Segregation of 'Hayward' kiwifruit for storage potential

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"Science is but an image of the truth."

Francis Bacon

Abstract

This study aimed to develop technologies to segregate 'Hayward' kiwifruit (*Actinidia deliciosa* (A.Chev) C.F. Liang et A.R. Ferguson) for storage potential. Such segregation will allow the industry to better match market opportunities with the storage potential of particular fruit thereby reducing fruit loss and assuring fruit quality in the market place.

The first part of the research rationalised methodologies to study storage potential of kiwifruit. These included firmness measurement, fruit temperature equilibration, calculation of storage life, sample preparation for mineral analysis and the feasibility of using compression force as an alternative to flesh firmness for firmness monitoring.

The second part of the research developed a model to segregate kiwifruit on a grower line basis. Based on data collected over 2 years from 108 grower lines, canonical discriminant analysis indicated that the first two canonical functions (CDF_1 and CDF_2) accounted for 95% variation of four softening-rate groups and correctly classified over 50% of the grower lines to the correct groups compared with a chance criterion of 25%. Grower lines with high CDF_1 (characterised by high Ca/N, high Mg, advanced maturity, late harvest and low lightness) softened at low rates and had long storage life. CDF_2 discriminated grower lines on prestorage delay. For grower lines with low CDF_1, extending prestorage delay improved storage potential. In contrast, extended prestorage delay reduced the storage potential of grower lines with high CDF_1.

The third part of the research developed a model to segregate kiwifruit on an individual fruit basis. NIR spectra taken at harvest were used to quantify many at-harvest fruit attributes, allowing for prediction of fruit firmness at the end of storage and discriminating disordered fruit from healthy fruit for fruit segregation on an individual fruit basis. Further work is needed to improve prediction and segregation accuracies by selecting appropriate NIR instrument and to incorporate the instrument with grading machines in a way that measurement error can be minimised. Factors affecting NIR measurement and possible improvements were also investigated.

The strategic application of segregation technologies and further research directions are discussed for the kiwifruit industry to develop cost-effective procedures to solve problems associated with fruit variation in storage potential.

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Chapter 3 Suggestions on rationalized methodologies to investigate kiwifruit storage life

Chapter 4 The application of compression force in the study of kiwifruit storage life

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α	A coefficient between internal ethylene concentration and the concentration of a hypothetic enzyme catalysing fruit softening	
A	Surface area of a fruit	m^2
A	The upper asymptote of a Richards function	
AA	Ascorbic acid	
ABS	Absorbance	
ABS+NM	ABS normalised to minimum and maximum	
ABS+QBC	Quadratic baseline compensation of ABS	
ABS+SNV	Standard normal variate transformation of ABS	
ABS_{671}	VNIR absorbance at 671 nm	
ABS_{824}	VNIR absorbance at 824 nm	
ACC	1-aminocyclopropane-1-carboxylic acid	
ACO	ACC oxidase	
ASTD	Average standard deviation	
b	Positions parameter of a Richards function	
C	Fruit chroma	
CC_p	Ppercentage chance criterion	%
Ca	Calcium concentration	mmol kg^{-1}
CA	Controlled atmosphere	
Ca/N	The ratio of calcium and nitrogen concentrations	%
CDA	Canonical discriminant analysis	
CDF_1	The first canonical function	
CDF_2	The second canonical function	
CDF_3	The third canonical function	
CDF_{1i}	CDF_1 of observation $_i$	
CDF_{2i}	CDF_2 of observation $_i$	
$\overline{CDF}_{1j}$	The mean CDF_1 of group j	
$\overline{CDF}_{2j}$	The mean CDF_2 of group j	
CF	Compression force	N

CF_0	Initial compression force	N
CF_{end}	A CF value equivalent to a flesh firmness of 8.5 N at 20 °C	N
CFS	CF measured at simulated shelf life	N
CI	Chilling injury	
CT	Computed tomography	
d	Day	
D	Compression distance	mm
D_1	First order derivative	
D_2	Second derivative of ABS	
$D_{2(684)}$	The second derivative at 684 nm	
$D_{2(700)}$	The second derivative at 700 nm	
D_2+NM	D_2 normalised to minimum and maximum	
D_2+SNV	Standard normal variate transformation of D_2	
D_{ij}	Mahalanobis distance of observation i to the centre of group j	
DD	Cumulative degree-days	°C d
DEXA	Differential energy X-ray analysis	
df	degree of freedom	
DL	Postharvest delay	d
DM	Dry matter content	%
DW	Dry weight	kg
ECC	Eccentricity	
Enz	A hypothetic enzyme catalysing fruit softening	
Enz(t)	The concentration of Enz at time t	mol L^{-1}
Enz_0	Initial concentration of Enz	mol L^{-1}
Enz_{pre}	Precursor of Enz	
F	Fruit firmness (compression force or flesh firmness) as a substrate of a hypothetic fruit softening reaction	
F(t)	F value at time t	
F_0	Initial fruit firmness	N
FC	Flesh chroma	
FF	Flesh firmness	N
FF_0	Initial flesh firmness	N
FF_1	The first FF reading measured on a fruit	N
FF_2	The second FF reading measured on a fruit	N

FFS	FF measured at the simulated shelf life	N
FH	Flesh hue angle	
FL	Flesh lightness	
FR	Fungal rots	
FT	Fourier transformation	
FW	Fresh weight	kg
H	Fruit hue angle	
h	hour	
HD	Harvest date (days after 1 April)	d
HEM	High energy counts of middle part of a fruit	
HEO	High energy counts of outer part of a fruit	
HEW	High energy counts of the whole fruit	
I_d	VNIR spectrum of a dark reference	
I_f	VNIR spectrum of a fruit	
I_i	Spectral datum at point i	
I_s	VNIR spectrum of a chemical solution	
I_w	VNIR spectrum of a white reference	
I_{H_2O}	VNIR spectrum of water	
$\bar{I}_g$	Means of the spectral data of group g	
ΔI_g	Difference in spectral data between adjacent groups	
IEC	Internal ethylene concentration	mol L^{-1}
IP	Inner pericarp	
k	Increase rate of a Richards function	
k	The rate coefficient of fruit softening	
k_p	The rate constant of a hypothetic fruit softening reaction	
K	Potassium concentration	mmol kg^{-1}
K tray	Single-layered kiwifruit trays with a polyliner	
KG_1	The first group of grower lines that softened at the lowest rate	
KG_2	The second group of grower lines that softened at the second lowest rate	
KG_3	The third group of grower lines that softened at the second highest rate	
KG_4	The fourth group of grower lines that softened at the highest rate	
L	Fruit lightness	
LEO	Low energy counts of outer part of a fruit	

LEM	Low energy counts of middle part of a fruit	
LEW	Low energy counts of the whole fruit;	
$LSD_{0.05}$	Least significant difference at P=0.05	
LTB	Low temperature breakdown	
Lth	The length of a fruit in pixels	
M	The mass of a fruit	kg
M tray	Interleaving tray commercially used in 20 kg apple packages	
Mg	Magnesium concentration	mmol kg^{-1}
MLR	Multiple linear regression	
MPLS	Modified partial least square regression	
MSC	Multiplicative scatter correlation technique	
MSPR	The means of the squared prediction error	
N	Nitrogen concentration	mmol kg^{-1}
N	Newton	
NIR	Near-infrared	
NLIN	Non-linear regression	
NS	Not significant	
NSD	Normalised second derivative	
OP	Outer pericarp	
ρ	Power factor of a power function	
P	Phosphorus concentration	mmol kg^{-1}
p_e	Partial pressures of ethylene of the environment	Pa
p_i	Partial pressures of ethylene inside the fruit	Pa
$P'_{C_2H_4}$	The permeance of the fruit skin to ethylene	mol s^{-1} m^{-2} Pa^{-1}
$\Delta p_{C_2H_4}$	The difference in partial pressures of ethylene between P_e and P_i	Pa
PC	Principal component	
PCA	Principal component analysis	
PCR	Principal component regression	
PG	Polygalacturonase	
PixM	Area of middle part of a fruit in pixels;	
PixO	Area of outer part of a fruit in pixels;	
PixW	Area of the whole fruit in pixels;	
PKG_1	Predicted KG_1	

PKG_2	Predicted KG_2	
PKG_3	Predicted KG_3	
PKG_4	Predicted KG_4	
PLS	Partial least square regression	
PME	Pectin methyl esterase	
PP	Purple patches	
PPT	Physiological pitting	
PRESS	Sum squares of predicted residual	
r	Correlation coefficient	
R^2	Coefficient of determination	
R^2_p	Coefficient of determination for validation data set	
$r_{C_2H_4}$	Ethylene production rate	mol kg^{-1} s^{-1}
$r'_{C_2H_4}$	Rate of ethylene transfer from fruit to the environment	mol s^{-1}
r_{CO_2}	Respiration rate	nmol kg^{-1} s^{-1}
REG	Regression	
RH	Relative humidity	%
RMSEP	Root mean square error of prediction	
s_g	Standard deviations of spectral data of group *g* at a wavelength	
SABS	Smoothed ABS	
SABS+NM	SABS normalised to minimum and maximum	
SABS+QBC	Quadratic baseline compensation of SABS	
SABS+SNV	Standard normal variate transformation of SABS	
SCC	Standardized canonical coefficient	
SDR	Data set standard deviation divided by RMSEP	
se	Standard error	
SEB	Stem end botrytis	
SEP	Standard error of prediction	
SL	Storage life	d
SP	Soft patches	
SR	Side rot	
SRD	The sum of relative difference between groups	
SSC	Soluble solids content	%
SSF	Soluble solids in whole fruit	%

SSFDM	The percentage of dry matter that have solubilized	%
STDP	Standard error of the mean predicted value	
STEPDISC	Stepwise discriminant analysis	
STP	Storage potential	
t	Storage time	d
$t_{7/8}$	Seven-eighth temperature equilibration time	h
TND	Trend	
ULO	Ultra low oxygen	
v	Inflexion point of a Richards function	
VNIR	Visible-near-infrared	
W_0	Initial fruit weight	kg
WL	Weight loss	%
WPI	Whey protein isolated	
Wth	The width of a fruit in pixels	
XET	Xyloglucan endotransglycosylase	