Does chemical treatment of malting barley to control insects affect malt quality ?

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Abstract

Storage of barley in Australia can take various forms such as small shipping containers kept on farms, various types and sizes of silos as well as sheds and bunkers containing very large tonnages. The chemical treatments applied to stored grain to control insects depend on storage design and construction, as well as the circumstances relating to conditions for potential infestation, barley transfer and end use. The most common forms of treatment used for malting barley include phosphine, fenitrothion/methoprene and dichlorvos. Until recently bioresmethrin / piperonyl butoxide was also commonly used, but bioresmethrin was deregistered in June 2001.

It is not uncommon for malting barley to exhibit quite variable protein modification under normal malting conditions, depending on its maturity and quality attributes. There is a perception held by some experienced maltsters in Australia that long storage times coupled with repeated chemical treatment can produce barley that may easily over-modify in the malthouse.

In this study we investigated conditions that might produce higher protein modification due to storage and chemical treatment. Four different barley varieties were treated with chemicals commonly used for the control of insects in malting barley. Samples were stored and treated under controlled conditions, and then malted on a micro scale prior to malt quality analysis. The results suggested that fenitrothion/methoprene has the potential to increase malt modification under certain conditions.

Key Words

barley/storage/pesticides/quality/protein modification

Introduction

This study was initiated in response to concerns from a number of experienced maltsters about the possible effects of pesticides applied to malting barley on the finished malt quality. Post harvest changes in malt quality are expected over time (Woonton 2004) and can both improve quality or cause deterioration. Storage conditions play a major role (Reuss, 2003) but the mechanisms responsible are not fully understood.

Some potential effects of chemical pesticides have been reported in Australia with reference made to bioresmethrin, fenitrothion and pirimiphos methyl. Possible changes were reported for rootlet growth, malt yields and malt extracts (Tempone 1979). In Australia only a very small number of agrochemicals are approved for the treatment of malting barley in store. The hypothesis in this study was that barley subjected to more than one treatment of a chemical over a period of time could produce a high Kolbach Index (KI). A study was carried out which included the most commonly applied chemical treatments for malting barley (refer to the list below). Although bioresmethrin was deregistered for use on barley in Australia in 2001 it was included in the study because it had been in use at the time when these issues were identified.

Chemical treatments investigated

- Fenitrothion
  A contact insecticide recommended for use in combination with methoprene.
  - Methoprene
    An insect growth regulator, checking growth in the immature stages of insects and thus breaking the cycle of infestation.
- Phosphine
  A commonly used fumigant available in solid or gas form.
- Dichlorvos
  A commonly used contact insecticide.
- Bioresmethrin
  A second generation synthetic pyrethroid. Its registration expired in June 2001 in Australia.
  - Piperonyl butoxide
    A synergist with no insecticide activity of its own but which increases the effectiveness of the other insecticides by inhibiting their breakdown.

All chemical treatments were applied at the CSIRO Stored Grain Research Laboratory (SGRL). The dosages were applied as precautionary treatments and not in response to infestation.
Applications of Fenitrothion (12g/T), Methoprene (0.6mg/kg), Bioresmethrin (1g/T) and Piperonyl butoxide (8g/T) were at maximum levels permissible for barley destined for malting and brewing as defined in the Malting and Brewing Industry Barley Technical Committee (MBIBTC) protocols.
Phosphine (3g/m3) and Dichlorvos (24g/T) were applied at twice the recommended label levels with the hypothesis that if no effect on malt quality were observed at high doses then it would be unlikely to see an effect at the normal application rates. Any significant effects at high levels could then be followed up with further work at normal levels.

Experiments were divided into sets comprising the variables in Table 1.

Table 1 Experiment variables

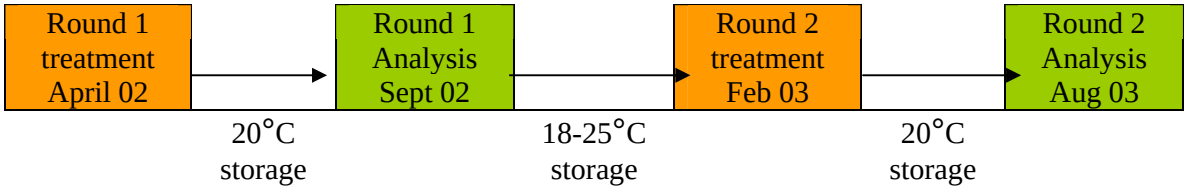
Barley varieties	Conditioned barley moisture	Chemical treatments	Gibberellic acid (GA3) application	Treatment storage regime
Arapiles Galaxy Franklin Gairdner	a)10 % b)12 %	a) NIL (control) b) Dichlorvos c) Phosphine d)Bioresmethrin/ piperonyl butoxide e)Fenitrothion/ methoprene	a) NIL b) 0.2 ppm	a) One pesticide treatment and storage at 20°C b) 2 pesticide treatments and warm storage (18-25°C)

Barley quality
Moisture levels were all close to 10 % while total nitrogen varied between 1.4 and 1.7 % (dry basis). Viability and germination energy levels were high (>98%).

Timing of treatments and storage conditions

Barley samples from the 2001 crop as per Table 1 were well mixed and conditioned to moisture levels of 10 and 12 %. Samples were chemically treated in April 2002 at the Stored Grain Research Laboratory in Canberra (SGRL). The treated barley samples were stored at room temperature (approx 20°C) for 5 months after which a portion of each sample was micromalted and analysed for malt quality in September 2002. Control samples with no chemical treatment were also stored under the same conditions.
The remaining portion of the treated and control samples were stored using a temperature gradient from 18 to 25°C over a further 5 months prior to a second round of chemical treatments and subsequent storage for 6 months at room temperature (20°C). These samples were then micromalted and analysed for malt quality. The gradual increase from 18 to 25°C was applied to mimic the commercial storage conditions that some of the south-eastern barley crop may encounter.

Figure 1. Timeline of treatments



Results and Discussion

When the data was analysed for each variety some trends of increased KI became apparent for fenitrothion/methoprene and dichlorvos treated samples. These trends are also apparent when the data from the four varieties are averaged (Table 2).

Table 2 Mean Kolbach Index (KI) values for different experiments and chemical treatments.

	First round treatments		Second round treatments	
Treatment	10%M barley	12 % M barley	10 % M barley	12 %M barley
Control	39.9	40.3	44.0	41.5
Phosphine	39.5	38.3	44.0	41.8
Fenitrothion/ methoprene	42.0	42.0	47.3	44.5
Dichlorvos	42.3	38.8	44.5	44.0
Bioresmethrin /piperonyl butoxide	42.5	38.5	43.0	42.3

Note: Standard deviation for KI of the control barley is 1.1

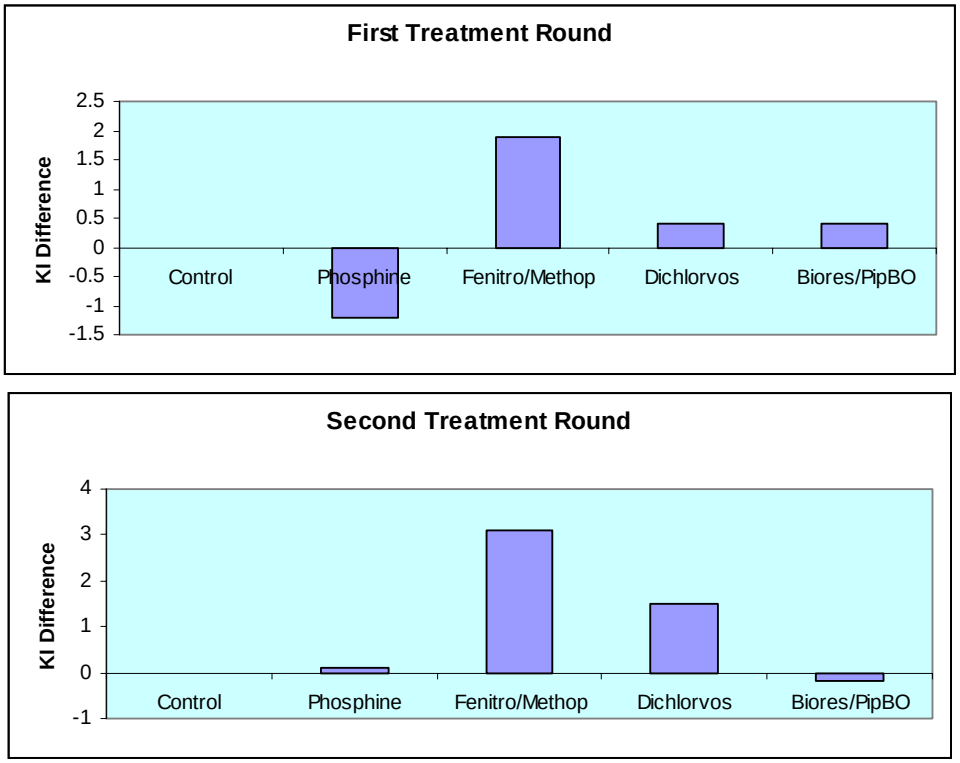
After Round one treatment Fenitrothion/methoprene was the only treatment that showed a similar and significant increase in KI at both moisture levels. Phosphine had almost no effect on KI at 10% moisture and a negative effect at 12%. The other treatments showed opposing effects at the two moisture levels with KI increased at 10% and decreased at 12%.

In the second round of treatments all KI levels had increased. This effect is often observed and would be expected. In this treatment round Fenitrothion/methoprene was the only application showing a significant positive

effect on KI at both moisture levels. Dichlorvos also showed a positive response but this was only significant at 12% moisture.

The data in Table 2 were averaged over the two moisture levels and plotted to reflect increase or decrease on KI in Figure 2.

Figure 2 Effect of Treatment Round on KI



Fenitrothion/methoprene and Dichlorvos would appear to be the two treatments that show indications of increasing KI with both applications and an increased effect with multiple treatments.

The experiments carried out (Table 1) comprised a large number of variables many of which are interactive. In addition Kolbach Index is only one means of gauging an increase in grain modification. KI expresses the ratio of solubilised protein to total protein occurring during malting. Grain modification is a complex process including a number of protein and carbohydrate degradations as well as enzyme synthesis and activation.
A scoring system was developed to include a broader range of endosperm modification related parameters and applied to the data collected from all the experimental subsets.

About the modification scoring system used:

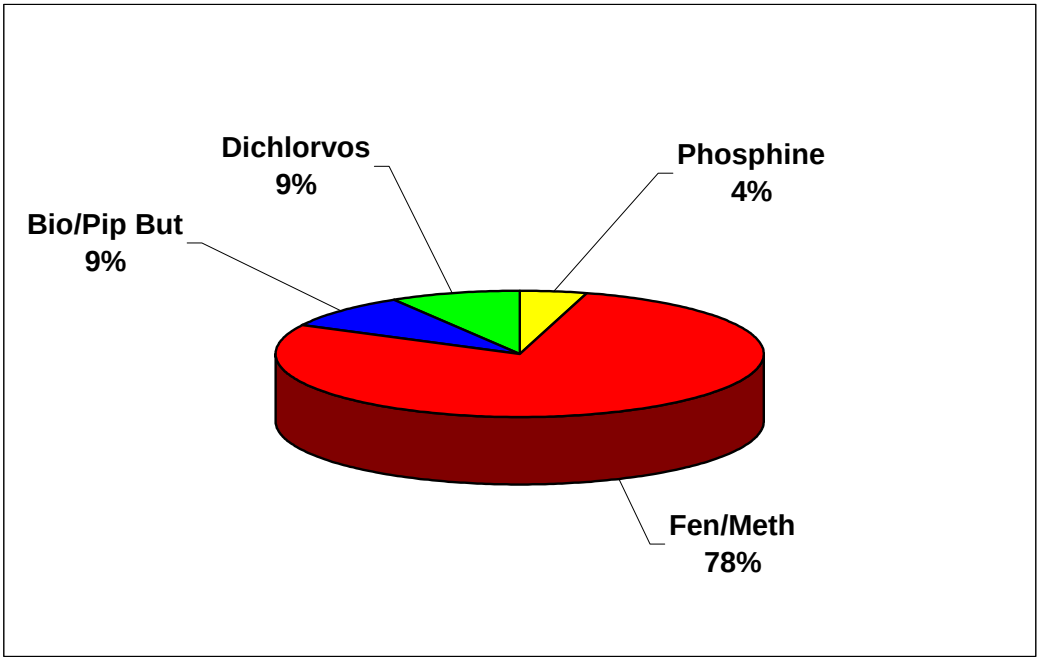
For the 24 experimental subsets (where either the time of application, barley moisture, barley variety or gibberellic acid level was varied) a score of 1 was given to each chemical treatment for each quality parameter showing the highest (or equal highest) modification in the experiment. Scores were assigned for the highest extract, colour, soluble nitrogen, Kolbach Index, fermentability and diastatic power and for the lowest viscosity and wort ß-glucan. See Table 3

Table 3. Example of scoring system

Treatment	Variety	Barley Moist	Ext	Col	SN	KI	Visc	AAL	WBG	DP	Modification score
BRM/PIP	Arapiles	12%	80.6	2.9	**0.74**	43	**1.51**	82.8	205	**91**	3
CONTROL	Arapiles	12%	80.2	3.0	0.71	41	1.57	81.9	262	**91**	1
DICHLORVOS	Arapiles	12%	80.6	2.9	0.72	41	1.57	82.0	274	84	0
FEN/METH	Arapiles	12%	**81.2**	**3.3**	**0.74**	**44**	1.55	**82.9**	**184**	85	6
PHOSPHINE	Arapiles	12%	80.6	2.9	0.70	41	1.60	81.9	292	88	0

In 78% of cases the Fenitrothion/methoprene treatment produced the highest modification score. This data is summarized in Figure 3.

Figure 3. Percent of experiments in which the treatment produced the highest modification score



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Conclusions

The data in Table 2 and Figure 2 shows that the fenitrothion/methoprene treatment generally produced KI values of about 2-3 units higher than the control malts. This is especially apparent following a second round of treatments. Therefore it would appear that fenitrothion/methoprene applied at maximum levels and particularly multiple times may cause an increase in endosperm protein modification. Some increases in KI for dichlorvos and bioresmethrin/piperonyl butoxide were also observed at the 10 % barley moisture level in the first round experiments however some skepticism must be applied to these results as further experiments showed opposing effects.

In this work Phosphine, applied at double the recommended dosage, showed almost no effect on KI and the least effect on modification score over all experimental subsets.

A summary of conclusions from this work is given below:

1. The increase in KI due to additional and warm storage alone (control barley) was between 1.5 and 3 units in these trials. Some chemical treatments increased KI by a further 2 units.
2. The use of chemical treatments to control insect infestation in malting barley coupled with prolonged storage appeared to cause some increase in endosperm modification but in some cases the effects are not significant and were inconsistent in the case of dichlorvos and bioresmethrin/piperonyl butoxide.
3. Only the fenitrothion/methoprene treatment consistently produced higher Kolbach Index over a range of treatments, barley moisture levels and GA3 applications. This was especially evident with barley stored for long periods and treated twice. The endosperm modification scores support this conclusion. The increases in KI observed in these experiments were up to 5 units.
4. The results for phosphine suggest that this treatment has no effect on malt quality at normal or even at increased levels of dosage.
5. The results for dichlorvos and bioresmethrin/piperonyl butoxide showed no clear trends. It is unlikely that significant effects on malt modification would occur at normal application levels.

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