Appendix 4: Modelling change in firmness of 'Cripps Pink' apples during NA storage

Appendix 4.1 Result of the non-linear regression analysis of fitting the exponential decay model (Eq. 4.6) to the six firmness data sets of 'Cripps Pink' apples stored at six temperatures from 0°C to 30°C in single stage of NA storage, using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage time (*t*) in Day was an independent variable of the firmness function *F(t)*.

Equation: Exponential decay (EXP)
$F(t) = \text{Fmin} + \text{Span}*\text{Exp}[-k_s*t]$

	I. 0°C	I. 2.5°C	I. 5°C	I.10°C	I. 20°C	I. 30°C	Global (shared)
Exponential decay (EXP)							
Best-fit values							
Fmin	1.6	1.6	1.6	1.6	1.6	1.6	
Span	7.36	7.36	7.36	7.36	7.36	7.36	7.36
k_s	0.002	0.00248	0.003059	0.00391	0.006163	0.0101	
Std. Error							
Span	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396
k_s	9.31E-05	0.0001129	0.0001409	0.0001858	0.0002851	0.0005347	
95% Confidence Intervals							
Span	7.279 to 7.440	7.279 to 7.440	7.279 to 7.440	7.279 to 7.440	7.279 to 7.440	7.279 to 7.440	7.279 to 7.440
k_s	0.001811 to 0.002189	0.002250 to 0.002710	0.002773 to 0.003345	0.003533 to 0.004288	0.005583 to 0.006742	0.009012 to 0.01119	
Goodness of Fit							
Degrees of Freedom							34
R^2	0.9661	0.9758	0.9736	0.9923	0.9811	0.9541	0.9745
Absolute Sum of Squares	0.1454	0.1076	0.1178	0.02778	0.06087	0.1171	0.5766
Sy.x							0.1302
Normality of Residuals							
Kolmogorov-Smirnov distance	0.3456	0.2361	0.2546	0.1855	0.2789	0.183	
P value	0.0115	P > 0.10	P > 0.10	P > 0.10	P > 0.10	P > 0.10	
D'Agostino & Pearson omnibus K2	0	0	0	0	0	0	

P value	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	
Shapiro-Wilk W	0.7413	0.8603	0.8826	0.9554	0.8575	0.9599	
P value	0.0103	0.1524	0.2382	0.7785	0.1438	0.8191	
Constraints							
Fmin	Fmin = 1.600	Fmin = 1.600	Fmin = 1.600	Fmin = 1.600	Fmin = 1.600	Fmin = 1.600	
Span	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	
k_s	k_s > 0.0	k_s > 0.0	k_s > 0.0	k_s > 0.0	k_s > 0.0	k_s > 0.0	
Data							
Number of X values	7	7	7	7	7	7	
Number of Y replicates	1	1	1	1	1	1	
Total number of values	7	7	7	7	7	6	
Number of missing values	0	0	0	0	0	1	

Appendix 4.2 Result of the non-linear regression analysis of fitting the Arrhenius equation (Eq. 4.7) to the best fit values of softening rate k_s in Table 4.2 using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage temperature (T) in K was an independent variable of the softening rate function, k_s in Day^{-1}.

Equation: The Arrhenius Equation

$k_s = A*Exp[-Ea/\{8.314*T\}]$

The Arrhenius Equation	
Best-fit values	
A	10846
EA	34988
Std. Error	
A	3850
EA	872.3
95% Confidence Intervals	

A	159.7 to 21533
EA	32567 to 37410
Goodness of Fit	
Degrees of Freedom	4
R^2	0.9979
Absolute Sum of Squares	9.68E-08
Sy.x	0.0001555
Normality of Residuals	
Kolmogorov-Smirnov distance	0.1695
P value	P > 0.10
D'Agostino & Pearson omnibus K2	0
P value	P<0.0001
Shapiro-Wilk W	0.9604
P value	0.8231
Data	
Number of X values	6
Number of Y replicates	1
Total number of values	6
Number of missing values	0

Appendix 4.3 Result of the non-linear regression analysis of fitting the three-dimensional compound model, including the exponential decay model (Eq. 4.8) and Arrhenius equation (Eq. 4.9) to the six firmness data sets of 'Cripps Pink' apples stored at six temperatures from 0^{o}C to 30^{o}C in single stage of NA, using the Least-Squares method with the iterative procedure of the software package DataFit 8.1, 2005. Storage temperature (T) in K and storage time (*t*) in Day were independent variables of the firmness function *F(t)*.

DataFit version 8.1.69
Equation ID: three-dimensional compound model
Model Definition:
k_s = A*Exp(-Ea/(8.314*T))
F(t) = 1.6 + Span*Exp(-k_s**t*)

Number of observations = 41
Number of missing observations = 0
Solver type: Nonlinear
Nonlinear iteration limit = 250
Diverging nonlinear iteration limit =10
Number of nonlinear iterations performed = 117
Residual tolerance = 0.0000000001
Sum of Residuals = -5.65830129822054E-03
Average Residual = -1.38007348737086E-04
Residual Sum of Squares (Absolute) = 0.701668435760315
Residual Sum of Squares (Relative) = 0.701668435760315
Standard Error of the Estimate = 0.135885830150895
Coefficient of Multiple Determination (R^2) = 0.9689573808
Proportion of Variance Explained = 96.89573808%
Adjusted coefficient of multiple determination (Ra^2) = 0.9673235587
Durbin-Watson statistic = 1.78970303744591

Regression Variable Results

Variable	Value	Standard Error	t-ratio	Prob(t)	
A	15332.5149227582	7801.62326843415	1.965298041	0.05672	
Ea	35828.5347904808	1193.22430933921	30.0266551	0.0	
Span	7.35449655919222	0.041234811941456	178.3564957	0.0	
68% Confidence Intervals					
Variable	Value	68% (+/-)	Lower Limit	Upper Limit	
A	15332.5149227582	7860.91560527425	7471.59931748392	23193.4305280324	
Ea	35828.5347904808	1202.29281409019	34626.2419763907	37030.827604571	
Span	7.35449655919222	4.15481965122111E-02	7.31294836268001	7.39604475570443	
90% Confidence Intervals					
Variable	Value	90% (+/-)	Lower Limit	Upper Limit	
A	15332.5149227582	13153.53683058	2178.97809217819	28486.0517533382	
Ea	35828.5347904808	2011.77618554591	33816.7586049349	37840.3109760268	
Span	7.35449655919222	6.95218929332949E-02	7.28497466625892	7.42401845212551	
95% Confidence Intervals					
Variable	Value	95% (+/-)	Lower Limit	Upper Limit	
A	15332.5149227582	15793.6061446181	-461.091221859926	31126.1210673763	
Ea	35828.5347904808	2415.5632918263	33412.9714986545	38244.0980823072	
Span	7.35449655919222	8.34757532942836E-02	7.27102080589793	7.4379723124865	
99% Confidence Intervals					
Variable	Value	99% (+/-)	Lower Limit	Upper Limit	
A	15332.5149227582	21154.1014923592	-5821.58656960103	36486.6164151174	
Ea	35828.5347904808	3235.42771477328	32593.1070757076	39063.9625052541	
Span	7.35449655919222	0.111808192579258	7.24268836661296	7.46630475177148	

Variance Analysis Source	DF	Sum of Squares	Mean Square	F Ratio	Prob(F)
Regression	2	21.9017218081421	10.9508609040711	593.0617556	0
Error	38	0.701668435760315	1.84649588357978E-02		
Total	40	22.6033902439024			

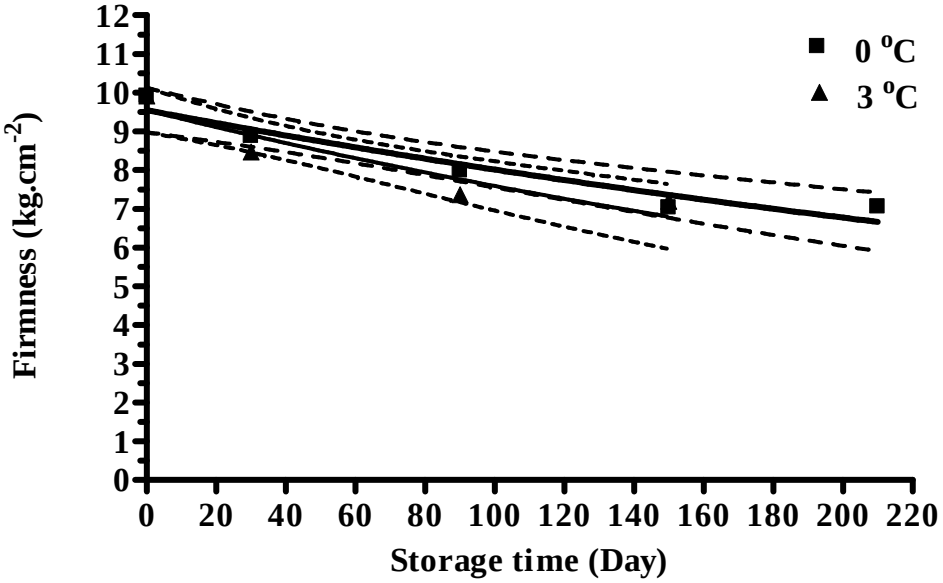
Appendix 4.4 Values of the parameters F_{min}, Span and k_s of the exponential decay model (Eq. 4.6) were calibrated by fitting the exponential decay model to the two firmness data sets of the 'Cripps Pink' apples harvested in Batlow, New South Wales, Australia in May 2006 and stored at 0°C and 3°C in commercial conditions of NA. Fitting was carried out by non-linear regression using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage time (*t*) in Day was an independent variable of the firmness function *F(t)*.

Equation: Exponential decay (EXP)
$F(t) = Fmin + Span*Exp[-k_s*t]$

	0 °C	3 °C	Global (shared)
Exponential decay (EXP)			
Best-fit values			
Fmin	1.6	1.6	
Span	7.949	7.949	7.949
k_s	0.002146	0.002829	
Std. Error			
Span	0.2356	0.2356	0.2356
k_s	0.0003495	0.0005149	
95% Confidence Intervals			
Span	7.372 to 8.525	7.372 to 8.525	7.372 to 8.525

k_s	0.001291 to 0.003001	0.001569 to 0.004089	
Goodness of Fit			
Degrees of Freedom			6
R^2	0.9258	0.8652	0.8996
Absolute Sum of Squares	0.4526	0.6307	1.083
Sy.x			0.4249
Normality of Residuals			
Kolmogorov-Smirnov distance	0.3046	0.2947	
P value	P > 0.10	P > 0.10	
D'Agostino & Pearson omnibus K2	0	0	
P value	P<0.0001	P<0.0001	
Shapiro-Wilk W	0.8293	0.7714	
P value	0.1374	0.06	
Constraints			
Fmin	Fmin = 1.600	Fmin = 1.600	
Span	Span > 0.0 and shared	Span > 0.0 and shared	
k_s	k_s > 0.0	k_s > 0.0	
Data			
Number of X values	4	4	
Number of Y replicates	1	1	
Total number of values	5	4	
Number of missing values	-1	0	

Appendix 4.5 Result of fitting the exponential decay model (Eq. 4.6) to the two firmness data sets of 'Cripps Pink' apples harvested in Batlow, New South Wales, Australia in May 2006 and stored at 0°C and 3°C in commercial conditions of NA using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage time (*t*) in Day was an independent variable of the firmness function *F(t)*. The symbols indicate the firmness mean of 10 apples. The continuous curves represent the model estimates describing responses of firmness to different storage temperatures. The two broken curves, above and below of each curve, show 95% confidence bands.



Appendix 4.6 Result of the non-linear regression analysis of fitting the three-dimensional compound model including the exponential decay model (Eq. 4.8) and Arrhenius equation (Eq. 4.9) to the two firmness data sets of 'Cripps Pink' apples harvested in Batlow, New South Wales, Australia in May 2006 and stored at 0^{o}C and 3^{o}C in commercial conditions of NA using the Least-Squares method with the iterative procedure of the software package DataFit 8.1, 2005. Storage temperature (T) in K and storage time (*t*) in Day were independent variables of the firmness function *F(t)*.

DataFit version 8.1.69
Equation ID: three-dimensional compound model
Model Definition:
k_s = A*Exp(-Ea/(8.314*T))
F(t) = 1.6 + Span*Exp(-k_s**t*)

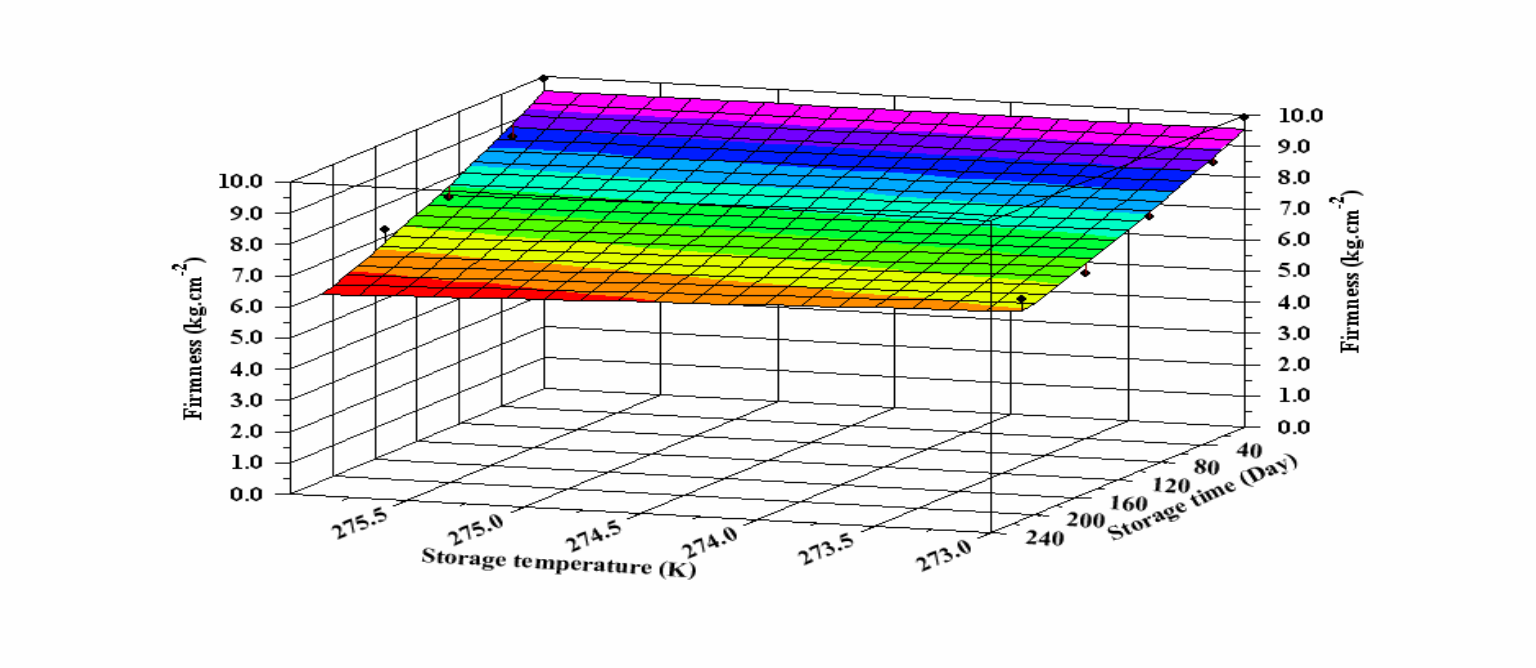
Number of observations = 9
Number of missing observations = 0
Solver type: Nonlinear
Nonlinear iteration limit = 250
Diverging nonlinear iteration limit =10
Number of nonlinear iterations performed = 76
Residual tolerance = 0.0000000001
Sum of Residuals = 2.80727606433917E-02
Average Residual = 3.11919562704352E-03
Residual Sum of Squares (Absolute) = 1.08329791808678
Residual Sum of Squares (Relative) = 1.08329791808678
Standard Error of the Estimate = 0.424911347241355
Coefficient of Multiple Determination (R^2) = 0.8995547165
Proportion of Variance Explained = 89.95547165%
Adjusted coefficient of multiple determination (Ra^2) = 0.8660729554
Durbin-Watson statistic = 1.93877407354144

Regression Variable Results

Variable	Value	Standard Error	t-ratio	Prob(t)	
A	233338994.711596	4307921591.73551	0.054165098	0.95856	
Ea	57678.4498963996	42094.2003652094	1.370223199	0.21967	
Span	7.94854254297352	0.235554588020631	33.74395128	0.0	
68% Confidence Intervals					
Variable	Value	68% (+/-)	Lower Limit	Upper Limit	
A	233338994.711596	4669787005.44129	-4436448010.7297	4903126000.15289	
Ea	57678.4498963996	45630.113195887	12048.3367005126	103308.563092287	
Span	7.94854254297352	0.255341173414364	7.69320136955916	8.20388371638789	
90% Confidence Intervals					
Variable	Value	90% (+/-)	Lower Limit	Upper Limit	
A	233338994.711596	8371153237.06044	-8137814242.34885	8604492231.77204	
Ea	57678.4498963996	81797.4501496749	-24119.0002532753	139475.900046074	
Span	7.94854254297352	0.457729675441691	7.49081286753183	8.40627221841522	
95% Confidence Intervals					
Variable	Value	95% (+/-)	Lower Limit	Upper Limit	
A	233338994.711596	10541053342.8176	-10307714348.106	10774392337.5292	
Ea	57678.4498963996	103000.298873631	-45321.8489772313	160678.74877003	
Span	7.94854254297352	0.576378521427683	7.37216402154584	8.52492106440121	
99% Confidence Intervals					
Variable	Value	99% (+/-)	Lower Limit	Upper Limit	
A	233338994.711596	15971188509.2002	-15737849514.4886	16204527503.9118	
Ea	57678.4498963996	156060.038433977	-98381.5885375777	213738.488330377	
Span	7.94854254297352	0.873295079627689	7.07524746334584	8.82183762260121	

Variance Analysis					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob(F)
Regression	2	9.70165763746878	4.85082881873439	26.86700715	0.00101
Error	6	1.08329791808678	0.180549653014464		
Total	8	10.7849555555556			

Appendix 4.7 Result of fitting the three-dimensional compound model of a 3D function of firmness changing with storage time and temperature (Eqs. 4.8 & 4.9) to the two firmness data sets of 'Cripps Pink' apples stored harvested in Batlow, New South Wales, Australia in May 2006 and stored at 0^{o}C and 3^{o}C in commercial conditions of NA, using the Least-Squares method with the iterative procedure of the software package DataFit 8.1, 2005. Storage temperature (T) in K and storage time (*t*) in Day were independent variables of the firmness function *F(t)*. The surface represents the prediction model while the symbols represent the stiffness mean of 10 apples.



Appendix 5: Modelling change in stiffness of 'Cripps Pink' apples during NA storage

Appendix 5.1 Result of the non-linear regression analysis of fitting the exponential decay model (Eq. 5.1) to the six stiffness data sets of 'Cripps Pink' apples stored at six temperatures from 0°C to 30°C in single stage of NA storage, using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage time (*t*) in Day was an independent variable of the stiffness function *S(t)*.

Equation: Exponential decay (EXP)
$S(t) = \text{Smin} + \text{Span}*\text{Exp}[-k_s*t]$

Exponential decay	0°C	2.5°C	5°C	10°C	20°C	30°C	Global (shared)
Best-fit values							
Smin	7	7	7	7	7	7	
Span	27.21	27.21	27.21	27.21	27.21	27.21	27.21
k_s	0.0003965	0.0007477	0.001763	0.002652	0.005757	0.01139	
Std. Error							
Span	0.2433	0.2433	0.2433	0.2433	0.2433	0.2433	0.2433
k_s	0.0001303	0.0001605	0.0002643	0.0002902	0.000536	0.0009246	
95% Confidence Intervals							
Span	26.71 to 27.70	26.71 to 27.70	26.71 to 27.70	26.71 to 27.70	26.71 to 27.70	26.71 to 27.70	26.71 to 27.70
k_s	0.0001310 to 0.0006620	0.0004207 to 0.001075	0.001225 to 0.002302	0.002061 to 0.003244	0.004665 to 0.006849	0.009504 to 0.01327	
Goodness of Fit							
Degrees of Freedom							32
R^2	0.593	0.698	0.9756	0.8971	0.9689	0.7387	0.8982
Absolute Sum of Squares	4.131	5.103	0.3165	2.098	1.014	8.412	21.07
Sy.x							0.8115
Runs test							
Points above curve	4	3	2	3	3	3	
Points below curve	3	4	4	4	2	4	
Number of runs	2	2	3	3	3	3	

P value (runs test)	0.05714	0.05714	0.4	0.2	0.5	0.2	
Deviation from Model	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	
Constraints							
Smin	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	
Span	Span is shared	Span is shared	Span is shared	Span is shared	Span is shared	Span is shared	
k_s	k_s > 0.0	k_s > 0.0	k_s > 0.0	k_s > 0.0	k_s > 0.0	k_s > 0.0	
Data							
Number of X values	8	8	8	8	8	8	
Number of Y replicates	1	1	1	1	1	1	
Total number of values	7	7	6	7	5	7	
Number of missing values	1	1	2	1	3	1	

Appendix 5.2 Result of the non-linear regression analysis of fitting the exponential model (Eq. 5.2) to the six stiffness data sets of 'Cripps Pink' apples stored at six temperatures from 0°C to 30°C in single stage of NA storage, using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Weight loss (*w*) in (%) was an independent variable of the stiffness function *S(w)*. $k_{s'}$ softening rate changing with weight loss (% $^{-1}$).

Equation: Exponential model

$S(w) = \text{Smin} + \text{Span}*\text{Exp}[-k_{s'}*w]$

Exponential model	0°C	2.5°C	5°C	10°C	20°C	30°C	Global (shared)
Best-fit values							
Smin	7	7	7	7	7	7	
Span	26.89	26.89	26.89	26.89	26.89	26.89	26.89
$k_{s'}$	0.04247	0.0858	0.2001	0.3082	0.6849	1.349	
Std. Error							
Span	0.1895	0.1895	0.1895	0.1895	0.1895	0.1895	0.1895
$k_{s'}$	0.01218	0.01501	0.02475	0.02719	0.05006	0.08636	
95% Confidence Intervals							

Span	26.51 to 27.28	26.51 to 27.28	26.51 to 27.28	26.51 to 27.28	26.51 to 27.28	26.51 to 27.28	26.51 to 27.28
$k_{s'}$	0.01759 to 0.06735	0.05514 to 0.1165	0.1496 to 0.2507	0.2526 to 0.3637	0.5827 to 0.7871	1.173 to 1.526	
Goodness of Fit							
Degrees of Freedom							30
R^2	0.8268	0.9395	0.9706	0.9233	0.9712	0.7892	0.936
Absolute Sum of Squares	0.685	0.4294	0.3807	1.565	0.936	6.788	10.78
Sy.x							0.5995
Normality of Residuals							
Kolmogorov-Smirnov distance	0.1928	0.1445	0.2687	0.2394	0.2507	0.2098	
P value	P > 0.10	P > 0.10	P > 0.10	P > 0.10	P > 0.10	P > 0.10	
D'Agostino & Pearson omnibus K2	0	0	0	0	0	0	
P value	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	
Shapiro-Wilk W	0.8817	0.9877	0.9011	0.8676	0.9016	0.9368	
P value	0.277	0.9829	0.3802	0.1767	0.4189	0.6103	
Runs test							
Points above curve	4	4	2	3	3	3	
Points below curve	2	2	4	4	2	4	
Number of runs	2	3	3	3	3	3	
P value (runs test)	0.1333	0.4	0.4	0.2	0.5	0.2	
Deviation from Model	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	
Constraints							
Smin	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	
Span	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	
Data							
Number of X values	110	110	110	110	110	110	
Number of Y replicates	1	1	1	1	1	1	
Total number of values	6	6	6	7	5	7	
Number of missing values	104	104	104	103	105	103	

Appendix 5.3 Result of the non-linear regression analysis of fitting the Arrhenius equation (Eq. 4.7) to the best fit values of softening rate k_s in Table 5.1 using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage temperature (T) in K was an independent variable of the softening rate function, k_s in Day^{-1}.

Equation: The Arrhenius Equation
k_s = A*Exp[-Ea/{8.314*T}]

The Arrhenius Equation	
Best-fit values	
A	4.81E+07
EA	55805
Std. Error	
A	7.57E+07
EA	3923
95% Confidence Intervals	
A	-162100000 to 2.583e+008
EA	44916 to 66694
Goodness of Fit	
Degrees of Freedom	4
R^2	0.99
Absolute Sum of Squares	8.76E-07
Sy.x	0.0004679
Normality of Residuals	
Kolmogorov-Smirnov distance	0.2457
P value	P > 0.10
D'Agostino & Pearson omnibus K2	0
P value	P<0.0001
Shapiro-Wilk W	0.8817

P value	0.277
Data	
Number of X values	6
Number of Y replicates	1
Total number of values	6
Number of missing values	0

Appendix 5.4 Result of the non-linear regression analysis of fitting the three-dimensional decay model of a 3D function of stiffness changing with storage time and temperature (Eqs. 4.7 & 5.1) to the six stiffness data sets of 'Cripps Pink' apples stored at six temperatures from 0°C to 30°C in single stage of NA, using the Least-Squares method with the iterative procedure of the software package DataFit 8.1, 2005. Storage temperature (T) in K and storage time (*t*) in Day were independent variables of the stiffness function *S(t)*.

DataFit version 8.1.69
Equation ID: Three-dimensional decay model
Model Definition:
k_s = A*Exp(-Ea/(8.314*T))
S(t) = 7 + Span*Exp(-k_s**t*)

Number of observations = 39
Number of missing observations = 0
Solver type: Nonlinear
Nonlinear iteration limit = 250
Diverging nonlinear iteration limit =10
Number of nonlinear iterations performed = 12
Residual tolerance = 0.0000000001
Sum of Residuals = 8.72359103381051E-02
Average Residual = 2.23681821379757E-03
Residual Sum of Squares (Absolute) = 38.4677616321609

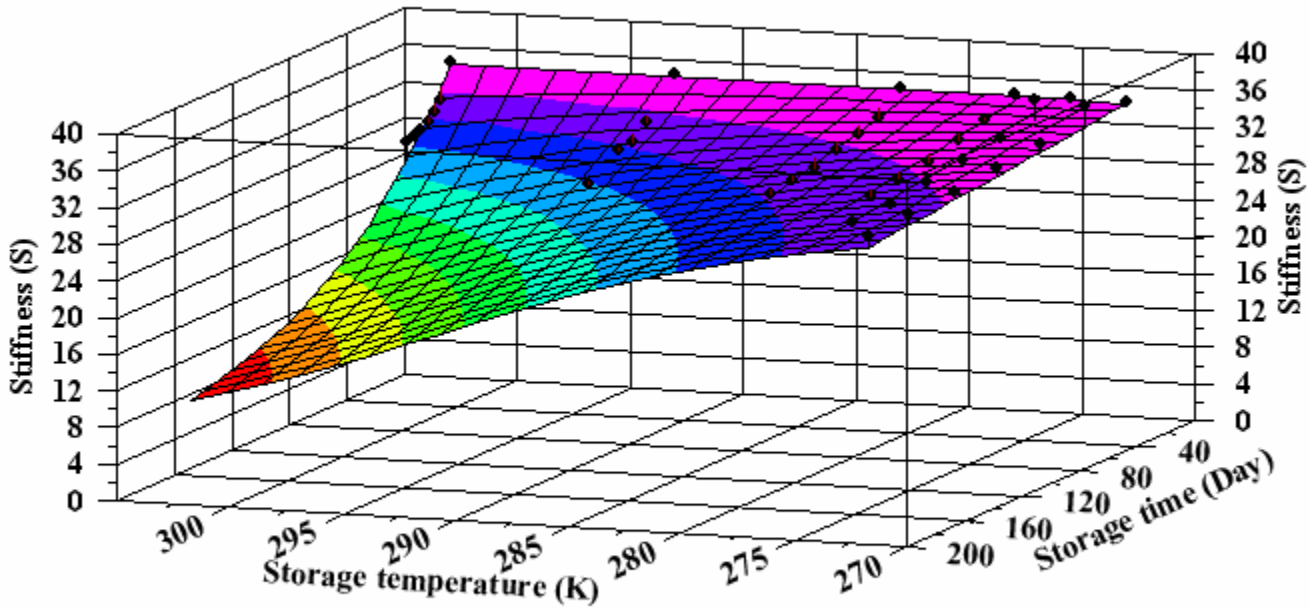
Residual Sum of Squares (Relative) = 38.4677616321609
Standard Error of the Estimate = 1.03370640620376
Coefficient of Multiple Determination (R^2) = 0.8141097255
Proportion of Variance Explained = 81.41097255%
Adjusted coefficient of multiple determination (Ra^2) = 0.803782488
Durbin-Watson statistic = 0.774660654200762

Regression Variable Results

Variable	Value	Standard Error	t-ratio	Prob(t)	
A	1839087946.87257	2904679470.37082	0.633146606	0.53064	
Ea	64799.0599692132	3900.61706437046	16.61251512	0.0	
Span	27.199336676751	0.306387077301086	88.7744252	0.0	
68% Confidence Intervals					
Variable	Value	68% (+/-)	Lower Limit	Upper Limit	
A	1839087946.87257	2929078777.92194	-1089990831.04936	4768166724.79451	
Ea	64799.0599692132	3933.38224771117	60865.677721502	68732.4422169243	
Span	27.199336676751	0.308960728750415	26.8903759480006	27.5082974055014	
90% Confidence Intervals					
Variable	Value	90% (+/-)	Lower Limit	Upper Limit	
A	1839087946.87257	4903970349.82706	-3064882402.95448	6743058296.69963	
Ea	64799.0599692132	6585.41178977664	58213.6481794365	71384.4717589898	
Span	27.199336676751	0.517273302607424	26.6820633741435	27.7166099793584	
95% Confidence Intervals					
Variable	Value	95% (+/-)	Lower Limit	Upper Limit	
A	1839087946.87257	5890980433.85906	-4051892486.98649	7730068380.73164	
Ea	64799.0599692132	7910.84146824973	56888.2185009635	72709.9014374629	

Span	27.199336676751	0.621383631474333	26.5779530452766	27.8207203082253	
99% Confidence Intervals					
Variable	Value	99% (+/-)	Lower Limit	Upper Limit	
A	1839087946.87257	7899275819.67345	-6060187872.80088	9738363766.54602	
Ea	64799.0599692132	10607.7281065555	54191.3318626577	75406.7880757686	
Span	27.199336676751	0.833219656720304	26.3661170200307	28.0325563334713	
Variance Analysis					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob(F)
Regression	2	168.470238367839	84.2351191839196	78.83131646	0
Error	36	38.4677616321609	1.06854893422669		
Total	38	206.938			

Appendix 5.5 Result of fitting the three-dimensional decay model of a 3D function of stiffness changing with storage time and temperature (Eqs. 4.7 & 5.1) to the six stiffness data sets of 'Cripps Pink' apples stored at six temperatures from 0°C to 30°C in single stage of NA, using the Least-Squares method with the iterative procedure of the software package DataFit 8.1, 2005. Storage temperature (T) in K and storage time (*t*) in Day were independent variables of the stiffness function *S(t)*. The surface represents the prediction model while the symbols represent the stiffness mean of 25 apples.



Appendix 5.6 Result of the non-linear regression analysis of fitting the improved exponential decay model (Eqs. 4.7 & 5.3) to the six stiffness data sets of 'Cripps Pink' apples stored at six temperatures from 0°C to 30°C in single stage of NA storage, using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage time (*t*) in Day and storage temperature (T) in K were independent variables of the stiffness function *S(t)*. Softening rate k_{sbc} (in Day^{-1}) caused by biochemical reactions was determined using Arrhenius equation (Eq. 4.7) while k_{swl} was a constant softening rate (in Day^{-1}) caused by weight loss of the apples.

Equation: Improved exponential decay model (Eqs. 4.7 & 5.3)

$S(t) = \text{Smin} + (1/2) * \text{Span}*[(\text{Exp}(-k_{sbc}*t)) + (\text{Exp}(-(k_{swl})*t))]$
$k_{sbc} = A*\text{Exp}[-E_a/(R*T)]$

	0°C	2.5°C	5°C	10°C	20°C	30°C	Global (shared)
Improved exponential decay model							
Best-fit values							
Smin	7	7	7	7	7	7	
Span	27.39	27.39	27.39	27.39	27.39	27.39	27.39
k_{sbc}	0.0009245	0.001703	0.004062	0.006265	0.01417	0.02864	
k_{swl}	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07
Std. Error							
Span	0.2652	0.2652	0.2652	0.2652	0.2652	0.2652	0.2652
k_{sbc}	0.002225	0.002408	0.002795	0.003152	0.004078	0.00491	
k_{swl}	0.001865	0.001865	0.001865	0.001865	0.001865	0.001865	0.001865
95% Confidence Intervals							
Span	26.85 to 27.93	26.85 to 27.93	26.85 to 27.93	26.85 to 27.93	26.85 to 27.93	26.85 to 27.93	26.85 to 27.93
k_{sbc}	0.0 to 0.005462	0.0 to 0.006615	0.0 to 0.009763	0.0 to 0.01269	0.005846 to 0.02248	0.01863 to 0.03866	
k_{swl}	0.0 to 0.003804	0.0 to 0.003804	0.0 to 0.003804	0.0 to 0.003804	0.0 to 0.003804	0.0 to 0.003804	0.0 to 0.003804
Goodness of Fit							
Degrees of Freedom							31
R^2	0.6543	0.7314	0.9793	0.9119	0.9867	0.812	0.9198

Absolute Sum of Squares	3.509	4.539	0.2683	1.797	0.4343	6.052	16.6
Sy.x							0.7318
Normality of Residuals							
Kolmogorov-Smirnov distance	0.386	0.45	0.2531	0.1285	0.1897	0.1517	
P value	0.0022	0.0001	P > 0.10	P > 0.10	P > 0.10	P > 0.10	
D'Agostino & Pearson omnibus K2	0	0	0	0	0	0	
P value	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	
Shapiro-Wilk W	0.6515	0.592	0.8911	0.9817	0.9586	0.9792	
P value	0.0011	0.0002	0.3238	0.9673	0.7983	0.9558	
Runs test							
Points above curve	4	3	3	3	3	3	
Points below curve	3	4	3	4	2	4	
Number of runs	2	3	3	3	3	3	
P value (runs test)	0.05714	0.2	0.3	0.2	0.5	0.2	
Deviation from Model	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	
Constraints							
Smin	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	Smin = 7.000	
Span	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	Span > 0.0 and shared	
k_{sbc}	k_{sbc} > 0.0	k_{sbc} > 0.0	k_{sbc} > 0.0	k_{sbc} > 0.0	k_{sbc} > 0.0	k_{sbc} > 0.0	
k_{swl}	k_{wsl} > 0.0 and shared	k_{wsl} > 0.0 and shared	k_{wsl} > 0.0 and shared	k_{wsl} > 0.0 and shared	k_{wsl} > 0.0 and shared	k_{wsl} > 0.0 and shared	
Data							
Number of X values	8	8	8	8	8	8	
Number of Y replicates	1	1	1	1	1	1	
Total number of values	7	7	6	7	5	7	
Number of missing values	1	1	2	1	3	1	

Appendix 5.7 Result of the non-linear regression analysis of fitting the Arrhenius equation (Eq. 4.7) to the best fit values of softening rate k_{sbc} in Table 5.2 using the Least-Squares method with the iterative procedure of the software package GraphPad Prism 4.03, 2005. Storage temperature (T) in K was an independent variable of the softening rate function, k_{sbc} in Day^{-1}.

Equation: The Arrhenius Equation

k_{sbc} = A*Exp[-Ea/{8.314*T}]

The Arrhenius Equation

Best-fit values	
A	2.47E+08
EA	57606
Std. Error	
A	3.83E+08
EA	3859
95% Confidence Intervals	
A	-814900000 to 1.309e+009
EA	46894 to 68319
Goodness of Fit	
Degrees of Freedom	4
R^2	0.9913
Absolute Sum of Squares	4.89E-06
Sy.x	0.001106
Normality of Residuals	
Kolmogorov-Smirnov distance	0.2198
P value	P > 0.10
D'Agostino & Pearson omnibus K2	0
P value	P<0.0001

Shapiro-Wilk W	0.9037
P value	0.3963
Data	
Number of X values	6
Number of Y replicates	1
Total number of values	6
Number of missing values	0

Appendix 5.8 Result of the non-linear regression analysis of fitting the three-dimensional improved model of a 3D function of stiffness changing with storage time and temperature (Eqs. 4.7 & 5.3) to the six stiffness data sets of 'Cripps Pink' apples stored at six temperatures from 0°C to 30°C in single stage of NA, using the Least-Squares method with the iterative procedure of the software package DataFit 8.1, 2005. Storage temperature (T) in K and storage time (*t*) in Day were independent variables of the stiffness function *S(t)*. Softening rate k_{sbc} (in Day^{-1}) caused by biochemical reactions was determined using Arrhenius equation (Eq. 4.7) while k_{swl} was a constant softening rate (in Day^{-1}) caused by weight loss of the apples

DataFit version 8.1.69

Equation ID: three-dimensional improved model

Model Definition:

k_{sbc} = A*Exp(-Ea/(8.314*T))

$S(t)$ = 7 + (1/2)*27.199336676751*(Exp(-k_{sbc} *t) + Exp(-0.0000001*t))

Number of observations = 39

Number of missing observations = 0

Solver type: Nonlinear

Nonlinear iteration limit = 250

Diverging nonlinear iteration limit =10
Number of nonlinear iterations performed = 85
Residual tolerance = 0.0000000001
Sum of Residuals = 2.12814373988663
Average Residual = 5.45677882022212E-02
Residual Sum of Squares (Absolute) = 33.473527587287
Residual Sum of Squares (Relative) = 33.473527587287
Standard Error of the Estimate = 0.951151898905501
Coefficient of Multiple Determination (R^2) = 0.8382436885
Proportion of Variance Explained = 83.82436885%
Adjusted coefficient of multiple determination (Ra^2) = 0.8338718963
Durbin-Watson statistic = 0.807506149527822

Regression Variable Results

Variable	Value	Standard Error	t-ratio	Prob(t)	
A	23727376367.7325	35325903900.0252	0.67167075	0.50597	
Ea	68952.0239028341	3590.90885973175	19.20183068	0.0	
68% Confidence Intervals					
Variable	Value	68% (+/-)	Lower Limit	Upper Limit	
A	23727376367.7325	35608511131.2254	-11881134763.4929	59335887498.9579	
Ea	68952.0239028341	3619.63613060961	65332.3877722245	72571.6600334437	
90% Confidence Intervals					
Variable	Value	90% (+/-)	Lower Limit	Upper Limit	

A	23727376367.7325	59598332469.7325	-35870956102	83325708837.465	
Ea	68952.0239028341	6058.22233725344	62893.8015655807	75010.2462400875	
95% Confidence Intervals					
Variable	Value	95% (+/-)	Lower Limit	Upper Limit	
A	23727376367.7325	71577346482.231	-47849970114.4986	95304722849.9635	
Ea	68952.0239028341	7275.89953158848	61676.1243712456	76227.9234344226	
99% Confidence Intervals					
Variable	Value	99% (+/-)	Lower Limit	Upper Limit	
A	23727376367.7325	95923959450.1284	-72196583082.396	119651335817.861	
Ea	68952.0239028341	9750.7539177156	59201.2699851185	78702.7778205497	
Variance Analysis					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob(F)
Regression	1	173.464472412713	173.464472412713	191.7391426	0
Error	37	33.473527587287	0.904689934791541		
Total	38	206.938			