Cooperation Centre for Scientific Research Relative to Tobacco

CORESTA Guide N° 12

Technical Guide for Controlled Atmosphere Parameters for the Control of Cigarette Beetle and Tobacco Moth

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Pest and Sanitation Management in Stored Tobacco Sub-Group

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Technical Guide for Controlled Atmosphere Parameters for the Control of Cigarette Beetle and Tobacco Moth

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Table of Contents

1. Introduction 4

2. Background 4

3. CA Parameters for Cigarette Beetles and Tobacco Moths 5

4. Potential Changes and Impact 6

5. Implementation 7

6. References 7

1. Introduction

Two insects, the cigarette beetle, *Lasioderma serricorne*, and the tobacco moth, *Ephestia elutella*, are major pests of cured tobacco, infesting the commodity during storage, manufacture and distribution. Insect control in stored tobacco has relied on the use of phosphine fumigation and contact pesticides applied as space or surface sprays within structures (not directly on the tobacco). Increasing concerns over the use of toxic compounds, linked to health and environmental fears, as well as the ineffectiveness of fumigations below 16 °C (61 °F) and the development of phosphine resistant populations (Zettler and Keever, 1994; Savvidou et al., 2003), have fuelled the need to find alternative control methods. Two such alternatives are deep freezing (the subject of CORESTA Guide N° 9) and controlled atmosphere treatments (the subject of this guide).

In controlled atmosphere (CA) treatments, an environment which is lethal to pest insects is created by altering the proportions of CO_2, O_2 and N_2 in the treated airspace. This is commonly achieved by the replacement of the existing air with N_2 so that the O_2 levels are reduced, preferably to below 1 %. There are various methods for altering the proportion of gases, but the studies used to generate the data for this guide employed the removal and replacement of O_2 with N_2 using oxygen absorbers/scrubbers or the generation of N_2-rich air.

The efficacy of CA treatments is affected by physical factors such as temperature, relative humidity, gas concentration, pressure and gas tightness of the container; and on biological factors, such as, insect species, strain and developmental stage (Adler et al., 2000). The toxic effects of CA treatments on insects are attributed to desiccation (Donahaye, 1991). Low O_2 (hypoxia or anoxia) levels force the spiracles of insects to open and remain open, which results in dehydration and in turn impacts on various other metabolic processes (Adler, 2000; Donahaye, 1991; Selwitz and Maekawa, 1998). *Lasioderma serricorne* is one of the most anoxia tolerant insect species, with the eggs and last instar larvae likely to be the most tolerant stages (Faustini and Modugno, 1988; Reirson et al., 1996; Rust and Kennedy, 1993).

2. Background

The potential loss of phosphine as a control tool as a consequence of regulation and/or resistance development necessitates finding alternative control methods. In 2008 the CORESTA Sub-Group on Pest and Sanitation Management in Stored Tobacco (hereafter referred to as the Sub-Group) commissioned Fera Science Ltd. (formerly the Food and Environment Research Agency and the Central Science Laboratory, UK) to conduct a literature review to assess the potential of using CAs for the control of *L. serricorne* and *E. elutella* in stored tobacco. The review concluded that the use of CA treatments may provide a viable option for use in the tobacco industry (Collins, 2008).

The use of CAs for the disinfestation of stored products is well documented for certain situations and they have been evaluated to disinfest bulk tobacco and finished products (Annis, 1987; Bell and Armitage, 1992; Benezet et al., 1990; Keever, 1989; Ryan and Lehman, 1988). However, previous studies on tobacco have generally been on a small laboratory scale or used high CO_2 atmospheres. The laboratory experiments were conducted under controlled conditions and can therefore only approximate the conditions experienced in a practical situation; and the use of large scale CO_2 treatments has environmental and safety concerns relating to the release of a greenhouse-effect gas. There is also no method for on-site generation of CO_2, whereas there are on-site methods for N_2 generation, making these atmospheres more competitive in price and easier to apply. Information was therefore required on the use of low O_2 concentrations under large scale practical conditions.

A CA work-group was formed to investigate the effects of low O_2 atmospheres against *L. serricorne* in stored tobacco, on behalf of the Sub-Group. Fifteen large scale trials and a series of laboratory experiments were undertaken by the work-group using low O_2 concentrations (<0.5 %) and various temperatures, commodities (leaf and finished product, i.e. cigars), exposure periods, strains (phosphine resistant and susceptible) and life-stages in order to determine the most effective treatment conditions. A wealth of information was generated which was subsequently collated and summarised by Fera (Collins, 2011). The information generated was used to determine the minimum conditions required to achieve >99 % mortality of *L. serricorne* in tobacco.

Laboratory studies were later conducted by Fera on behalf of the Sub-Group to investigate if the same parameters needed to control all life stages of the cigarette beetle were also effective in controlling the tobacco moth even though it is the cigarette beetle that is considered to be one of the most anoxia tolerant insect species (Collins, 2012). These studies confirmed that the same parameters can be used for both insects. It should be considered that although the insect strains used in the studies were originally collected from the field, they had been in laboratory culture for several years and may therefore differ in their responses compared to naturally 'wild' strains. Also, although relative humidity was monitored in the large scale trials it was not controlled. In practice it is difficult and time consuming to reduce the relative humidity of a tobacco bale due to its density. Therefore, although relative humidity is an influencing factor, it was considered impractical for it to be adequately controlled during a CA treatment.

Commodity temperatures around 33 ºC (91.4 ºF) of stored tobacco are common in many tropical and sub-tropical regions. Therefore in 2019 field trials were conducted by Japan Tobacco International and Fera to assess the efficacy of controlled atmospheres against cigarette beetle and tobacco moth at this temperature parameter (Collins, 2019).

Chemical and organoleptic analyses have shown no difference between treated tobacco samples and untreated control samples.

3. CA Parameters for Cigarette Beetles and Tobacco Moths

The following parameters must be considered for the effective use of CA treatments:

- Oxygen concentration – the lower the oxygen concentration that can be achieved and maintained, the greater the efficacy of the treatment.
- Temperature – increasing the temperature enhances the efficacy of CA treatments by increasing insect respiration and water loss.
- Relative humidity – decreasing the relative humidity enhances the anoxic effect by increasing water transport and loss through the insects' open spiracles, but relative humidity is difficult to control in practice. Even though humidity is not controlled as a parameter, CA chamber operations of lowering oxygen also reduce humidity to acceptable levels.
- Seal quality – ensuring a good seal quality in the treatment chamber will ensure that low gas concentrations are maintained.
- Total treatment time – this is dependent on the time taken to reach the lethal conditions. For example, the initial temperature of the tobacco, the amount of tobacco to be treated and the position of the tobacco within the chamber will all affect the time required to reach the lethal conditions. Only when the required temperature and O_2 concentrations have been achieved can the exposure periods commence.

It is vital that the temperatures and O_2 concentrations in the commodity are recorded continuously and accurately using calibrated monitors, so that it is known when and for how long the tobacco has been at the lethal conditions.

The Sub-Group recommends the following CA parameters for use in controlling cigarette beetle and tobacco moth infestations:

Table 1. Minimum conditions required to achieve >99 % control of all stages of cigarette beetle and tobacco moth AFTER commodity has reached 0.5 % O_2 and the required temperature in the centre of bales at the bottom of a stack.

Temperature (°C)	Temperature (°F)	Time (days)
28	82.4	9
33	91.4	5
38	100.4	4

4. Potential Changes and Impact

It is essential that temperature and O_2 concentrations are monitored in the centre of bales at the bottom of a stack, as these are likely to take the longest time to reach the target levels, rather than using airspace readings. Each treatment should be considered separately as variations will occur between treatments. For example, variations in the initial temperature of the tobacco, amount of tobacco to be treated, the CA system used, etc. which will all affect the time taken to reach the target levels. Good circulation of temperature and O_2 within the treatment chamber will help ensure that the entire commodity has reached the target levels and will reduce the time required to achieve these levels.

Important aspects to consider:

- Treatment chambers have to be made gastight, to ensure that homogenous levels of the desired gas concentrations are achieved. As reference, the international norm applied for controlled atmosphere storage (ISO 6949) can be used. This norm allows a leakage of 0.2 $cm^2/100\ m^3$ over 10 or 30 minutes depending on the under/over pressure testing method used to verify whether this level of gas tightness is indeed achieved.
- Treatment chambers are to be insulated well (flooring, walls, ceiling, doors & possible windows), to avoid condensation.
- Flooring has to be able to resist the maximum loading capacity without cracking, as cracks may cause leakage and humidity problems.
- Internal logistics may need to be adjusted according to the duration, location, timing and capacity of the CA treatment facility.

CAs, when used as part of an integrated pest management strategy, provide a viable alternative to the use of phosphine fumigations and/or freezing. They can be used in situations where resistance to phosphine is an issue and where the use of phosphine is unacceptable.

In many countries, phosphine fumigations are the only acceptable criteria for the issuing of phytosanitary certificates. The Sub-Group recommends that proper CA treatments should be added as a viable option.

5. Implementation

The essential components of the CA system are:

- Gastight chamber.
- Central oxygen absorber / scrubber or nitrogen generator.
- Central measuring, registration & control system (oxygen, temperature and humidity).
- Calibrated sensors to monitor oxygen and temperature inside the commodity.
- Heating and O_2 circulation inside the chamber.

The system should monitor, control and register the conditions inside the room continuously during the treatment. In order to implement an effective CA treatment, it is of utmost importance that the conditions (O_2 concentration and temperature) throughout the treatment chambers are achieved and maintained at the target levels for the prescribed duration. To achieve homogenous conditions inside the chamber, the gas tightness of the chamber and air circulation inside the chamber are important. As a result of ineffective air circulation and/or insufficient heating capacity, some of the commodity inside the treatment chamber may not reach the required product temperature. It is therefore important that temperatures and O_2 concentrations are monitored in the centre of the commodity using calibrated monitoring devices placed in positions likely to take the longest time to reach the target levels (for example in the centre of a low level bale).

CA treatments may provide a viable alternative option for the tobacco industry. The treatments are environmentally safe, leave no chemical residue, do not negatively affect commodity quality, have a low risk of resistance development, and treatment times are comparable to phosphine fumigations and freezing treatments. The registration of CAs also varies with country, therefore it is important to check with the relevant regulatory authority as to whether CAs are registered for specific uses. The Sub-Group is conducting worldwide joint training sessions to share its knowledge and experience of this alternative control method with the Industry.

6. References

[1] Adler C., Corinth H-G., Reichmuth C. (2000). Modified atmospheres. In: Subramanyam B., Hagstrum D.W. (Eds), Alternatives to pesticides in stored-product IPM. Kluwer Academic Publishers, London, pp. 73-104.

[2] Annis P.C. (1987). Towards rational controlled atmosphere dosage schedules: A review of current knowledge. In: Donahaye E. and Navarro S. (Eds). Proceedings of the 4th International Working Conference Stored-Product Protection, Tel Aviv, Israel, Sept. 1986, pp. 128-148.

[3] Bell C.H. and Armitage D.M. (1992). Alternative storage practices. In: Sauer D.B. (Ed.) Storage of cereal grains and their products. American association of cereal chemists Inc., St Paul, Minnesota, USA.

[4] Benezet H.J., McConnell B.C., Helms C.W. and Landeth K.S. (1990). Cigarette beetle control by chamber carbon dioxide fumigation with a computer controlled delivery system. Research report for RJ Reynolds, USA no. 109, 38 pp.

[5] Collins D.A. (2008). Literature review on the potential of controlled/modified atmospheres for the control of *Lasioderma serricorne* and *Ephestia elutella* in stored tobacco A report prepared for the CORESTA Sub-Group on Pest and Sanitation Management in Stored Tobacco. 30 pp.

[6] Collins D.A. (2011). Review of controlled atmosphere (CA) trials undertaken by the CA working group. A report prepared for the CORESTA Sub-Group on Pest and Sanitation Management in Stored Tobacco. 26 pp.

[7] Collins D.A. (2012). The effect of controlled atmospheres on the eggs and diapausing larvae of *Ephestia elutella.* A report prepared for the CORESTA Sub-Group on Pest and Sanitation Management in Stored Tobacco. 20 pp.

[8] Collins, D. A. 2019. Field trial to assess the efficacy of controlled atmospheres (CA) against *Lasioderma serricorne* and *Ephestia elutella* at 33 ºC. 12 pp.

[9] Donahaye E.J. (1991). The potential for stored-product insects to develop resistance to modified atmospheres. In: Fleurat-Lessard F. and Ducom P. (Eds). Proceedings of the 5th International Working Conference Stored-Product Protection, Bordeaux, France, September, pp. 989-997.

[10] Faustini D.L. and Modugno C.A. (1988), Control of *Lasioderma serricorne* with modified atmospheres for export tobacco. Research report for Philip Morris USA. 11 pp.

[11] ISO 6949:1988 *Fruits and vegetables — Principles and techniques of the controlled atmosphere method of storage*

[12] Keever D.W. (1989). Use of carbon dioxide to disinfest a tobacco warehouse of cigarette beetle. Journal of Agricultural Entomology, 6: pp. 43-51.

[13] Reirson D.A., Rust M.K., Kennedy J.M., Daniel V., Maekawa S. (1996). Enhancing the effectiveness of modified atmospheres to control insect pests in museums and similar sensitive areas. In: Wildey K.B. (Ed.). Proceedings of the 2nd Conference on Insect Pests in the Urban Environment, 7–10 July 1996, Edinburgh, UK, pp. 319–327.

[14] Rust M.K. and Kennedy J.M. (1993). The feasibility of using modified atmospheres to control insect pests in museums. GCI Scientific program report March 1993. pp. 55-64.

[15] Ryan L. and Lehman R. (1988). The application of carbon dioxide to control cigarette beetles in bulk storage warehouses – second trials. Research report for Philip Morris USA. 13 pp.

[16] Savvidou N., Mills K.A., Pennington A. (2003). Phosphine resistance in *Lasioderma serricorne* (F.) (*Coleoptera: Anobiidae*). In: Credland P.F., Armitage D.M., Bell C.H., Cogan P.M., Highley E. (Eds), Proceedings of the Eighth International Working Conference on Stored-product Protection, 22-26 July 2002, York, UK, CAB International, Wallingford, UK, pp. 702-712.

[17] Selwitz C. and Maekawa S. (1998). Inert gases in the control of museum insect pests. Research in conservation. The Getty Conservation Institute, USA. 107 pp.

[18] Zettler J.L., Keever D.W. (1994). Phosphine resistance in cigarette beetle (*Coleoptera: Anobiidae*) associated with tobacco storage in the southeastern United States. Journal of Economic Entomology 87, pp. 546-550.