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Effect of post-harvest fumigation on quality of asparagus spears

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Abstract Asparagus spears were damaged by post-harvest fumigation treatments using moderate or high doses of methyl bromide. Damage was expressed both as the earlier development of decay during shelf-life evaluation and as a reduction in eating quality of spears which showed no visible damage. Fumigation stimulated both respiration rate and ethylene production by asparagus spears.

INTRODUCTION

Despite careful grading and pre-export inspections, New Zealand fresh asparagus sent to Japan is frequently found to harbour live insects during Japanese quarantine inspections. Such shipments are fumigated with either methyl bromide (48.5 g/m³ for 3 h) or hydrogen cyanide (1.8 g/m³ for 30 min), depending on the type of insect found, before being released to the importer (Eguchi pers. comm.). The fumigation treatment itself, as well as the sometimes considerable delay until a fumigation chamber becomes available, is thought to have a marked detrimental influence on the quality of spears reaching the consumer (Anon. 1983). Although any delay in marketing asparagus is important since it reduces the already very short shelf life of the product, the effects of the fumigation treatments themselves are not known. The experiments reported here investigate the effect of fumigation treatments on quality and storage life of asparagus spears.

METHODS

Asparagus spears, cv. Mary Washington 500, were hand harvested from the DSIR Research Station at Pukekohe from September to November 1983, and washed, graded, and cut to a length of approximately 18 cm. Excess water was removed from the spears before they were stored overnight at 1°C. Spears were then pre-conditioned to the fumigation temperature for 2-4 h before the fumigation treatment.

Five to 10 replicate bunches, each of 15-25 spears, were used per treatment. Fumigations were carried out in 24-litre perspex chambers in a room maintained at the fumigation temperature (12°C) unless otherwise specified. Methyl bromide was added by the injection of the required volume of methyl bromide gas. Hydrogen cyanide was generated within the chamber by the addition of excess sulphuric acid to the appropriate amount of potassium cyanide. The 'nominal dose' — the gas concentration used to charge the fumigation chamber calculated on the basis of the volume of the empty chamber — varied for different experiments over a range of concentrations being tested concurrently for insect mortality (Foster unpublished data). During fumigation and aeration, the atmosphere within the chamber was recirculated by an internal fan.

For any one trial, fumigation treatments were carried out concurrently, with the non-fumigated control spears remaining at 12°C until the fumigations were completed. Methyl bromide concentrations in the chamber were measured at intervals during the fumigation period by withdrawing 1 ml gas samples and injecting them into a gas chromatograph with a 2 m OV101 column and an FID detector. The methyl bromide concentration was calculated by comparing the resulting peak areas with those from known standards, and the values obtained were averaged over the fumigation period to calculate the 'actual dose'. Hydrogen cyanide concentrations in the chamber during the fumigation treatment were not measured.

At the end of the fumigation period the chamber was aerated for 2 h by flushing with fresh air at approximately 3.5 complete air changes/h, a rate selected to simulate aeration in large commercial chambers. Spears were then packed upright on dry foam pads inside perforated plastic bags, which
Fig. 1 The concentration of methyl bromide in the atmosphere of the fumigation chamber during a typical 2 h fumigation. Nominal dose = 48 g/m³, actual average dose = 42.59 g/m³, loading = 1.5 kg, temperature = 12°C, chamber volume = 24 litres.

Fig. 2 Damage showing in asparagus spears during storage at 20°C following fumigation with methyl bromide at different concentrations. Fumigations were for 2 h at 12°C. Standard errors are based on five 15-spear replicates.
Fig. 3 Damage in asparagus spears after fumigation for 2 h with methyl bromide at either 12 or 20°C. Spears were stored overnight at 1°C following fumigation and then continuously at 20°C. Standard errors are based on six 20-spear replicates.

were placed inside 4.8 kg asparagus export cartons. The cartons were stored at 1°C for 24 h and then continuously at 15 or 20°C to approximately simulate storage temperatures during marketing overseas.

Spears were examined each day until their condition had deteriorated well past that which would be considered commercially acceptable. Counts were made of the following disorders: rots at the cut end (butt rot), wilting, pits or lesions on the stem, and tip rots. In early trials, wilting was found to be unrelated to fumigation treatment and has been excluded from the results. The other types of damage were scored for each spear (maximum value = 3) and expressed as a percentage of the damage possible (i.e., 3 x number of spears). Treatments were regarded as significantly different from one another if they differed at the 5% level (analysis of variance).

Respiration rate and ethylene production by spears was measured by placing spears, typically 15-20, in 5 litre jars at 15°C and flushing with a steady air stream. Samples (1 ml) of the exhaust air were taken daily and analysed for CO₂ and ethylene by gas chromatography.

To determine the effect of fumigation on eating quality, spears were harvested, fumigated, stored for 24 h at 1°C, and then kept at 12°C for 3 days before being assessed. The spears were retrimmed to a length of 15 cm, cooked for 7-10 min in boiling salted water (time depending on spear diameter) and allowed to cool to room temperature. Each of 29 assessors compared a pair of visually matched spears, one fumigated and the second non-fumigated. For each person this paired presentation was repeated twice. Assessments were made of intensity of characteristic asparagus flavour and off-flavours, acceptability of flavour, and overall acceptability. Comments about the flavour and overall acceptability rating were also sought.

Inorganic bromine residue was determined in spears that had been stored for 7 days at 20°C following fumigation. Samples of 5 spears were macerated in an equal weight of warm distilled water, the homogenate was centrifuged (375g for 15 min) and the supernatant stored frozen until
required. To 25 ml of thawed supernatant, 0.5 ml of 5M NaNO₃ and 0.1 ml of 2M Ni(NO₃)₂ was added and the bromine concentration determined with an Orion bromide ion-selective electrode (Gnanasunderam & Triggs 1983).

RESULTS

Adsorption of methyl bromide by spears
Fig. 1 shows the concentration of methyl bromide in the chamber atmosphere during a typical fumigation treatment. Adsorption of the gas by the spears reduced the concentration in the atmosphere from the nominal applied dose of 48 g/m³ to approximately 39 g/m³ at the end of the 2 h fumigation period. The 1.5 kg loading of spears in the fumigation chamber, in this trial, reduced the nominal dose of 48 g/m³ to an actual dose of only 42.6 g/m³.

Effect on storage life
Damage in spears treated with a nominal dose of 48 g/m³ (actual dose 48.3 g/m³) for 2 h at 12°C was not significantly different from that of non-fumigated spears 8 days after harvest. However, after 9 days a significantly higher level of damage was found (Fig. 2). Higher nominal doses of methyl bromide, of 72 and 96 g/m³ (actual doses of 65.4 and 79.9 g/m³ respectively) for 2 h at 12°C, resulted in significantly more damage 1 week after fumigation than in non-fumigated spears.

Damage symptoms found on fumigated and non-fumigated spears included tip rot, butt rot, and lesions (pits or rot lesions) along the spear. The effect of high methyl bromide doses was to accelerate their development. No symptoms were found which could be attributed only to the fumigation treatment.

In a subsequent trial in 1984, spears were found to be slightly more sensitive to fumigation treatments. Then, spears treated at 48 g/m³ (actual dose 37.1 g/m³) for 2 h at 12°C had a higher level of damage than control spears 8 days after harvest.

Effect of fumigation temperature
Spears fumigated at either 12 or 20°C showed no increase in damage over that in control spears...
Table 1 Mean scores for sensory attributes of non-fumigated and fumigated spears assessed 5 days after harvest.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Non-fumigated</th>
<th>Fumigated</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>asparagus flavour</td>
<td>74.8</td>
<td>62.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Off-flavours</td>
<td>34.2</td>
<td>54.2</td>
<td>6.3</td>
</tr>
<tr>
<td>Overall flavour</td>
<td>89.0</td>
<td>67.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>89.3</td>
<td>65.2</td>
<td>5.1</td>
</tr>
</tbody>
</table>

1 0 = absent, 150 = extremely strong.
2 0 = extremely unacceptable, 75 = neither unacceptable nor acceptable, 150 = extremely acceptable.
3 Fumigation at 12°C for 2 h one day after harvest. Nominal dose 60 g/m³, actual dose 44 g/m³.

Fig. 5 Ethylene production at 15°C by asparagus spears after fumigation with methyl bromide at different concentrations for 3 h at 12°C. Standard errors are based on three 20-spear replicates.

Effect of methyl bromide fumigation on physiological activity

Fumigation with methyl bromide stimulated both respiration rate and ethylene production by asparagus spears (Fig. 4 and 5). A marked stimulation of respiration rate occurred in the 24 h following fumigation but even during the subsequent 6 days the rate remained approximately 1½ times that of unfumigated controls. Ethylene production was nearly doubled by fumigation at 48 g/m³ (actual dose 47.4 g/m³) for 3 h at 12°C but even higher production was initiated by the higher dose of 96 g/m³ (actual dose 79.7 g/m³) for 3 h at 12°C.

Sensory evaluation of fumigated spears

Asparagus spears fumigated at 60 g/m³ (actual dose 44 g/m³) for 2 h at 12°C were assessed as having a significantly ($P < 0.01$) lower characteristic asparagus flavour, a higher level of off-flavours, and a
DISCUSSION

None of the damage symptoms found in this study were caused exclusively by fumigation. Wilting, stem lesions, butt rots, and tip rots were found in both fumigated and non-fumigated spears. However, fumigation increased the rate of development of these symptoms compared to that in non-fumigated controls, and thereby shortened the storage life.

Fumigation at high dose rates, such as methyl bromide at 96 g/m³ at 20°C for 2 h or hydrogen cyanide at 6 g/m³ at 20°C for 1 h, undoubtedly caused damage to asparagus spears which, although not visible in the first few days following fumigation, would substantially reduce the storage life. Fumigation at a moderate dose rate (methyl bromide at up to 48 g/m³ at 12°C for 2 h) caused slight damage resulting in a slightly shorter storage life. Thus a dose of 48 g/m³ for 3 h, at ambient temperature (approximately 20°C), which is used in Japan to fumigate New Zealand asparagus, causes some reduction in storage life. Since no damage symptoms unique to fumigation were found, and considerable natural variation in storage life occurs for individual spears, a small amount of fumigation damage is difficult to identify. In addition, fumigation damage does not become visible for several days after treatment, so that rapid handling and marketing of the crop may result in much of the damage remaining unobserved.

The stimulation of both respiration rate and ethylene production of asparagus by fumigation, even in the absence of visible damage, is similar to results we have obtained with other crops — e.g., apples, nectarines, and cherries (Beever & Yearsley unpublished data). Although these biochemical effects may not be of commercial significance, the increased metabolic activity indicates a faster rate of senescence and shorter storage life.

Inorganic bromine residue values found in non-fumigated asparagus were higher than those found in many other fruit and vegetables. After fumigation however, values were similar to those found in fumigated spears by Seo et al. (1970).

Of greater significance however is the effect of fumigation on eating quality. Methyl bromide fumigation at a nominal dose of 60 g/m³ (actual average dose 44 g/m³) for 2 h at 12°C had a significant effect on each of the sensory attributes assessed. Fumigated spears were always assessed as inferior to non-fumigated spears. Although a few assessors found off-flavours in non-fumigated spears most assessors found off-flavours, especially a bitter/metallic flavour, in the tips of fumigated spears.

These results show that even a moderate fumigation treatment has a direct and detrimental effect on asparagus storage quality, in addition to any effect on the insect pest which is being controlled, and casts doubt on the suitability of fumigation as a method of insect disinfection for asparagus.
REFERENCES

