

## **ABSTRACT**

The goal of this research was to investigate changes in the physiological properties including firmness, stiffness, weight, background colour, ethylene production and respiration of 'Cripps Pink' apple stored under different temperature and atmosphere conditions,. This research also seeks to establish mathematical models for the prediction of changes in firmness and stiffness of the apple during normal atmosphere (NA) storage.

Experiments were conducted to determine the quality changes in 'Cripps Pink' apple under three sets of storage conditions. The first set of storage conditions consisted of NA storage at 0°C, 2.5°C, 5°C, 10°C, 20°C and 30°C. In the second set of conditions the apples were placed in NA cold storage at 0°C for 61 days, followed by NA storage at the aforementioned six temperatures. The third set of conditions consisted of controlled atmosphere (CA) (2 kPa O<sub>2</sub> : 1 kPa CO<sub>2</sub>) at 0°C storage for 102 days followed by NA storage at the six temperatures mentioned previously.

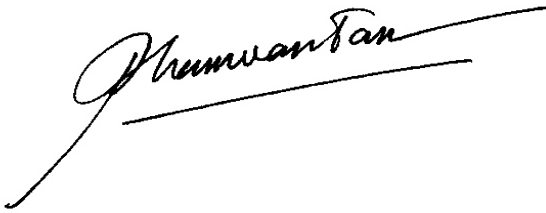
The firmness, stiffness, weight loss, skin colour, ethylene and carbon dioxide production of the apples were monitored at specific time intervals during storage. Firmness was measured using a HortPlus Quick Measure Penetrometer (HortPlus Ltd, Hawke Bay, New Zealand); stiffness was measured using a commercial acoustic firmness sensor-AFS (AWETA, Nootdorp, The Netherlands). Experimental data analysis was performed using the GraphPad Prism 4.03, 2005 software package. The Least-Squares method and iterative non-linear regression were used to model and simulate changes in firmness and stiffness in GraphPad Prism 4.03, 2005 and DataFit 8.1, 2005 softwares.

The experimental results indicated that the firmness and stiffness of 'Cripps Pink' apple stored in NA decreased with increases in temperature and time. Under NA, the softening pattern was tri-phasic for apples stored at 0°C, 2.5°C and 5°C for firmness, and at 0°C and 2.5°C for stiffness. However, there were only two softening phases for apples stored at higher temperatures. NA at 0°C, 2.5°C and 5°C improved skin background colour and extended the storage ability of apples compared to higher temperatures. CA during the first stage of storage better maintained the firmness and stiffness of the apples. However, it reduced subsequent ethylene and carbon dioxide (CO<sub>2</sub>) production after removal from storage. Steep increases in ethylene and CO<sub>2</sub> production coincided with rapid softening in the fruit flesh and yellowing of the skin background colour, under NA conditions.

The exponential decay model was the best model for predicting changes in the firmness, stiffness and keeping quality of the apples. The exponential decay model satisfied the biochemical theory of softening in the apple, and had the highest fitness to the experimental data collected over the wide range of temperatures. The softening rate increased exponentially with storage temperature complying with the Arrhenius equation. Therefore a combination of the exponential decay model with the Arrhenius equation was found to best characterise the softening process and to predict changes in the firmness and stiffness of apples stored at different temperatures in NA conditions.

## DECLARATION OF ORIGINALITY

The contents and subject matter of this thesis are the original work conducted by the author, except where otherwise acknowledged. This thesis contains no materials that has been submitted for the award of any other degree or diploma in any university. Some of the results of this research have been published and presented at several national and international conferences (Appendix 1).

A handwritten signature in black ink, reading "Pham Van Tan", written in a cursive style. The signature is positioned above a horizontal line that extends to the right.

Tan Van Pham

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## LIST OF ABBREVIATIONS

A	Frequency factor ( $\text{Day}^{-1}$ )
ACC	1-aminocyclopropane-1-carboxylic acid
ACC-O	ACC oxidase
ACS	ACC synthase
AFS	Acoustic firmness sensor
Ar	Argon
AVG	Aminoethoxyvinylglycine
C*	Chroma, intensity of colour
CA	Controlled atmosphere
CO <sub>2</sub>	Carbon dioxide
C <sub>2</sub> H <sub>4</sub>	Ethylene
Ea	Activation energy ( $\text{J}\cdot\text{mol}^{-1}$ )
Fmin	Minimum firmness ( $\text{kg}\cdot\text{cm}^{-2}$ )
<i>f</i>	Resonant frequency (Hz)
<i>h</i>	Hue angle of colour
IEC	Internal ethylene concentration
K	Potassium
<i>k<sub>s</sub></i>	Softening rate ( $\text{Day}^{-1}$ )
<i>k<sub>s'</sub></i>	Softening rate caused by weight loss ( $\%^{-1}$ )
<i>k<sub>sbc</sub></i>	Softening rate caused by biochemical reactions ( $\text{Day}^{-1}$ )
<i>k<sub>swl</sub></i>	Softening rate caused by weight loss ( $\text{Day}^{-1}$ )
L*	Lightness of colour
LE	Low-ethylene
LE-CA	Low-ethylene controlled atmosphere
LO	Low-oxygen
LO-CA	Low-oxygen controlled atmosphere
MA	Modified atmosphere
MT	Magness-Taylor
m	The mass of the plunger (kg)
N <sub>2</sub>	Nitrogen
NA	Normal atmosphere (21kPa O <sub>2</sub> :0.04kPa CO <sub>2</sub> :78kPa N <sub>2</sub> :0.9kPa Ar)
NAA	Napthaleneacetamide
O <sub>2</sub>	Oxygen
P	Phosphorus
<i>p<sub>a</sub></i>	Water vapour pressure of the air (Pa)
PAL	Phenylanune ammonia-lyase
PME	Pectin methyl esterase
<i>p<sub>s</sub></i>	Water vapour pressure at the surface of apple (Pa)
PG	Polygalacturonase
R	The universal gas constant, $R = 8.314 \text{ J}\cdot\text{mol}^{-1}\text{K}^{-1}$
RH	Relative humidity of air (%)
S	Stiffness index

S <sub>min</sub>	Minimum stiffness (Stiffness Index - S)
Span	The drop in firmness (or stiffness) from the initial value to the minimum value (kg.cm <sup>-2</sup> or S)
S( <i>w</i> )	Stiffness of apple at weight loss level - <i>w</i> , (S)
T	Storage temperature (°C or K)
<i>t</i>	Storage time (Day)
TSS	Total soluble solids (%)
ULO	Ultra-low oxygen
W	Weight of apple fruit (kg)
<i>w</i>	Weight loss of apple (%)
<i>W<sub>i</sub></i>	Weight of the apple at the beginning of storage (g)
<i>W<sub>t</sub></i>	Weight of the apple at the storage time - <i>t</i> (g)
wvpd	Water vapour pressure deficit, the difference in pressure between the fruit and the air (Pa)