MODIFIED ATMOSPHERES AT RAISED TEMPERATURES FOR TREATMENT OF DURABLE COMMODITIES

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For many commodities a rapid treatment time is needed to fulfil phytosanitary regulations at the time of export or deal with infestation problems diagnosed during trading. For many years methyl bromide has been relied upon for this purpose and fumigations have been carried out in containers or sheeted stacks all over the world. Now alternatives are required before its impending phase-out in 2005. Modified atmospheres (MAs) have the potential to all kill pests but require supplementary measures to increase their speed of action. Raised pressure or temperature can each shorten treatment times to those used in methyl bromide container fumigations. The aim of the present study, under the UK FoodLINK scheme, was to evaluate the efficacy of MAs at raised temperatures in controlling pests, while preserving other commodity qualities such as shelf life.

Tests at raised temperatures on a range of commodities have shown no unacceptable quality or shelf life effects from exposures up to 6 days at temperatures up to 45 to 55°C. One of the more susceptible commodities to heating was dried apricots, but even for these a temperature limit of 45°C was identified over a 4-day exposure in low oxygen atmosphere. Rice was unaffected by exposure at 55°C for 6 days. For any quick turn-round treatment based on heat, the ability to raise temperatures to the required level rapidly is essential. For bulk or bagged commodities this depends on the rate of heat transfer that can be achieved which in turn depends of the power source and the temperature differentials that can be tolerated between the heating agent and the commodity to be heated. The strategy for the current programme was to use forced hot air, converting a freight container to house a heated-air rapid circulation system, recirculating the container atmosphere over heating elements and up through the commodity via a ventilated floor. The tests on commodity quality determined the upper temperature limit for the heated air and the experiments described here were conducted to find the temperature levels required to achieve control of those pests most commonly occurring on each of several commodity groupings, including bagged rice, dried spices and herbs, dried fruit and nuts, and cocoa and coffee beans.

Experimental

Tests were conducted on ten pest species grouped with various commodities as follows:

Rice	-	*Sitophilus oryzae, Rhyzopertha dominica, Tribolium castaneum.*
Herbs and spices	-	*Stegobium paniceum, T. castaneum, Lasioderma serricorne, Ephestia elutella*
Dried fruit and nuts	-	*Ephestia cautella, Plodia interpunctella, Carpophilus dimidiatus, Carpoglyphus lactis, Oryzaephilus mercator, T. castaneum*
Cocoa and coffee beans	-	*E. cautella, E. elutella, T. castaneum, O. mercator*

Tests were conducted in a constant temperature room in 6-litre desiccators. Insects were exposed to heat alone or heat and MA combinations in three replicates of 30 of each life stage or age group in 60x60 mm glass jars containing their standard culture medium. A further set of replicates were held as controls at the rearing temperature without exposure to MA. The MAs were generated by mixing nitrogen, carbon dioxide (CO_2) and compressed air in a gas blender (Signal Instrument Co. Ltd., Camberley, Surrey, UK). The atmosphere chosen for most tests was based on that produced by combustion of propane, 0.5% oxygen, 13% CO_2 with the balance as nitrogen. The dry gases were humidified to 70% by bubbling through an 80 ml column of glycerol/distilled water solution in a 100 ml measuring cylinder. The gas stream was fed into the base of the desiccator via a tube from the lid port and exited via a second tube. The relative humidity (r.h.) was measured at the outlet tube by use of a Protimeter DP9879M (Protimeter plc., Marlow, Bucks, UK). After the allotted exposure, insects were returned to the rearing conditions for incubation and a weekly assessment of survival based on egg hatch or adult emergence.

Results and Discussion

The tests showed that an adequate window existed for conducting heat treatments for insect control without damaging the product, most pests being controlled within 24 h or less at temperatures 10^{o}C below the maximum tolerated by the commodities with which they were chiefly associated. Results obtained are summarised for the four commodity groupings in Tables 1-4. The data show the great benefit of the MA treatment based on burner gas with heating over heat alone. The most tolerant species was, as expected, the lesser grain borer, for which a temperature of 44^{o}C was required for control within 24 h in the MA. In second place was the rice weevil with a requirement for 42^{o}C. These two pests were fortuitously associated with rice, one of the most heat tolerant products. At the other end of the scale the common cocoa and coffee pests were all controlled by a 16h exposure at 35^{o}C (Table 3). For herbs and spices a target temperature of 40^{o}C should prove adequate to achieve control within 24 h while for dried fruit and nuts, 38^{o}C held for 24 h should prove adequate for complete disinfestation.

For a successful replacement of methyl bromide, however, the time needed for temperatures to reach the target level at all points in the treated commodity is critical and may well be longer than the treatment time itself. Thus target temperatures may need to be increased slightly to allow more time for heating the commodity. Pilot tests in a converted freight container have indicated that it should be possible to get heating times to well blow 24 h using high air flow recirculation of humidified atmosphere.

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Table 1. The exposure time (hours) required for complete mortality of all stages of three rice pests at 40, 42 or 44°C and 70% r.h. with or without a modified atmosphere (MA) of 0.5% oxygen, 13% carbon dioxide and 86.5% nitrogen

Temp. (°C) - or + MA	***Tribolium castaneum*** Rust-red flour beetle	***Sitophilus oryzae*** Rice weevil	***Rhyzopertha dominica*** Lesser grain borer
40	>48	>48	>48
40 + MA	<16	48	>48
42	-	48	>48
42 + MA	-	16	48
44	-	-	>48
44 + MA	-	-	24

Table 2. The exposure time (hours) required for complete mortality of all stages of four pests of herbs and spices at 35 to 40°C, 70% r.h., with a modified atmosphere (MA) of 0.5% oxygen, 13% carbon dioxide and 86.5% nitrogen

Temp. (°C) – or + MA	***Stegobium paniceum*** Biscuit beetle	***Lasioderma serricorne*** Cigarette beetle	***Oryzaephilus mercator*** Merchant grain beetle	***Ephestia elutella*** Warehouse moth
35	-	-	>48	>48
35 + MA	-	-	6	10
36	>48	-	>48	>48
36 + MA	16	-	<16	<16
38	>48	>48	>48	>48
38 + MA	<16	48	<16	<16
40	>48	>48	>48	>48
40 + MA	<16	24	<16	<16

Table 3. The exposure time (hours) required for complete mortality of all stages of six pests of dried fruit and nuts at 34 to 38°C, 70% r.h., with a modified atmosphere (MA) of 0.5% oxygen, 13% carbon dioxide and 86.5% nitrogen

Temp. (°C) – or + MA	***Tribolium castaneum*** Rust-red flour beetle	***Carpophilus dimidiatus*** Dried fruit beetle	***Carpoglyphus lactis*** Dried fruit mite	***Ephestia cautella*** Tropical warehouse moth	***Oryzaephilus mercator*** Merchant grain beetle	***Plodia interpunctella*** Indian-meal moth
34	>48	>48	-	>48	>48	>48
34 + MA	24-48	48	-	<16	<16	<16
35	>48	>48	-	>48	>48	>48
35 + MA	16	24	-	10	6	4
36	>48	>48	>48	>48	>48	>48
36 + MA	<16	24	24-48	<16	<16	<16
38	>48	>48	>48	>48	>48	>48
38 + MA	<16	<16	14	<16	<16	<16

Table 4. The exposure time (hours) required for complete mortality of all stages of four pests of cocoa and coffee beans at 34 to 36°C, 70% r.h., with a modified atmosphere (MA) of 0.5% oxygen, 13% carbon dioxide and 86.5% nitrogen

Temp. (°C) – or + MA	***Ephestia cautella*** Tropical warehouse moth	***Ephestia elutella*** Warehouse moth	***Oryzaephilus mercator*** Merchant grain beetle	***Tribolium castaneum*** Rust-red flour beetle
34	>48	-	>48	>48
34 + MA	<16	-	<16	24-48
35	>48	>48	>48	>48
35 + MA	10	10	6	16
36	>48	>48	>48	>48
36 + MA	<16	<16	<16	<16