter reductions of 5% and 21% respectively. Within-tree position of apples did not consistently influence susceptibility to bruising in either variety. Foliar sprays of calcium ( $\text{CaCl}_2$ ) and phosphorus ( $\text{H}_3\text{PO}_4$ ) did not influence fruit mineral contents or susceptibility to bruising. Apples from non-irrigated 'Braeburn' trees had smaller bruise diameters (6%), less calcium and tended to have more dry matter than apples from normally irrigated trees.

'Golden Delicious' apples harvested later in the day were less susceptible to bruise damage (7.3%) than those harvested early in the morning; elevated temperatures and reduced water status were identified as causative factors. As temperature increased from 0 to 20°C susceptibility to bruising showed a non-linear reduction. Bruise diameter and grader damage reduced 5% and 24% respectively when 'Granny Smith' apples were bruised at 20°C rather than when bruised at 0°C. If 'Royal Gala' were cooled to 2°C and then rewarmed to 20°C they sustained 36% less grader damage than if graded immediately after harvest. Useful reductions in grader damage (25%) were achieved by holding freshly harvested 'Royal Gala' at ambient temperatures for one day before grading. Storing the bruise susceptible cultivar 'Splendour' apples for 54 h at 20°C before bruising resulted in a 9% reduction in bruise diameter. A 24 h delay in pre-cooling of 'Royal Gala' was associated with a 0.5% weight loss and a 3% reduction in bruise diameter; delays of more than 24 h before pre-cooling were associated with enhanced ripening and greater weight loss but no measurable change in susceptibility to bruising.

In the 1991 survey, there were large between-orchard differences in hue angle of bruised 'Granny Smith' apple tissue (16°) and light brown bruise tissue was associated with higher fruit nitrogen content ( $R^2 = 0.55$ ). Between-tree differences in hue angle of bruised tissue from 'Royal Gala' apples were large (15°) but with 'Granny Smith' were insignificant. Differences in bruised tissue colour due to enhanced maturity or within-tree position in both cultivars were not consistent. Cool storing 'Splendour' for 414 h before bruising appeared to increase bruise lightness.

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## LIST OF ABBREVIATIONS AND SYMBOLS

<i>A</i> .....	bruise area (mm <sup>2</sup> )
AA.....	ascorbic acid
°C.....	degrees Centigrade
CRI.....	cell roundness index
CV.....	coefficient of variation
<i>d</i> .....	bruise diameter (mm)
<i>d</i> <sub>1</sub> .....	major bruise diameter (mm)
<i>d</i> <sub>2</sub> .....	minor bruise diameter (mm)
DSP.....	deformation at skin puncture (mm)
<i>E</i> .....	Energy ( <i>J</i> )
EC.....	Enzyme Nomenclature
ENZA.....	New Zealand Apple and Pear Marketing Board
FCU.....	Fruit Crops Unit
Fig.....	Figure
g.....	gram
<i>g</i> .....	gravitational constant (9.81 m/s <sup>2</sup> )
<i>H</i> .....	drop height (m)
<i>H</i> <sub>1</sub> .....	rebound height (m)
<i>h</i> .....	bruise depth (mm)
h.....	hour
ISO.....	European International Organisation for Standardization
kPa.....	kilopascal
kg.....	kilogram
L.....	litre
LS.....	lower south tree position
<i>M</i> .....	mass (kg)
m.....	metre
ml.....	millilitre
mm.....	millimetre
N.....	Newton
n.....	number

nm.....	nanometre
NZ.....	New Zealand
$P$ .....	perimeter (mm)
PPF.....	photosynthetic photon flux ( $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ )
PPO.....	polyphenol oxidase
$R$ .....	radius of apple (mm)
$R^2$ .....	coefficient of determination
$r$ .....	correlation coefficient
$S$ .....	inner bruise boundary area ( $\text{mm}^2$ )
$s$ .....	seconds
SED.....	standard error of the difference
UK.....	United Kingdom
UN.....	upper north tree position
USA.....	United States of America
$V$ .....	bruise volume ( $\text{mm}^3$ )
$V_1$ .....	bruise volume ( $\text{mm}^3$ ); Chen and Sun (1981)
$V_2$ .....	bruise volume ( $\text{mm}^3$ ); Holt and Schoorl (1977)
$x$ .....	height of bruise above contact plane (mm)
$\chi^2$ .....	chi squared