Gas Exchange, Ripening Behaviour and Postharvest Quality of Coated Pears

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To my parents,
Iraci and João Welington,
and my brother Alessandro,
for so much love,
support and encouragement

Abstract

Pear cultivars 'Bartlett', 'Beurre Bosc', 'Doyenne du Comice', and 'Packham's Triumph' were treated with different levels of deposits of a carnauba based wax on the skin and assessed for gas exchange, ripening behaviour and postharvest quality. The response to coating treatments was strongly dependent on cultivar, ripening stage and environmental temperature. 'Bartlett', 'Comice' and 'Packham's', with non-lignified skin, had substantial reductions in skin permeance (P_j') with small increases in coating deposit. Magnitudes of reduction in P_j' to different gases were observed in the order: $P_{O_2}' > P_{CO_2}' >> P_{H_2O}'$. The skin of 'Bosc', with lignified cells, had high P_{H_2O}' and low P_{CO_2}', and increasing the amount of coating deposited on the skin resulted in small reductions of P_{H_2O}' and a gradual reduction of P_{O_2}' and P_{CO_2}'. 'Bartlett' and 'Bosc' had a high risk of developing internal disorders caused by excessive internal accumulation of CO_2 at low temperatures when treated with substantial coating deposits, as a result of high respiration rate ('Bartlett') or low P_{CO_2}' of coated skin ('Bosc'). These cultivars were also less tolerant to hypoxia (expressed in terms of internal lower O_2 limit, LOL^i) created by high coating concentrations, and their level of tolerance reduced with increasing ripeness. 'Comice' and 'Packham's' were highly tolerant of hypoxia [the fruit did not ferment despite of an internal O_2 partial pressure ($p_{O_2}^i$) ≅ 0 kPa]. Respiration rates, softening and colour change followed a Michaelis-Menten model when plotted against $p_{O_2}^i$, while internal CO_2 partial pressure ($p_{CO_2}^i$) had virtually no explanatory power for these variables during shelf life. Variable cover of skin pores in cultivars having high P_j' might result in variable P_{O_2}' and, consequently, variable $p_{O_2}^i$. This could increase the naturally high ripening variability of pears treated with a given coating concentration. Softening had a lower Michaelis-Menten constant for $p_{O_2}^i$ than skin colour. Therefore, coated pears with intermediary $p_{O_2}^i$ might have variable postharvest quality mainly in terms of colour change, and the fruit may still soften while being unable to change in colour. For 'Comice', higher levels of coating deposit resulted in more substantial modification of internal atmosphere during cold storage, slightly increasing ripening delay. These treatments reduced wastage by diminishing the incidence of senescent breakdown and senescent scald after long term storage and by reducing skin friction discolouration during shelf life. Increasing the amount of coating deposit improved skin gloss and reduced senescent breakdown of 'Bartlett', 'Comice' and 'Packham's' during shelf life. The results show that optimisation of surface coatings should take into account differences between cultivars, ripening stage when the fruit is coated and storage temperature to avoid the risk of fermentation and physiological disorders. Even though there are some quality problems due to uneven ripening, wax coatings represent a technology with high potential for the pear industry, improving the finish of the skin, reducing water loss, delaying ripening and reducing the incidence of senescence related disorders.

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Table of Contents

Chapter 6 Effects of Coating Concentration, Ripening Stage, Water Status and Fruit Temperature on Pear Susceptibility to Friction Discolouration

Chapter 7 General Discussion

Appendix 1 Equilibration of surface chambers to the internal atmosphere of 'Doyenne du Comice' pear

Appendix 2 Attendance to Postharvest Conferences

List of Tables

Chapter 5 Characterising Ripening Behaviour and the Lower Oxygen Limit in Relation to the Internal Atmosphere of Coated Pears

List of Figures

Chapter 1 General Introduction

Chapter 2 Literature Review

Chapter 3 Ripening Behaviour, Postharvest Quality and Physiological Disorders of Coated Pears

Chapter 4 Relationship Between Character of Skin Cover and Permeance to Gases of Coated Pears

Chapter 5 Characterising Ripening Behaviour and the Lower Oxygen Limit in Relation to the Internal Atmosphere of Coated Pears

Chapter 6 Effects of Coating Concentration, Ripening Stage, Water Status and Fruit Temperature on Pear Susceptibility to Friction Discolouration

List of Symbols and Abbreviations

A	=	surface area (m^2)
Å	=	Ångstrom
AAT	=	alcohol acyltransferase
ACC	=	1-aminocyclopropane-1-carboxylic acid
ACC-O	=	ACC oxidase
ACC-S	=	ACC synthase
Acet	=	acetaldehyde
ACP	=	anaerobic compensation point
ACP^e	=	external anaerobic compensation point
ACP^i	=	internal anaerobic compensation point
ADP	=	adenosine diphosphate
ADH	=	alcohol dehydrogenase
ANOVA	=	analysis of variance
ATP	=	adenosine triphosphate
ATP-PFK	=	ATP-phosphofructokinase
c^i_{EtOH}	=	internal ethanol concentration ($mol \cdot m^{-3}$)
CA	=	controlled atmosphere
CCA	=	canonical correlation analysis
CDA	=	canonical discriminant analysis
CDF_n	=	canonical discriminant function number n
C_2H_4	=	ethylene
cm	=	centimetre
CMC	=	carboxymethylcellulose
CO_2	=	carbon dioxide
D_j	=	diffusion coefficient for gas j ($m^2 \cdot s^{-1}$)
df/dt	=	derivative of fruit firmness for time
dh/dt	=	derivative of fruit hue angle for time
DHAP	=	dihydroxyacetone phosphate

DL	=	change in lightness of the skin after FD
DNA	=	deoxyribonucleic acid
DRC	=	parallel discriminant ratio coefficient, defined as the product of SCC and *r*.
DS	=	degree of substitution, or number of substituted hydroxyl groups per monomeric cellulose unit
dy/dt	=	derivative of fruit ripening process *y* for time
E_p	=	activation energy ($kJ \cdot mol^{-1}$)
EDTA	=	ethylene-diaminetetraacetic acid
EP	=	extinction point
Eq.	=	equation
EtAc	=	ethyl acetate
ETC	=	electron-transport system
EtOH	=	ethanol
f	=	'Kiwifirm' fruit firmness (arbitrary units)
F1,6-P_2	=	fructose 1,6-biphosphate
F2,6-P_2	=	fructose 2,6-biphosphate
F6P	=	fructose 6-phosphate
FD	=	friction discolouration
Fig(s).	=	figure(s)
FT	=	fermentation threshold
FT^i	=	internal fermentation threshold
FT^i_{EtOH}	=	internal fermentation threshold based on ethanol accumulation
FT^i_{RQ}	=	internal fermentation threshold based on respiratory quotient
g	=	gram
GAP	=	3-phosphoglyceraldehyde
Glu	=	glucose
G6P	=	glucose 6-phosphate
h	=	hour
h^o	=	fruit skin hue angle

H_2O	=	water
HPC	=	hydroxypropylcellulose
HPMC	=	hydroxypropyl methylcellulose
kg	=	kilogram
K_m	=	Michaelis-Menten constant
kPa	=	kilopascal
l	=	liter
Lac	=	lactate
LDH	=	lactate dehydrogenase
LOL	=	lower oxygen limit
LOL^e	=	external lower oxygen limit
LOL^i	=	internal lower oxygen limit
M	=	mass (kg)
m	=	metre
MA	=	modified atmosphere
MC	=	methylcellulose
mg	=	milligram
min	=	minute
mm	=	millimetre
mN	=	millinewton
mol	=	mole
mRNA	=	messenger ribonucleic acid
μm	=	micrometre
μM	=	micromolar
N	=	newton
N_2	=	nitrogen
NAD^+	=	adenine dinucleotide (oxidised form)
NADH	=	adenine dinucleotide (reduced form)
nm	=	nanometre
nmol	=	nanomole

O_2	=	oxygen
OAA	=	oxaloacetate
OPP	=	*o*-phenylphenol
P	=	probability or level of significance of a statistical test
$P_{C_2H_4}$	=	permeability to ethylene ($mol \cdot s^{-1} \cdot m \cdot m^{-2} \cdot Pa^{-1}$)
$P'_{C_2H_4}$	=	permeance to ethylene ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
P_{CO_2}	=	permeability to carbon dioxide ($mol \cdot s^{-1} \cdot m \cdot m^{-2} \cdot Pa^{-1}$)
P'_{CO_2}	=	permeance to carbon dioxide ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
P_{H_2O}	=	permeability to water ($mol \cdot s^{-1} \cdot m \cdot m^{-2} \cdot Pa^{-1}$)
P'_{H_2O}	=	permeance to water ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
P_i	=	inorganic orthophosphate
P_j	=	permeability to gas j ($mol \cdot s^{-1} \cdot m.m^{-2} \cdot Pa^{-1}$)
p_j	=	partial pressure of gas j (Pa)
P'_j	=	permeance to gas j ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
$P'_{j,k}$	=	permeance of coating film k to gas j ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
$P'_{j,skin}$	=	permeance of the commodity skin to gas j ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
$P'_{j,total}$	=	total permeance to gas j of a commodity coated with a tightly adhering film ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
P_{O_2}	=	permeability to oxygen ($mol \cdot s^{-1} \cdot m \cdot m^{-2} \cdot Pa^{-1}$)
P'_{O_2}	=	permeance to oxygen ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$)
$P'^{T}_{O_2}$	=	permeance to oxygen at temperature T ($mol \cdot s^{-1} \cdot m^{-2} \cdot Pa^{-1}$);
$p^e_{CO_2}$	=	external partial pressure of carbon dioxide (Pa)
p^e_j	=	partial pressure of gas j in the external atmosphere (Pa)
$p^e_{O_2}$	=	external partial pressure of oxygen (Pa)
$p^i_{CO_2}$	=	internal partial pressure of carbon dioxide (Pa)
p^i_j	=	partial pressure of gas j in the internal atmosphere (Pa)
$p^i_{O_2}$	=	internal partial pressure of oxygen (Pa)
Pa	=	pascal
PCK	=	pyruvate carboxykinase
PDC	=	pyruvate decarboxylase

PDH	=	pyruvate dehydrogenase
PEP	=	phosphoenolpyruvate
PEPC	=	phosphoenolpyruvate carboxylase
PEP-CK	=	phosphoenolpyruvate carboxykinase
pH	=	measure of a solution concentration of hydrogen ions
PK	=	pyruvate kinase
pmol	=	picomole
PP_i	=	inorganic pyrophosphate
PPi-PFK	=	pyrophosphate phosphofructokinase
ppm	=	part per million
PPO	=	polyphenol oxidase
PYR	=	pyruvate
Δp_{H_2O}	=	water vapour pressure difference between the fruit and air stream (Pa)
Δp_j	=	difference in partial pressures of gas j between the internal and the external atmospheres (Pa)
Q_{10}	=	temperature coefficient (=[rate of O_2uptake at (T+10°C] / [rate of O_2 uptake at T])
r	=	canonical correlation, or "pooled within-group canonical structure" (correlation between "within-group standardized canonical discriminant functions" and original variables)
®	=	registered brand
R^2	=	coefficient of determination (%), or proportion of variation in y values that is explained by x
r_{CO_2}	=	specific rate of transfer of carbon dioxide between internal and external atmospheres ($mol \cdot kg^{-1} \cdot s^{-1}$)
$r_{CO_2(ox)}$	=	specific rate of oxidative CO_2 production ($mol \cdot kg^{-1} \cdot s^{-1}$)
$r_{CO_2(fer)}$	=	specific rate of fermentative CO_2 production ($mol \cdot kg^{-1} \cdot s^{-1}$)
$r_{CO_2(tot)}$	=	specific rate of total CO_2 production ($mol \cdot kg^{-1} \cdot s^{-1}$)

r_{H_2O}	=	specific rate of transfer of water between the fruit and external atmosphere ($mol \cdot kg^{-1} \cdot s^{-1}$)
r_j	=	specific rate of transfer of gas j between internal and external atmospheres ($mol \cdot kg^{-1} \cdot s^{-1}$)
r'_j	=	rate of transfer of gas j between internal and external atmospheres ($mol \cdot s^{-1}$)
$r'_{j,k}$	=	rate of transfer of gas j through the coating film k ($mol \cdot s^{-1}$)
r_{O_2}	=	specific rate of transfer of oxygen between internal and external atmospheres ($mol \cdot kg^{-1} \cdot s^{-1}$)
r'_{O_2}	=	rate of transfer of oxygen between internal and external atmospheres ($mol \cdot s^{-1}$)
$r'^{T}_{O_2}$	=	rate of oxygen uptake for the system at temperature T ($mol \cdot s^{-1}$)
RH	=	relative humidity
rpm	=	rotations per minute
RQ	=	respiratory quotient
RQB	=	respiratory quotient breakpoint
s	=	second
S_{CO_2}	=	solubility for carbon dioxide ($mol \cdot m^{-3} \cdot Pa^{-1}$)
S_{H_2O}	=	solubility for water ($mol \cdot m^{-3} \cdot Pa^{-1}$)
S_j	=	solubility for gas j ($mol \cdot m^{-3} \cdot Pa^{-1}$)
S_{O_2}	=	solubility for oxygen ($mol \cdot m^{-3} \cdot Pa^{-1}$)
$[S]^{[O_2]e}_{0.5}$	=	half-saturating substrate concentration with respect to O_2 in the external atmosphere for ACC-O activity
SAM	=	S-adenosylmethionine
SCC	=	standardized canonical coefficient
SD	=	standard deviation
SDH	=	succinate dehydrogenase
SE	=	standard error
T	=	temperature
v	=	volume (m^3)

V_{max}	=	maximum rate constant of Michaelis-Menten model
w	=	weight (kg)
Δx	=	film thickness (m)