

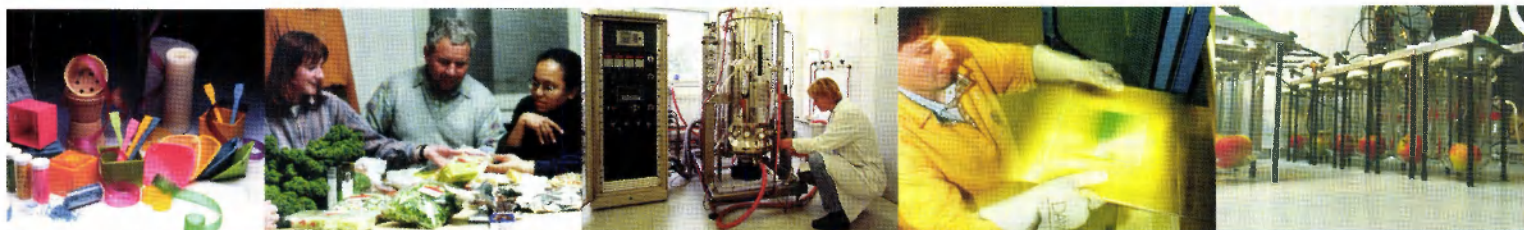


# Literature study on the effects of MA on Plums, Peaches and Nectarines

Report No. B493 / January 2001

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# 1 Introduction

This literature study has been done at the request of Kappa Quama. The aim of this study is to 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<sub>2</sub> and CO<sub>2</sub> 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<sub>2</sub> concentration smaller than 5% and a CO<sub>2</sub> 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<sub>2</sub> concentrations smaller than 5% in a Quama packaging in combination with CO<sub>2</sub> concentrations larger than 15%. Since the individual effects of O<sub>2</sub> and CO<sub>2</sub> are not described, it is not clear which gas (O<sub>2</sub> or CO<sub>2</sub>) affects the quality most. Therefore it might be possible that the combination of  $\pm 15\%$  O<sub>2</sub> with  $\pm 5\%$  CO<sub>2</sub> 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<sub>2</sub> and 0,035% CO<sub>2</sub>. With exception of the work of Taylor (44), only CO<sub>2</sub> 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 <sub>2</sub> )	54		
	6	74.4	10°C (CO <sub>2</sub> )			
	12	148.8	20°C (CO <sub>2</sub> )			
	2.7	33.5	5°C (CO <sub>2</sub> )	16		
	4.1	50.8	10°C (CO <sub>2</sub> )			
8.5		53.7	0°C (CO <sub>2</sub> )	38		
13.8		87.1	4°C (CO <sub>2</sub> )			
18		113.6	8°C (CO <sub>2</sub> )			
23.3		147.1	12°C (CO <sub>2</sub> )			
35.5		224.1	16°C (CO <sub>2</sub> )			
40		252.5	20°C (CO <sub>2</sub> )	39		
	42.5	527	25°C (CO <sub>2</sub> )	44	Laetitia	
	32.2	399.3	25°C (O <sub>2</sub> )			
	32.8	406.7	25°C (CO <sub>2</sub> )			
	11.5	142.6	25°C (O <sub>2</sub> )		Songold	

**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<sub>2</sub> and O<sub>2</sub> respiration rates at 0 °C and 10 °C the Ea from CO<sub>2</sub> 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<sub>2</sub> and CO<sub>2</sub> 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<sub>ref</sub>** = respiration rate at reference temperature

**T<sub>ref</sub>** = reference temperature

**R** = constant, 8.31

**Ea** = activation energy

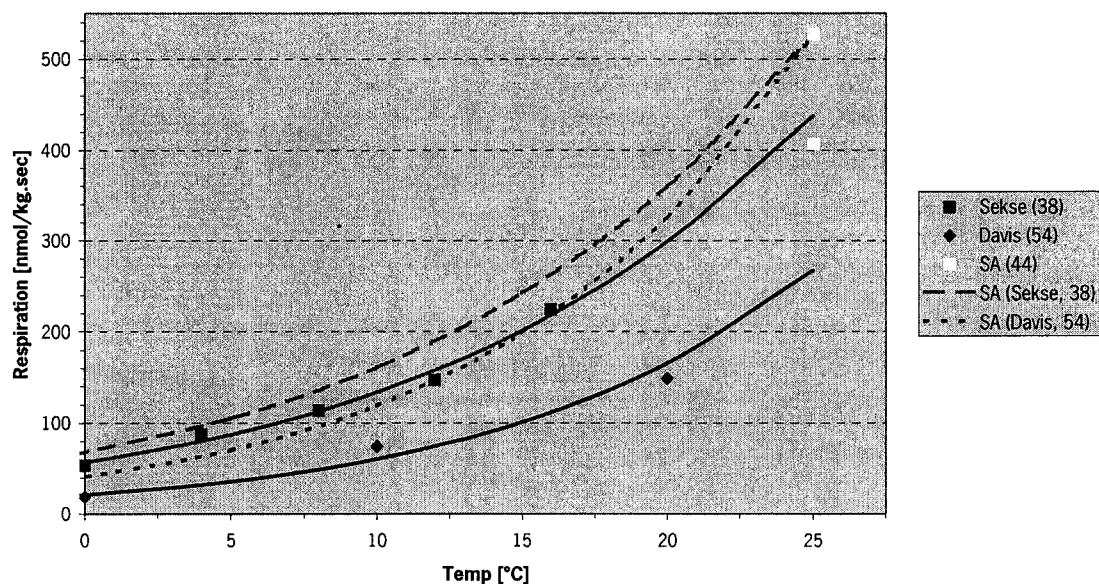
The calculated respiration rates of South African plums at 0 °C and 10 °C at ambient air conditions are shown in Table 2. The results show a large difference between the highest and the lowest estimation of the respiration rate. We assumed that the harvest maturity of the plums is optimal.

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

**Table 2** Calculated CO<sub>2</sub> production of South African plums at 0°C and 10°C and 21% O<sub>2</sub> and 0.035% CO<sub>2</sub>.

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.

### Respiration activity



**Figure 1** Found respiration rate in literature and calculated respiration rate depending on temperature of South African plums. Based on  $E_a$  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		
<b>Box</b>	<b>Dimensions</b>	39 x 29 x 12 cm (length x width x height)		
	<b>Content</b>	0.013572 m <sup>3</sup>		
	<b>Area</b>	0.3894 m <sup>2</sup>		
	<b>Permeation</b>	2.5 ml/min.bar		
<b>Product</b>	<b>Mass</b>	5 kg		
	<b>Cultivar</b>	<b>Laetitia</b>	<b>Songold</b>	
	<b>Reference temperature</b>	10°C	10°C	
	<b>RQ</b>	0.75	0.35	
<b>Source</b>	<b>38</b>	<b>Respiration O<sub>2</sub></b>	121.8 nmol/kg.sec	43.5 nmol/kg.sec
		<b>Respiration CO<sub>2</sub></b>	160.8 nmol/kg.sec	124.1 nmol/kg.sec
		<b>E<sub>a</sub></b>	55529 J/mol	
	<b>54</b>	<b>Respiration O<sub>2</sub></b>	90.5 nmol/kg.sec	32.3 nmol/kg.sec
		<b>Respiration CO<sub>2</sub></b>	119.4 nmol/kg.sec	92.2 nmol/kg.sec
		<b>E<sub>a</sub></b>	69427 J/mol	
<b>Temperature profile</b>		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 <sub>2</sub>	CO <sub>2</sub>	O <sub>2</sub>	CO <sub>2</sub>	O <sub>2</sub>	CO <sub>2</sub>
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<sub>2</sub> or O<sub>2</sub>;
- 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 (wooliness), 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<sub>2</sub> and CO<sub>2</sub> 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<sub>2</sub> concentrations larger than 1.0% (12, 25, 35). The effects of O<sub>2</sub> on chilling injury are not clear from literature. Low O<sub>2</sub> might be only slightly or even not effective in reducing chilling injury. Low O<sub>2</sub> in combination with high CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> production rates at 21% O<sub>2</sub> and 0,035% CO<sub>2</sub>. 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 °C	Source	Cultivar
mg/kg.h	ml/kg.h	Mmol/kg.h	Nmol/kg.s			
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		
	32-55		396.8 – 682	20 °C		
	1.9		23.6	0 °C	17	
30-60			189.4 – 378.8	20 °C	20	Fiesta Red

**Table 5** CO<sub>2</sub> production rates of nectarines at various temperatures.

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

**Table 6** CO<sub>2</sub> 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.

Parameter		Value	
<b>Box</b>	<b>Dimensions</b>	39 x 29 x 12 cm (length x width x height)	
	<b>Content</b>	0.013572 m <sup>3</sup>	
	<b>Area</b>	0.3894 m <sup>2</sup>	
	<b>Permeation</b>	5 ml/min.bar	
<b>Product</b>	<b>Mass</b>	5 kg	
	<b>Respiration rate</b>	<b>High</b>	<b>Low</b>
	<b>Reference temperature</b>	10 °C	10 °C
	<b>RQ</b>	0.9	0.9
	<b>O<sub>2</sub> consumption</b>	133.9 nmol/kg.sec	89.3 nmol/kg.sec
	<b>CO<sub>2</sub> production</b>	148.8 nmol/kg.sec	99.2 nmol/kg.sec
	<b>Ea</b>	96682 J/mol	92208 J/mol
	<b>Temperatures</b>	0.5 °C, 5 °C, 10 °C	

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

Parameter		Value	
<b>Box</b>	<b>Dimensions</b>	39 x 29 x 12 cm (length x width x height)	
	<b>Content</b>	0.013572 m <sup>3</sup>	
	<b>Area</b>	0.3894 m <sup>2</sup>	
	<b>Permeation</b>	5 ml/min.bar	
<b>Product</b>	<b>Mass</b>	5 kg	
	<b>Respiration rate</b>	<b>High</b>	<b>Low</b>
	<b>Reference temperature</b>	15 °C	10 °C
	<b>RQ</b>	0.9	0.9
	<b>O<sub>2</sub> consumption</b>	468.7 nmol/kg.sec	89.2 nmol/kg.sec
	<b>CO<sub>2</sub> production</b>	520.8 nmol/kg.sec	99.2 nmol/kg.sec
	<b>Ea</b>	8616.3 J/mol	92208 J/mol
	<b>Temperatures</b>	0.5°C, 5°C, 10°C	

**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.

<b>Nectarines</b>		
<b>Temperature</b>	<b>Low respiration</b>	<b>High respiration</b>
<b>- 0.5 °C</b>	3.8	5.0
<b>5.0 °C</b>	7.2	9.3
<b>10.0 °C</b>	11.6	14.8

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

<b>Peach</b>		
<b>Temperature</b>	<b>Low respiration</b>	<b>High respiration</b>
<b>- 0.5 °C</b>	2	7.3
<b>5.0 °C</b>	3.9	10.8
<b>10.0 °C</b>	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<sub>2</sub> concentrations larger than 10%. These calculations prove that at the recommended transportation/storage temperature of ±0 °C the building up of CO<sub>2</sub> in the Quama boxes will not reach such levels of CO<sub>2</sub>. 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<sub>2</sub> concentrations larger than 10%.
- In the Quama boxes, these high CO<sub>2</sub> 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.

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#### **Thesis**

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