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**THE DESIGN OF MODIFIED ATMOSPHERE
PERFORATED PLASTIC PACKAGING
FOR FRESH CHILLIES**

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Technology in Packaging Technology

at Massey University, Palmerston North
New Zealand.

Weerawate Utto

2001

Errata

p. xxiii and p. 39:

Density, $\rho = \text{g cm}^{-3}$ not g cm^{-1}

p. 10:

673 kcal mol⁻¹ glucose not “kcal”

p. 41:

psychrometric, not psychometric

p. 54: Figure 4-2, vertical axis

Permeance: $\text{pmol.s}^{-1}.\text{m}^{-2}.\text{Pa}^{-1}$ not $\text{pmol.s}^{-1}.\text{m}^{-1}.\text{Pa}^{-1}$

p. 66: Figure 4-9 Legend:

“wet bulb temperature” not “skin temperature”

p. 73 and p. 138:

Analysis of variance tables do not have all the significant effects asterisk; the text is correct but the tables are not.

P. 103:

The diagram labels from k – o are wrong, they should be:

k) Evaporation of water vapour from the product to the air

l) Water vapour transport through packaging material by effective diffusion

m) Water vapour transport through the holes by diffusion, capillary action or both

n) Absorption or desorption of water vapour by the packaging material

o) Carbon loss from respiration.



“... to see what everyone has seen and think what no one has thought”

Albert Szent-Györgyi

(1893-1986)

ABSTRACT

The quality of fresh chillies changes rapidly and under the Thai ambient conditions (30 ± 5 °C and 75 ± 5 % RH), these products spoil in a short time frame. This rapid quality deterioration causes a direct loss in returns to growers and marketers. The objectives of this study were to design a modified atmosphere perforated plastic packaging system to extend shelf life and marketability of fresh chillies.

Physiological data about fresh green 'Cayenne' chillies was measured; respiration rate, internal partial pressure of O₂ ($p_{O_2}^i$) and CO₂ ($p_{CO_2}^i$), skin permeance to O₂ ($P_{O_2}^i$), CO₂ ($P_{CO_2}^i$) and water vapour ($P_{H_2O}^i$) as well as, water activity (a_w). The extent to which these attributes were affected by a range of temperatures 5, 10, 20 and 30°C was also characterised. Respiration dramatically increased as storage temperature was increased from 5 to 30°C, whilst $P_{O_2}^i$ and $P_{CO_2}^i$ slightly increased. The differing effects of temperature on these two variables were responsible for the depression of internal partial pressure of O₂ and elevation of CO₂ internal partial pressure.

The skin permeances to O₂ and CO₂ were very close (approximate ratio $P_{CO_2}^i : P_{O_2}^i$ as 1.06) and it was determined that the major pathway for gas exchange of green 'Cayenne' chillies was dominated by movement through pores (through the stem area), rather than the cuticle. Average value of skin permeance to water vapour of green 'Cayenne' chillies was $201.78 \text{ nmol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$. Water vapour permeances were inconsistent over the 5-30°C temperature range due to errors from thermistor probes and environment around chillies. Surface area of green 'Cayenne' chillies provided the positive relationship with fresh weight, volume and the rate of water loss (measured at ambient temperature $\approx 20^\circ\text{C}$). Fresh weight and a_w of fresh chillies decreased as the storage temperature increased from 5 to 30°C.

Storage temperatures (5, 10, 20 and 30°C) and packaging types (perforated/nonperforated plastic bags and unpackaging) had significant impact on storage qualities (colour, firmness, weight and decay) of fresh green 'Cayenne' chillies

during a 2-week storage trial period. Refrigerated storage temperatures and perforated plastic bag showed promise in reducing quality attributes changes and eliminating condensation. At 5 and 10°C, no signs of chilling injury were detected on green 'Cayenne' in any packaging type used during the trial period. The atmospheres inside perforated plastic bag were similar to ambient air condition, thus ensuring that there were aerobic conditions inside.

The rate of weight loss of packaged chillies varied with storage temperature, perforation area and size of perforation. The optimum storage condition and package for a 100g retail pack of chillies during a 2-week storage period is 5°C and 152.40 × 228.60 mm plastic bag with 0.49% perforation area (2.5 mm perforation size). Chillies stored under this condition had low percentage of weight loss (less than 2.5%) with no signs of chilling injury and their quality attributes were within the marketable levels.

Bell peppers (*Capsicum annuum* L.) were used to study effects of postharvest disinfecting treatments (sodium hypochlorite (NaClO, 2%w/v) and hot water dip (HWD, 53°C 4 minutes)) on storage quality. Both disinfectants significantly reduced decay appearances on bell peppers particularly on those stored at high temperature (20 and 30°C), during a trial 2-week storage period. The application of these disinfecting treatments will be further researched on fresh chillies, for minimising decay appearance.

The 'Weight Loss Simulator' model developed by Tanner (1998) was tested by comparing predicted weight loss with experimental data. The model had general agreement with the experimentally observed trends. Lack of fit of model predictions to experimental data however, was obvious in some cases. Variations, e.g. storage temperature/relative humidity, packaging and dynamic changes in biological properties of stored chillies can deviate the predicting result of this model. Sensitivity analyses performed on the model showed that the observed lack of fit could largely be explained by estimated uncertainties in the respiration rate data. From this model testing, the accuracy of the 'Weight Loss Simulator' model appeared to be limited by assumptions, input data and uncertainties occurred during data collection rather than by shortcomings in the model itself.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	surface area of fruit	m ²
a _w	water activity	
C	constants in sorption isotherm	
CO ₂	carbon dioxide	
°C	celsius	
C*	chroma of fruit skin	
CA	controlled atmosphere	
cal	calories	
CI	chilling injury	
D	dried look in visual quality	
DM	dry matter	%
Ea	energy of activation	J·mol ⁻¹
$Ea_{r_{CO_2}^{max}}$	the energy of activation of $r_{CO_2,ref}^{max}$	J·mol ⁻¹
Ea_i'	the energy of activation of skin permeance to gas i	J·mol ⁻¹
ERH	equilibrium relative humidity	%
F	fresh look in visual quality	
g	gram	
GLM	general linear model	
h°	hue angle of fruit skin	
H ₂ O	water	
HDPE	high density polyethylene	
HWD	hot water dip	
K	constant in sorption isotherm	
K	kelvin	
K _i	parameter used for the respiration model proposed by (Lee <i>et al.</i> 1994)	%(CO ₂)

K_m	parameter used for the respiration model proposed by (Lee <i>et al.</i> 1994)	$\%(\text{O}_2)$
k_{ref}	rate at T_{ref}	
K_{pkg}	mass transfer coefficient of packaging	$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
K_{skin}	mass transfer coefficient of fruit skin	$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
l	litre	
L^*	brightness of fruit skin	
LDPE	low density polyethylene	
LLDPE	linear low density polyethylene	
LLDPE/LDPE	linear low density polyethylene blended with low density polyethylene	
M	fruit mass	kg
m	metre	
min	minute	
MA	modified atmosphere	
MAP	modified atmosphere packaging	
MDPE	medium density polyethylene	
MC	moisture content (dry basis)	
Mt	mass at determined time-t (fresh weight)	
M0	mass at starting time-0 (wet basis)	
Mo	monolayer moisture content (dry basis)	
mol	mole	
N	no condensation in visual quality	
N/A	not available	
NaClO	sodium hypochlorite	
n	number of observations	
O_2	oxygen	

Pa	pascal	
PP	polypropylene	
$P_{\text{CO}_2}^{\text{final}}$	CO ₂ in jar at the end of time t	%
$P_{\text{CO}_2}^{\text{initial}}$	initial CO ₂ in jar	%
P^{tot}	air pressure	Pa
$P'_{\text{H}_2\text{O}}$	water permeance of fruit surface	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
$P'_j{}^{\text{fruit}}$	skin permeance to gas j	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
P'_{CO_2}	skin permeance to CO ₂	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
P'_{O_2}	skin permeance to O ₂	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
$P'_{i,\text{ref}}$	skin permeance to gas i , (O ₂ and CO ₂), at T_{ref}	$\text{pmol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
$P'_{\text{CO}_2,\text{ref}}$	skin permeance to CO ₂ at T_{ref}	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
$P'_{\text{O}_2,\text{ref}}$	skin permeance to O ₂ at T_{ref}	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
$P_{\text{H}_2\text{O}}^{\text{sat}}(T_f)$	saturated partial pressure of water vapour at T_f	Pa
$P_{\text{H}_2\text{O}}^{\text{sat}}(T_w)$	saturated partial pressure of water vapour at T_w	Pa
p_j^i	internal partial pressure of gas j	Pa
p_j^e	external partial pressure of gas j	Pa
$p_{\text{H}_2\text{O}}^f$	partial pressure of water vapour in fruit	Pa
$p_{\text{H}_2\text{O}}^e$	partial pressure of water vapour in air	Pa
$\Delta p_{\text{H}_2\text{O}}$	difference in partial pressure of water vapour between fruit and environment	Pa
Δp_j	partial pressure difference for diffusion of gas j	Pa
ρ_{fruit}	density of the fruit	$\text{g}\cdot\text{cm}^{-3}$
R	rotted appearance in visual quality	

R	gas constant (8.314)	$\text{m}^3 \cdot \text{Pa} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
R^2	percentage variance accounted for	%
RC	resistance coefficient to water vapour transmission of perforated plastic films	
RH	relative humidity	%
r_{CO_2}	respiration rates	$\text{mol} \cdot \text{kg}^{-1} \cdot \text{s}^{-1}$
$r_{\text{CO}_2, \text{ref}}^{\text{max}}$	the maximum CO_2 production rate at T_{ref}	$\text{mol} \cdot \text{kg}^{-1} \cdot \text{s}^{-1}$
$r'_{\text{H}_2\text{O}}$	rate of water loss from product	$\text{mol} \cdot \text{s}^{-1}$
r_j	rate of transfer of gas j	$\text{mol} \cdot \text{kg}^{-1} \cdot \text{s}^{-1}$
γ	psychometric constant (equals 67 $\text{Pa} \cdot ^\circ\text{C}^{-1}$)	$\text{Pa} \cdot ^\circ\text{C}^{-1}$
S	shrivelled or soft appearance in visual quality	
s	seconds	
SE	standard errors	
SED	standard error of the difference	s
t_0	time at beginning of the fruit of the first conditions	s
t_1	time at end of the fruit of the first conditions	s
T_e	temperature of air (dry bulb temperature)	$^\circ\text{C}$
T_f	temperature at fruit skin	$^\circ\text{C}$
THA	a type of perforation manually punctured, using cork bore with 5 mm diameter bore, to make 6 holes	
T_{ref}	reference temperature (288.15 K, (15°C))	$^\circ\text{C}$
T_w	dew point temperature (wet bulb temperature)	$^\circ\text{C}$

t	time for the reading	s
UNT	bell peppers untreated with postharvest disinfecting	
V_{jar}	volume of jar	ml
V_m	parameter used for the respiration model proposed by (Lee <i>et al.</i> 1994)	$\text{ml}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$
w/v	weight per volume	
Y	presence of condensation in visual quality	