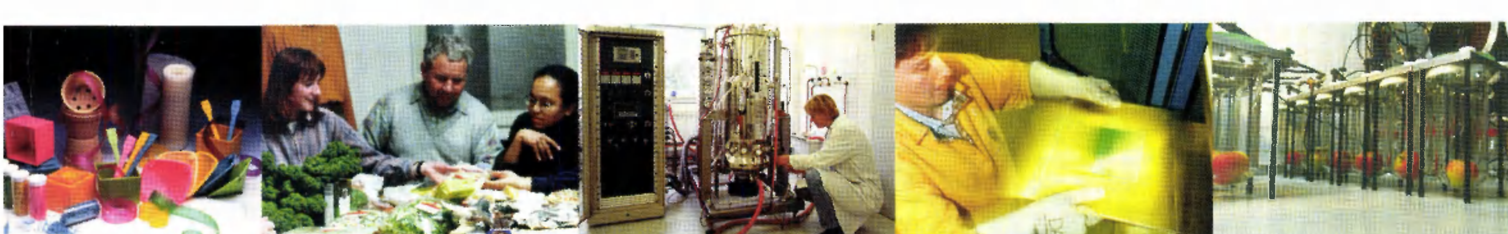
ATO

Literature study on the effects of MA on Plums, Peaches and Nectarines

Report No. B493 / January 2001

Gérard van den Boogaard
Anneke Polderdijk



WAGENINGEN UR

ATO

Literature study on the effects of MA on Plums, Peaches and Nectarines

Report No. B493 / January 2001

Contact person:
G.J.P.M. van den Boogaard
Agrotechnological Research Institute (ATO)
Bornsesteeg 59
P.O. Box 17
6700 AA Wageningen
The Netherlands
Tel: +31.317.475267
Fax: +31.317.475347
Email: G.J.P.M.vandenBoogaard@ato.wag-ur.nl

Table of contents

1 Introduction

This literature study has been done at the request of Kappa Quama. The aim of this study isto investigate the possibilities for using Quama packages in South Africa for plums, nectarines and peaches.
The method used in this literature study is to:

- summarise the effects of altered O_2 and/or CO_2 concentrations (CA and MA) on the quality of plums, peaches and nectarines;
- summarise the rates of respiration of plums, peaches and nectarines as found in literature. And if possible, estimate the respiration rate of South African products;
- investigate the possibilities of releasing the desired concentrations of O_2 and CO_2 inside Quama packages for plums, peaches and nectarines;
- estimate the application of Quama boxes for South African plums, nectarines and peaches.

2 Plums

2.1 Introduction

Plums have several quality problems during post-harvest. Up to 50% is considered lost on arrival at the place of sale, with an average of 9,2% (55). Most quality problems occur during the shelf-life period after cold storage. The most common quality problems are over-ripeness (OR), internal breakdown (IBR), gel breakdown (GB) and bladderiness (BL). (46, 47, 48). In this study, the possibilities to reduce these quality problems by using MA are explored.

2.1.1 Effect of O_2 and CO_2 concentrations on the quality of Plums

In the literature, the various effects of MA/CA on plums are described (4, 11, 37, 49, 52, 54). When plums are stored at an O_2 concentration smaller than 5% and a CO_2 concentration of at least 5%, positive effects on firmness, taste, soluble solids, organic acids, internal breakdown, rot, mealiness, shrivel and ground colour are found.
At the moment it is only possible to realise O_2 concentrations smaller than 5% in a Quama packaging in combination with CO_2 concentrations larger than 15%. Since the individual effects of O_2 and CO_2 are not described, it is not clear which gas (O_2 or CO_2) affects the quality most. Therefore it might be possible that the combination of ± 15% O_2 with ± 5% CO_2 has a positive effect on the quality of the plums.
Another remark has to be made regarding the storage conditions. Only in the research of Crouch (11), the South African dual temperature storage (46) was applied. All other research was done at one steady state temperature. Dual temperature is necessary for some South African plum cultivars (46). The effect of applying MA in a dual temperature storage system cannot be fully understood from the available sources.

2.1.2 Respiration rate of Plums

The various respiration rates of plums are summarised in Table 1. These are all respiration rates at 21% O_2 and 0,035% CO_2. With exception of the work of Taylor (44), only CO_2 production is given. This gives an incomplete picture of the behaviour of the product under altered atmospheric conditions. For this reason, the predicted gas-concentrations will differ from the gas-concentrations in a real package.

Unit (Literature)		Unit (SI)	Temp (gas)	Author	Cultivar
Mg /kg.h	Ml /kg.h	Nmol /kg.s			
	1.5	18.6	0°C (CO_2)	54	
	6	74.4	10°C (CO_2)		
	12	148.8	20°C (CO_2)		
	2.7	33.5	5°C (CO_2)	16	
	4.1	50.8	10°C (CO_2)		
8.5		53.7	0°C (CO_2)	38	
13.8		87.1	4°C (CO_2)		
18		113.6	8°C (CO_2)		
23.3		147.1	12°C (CO_2)		
35.5		224.1	16°C (CO_2)		
40		252.5	20°C (CO_2)	39	
	42.5	527	25°C (CO_2)	44	Laetitia
	32.2	399.3	25°C (O_2)		
	32.8	406.7	25°C (CO_2)		Songold
	11.5	142.6	25°C (O_2)		

Table 1 Respiration rates of plums at various temperatures.

With the data shown in Table 1 two different values for the activation energy (Ea) are estimated, based on the respiration rate data (38, 54). The Ea is estimated using the Arrhenius equation and the respiration rates at the various temperatures. Subsequently, this estimated activation energy is used to extrapolate the respiration rate of South African plums (Laetitia and Songold) to other temperatures, also using the Arrhenius equation. To calculate both CO_2 and O_2 respiration rates at 0 °C and 10 °C the Ea from CO_2 is used. The response on altered gas-concentrations cannot be estimated with the available data.
The calculated values of the activation energy are 55529 J/mol (38) and 69427 J/mol (54). The ratio between O_2 and CO_2 respiration rate (RQ) of Songold plums is considered as very small.

Arrhenius equation

$$V = V_{ref} \cdot e^{\frac{Ea}{r}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)}$$

Where:
V = respiration rate at T
T = temperature
V_{ref} = respiration rate at reference temperature
T_{ref} = reference temperature
R = constant, 8.31
Ea = activation energy

The calculated respiration rates of South African plums at 0 °C and 10 °C at ambient air conditions are shown in Table 2 The results show a large difference between the highest and the lowest estimation of the respiration rate. We assumed that the harvest maturity of the plums is optimal.

Ea		0°C nmol/kg.sec	10°C nmol/kg.sec
Laetitia	**Ea (38)**	67.8	160.8
	Ea (54)	40.6	119.4
Songold	**Ea (38)**	52.3	124.1
	Ea (54)	31.3	92.2

Table 2 **Calculated CO_2 production of South African plums at 0°C and 10°C and 21% O_2 and 0.035% CO_2.**

In Figure 1 the temperature dependence of the calculated respiration rate is shown. The solid lines are the respiration rates found in literature (38, 54). The dotted lines are the calculated respiration rates depending on temperature. As a reference, the activity of Laetitia (44) was chosen. Note that the respiration rate of plums also depends very strongly on the maturity of the product.

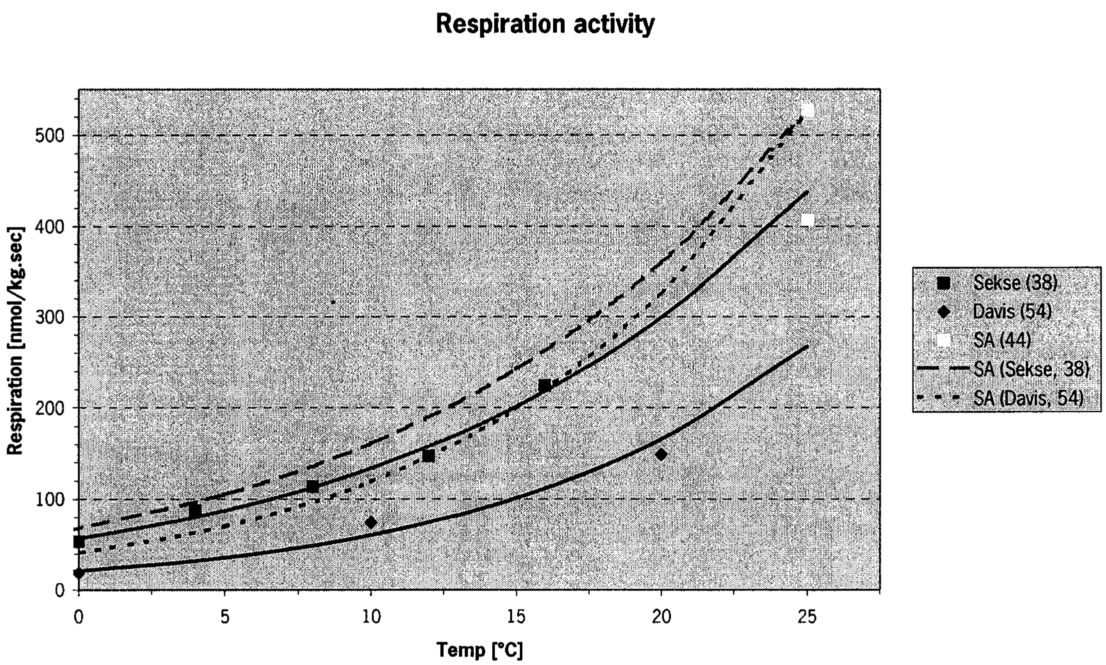


Figure 1 **Found respiration rate in literature and calculated respiration rate depending on temperature of South African plums. Based on Ea of Sekse (dashed line) and Davis (dotted line).**

2.2 Calculated expected MA-conditions in Quama boxes for Plums

For the prediction of the MA-conditions in a Quama package, a model is used. This model is based on the doctoral thesis of Peppelenbos (I). The parameters used in the model are summarised in Table 3.

Parameter			Value	
Box		**Dimensions**	39 x 29 x 12 cm (length x width x height)	
		Content	0.013572 m^3	
		Area	0.3894 m^2	
		Permeation	2.5 ml/min.bar	
Product		**Mass**	5 kg	
		Cultivar	**Laetitia**	**Songold**
		Reference temperature	10°C	10°C
		RQ	0.75	0.35
Source	**38**	**Respiration O_2**	121.8 nmol/kg.sec	43.5 nmol/kg.sec
		Respiration CO_2	160.8 nmol/kg.sec	124.1 nmol/kg.sec
		Ea	55529 J/mol	
	54	**Respiration O_2**	90.5 nmol/kg.sec	32.3 nmol/kg.sec
		Respiration CO_2	119.4 nmol/kg.sec	92.2 nmol/kg.sec
		Ea	69427 J/mol	
Temperature profile			10 days –0.5°C, 18 days 7.5°C, 14 days –0.5 °C, 7days 10°C	

Table 3 **Used parameters to estimate MA-conditions in Quama packaging.**

Using these respiration rates, a rough estimation of the conditions in a Quama package is possible. The calculated equilibrium concentrations are shown in Table 4.

Cultivar	Respiration based on	-0.5°C		7.5°C		10°C	
		O_2	CO_2	O_2	CO_2	O_2	CO_2
Laetitia	**38**	13.1	7.0	9.5	11.5	8.4	13.2
	54	15.6	4.6	11.2	9.1	9.8	10.8
Songold	**38**	17.1	2.2	14.5	4.2	13.4	5.2
	54	18.8	1.2	16.0	3.0	14.9	3.8

Table 4 **Estimated gas-concentrations in Quama boxes depending on temperature and estimated respiration rate.**

2.3 Conclusions / Possibilities of QUAMA

Combining the data from section 2.1.1 and Table 4 shows that the claimed positive MA-conditions can be realised in a Quama package depending on the source referred to. . There are still various unanswered questions regarding for example:

- the effect of dual storage temperature;
- the effect of altered gas-concentrations on respiration rates;
- the decisive gas-concentration affecting quality, CO_2 or O_2;
- the accurate respiration rate of South African plums at 0 °C and 10 °C;
- differences between cultivars.

3 Peaches and Nectarines

3.1 Introduction

The maximum marketing life of peaches varies from one to five weeks and for nectarines from one to seven weeks (13). There are hundreds of peach and nectarine cultivars. Market life varies among them. In addition, market life varies with maturity and growing conditions (12, 13, 28). The optimum storage and transportation temperature is -1 - 0°C with an optimum relative humidity of 90-95%. Brown rot, grey mould and Rhizopus rot are the most important postharvest pathological disorders (13, 28). Internal breakdown or chilling injury is the most important physiological disorder (13, 28). Chilling injury is characterised by flesh internal browning, flesh mealiness (woollyness), flesh bleeding, failure to ripen and flavour loss. These symptoms develop during ripening after a cold storage period at temperatures < 10°C (28). The most susceptible temperature range for this disorder is 2.2-7.6 °C (13, 28). Normal ripening occurs at storage temperatures varying from 15-20 °C. Woolly breakdown can be postponed by storage at 20 °C during at least 1-2 days before cold storage or by intermittent warming during storage (2, 3, 6, 14, 16, 41, 43, 51, 56). Woolly breakdown is caused by a disturbance in the pectic metabolism (2, 3, 6).

3.1.1 Effect of O_2 and CO_2 concentrations on the quality of nectarines and peaches.

For both peaches and nectarines, the most important long-term storage disorders are woolliness and internal breakdown (chilling injury). Many researchers report on the effects of CA/MA on woolliness and/or internal breakdown after cold storage of peaches and nectarines (7, 9, 12, 13, 14, 15, 16, 20, 25, 27, 30, 34, 42, 43, 45, 51, 56, 57). Chilling injury is best reduced by CO_2 concentrations larger than 10% (12, 25, 35). The effects of O_2 on chilling injury are not clear from literature. Low O_2 might be only slightly or even not effective in reducing chilling injury. Low O_2 in combination with high CO_2 might cause off-taste and inhibited ripening after cold storage (57). Results may strongly vary among varieties, maturity, fruit size, growing conditions and shipping period (12, 14, 20). The effects on peaches might be smaller than on nectarines (13, 35), though one South African study did result in no effects of CA on woolliness of nectarines. Low O_2 is also effective in delaying ripening and better retention of firmness and ground colour (20).

Most studies were carried out at optimum storage temperatures so the effect of MA / CA at sub optimum temperatures is not clear. It may be presumed though that the effect at sub optimum temperatures is relatively higher.

3.1.2 Respiration rate of Peaches and Nectarines

For peaches and nectarines, the same method is used as was used for plums to calculate the respiration rates at different storage temperatures.

The diverse respiration rates of peaches and nectarines are summarised in Table 5 and Table 6. These are all CO_2 production rates at 21% O_2 and 0,035% CO_2. This gives an incomplete picture of the behaviour of the product under altered atmospheric conditions. For this reason the predicted gas-concentrations will differ from the gas-concentrations in a real package.

Unit (Literature)			Unit (SI)			
mg/kg.h	ml/kg.h	Mmol/kg.h	Nmol/kg.s	Temp °C	Source	Cultivar
58			366.2	20 °C	4	
		1.4-1.8	388.9 - 500	20 °C	6	Fantasia
	2-3		24.8 – 37.2	0 °C	10	
	8-12		99.2 – 148.8	10 °C	10	
	32-55		396.8 – 682	20 °C	10	
	1.9		23.6	0 °C	17	
30-60			189.4 – 378.8	20 °C	20	Fiesta Red

Table 5 CO_2 production rates of nectarines at various temperatures.

<table>
<tr><th colspan="2">Unit (Literature)</th><th>Unit (SI)</th><th rowspan="2">Temp °C</th><th rowspan="2">Literature</th><th rowspan="2">Cultivar</th></tr>
<tr><th>mg/kg.h</th><th>ml/kg.h</th><th>nmol/kg.s</th></tr>
<tr><td></td><td>2-3</td><td>24.8 – 37.2</td><td>0 °C</td><td rowspan="3">10</td><td></td></tr>
<tr><td></td><td>8-12</td><td>99.2 – 148.8</td><td>10 °C</td><td></td></tr>
<tr><td></td><td>32-55</td><td>396.8 – 682.0</td><td>20 °C</td><td></td></tr>
<tr><td>3.7</td><td></td><td>23.4</td><td>0 – 5 °C</td><td rowspan="2">13</td><td rowspan="2">Paraguayo</td></tr>
<tr><td>37</td><td></td><td>233.6</td><td>20 °C</td></tr>
<tr><td></td><td>4-6</td><td>49.6 – 74.4</td><td>0 °C</td><td rowspan="6">15</td><td></td></tr>
<tr><td></td><td>6-9</td><td>74.4 – 111.6</td><td>4 - 5 °C</td><td></td></tr>
<tr><td></td><td>16</td><td>198.4</td><td>10 °C</td><td></td></tr>
<tr><td></td><td>33-42</td><td>409.2 – 520.8</td><td>15 - 16 °C</td><td></td></tr>
<tr><td></td><td>59-102</td><td>731.6 – 1264.9</td><td>20 - 21 °C</td><td></td></tr>
<tr><td></td><td>81-122</td><td>1004.5 – 1512.9</td><td>25 - 27 °C</td><td></td></tr>
<tr><td></td><td>2-3</td><td>24.8 – 37.2</td><td>0 °C</td><td>17</td><td></td></tr>
<tr><td></td><td>39</td><td>483.6</td><td>25 °C</td><td>19</td><td>Batsch</td></tr>
</table>

Table 6 **CO_2 production rates of peaches at various temperatures.**

3.2 *Calculated expected MA-conditions in Quama boxes for peaches and nectarines*

The parameters used for the calculation of the equilibrium gas concentrations in the Quama packages are shown in Table 7 and Table 8.

<table>
<tr><th colspan="2">Parameter</th><th colspan="2">Value</th></tr>
<tr><td rowspan="4">Box</td><td>Dimensions</td><td colspan="2">39 x 29 x 12 cm (length x width x height)</td></tr>
<tr><td>Content</td><td colspan="2">0.013572 m^3</td></tr>
<tr><td>Area</td><td colspan="2">0.3894 m^2</td></tr>
<tr><td>Permeation</td><td colspan="2">5 ml/min.bar</td></tr>
<tr><td rowspan="7">Product</td><td>Mass</td><td colspan="2">5 kg</td></tr>
<tr><td>Respiration rate</td><td>High</td><td>Low</td></tr>
<tr><td>Reference temperature</td><td>10 °C</td><td>10 °C</td></tr>
<tr><td>RQ</td><td>0.9</td><td>0.9</td></tr>
<tr><td>O_2 consumption</td><td>133.9 nmol/kg.sec</td><td>89.3 nmol/kg.sec</td></tr>
<tr><td>CO_2 production</td><td>148.8 nmol/kg.sec</td><td>99.2 nmol/kg.sec</td></tr>
<tr><td>Ea</td><td>96682 J/mol</td><td>92208 J/mol</td></tr>
<tr><td colspan="2">Temperatures</td><td colspan="2">0.5 °C, 5 °C, 10 °C</td></tr>
</table>

Table 7 **Used parameters to estimate MA-conditions in Quama packaging with Nectarines.**

<table>
<tr><th colspan="2">Parameter</th><th colspan="2">Value</th></tr>
<tr><td rowspan="4">Box</td><td>Dimensions</td><td colspan="2">39 x 29 x 12 cm (length x width x height)</td></tr>
<tr><td>Content</td><td colspan="2">0.013572 m^3</td></tr>
<tr><td>Area</td><td colspan="2">0.3894 m^2</td></tr>
<tr><td>Permeation</td><td colspan="2">5 ml/min.bar</td></tr>
<tr><td rowspan="7">Product</td><td>Mass</td><td colspan="2">5 kg</td></tr>
<tr><td>Respiration rate</td><td>High</td><td>Low</td></tr>
<tr><td>Reference temperature</td><td>15 °C</td><td>10 °C</td></tr>
<tr><td>RQ</td><td>0.9</td><td>0.9</td></tr>
<tr><td>O_2 consumption</td><td>468.7 nmol/kg.sec</td><td>89.2 nmol/kg.sec</td></tr>
<tr><td>CO_2 production</td><td>520.8 nmol/kg.sec</td><td>99.2 nmol/kg.sec</td></tr>
<tr><td>Ea</td><td>8616.3 J/mol</td><td>92208 J/mol</td></tr>
<tr><td colspan="2">Temperatures</td><td colspan="2">0.5°C, 5°C, 10°C</td></tr>
</table>

Table 8 **Parameters used to estimate MA-conditions in Quama packaging with peaches.**

Using these respiration rates, a rough estimation of the conditions in a Quama package is possible. The calculated equilibrium concentrations are shown in Table 9 for nectarines and in Table 10 for peaches.

	Nectarines	
Temperature	**Low respiration**	**High respiration**
- 0.5 °C	3.8	5.0
5.0 °C	7.2	9.3
10.0 °C	11.6	14.8

Table 9 **Estimated gas-concentrations in Quama boxes with nectarines, depending on temperature and estimated respiration rate.**

	Peach	
Temperature	**Low respiration**	**High respiration**
- 0.5 °C	2	7.3
5.0 °C	3.9	10.8
10.0 °C	6.7	14.7

Table 10 **Estimated gas-concentrations in Quama boxes with peaches, depending on temperature and estimated respiration rate.**

As we learned from literature, the best MA results to inhibit woolliness and internal breakdown are found at CO_2 concentrations larger than 10%. These calculations prove that at the recommended transportation/storage temperature of ±0 °C the building up of CO_2 n the Quama boxes will not reach such levels of CO_2. Therefore the MA-effect will not be at its maximum during transportation at optimum temperature. On the other hand, MA-conditions will be at the recommended level during transport or storage at sub-optimal temperature conditions.
An MA-effect will be possible though, especially for the suitable varieties (high respiration rate, good CA/MA effect etc.), and at the end of the distribution (distribution centres, mixed loads in trucks) when higher temperatures are more likely to occur.

3.3 Conclusions/Possibilities for QUAMA

- Results depend on variety, maturity, size, shipping period, etc.
- Peaches and nectarines profit from CA/MA especially at CO_2 concentrations larger than 10%.
- In the Quama boxes, these high CO_2 levels will probably be reached at sub optimum temperatures of at least 5 °C.
- In the Quama boxes, a positive effect of MA on woolliness and internal breakdown is presumable.

Due to a lack of relevant literature based on the South African situation, it is hard to extrapolate the effects of CA/MA on South African nectarines and peaches. It is plausible though to expect comparable results.

Reference:

Literature

1. Aly, M.M. et al. (1981). Ethylene production and firmness of peach and nectarine fruits as related to storage. Proc. Fla. Hort. Soc. 94, pp 291-294.
2. Ben-Arie, R. et al. (1971). Pectic changes occurring in Elberta peaches suffering from woolly breakdown. Phytochemistry Vol. 10, pp 531-538.
3. Ben-Arie, R. et al. (1980). Pectolytic enzyme activity involved in woolly breakdown of stored peaches. Phytochemistry Vol. 19, pp 2553-2555.
4. Ben J., et al. (1992).The effect of increasing concentration of carbon dioxide in controlled atmosphere storage of plums *cv.* Wegierka Zwykla (*Prunus domestica* L.). II Changes in content of soluble sugars, organic acids, and total phenols in aspect of fruit taste. Acta Phy Plant; 14 3; 151-158
5. Bryan, R. A. et al. (1989). Decay control and quality maintenance after moist air heat treatment of individually plastic wrapped nectarines. J. Amer. Soc. Hort. Sci 114(6), pp 946-949.
6. Buescher, R.W. et al. (1978). Role of pectinesterase and polygalacturonase in the formation of woolliness in peaches. J. of Food Sci. Vol 43, pp 264-270.
7. Burmeister, D.M. et al. (1998). Effect of fruit maturity on the succes of CA storage of Fantasia nectarines. Acta H. 464, pp 363-368.
8. Ceponis, M.J. (1987). Disorders in plum, peach and nectarine shipments to the New York market, 1972-1985. Plant Disease Vol 71 no 10, pp 947-952.
9. Choi, J.H. (1997). Effect of MA storage on woolliness of Yumyeong peaches. Proceedings CA 97 Vol 3, Davis, California, USA, pp132-138.
10. Combrink J.C., et al. (1997). Effect of partial cooling prior to packing on the quality of apricots, nectarines, peaches and plums after storage. Deciduous fruit grower September; 356-359.
11. Crouch I.J. (1998). Effect of Modified Atmosphere Packaging (MAP) on Control of Shrivel and Overall Quality of 'Laetitia' Plums. Acta Hort.: 464: 394-396
12. Crisosto, C.H. et al. (1997). Predicting market life for 'O'Henry and Elegant Lady peaches under CA conditions. Proceedings CA 97 Vol 3, Davis, California, USA, pp121-131.
13. Crisosto, C.H. (1996). Produce facts; Peaches & nectarines. Perishable handling no. May 1996, Davis, California, USA, pp 17-18.
14. Crisosto, C.H. (1996). Stonefruit disorders. Perishable handling no. May 1996, Davis, California, USA, pp 22-24.
15. Eksteen, G.J. et al. (1986). CA storage of South African grown nectarines and plums. Deciduous fruit grower, April 1986, South Africa, pp 128-132.
16. Fernandez-Trujillo, J.P. et al. (1997). Quality improvement of peaches by intermittent warming and MA-packaging. Z. Lebensm. Unters Forsch. A. Vol 205, pp 59-63.
17. Folchi A., et al. (1994). Effects of Oxygen Stress on Stone Fruits. Conference abstract. 107-111.
18. Gorini, F. et al. (1979). Indagine sulla conservabilita frigorifera delle nettarine a confronto con pesche e percoche. Unknown, pp 98-99.
19. Hardenburg, R.E. et al. (1986). The commercial storage of fruits vegetables and florist and nursery stocks. Agriculture handbook 66, USDA, USA, pp 11-12.
20. Kader, A.A. (1987). A summary of CA requirements and recommendations fir fruits other than apples and pears. Proceedings CA 97 Vol 3, Davis, California, USA, pp 21,25.
21. Ke D. et al. (1992). External and Internal Factors Influence Fruit Tolerance to Low-oxygen Atmospheres. J. Amer. Soc. Hort. Sci: 117 6: 913-918
22. Ke, D. et al. (1994). Tolerance of peach and nectarine fruits to insecticidal CA as influenced by cultivar, maturity and size. Postharves Biology and Technology 4, pp 135-146.
23. Kiss, Z.L. (1999). Production and storage of stone fruits in Hungary. Acta Hort. 485, pp 215-217.
24. Kubo,Y. et al. (1990). Respiration and C_2H_2 production in various harvested crops held in CO_2-enriched atmospheres. J. Amer. Soc. Hort. Sci. 115(6), pp 975-978.
25. Levin, A. et al. (1995). Physiological effects CA storage on Fiesta Red nectarines. Acta H. 379, pp 121-127.
26. Lurie S. et al. (1997). Modified Atmosphere Storage of Stone Fruits. CIPA International Congress. 536-541

27. Lurie, S. (1992). CA storage to decrease physiological disorders in nectarines. Int. J. of Food Sci. and Techn. 27, pp 507-514.
28. Mitchell, F.G. (1986). Influence of cooling and temperature maintenance on stone fruit quality. Sagtevrugteboer, June 1986, pp 205-211.
29. Murray, R. et al. (1999). Storage life and quality of peach harvested at different stages of maturity. Acta Hort. 465, pp 455-462.
30. Nanos, G.D. et al. (1991). Carbon dioxide injury and flesh softening following hig-temperature conditioning in peaches. HortScience 26(5), pp 562-563.
31. Otey, J.M. et al. (1991). CA storage of fruits and vegetables: a review. Amer. Soc. Of Agricult. Engineers. Paper no. 911574. Pp 1-23.
32. Pressey, R. et al. (1978). Difference in polygalacturonase composition of clingstone and freestone peaches. J. of Food Sci. Vol 43 no 5, pp 1415-1419.
33. Rajapakse, N.C. (1990). Development of oxygen concentration gradients in flesh tissues of bulky plant organs. J. Amer. Soc. Hort. Sci. 115(5), pp 793-797.
34. Retamales, J. et al. (1997). Hogh CO_2 MA can be effective in preventing woolliness in nectarines. Proceedings CA 97 Vol 3, Davis, California, USA, pp 46-53.
35. Rij, R.E. (1977). Performance of 35-pound fibreboard boxes jumble-packed with peaches and nectarines. U.S. government printing office, pp 7.
36. Rodriguez, L. et al. (1989). Relation between gas diffusion resistance and ripening in fruits. Proceedings CA 89, Wenatchee, USA, pp 1-7. Sekse L. (1989). Storage and Storage Potential of Plums (Prunus domestica L.) as Related to Respiration Rate. Agrric Scand. 39: 15-21.
37. Rushing J.W., et al. (1996). Simulated Shipment of Peaches, Plums and Nectarines Under Controlled Atmospheres. Conference Abstract. 202-222
38. Sekse L. (1989). Storage and Storage Potential of Plums (Prunus domestica L.) as Related to Respiration Rate. Agrric Scand. 39: 15-21
39. Sekse L. (1988). Respiration of Plum (*Prunus domestica* L.) and Sweet Cherry (P. avium L.) Fruits during Growth and Ripening. Acta Agrric Scand. 38: 317-320.
40. Smith C. (1999). The Future of Yellow skin Plums for the South African Plum Industry. DFG SVB july: 15-16
41. Snowdon, A.L. (1984). A colour atlas of postharvest diseases and disorders of fruits and vegetables Vol 1, pp 218,219, 236,237.
42. Stead, D.E. (1980). Studies on the storage of tropical fruits in polyethylene bags. J. Sci. Tech. (Malawi) 1 (2), pp 3-9.
43. Streif, J. et al. (1994). Preventing cold storage disorders in nectarines. Acta H. 368, pp 160-165.
44. Taylor M.A. (1998). Effect of Gamma Irradiation on Respiration, Ethylene Production and Quality of cold stored Laetitia and Songold plums. DFG SVB: 48 4:
45. Taylor M.A., Kock de A. (1997). Commercialisation of controlled atmosphere technology to improve storage quality of export stone fruit. CPA proceedings
46. Taylor M.A. (1996). Internal disorders in South African plums. Deciduous Fruit Grower September; 328-335
47. Taylor M.A. et al. (1994). Effect of storage regimes on pectolytic enzymes, pectic substances, internal conductivity and gel breakdown in cold stored 'Songold' plums. Jour of Hort Sci; 69 3; 527-534.
48. Taylor M.A. et al. (1993). Physiological factors associated with over-ripeness, internal breakdown and gel breakdown in plums stored at low temperature. Jour of Hort Sci; 68 5; 825-830.
49. Testoni A., et al. (1996). Controlled Atmosphere Storage Trails with Kiwifruits, Prickly pears, and Plums. Conference abstract. 131-136
50. Thai, C.N. et al. (1990). Peach quality changes at different constant storage temperatures: empirical models. Amer. Soc.of Agric. Eng. Vol 33 (1), pp 227-233.
51. Thompson, A.K. (1996). Postharvest technology of fruits and vegetables, pp 297, 303, 304.
52. Tonini G., et al. (1994). CA Storage of Stone Fruits; Effects on Diseases and Disorders. Conference abstract. 95-103.
53. Verstreken, E. et al. (1994). Influence of different storage conditions on the evolution of the maturity of nectarines. Acta H. 368, pp 43-50.
54. Website University of California. http://postharvest.ucdavis.edu
55. Wells J.M. et al. (1994). Diseases, Physiological Disorders, and Injuries of Plums Marketed in Metropolitan New York. Plant Disease; 78 6; 642-644

56. Zhou, H., et al. (2000). Delayed storage of CA storage of nectarines: two strategies to prevent woolliness. Postharvest Biology and Technology 18, pp 133-141.
57. Zoffoli, J. P. et al. (1997). Development of high concentration carbon dioxyde MA-packaging systems to maintain peach quality. Proceedings CA 97 Vol 3, Davis, California, USA, pp 37-45.

Thesis

I. Peppelenbos, H.W. (1996). The use of gas exchange characteristics to optimize CA storage and MA packaging of fruits and vegetables.