Role of Calcium and Mechanical Damage in the Development of Localised Premature Softening in Coolstored Kiwifruit

A dissertation presented in partial fulfilment of the
requirements for the degree of
Doctor of Philosophy in Plant Science
at
Massey University

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1997

This thesis is dedicated to Nigel, Cliff and Nagin.

My thanks for the opportunity they provided, patience shown, motivation given and standard of excellence set.

"....know the truth and the truth will set you free."

General Abstract

Preharvest, harvest, and postharvest factor(s) were examined to identify the causes of premature quality loss during long term coolstorage of kiwifruit (*Actinidia deliciosa*). Investigation centred around the role of mechanical damage and calcium in the development of softening disorders, including soft patches (localised soft areas on fruit surface), premature softening, and low temperature breakdown (LTB) during storage.

Kiwifruit were vulnerable to compression and impact from harvest onwards, with damage usually being expressed after a period of coolstorage. Physical damage normally just affected the fruit tissue in direct contact with the applied force. Impact damage, and to a lesser extent compression damage, depended on the size of the force and firmness of fruit when damaged. As kiwifruit softened, their susceptibility to soft patch development as a result of physical damage increased whereas the likelihood of flesh fracture in response to impact declined. These changes are attributed to the change in nature of the flesh, which is 'brittle' at harvest and 'viscoelastic' after softening. Physical damage to coolstored kiwifruit caused a slight drop in final firmness whereas there was no effect on firmness if it occurred at harvest.

Fruit with softening disorders consistently had lower calcium contents (about 12% less) than equivalent healthy fruit. Fruit with soft patches had a high phosphate content, low dry matter, and at harvest, a low soluble solids content. A causative role for calcium in soft patch development was demonstrated by preharvest calcium treatments that elevated calcium content of the harvested fruit. Other orchard factor(s) were probably the cause of a weaker relationship between calcium content at harvest and storage behaviour of fruit. Although firmness at harvest declined with later picking, after coolstorage, fruit harvested more mature had a higher firmness and lower incidence of LTB. Symptoms for LTB were consistent with chilling injury whereas soft patches appeared to be due to localised premature senescence and not low temperature.

A conceptual model of key factor(s) which cause the initiation and development of softening disorders in kiwifruit is proposed. Implications of this model for further investigation of these phenomena and for commercial handling of fruit are discussed. Further development of this model to produce a predictive model of fruit storage potential would require further characterisation of other important influences in storage behaviour.

Acknowledgement

I mention the following people which may go some way to express my thanks and appreciation for the contribution they made to the completion of this thesis.

My supervisors, Prof Nigel H. Banks, Dr Clifford J. Studman and Dr Nagin Lallu for their help in design, construction and completion of this thesis.

To the New Zealand Kiwifruit Marketing Board for their financial support of projects and stipends. The many kiwifruit growers who made their time, orchards, packhouses, and fruit available for setting up and running of experiments.

To Massey University and its people who are dedicated to provide the opportunity and environment for education and research. Staff and students within the Department of Plant Science, the Plant Growth Unit, and Fruit Crops Unit.

Thanks to Anthony for his friendship. To all past and present flatmates of 116 Cuba street, such as Elana, Leanne, Sharn and Cory. Thanks to the "family" at the Good News Apostolic church for their support and humour over the years. To Mr and Mrs Yeoman for their friendship and support.

I would also like to acknowledge the help and moral support I received from my parents (Betty and Jack), brother (Craig), and sister (Suzanne). Thanks to Mandy, for the number of times she put my thesis first and herself second.

Finally, and most importantly my thanks go to the Banks family, for the time they sacrificed being with Nigel while he was helping me complete this thesis.

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List of Abbreviations

Abs . . . . . absorbance
A^E . . . . . area of soft patches on fruit excluding those at the impact site (m^2; Sections 4.2.4, 7.2.2.2)
AH . . . . . treatment: compression 96 h immediately after harvest (Section 3.2.2)
A^I . . . . . area of soft patches at the impact site (m^2; Sections 4.2.4, 7.2.2.2)
ap . . . . . number of oil applications
A^{sp} . . . . . area of soft patches (m^2; Sections 3.2.3, 5.2.5, 6.2.4, 7.2.5.2, 8.2.3.2)
A^T . . . . . area of soft patches on the total fruit surface (m^2; Section 4.2.4)
B . . . . . treatment: fruit taken from the bottom layer of bin (Section 6.2.2.2)
C . . . . . treatment: control fruit, not graded (Section 6.2.2.2)
CA . . . . . controlled atmosphere
card . . . . . treatment: fruit held in a cardboard single layer tray (Section 6.2.2.2)
cp . . . . . phosphate concentration (mmol/kg)
C_0 . . . . . treatment: fruit not graded with a flesh at 0°C (Section 6.2.2.2)
C_{16} . . . . . treatment: fruit not graded with a flesh at 16°C (Section 6.2.2.2)
d . . . . . number of calcium dips
DT . . . . . treatment: compression when fruit transported by truck (450 km: Section 3.2.2)
E^I . . . . . impact energy (J)
ET . . . treatment: compression during early phase of coolstorage (12 weeks; Section 3.2.2)
Δf . . . . . difference between initial and final firmness (N)
f . . . . . firmness (N)
$f^{initial}$ . . . . . initial firmness (N)
f^{final} . . . . . final firmness (N)
g . . . . . gravitational constant (m/s^2)
G . . . . . treatment: graded (Section 6.2.2.2)
G_M . . . . . treatment: modified grader (Section 6.2.2.2)
G_0 . . . . . treatment: fruit graded with flesh at 0°C (Section 6.2.2.2)
G_{16} . . . . . treatment: fruit graded with flesh at 16°C (Section 6.2.2.2)
h . . . . . hours
h^I . . . . . drop height (m)
LC . . . . . treatment: compression during late coolstorage (Section 3.2.2)
LTB . . . . . Low temperature breakdown
m . . . . . mass (kg)
NZKMB . . . . . New Zealand Kiwifruit Marketing Board
p . . . . . individual fruit positions within pipes
P'_{H_2O} . . . . . permeance to water vapour ($mol/s.m^2.Pa$)
R^E . . . . . percentage of rejectable fruit due to soft patches outside the impact site (%)
Rj . . . . . percentage of rejectable fruit due to soft patches (%)
sg . . . . . severity of grading
SL . . . . . treatment: compression during simulated shelf-life (Section 3.2.2)
$SP_{contact}$ . . . . . soft patches present on fruit at the contact site (m^2; Section 3.2.3)
$SP_{outside}$ . . . . . soft patches present on fruit, but not at the contact site (m^2; Section 3.2.3)
ss . . . . . soluble solids (%)
t . . . . . time (weeks)
T . . . . . treatment: fruit taken from the top layer of bin (Section 6.2.2.2)
tp^B . . . . . treatment: fruit held in tri-pack bottom layer (Section 5.2.2)
tp^M . . . . . treatment: fruit held in tri-pack middle layer (Section 5.2.2)
tp^T . . . . . treatment: fruit held in tri-pack top layer (Section 5.2.2)
wood . . . . . treatment: fruit held in wooden single layer tray (Section 5.2.2)