Influence of handling at harvest on the softening behaviour of kiwifruit.

A thesis presented in partial fulfilment of

the requirement for the degree of

Master in Horticultural Science

at Massey University

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1992

Acknowledgement

I wish to express my utmost appreciation to Dr Nigel Banks for guidance and support with the design and execution of the experiments and construction of the thesis.

There are a few other people I would also like to thank:
my parents who made me possible, whose love and example provided me with the guts to accomplish the goal.
my brother Craig and sister Suzanne who are considered my closest friends.
to Grandma and Granddad Turner who germinated my love of horticulture.
to Nana and Granddad Davie whose generosity taught me to keep on giving.
to Auntie Bea whose cooking, love and patience kept me sane and mature.
to all my relatives (Auntie Lucy, Uncle Gordon, etc.) whose interest in my work never ceases.
to Mr and Mrs Yeoman, who became like parents to me, whose acceptance and love makes me feel more close to God.
to Carl Smart who gave such valued Christian friendship and taught me how to accept people as they are.
to Mrs McDonald and Tracey who feed and cared for this student, making him always feel so welcome and appreciated.
to the Evensons who got me to laugh, realise life is not so serious and taught me that being a christian is really very simple.
to Tim and the rest of the Higgins family, for keeping up the friendship and support over so many years.
to the Baxters who make you feel part of their family and who love people as they love themselves.
to the Nevilles who opened up their home to me, got me to mellow out and taught me how to burp.
to my flat mates, Anthony, De Anne, Mike, Nicci and Rob, who turned a flat into a home, and set incredible examples of being Christian and still live in the real world.
to Bruce Christie for all his help, advice, and patience.
To my God, who out works his plan for my life and makes life so much fun to live.

Abstract

The New Zealand Kiwifruit industry in 1991 lost an estimated $54 million due to premature softening of kiwifruit during postharvest storage. The present study sought to determine if premature softening might be associated with the physical damage resulting from handling at harvest.

The influence of physical damage on fruit was investigated on fruit from eleven kiwifruit properties from the Bay of Plenty region in New Zealand. Fruit were harvested and stored at 0°C and 20°C; firmness was destructively assessed. Softening behaviour of fruit sampled immediately after harvest from the vine (no physical damage) were compared with fruit from the same orchard block handled through the normal postharvest handling chain and packed in a packhouse. Analysis of variance and nonlinear regression using two, three and four parameter models were used to help in describing any differences in firmness values for fruit held in cool storage (0°C). The advantages and disadvantages of using analysis of variance and nonlinear regression to describe differences in firmness values between treatments are discussed.

Analysis of variance determined that the packhouse and vine fruit on average were of a similar firmness. Nonlinear three parameter model:

$$\text{Firmness} = a \exp^{-b\,t} + c \quad \text{(starting values: } a = 6,\ b = 0.01 \text{ and } c = 0.5\text{)}$$

where:

- a = difference between initial and final asymptotic firmness
- b = exponent describing rate of decline in firmness
- c = final asymptotic value for fitted firmness

was found to best characterise changing fruit firmness values over time. An analysis of variance was then performed on the resulting parameter values a, b and c which found that vine fruit on average had a slightly faster rate of softening than packhouse fruit. Packhouse fruit were not expected on average to have a similar firmness to vine fruit, as packhouse

fruit were thought to have been exposed to potentially damaging impacts during handling. This may have been due to vine fruit being of a smaller size, position of fruit trays in cool storage or the rewarming of fruit during transportation.

A non-destructive measure of firmness would help to identify the factors leading to premature softening and help to quantify fruit to fruit variability. A second part of this study therefore involved development and evaluation of a non-destructive instrument for measuring kiwifruit firmness (softness meter) compared with a penetrometer and its ability to repeatedly measure an individual fruit's firmness over time.

The non-destructive softness meter characterised fruit firmness by measuring changes in deformation over time. Plots of deformation versus the natural log of time were linear and the gradient of the line was used as the measure of firmness (softness coefficient). Fruit with a range of firmness values were assessed using the softness meter, then penetrometer readings were obtained on the same location of each fruit and the relationship between the two instruments established. Within-fruit variation for both softness coefficients and penetrometer data was strongly related to fruit firmness, with coefficients of variation remaining approximately constant at about 10% for each variable. The softness meter will help to identify how localised treatments applied to fruit affect firmness and help to identify premature softening causes in individual fruit.

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Chapter One

1.0 Introduction

Kiwifruit (*Actinidia deliciosa* cv Hayward; Liang and Ferguson, 1986) in 1991 were New Zealand's sixth largest export earning (New Zealand Kiwifruit Marketing Board (NZKMB), 1991). In 1991 the crop earned $621.5 million with $54 million being lost due to fruit losses (NZKMB, 1991). The principal causes of fruit losses were soft fruit (71.2%), *Botrytis cinerea* (16.0%) and other causes (12.8%) (Hugh King, NZKMB; personal communication, 1992).

A important part of the NZKMB's success in marketing the large volume of kiwifruit produced in this country each year lies in the ability to store the fruit over an extended period before export. This creates opportunities to export fruit in an orderly way over six months to different markets around the world without creating a glut in the few months after harvest time. New Zealand is competing against other kiwifruit-exporting countries from the southern hemisphere and fruit carried over from the previous season in the northern hemisphere. Quality therefore plays an important role in maintaining a premium price and market share for the New Zealand crop: fruit quality must remain high throughout the storage period and during handling through the distribution chain until it reaches the consumer. Fruit quality is rigorously checked on all lines of fruit on a pallet by pallet basis before export.

Fruit are harvested by hand when the soluble solids (SS) level is at 6.2% or above at 20°C (NZKMB, 1992). Fruit firmness is usually around 8 kilograms force (kgf; Newtons = kgf x 9.81 ms^{-2}) when picked from the vine at the start of the harvesting season in early May. Fruit are harvested into picking bags, then put into wooden field bins to be transported to a packhouse. The NZKMB (1992) recommends that fruit are not dropped more than 30 cm onto a hard surface e.g. into field bins or on grading equipment. At the packhouse fruit are passed over a grader, packed by hand or partly by machine within 96 hours of picking. Fruit are then palletised, force air cooled and placed in coolstore at 0°C within 24 hours of being packed (NZKMB, 1992).

The residual firmness at the time of export must be sufficient to enable it to undergo a further period of transport and handling without becoming excessively soft.

During storage the fruit softens from its original high value at harvest (Fig. 1.1).

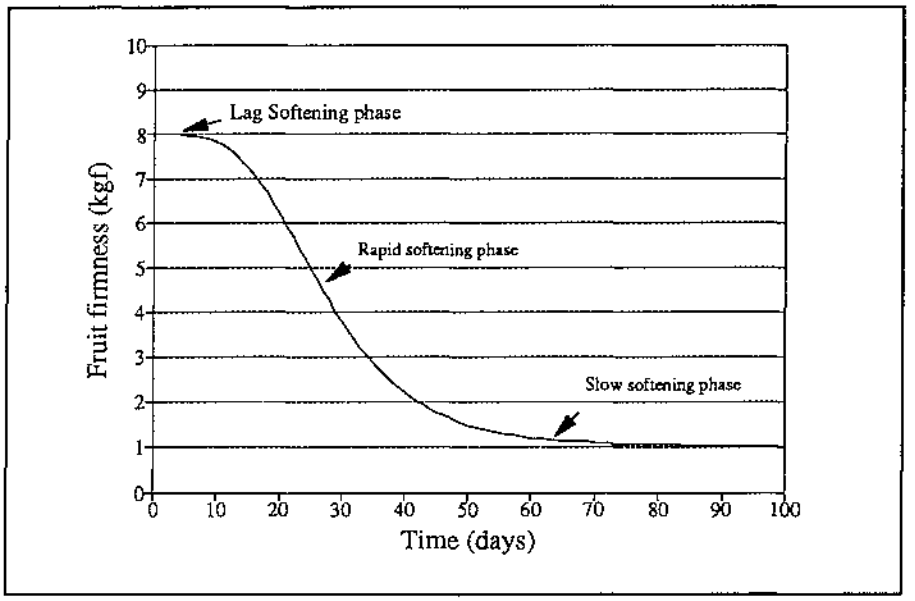

Fig. 1.1 Diagrammatic representation of softening in kiwifruit.

Fruit firmness is therefore used by the NZKMB as a quality criterion in deciding if a line of fruit is accepted or rejected for export. Once fruit has been in a coolstore for longer than 8 weeks from packing it must be condition checked before being exported. Six trays are randomly selected from any one of the corner columns of each pallet. All fruit in each of the six trays are inspected for defects. From each tray the number of soft fruit are recorded as a defect then, following NZKMB guidelines the need for repacking is determined. The average firmness of 20 fruit from a grower's line (randomly selecting four fruit from five trays for a grower by pack date) must be above 1.2 kgf to avoid repacking (NZKMB, 1992).

Fruit described as prematurely soft are rejected for export when their individual firmness (or any area on the fruit surface) is not greater than the export firmness threshold, set by the NZKMB at 1.0 kgf for fruit tested at between 0 and 5°C (NZKMB, 1992). Firmness is very critical 8 weeks after harvest when fruit have softened close to the export

firmness threshold. It is therefore very important to growers that their fruit remains above this level of firmness at least until they have been exported. At present it is not possible for the NZKMB to predict accurately which lines of fruit will have the fastest rate of softening, nor is it possible to assess the likely storage performance of a given line of fruit from its storage behaviour in previous years.

There is, therefore, considerable industry interest in identifying those factors most responsible for influencing fruit firmness. It is thought that mechanical damage resulting in bruising of fruit tissue can cause fruit to soften prematurely (Hopkirk and Finch, 1989). Damage caused by handling at harvest has been associated with the tendency of fruit to develop water-soaked soft patches areas during extended storage (Banks, 1991).

Another problem faced by the industry is the difficulty in accurately assessing firmness of fruit that are close to the export firmness threshold. This is normally done subjectively, by touch, in the condition checking of large numbers of stored fruit. However, an objective, non-destructive method of assessing firmness could be of great value in calibrating an individual's perception of the export firmness threshold or, if rapid enough, in the routine testing of fruit at condition checking.

This thesis examines a number of issues relating to the softening behaviour of kiwifruit. Literature on factors affecting fruit texture and its measurement are reviewed in Chapter 2. In Chapter 3, the potential role of mechanical damage in affecting softening behaviour is examined on fruit stored for an extended period. These same data are used to examine a number of different mathematical approaches to the description of kiwifruit softening behaviour over time. In chapter 4, a non-destructive method for assessing kiwifruit firmness is outlined and compared to the standard method for assessing fruit firmness (the penetrometer; NZKMB, 1992).