TOXICITY OF CARBONYL SULFIDE AND METHYL IODIDE TO INSECT PESTS OF DRIED FRUITS AND NUTS

J. Larry Zettler and J. G. Leesch

ABSTRACT Because methyl bromide (MB) has been designated as an ozone depleter, its use as a fumigant will be curtailed by the Clean Air Act in 2001 and eventually phased out. Because there is a critical need to find replacements for this very important fumigant, the toxicities of carbonyl sulfide (COS) and methyl iodide (MI) were tested against five species of stored product insects commonly found in dried fruits and nuts to evaluate their effectiveness for replacing MB in commodity fumigations. Laboratory fumigations were performed in modified 2.5-L desiccator jars at 25°C and 60% RH. Test insects were larval navel orangeworm, Amyelois transitella (Walker), adult sawtooth grain beetle, Oryzaephilus surinamensis (L.), adult driedfruit beetle, Carpophilus hemipterus (L.), adult cigarette beetle, Lasioderma serricorne (F.), and four life stages of confused flour beetle, Tribolium confusum Jacquelin duVal. COS was toxic to all species and life stages, each of which was unique in its inherent susceptibility to the fumigant. Susceptibilities of life stages of T. confusum, the most tolerant species, varied. The egg and pupal stages were least susceptible, requiring concentration times time products (CtTs) of 1,008 and 750 mg/liter/hr, respectively, for LC99.9 during a 24-hour exposure period. MI was tested against T. confusum and toxic to all life stages of T. confusum. The egg and larval stages were the most susceptible. Based on their toxicity to stored product insects, COS and MI have potential as effective fumigants for dried fruits and nuts.

OBJECTIVES Because MB will eventually be banned as a fumigant, laboratory studies were designed to evaluate potential alternative chemical fumigants against postharvest insect pests commonly infesting dried fruits and nuts. Because COS and MI have been identified as potential replacements for MB, the toxicities of these two chemicals were evaluated against the following insect pests: larval navel orangeworm, Amyelois transitella (Walker), adult sawtooth grain beetle, Oryzaephilus surinamensis (L.), adult driedfruit beetle, Carpophilus hemipterus (L.), adult cigarette beetle, Lasioderma serricorne (F.), and egg, larva, pupa, and adult confused flour beetle, Tribolium confusum Jacquelin duVal.

PROCEDURES Fumigations were performed in 2.5-L desiccator jars modified for the introduction of the fumigant dose. The required number of insects for each test was counted, placed in dishes, and stacked randomly in the desiccators. All bioassay insects were prepared the day before fumigation and allowed to acclimate overnight in the desiccators in a controlled environment room maintained at 27°C, 12:12 (L:D) hour and 60% RH. Each treatment was replicated at least three times, each on a different day, over a period of 4-6 weeks. On the day of the fumigation, each desiccator was treated with the appropriate concentration of fumigant. Exposure period for COS was 24 hours and that for MI was 3 hours. Preliminary tests showed that T. confusum was the most tolerant species so MI was tested against all life stages of this species. Dosing concentrations were verified by gas chromatography both at the beginning and end of the fumigation period. The average of these two readings represented the actual treatment dose.
RESULTS AND CONCLUSIONS The following results and conclusions are presented to give
an assessment of the potential of the two fumigants studied as possible replacements for MB.
Both fumigants show some promise to replace MB uses on dried fruit and nuts. Further testing is
planned to give more definitive answers as to the usefulness and marketing points where these
fumigants might be introduced as alternatives for methyl bromide.

--Carbonyl Sulfide-- COS was toxic to the five species of pests tested, and each was unique in its
inherent susceptibility to the fumigant (Table 1). Toxicities (LC50) for beetle adults and A.
transitella larvae ranged form 1.7 to 11.4 mg/liter, reflecting decreasing susceptibilities on the
order of A. transitella larvae, O. surinamensis, C. hemipterus, L. serricorne, and T. confusum.
The egg and pupal stages of stored product insects are generally more tolerant than larvae or
adults to the fumigants MB, phosphine, and COS. Our data support this generalization. Because
T. confusum was the most tolerant species, COS was tested against all its life stages. Results of
these data (Table 1) reflect decreasing susceptibilities on the order of larva, adult, pupa, and egg,
respectively. When compared with other reports on COS toxicity, eggs and pupae of T.
confusum tested in our experiments appear to be more tolerant than other species. Our results on
COS toxicity indicate there is a broad range of susceptibility to COS among different insect
species and populations.

Although sublethal effects of COS were not studied, effects relating to time of development were
noticed. Surviving A. transitella treated as immature stages were delayed in their development
when compared with the untreated control larvae. For example, pupating larvae were smaller,
and they took about 7 days longer to emerge as adults when compared with the untreated
controls.

--Methyl Iodide-- MI was tested against all life stages of T. confusum. Results of these tests are
shown in Table 2. MI was toxic to all life stages, exhibiting a range of toxicity varying between
eggs, the most susceptible stage, and adults, the least susceptible stage. The larval stage was
nearly as tolerant as was the adult stage and the pupal stage was intermediate in its susceptibility
between eggs and larvae. These results were supervising because for most fumigants the adult
and larval stages are the most susceptible stages of the insect’s life stages while the eggs and
pupae are the least susceptible. At least for T. confusum, the toxicity to the life stages is
reversed. MI was more toxic to the test insects than was COS, showing comparable LC values
during 3-hour fumigations compared with 24-hour fumigations for COS.

--General Discussion-- In addition to rapid toxicity, a fumigant should have no adverse impact on
commodity quality. Chemically, COS is a relatively stable, environmentally friendly molecule
but can undergo a variety of reactions, including hydrolysis, oxidation, and reduction. These
reactions, as well as others with amines, could result in commodity taints or significant toxic
residues. The presence of hydrogen sulfide, a hydrolysis product of COS, could preclude its use
in humid conditions (e.g., fumigation of fresh fruits and vegetables). MI has great potential for
use as an alternative preplant treatment for MB but because it is known to cause cancer, its
registration for use on postharvest commodities may be problematic. However, based on pest
toxicity, COS and MI have potential for use as fumigants for dried fruits and nuts.

--Present Status of Research-- Presently we are investigating the toxicity of the two fumigants
with commodity (walnut kernels), the sorption of fumigant by the walnut kernels and the residue
accumulation of the fumigants. We are now developing a residue method that can be used to
determine the desorption of the fumigants from treated and can assess the amount of residue, if
any, that will remain on kernels permanently. Following these studies, we will be looking at the
effects of the fumigants on quality of nuts following treatment.
Table 1. Probit analysis data for carbonyl sulfide against five species of stored product pests resulting from 24 hour laboratory fumigations

<table>
<thead>
<tr>
<th>Insect(^a)</th>
<th>n(^b)</th>
<th>Slope ± S.E.M.</th>
<th>LC(_{50}) (mg/L)</th>
<th>95% C.I.</th>
<th>LC(_{90}) (mg/L)</th>
<th>95% C.I.</th>
<th>[H](^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOW larvae</td>
<td>1692</td>
<td>6.95 ± 0.465</td>
<td>1.74</td>
<td>1.569-1.886</td>
<td>2.66</td>
<td>2.428-3.001</td>
<td>2.13</td>
</tr>
<tr>
<td>STGB adults</td>
<td>771</td>
<td>6.85 ± 0.645</td>
<td>5.98</td>
<td>5.528-6.391</td>
<td>9.20</td>
<td>8.388-10.554</td>
<td>1.25</td>
</tr>
<tr>
<td>DFB adults</td>
<td>750</td>
<td>6.50 ± 0.479</td>
<td>7.06</td>
<td>5.746-8.081</td>
<td>11.11</td>
<td>9.682-13.818</td>
<td>3.41</td>
</tr>
<tr>
<td>CB adults</td>
<td>1704</td>
<td>8.97 ± 0.453</td>
<td>7.72</td>
<td>7.365-8.091</td>
<td>10.76</td>
<td>10.177-11.560</td>
<td>2.75</td>
</tr>
<tr>
<td>CFB adults</td>
<td>1750</td>
<td>9.81 ± 0.434</td>
<td>11.38</td>
<td>10.312-12.282</td>
<td>15.37</td>
<td>14.067-17.795</td>
<td>12.58</td>
</tr>
<tr>
<td>larvae</td>
<td>2340</td>
<td>8.10 ± 0.457</td>
<td>10.51</td>
<td>9.009-11.562</td>
<td>15.13</td>
<td>13.708-17.870</td>
<td>6.01</td>
</tr>
<tr>
<td>eggs</td>
<td>10800</td>
<td>17.439 ± 0.571</td>
<td>29.96</td>
<td>27.300-30.276</td>
<td>34.30</td>
<td>32.661-37.039</td>
<td>17.37</td>
</tr>
</tbody>
</table>

\(^a\)NOW navel orangeworm; STGB, sawtooth grain beetle; DFB, driedfruit beetle; CB, cigarette beetle; CFB, confused flour beetle.

\(^b\)Number treated excluding controls.

\(^c\)Heterogeneity factor, $X^2$/degrees of freedom ($X^2$ is significant; $P < 0.05$).
Table 2. Probit analysis data for methyl iodide against *Tribolium confusum* resulting from 3 hour laboratory fumigations

<table>
<thead>
<tr>
<th>Life stage&lt;sup&gt;a&lt;/sup&gt;</th>
<th>n&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Slope ± S.E.M.</th>
<th>LC&lt;sub&gt;50&lt;/sub&gt; (mg/L)</th>
<th>95% C.I.</th>
<th>LC&lt;sub&gt;90&lt;/sub&gt; (mg/L)</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>adults</td>
<td>600</td>
<td>14.24 ± 0.584</td>
<td>9.75</td>
<td>7.41-12.01</td>
<td>13.99</td>
<td>11.52-31.25</td>
</tr>
<tr>
<td>pupae</td>
<td>950</td>
<td>11.69 ± 0.024</td>
<td>3.36</td>
<td>2.14-5.06</td>
<td>7.77</td>
<td>5.82-12.50</td>
</tr>
<tr>
<td>larvae</td>
<td>850</td>
<td>13.36 ± 0.395</td>
<td>7.09</td>
<td>5.05-8.99</td>
<td>12.41</td>
<td>9.60-29.69</td>
</tr>
<tr>
<td>eggs</td>
<td>950</td>
<td>10.60 ± 0.458</td>
<td>0.44</td>
<td>0.26-0.54</td>
<td>0.81</td>
<td>0.67-1.32</td>
</tr>
</tbody>
</table>

<sup>a</sup>*Tribolium confusum*, confused flour beetle, CFB

<sup>b</sup>Number treated excluding controls.