Gas Exchange and Brown Heart in Conference Pears

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Abstract

Brown heart is a tissue disorder found in Conference pears during CA storage. Differences in susceptibility for brown heart have been found between countries, orchards, harvest dates and storage conditions. One hypothesis is that brown heart is caused by increased internal CO_2. This research focussed on establishing internal CO_2 levels by measuring gas exchange rates and the resistance to gas diffusion. Different harvest dates, post-harvest treatments and storage periods have been compared with regard to respiration, fermentation and diffusion resistance and internal CO_2 concentration was estimated. Comparing less sensitive and sensitive pears showed the same maximum respiration rate and lower maximum fermentation rate but also more brown heart for the sensitive pears after storage. This indicates that internal CO_2 is not the primary cause of brown heart.

INTRODUCTION

Brown heart in Conference pears is browning of the flesh, especially the core region, and the development of cavities. It is often assumed that the occurrence is influenced by weather conditions, orchard factors (location, nutrition), harvest date, post-harvest treatment, storage conditions and storage duration. However, the causes that underlie the development of this disorder are unknown. In the European Project "Europear" (1997-2001) partners from 5 countries worked together to get more fundamental knowledge about the physiological and biological processes that cause brown heart in pears. This paper only presents a small part of that work, focussing on the hypothesis that brown heart in pears is the result of increased CO_2 concentrations inside the fruit.

MATERIALS and METHODS

Product, Harvest Times, Storage and Susceptibility to Brown Heart

In 1997 and 1998 conference pears not very susceptible to brown heart were used, from one orchard in the centre of the Netherlands. The pears were harvested 5 times, ranging from 2 weeks before until 2 weeks after the commercial harvest date. The pears from the commercial harvest date were stored directly at CA conditions (0 kPa CO_2, 2 kPa O_2 and 0°C) or after a delay treatment (= 6 weeks ambient air before CA). Storage duration was 8 months. In 1999 only the commercial and the late harvest (2 weeks later) were used for these treatments. Pears from two orchards were used; with a known history of high and low sensitivity for brown heart. Pears from the late harvest date were directly stored for about 2, 4 and 6 months at 0°C, 2 kPa O_2 and 0 kPa CO_2 or were subjected to the delay treatment.

Gas Exchange Measurements

To determine volume and porosity the method of Bauman and Henze (1983) was used. Cuvettes of 1500 ml, with two pears each, were connected to a flow through system. Gas conditions were all combinations of 0, 0.5, 1, 2.5, 6 and 21 kPa O_2 with 0 kPa CO_2. Relative humidity was high (>95%) as the gas was led through water flasks. Temperature was 2°C. After 4 days, O_2 uptake and CO_2 production were determined by disconnecting the cuvettes from the flow through system and sampling the headspace directly and after a period of 5 hours. The GC used was a Chrompack CP 2002. Measured O_2, CO_2 and N_2 were corrected to 100% to account for possible pressure variations inside the GC. The measured actual pressure inside the cuvette and the volume of the pear and the cuvette were used to express gas exchange in nmoles/kg.s. Gas exchange rates were analysed using non-linear regression analysis of the statistical package Genstat. The models used were derived from Peppelenbos and van 't Leven (1996) and Peppelenbos et al. (1996).

To measure the diffusion resistance the inert gas neon was injected in the cuvette. Then the pears stayed in 5000-6000 ppm overnight. It was assumed that by that time an equilibrium was reached between the internal gas volume in the pear and the free gas volume in the cuvette. Subsequently the neon concentration in the flask was measured, the pears were transferred to a cuvette with air and immediately afterwards the diffusion of neon out of the pear was measured 4 times at intervals of 90 seconds. With Grahams Law the diffusion resistance for CO_2 was calculated. Length and maximum circumference of the pears were measured to calculate the outer surface area. The internal CO_2 concentration was estimated by combining respiration, fermentation, diffusion resistance and the porosity of the pear, calculated with the specific weight of the pear juice.

RESULTS

Harvest Date

Different harvest dates did not show much difference in respiration and fermentation rates. Also differences in diffusion resistance between the 5 harvest dates were minimal and not significant considering the large variation between individual pears. Diffusion resistance values in the first year were remarkably higher than in the second and third year.

Postharvest Treatment: Delayed CA

The first two years pears directly subjected to CA conditions showed a lower respiration and fermentation rate than pears that were subjected to delayed CA (ambient air). Differences were greater in the first than in the second year. The diffusion resistance did not differ significantly for direct and delayed CA storage. In the third year the less sensitive pears showed a lower respiration and fermentation after delayed CA storage compared with direct CA (table 1). Comparing the less sensitive and the sensitive pears there was no difference in maximum fermentation rate and also the difference in maximum respiration rate was small. The diffusion resistance for both less sensitive and sensitive pears was higher after direct CA than after delayed CA storage (table 1). The variation between individual pears was large.

Storage

Over the 3 years less sensitive pears showed very comparable maximum respiration rates (VmO_2) and maximum fermentation rates ($VmfCO_2$). VmO_2 did not change much during storage. $VmfCO_2$ however decreased strongly the first two months during storage (fig.1 and 2). The sensitive pears showed a lower maximum fermentation rate after storage than the less sensitive pears (table 1 and fig.2).

Internal CO_2

The calculated internal CO_2 concentration did not differ much with harvest date. On the other hand large differences in browning are found between different harvest dates (Veltman et al., 2000). This indicates that there is no obvious relation between internal CO_2 and browning. Also direct or delayed CA storage caused great difference in internal CO_2 concentration. The third year internal CO_2 was lower after delayed CA storage compared with direct CA, especially for the sensitive pears (fig.3). During storage the internal CO_2 varied the first year from 0.4-0.5, the second year from 0.2-0.35 and the third year from 0.3-0.5 kPa for the less sensitive pears. This was not very different for the sensitive pears (fig.3).

DISCUSSION

In the first two years, pears stored directly under CA showed a lower respiration and fermentation than pears subjected to a delayed CA treatment (ambient air). The third year, however, the opposite was found, while in all three years brown heart was prevented by the delayed CA treatment. During storage the maximum respiration rate was very comparable for the three years, as well as for the sensitive and less sensitive pears. Fermentation rates measured in three years did show differences between the sensitive and the less sensitive pears. For the less sensitive pears maximum fermentation rates decreased during the first 2 months of storage, the period where browning begins, and then increased again. $VmfCO_2$ of the sensitive pears, however, remained at a lower level.

Although the internal CO_2 was not very different for the sensitive and less sensitive pears during storage only the sensitive pears got brown heart. Also the delay treatment did not cause big differences in internal CO_2 concentrations. In fact the calculated internal CO_2 concentrations after the delay treatment were higher in the first two years (data not shown). Combined with the results on harvest date this indicates that the internal CO_2 concentration is not the primary cause of brown heart. Metabolic rates do seem to be involved in the start of this disorder, however, probably not by internal CO2 concentration but by energy generation.

ACKNOWLEDGEMENTS

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Tables

Table 1. Maximum respiration and fermentation rates and CO2 resistance in the third year

	pears	*delayed CA (std)*		*direct CA (std)*		*4 m. storage (std)*	
VmO_2	less sensitive	17.0		21.4		16.9	
(nmol/kg.s)	sensitive	19.5		19.3		19.0	
$VmfCO_2$	less sensitive	12.9		15.0		17.1	
(nmol/kg.s)	sensitive	12.7		14.5		9.9	
CO_2 resist.	less sensitive	623	(206)	893	(303)	754	(206)
(s/mm)	sensitive	446	(252)	982	(466)	779	(164)

Figures

Fig.1. Maximum respiration rate

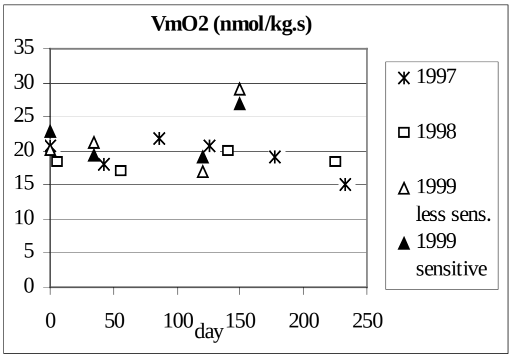
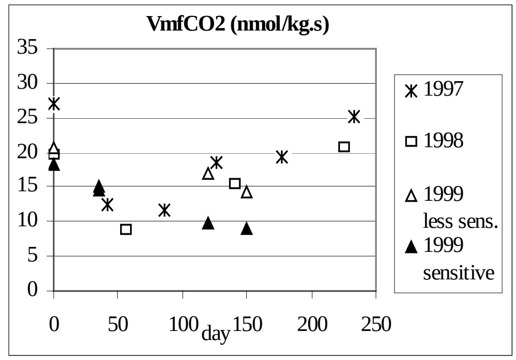


Fig. 2. Maximum fermentation rate



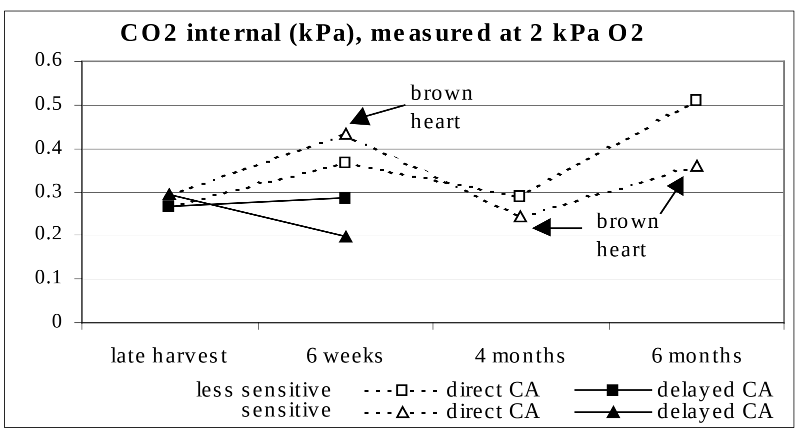


Fig. 3. Estimated internal CO_2 concentrations