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THE MEASUREMENT AND CONTROL OF LOW OXYGEN AND HIGH CO_2 ATMOSPHERES

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ABSTRACT

Low oxygen and high CO_2 storage is standard practice in the fruit storage industry which has developed over many years to provide reliable and competitive systems with simple to operate computer based interfaces.
Recent developments in dynamic CA for fruit storage has resulted in the need to measure oxygen to even lower levels of sensitivity which could be appropriate for the MA atmospheres used for crop de-infestation.
Many lessons have been learnt about the use and operation of high accuracy gas analysers in an agricultural environment. This experience is discussed in its application to the de-infestation of stored products.
The construction, sealing and testing of low oxygen fruit stores have many similarities with the requirements for fumigation: the current construction and testing procedures will be discussed.
Key Words: Oxygen, Carbon Dioxide, Gas Analyser, Controlled Atmosphere, Oxygen sensors

BACKGROUND

The establishment of low oxygen and enhanced Carbon Dioxide (CO_2) atmospheres is used extensively for the commercial long term storage of fresh fruit and vegetables.

The significant difference between fresh produce storage and the use of low oxygen for product de-infestation is that fruit and vegetables respire, helping to create their own low oxygen atmosphere, requiring that product generated carbon dioxide is removed without increasing the oxygen concentration. For pest eradication the product is essentially inert with the atmosphere modification relying totally on external equipment with no requirement for carbon dioxide removal.

To illustrate the similarities and differences between the two applications, Table 1 shows some typical controlled atmosphere conditions for various products. These conditions are regularly established in many thousands of CA storage rooms throughout the world.

Recent advances in the use of dynamic controlled atmosphere substitute the need for "recipe" levels of oxygen with "variable" oxygen concentrations. The fruit in the storage room is monitored using various methods to detect anaerobic stress and the oxygen is maintained at a threshold just above the measured stress point. This can require the maintenance of oxygen down to a level as low as 0.2%.

Table 1. Typical CA conditions for various fresh produce

Product	Oxygen %	Carbon Dioxide %	Temperature ^{o}C
Apples (Gala)	1	< 1	0.5
Apples (Bramley)	1	5	4.5
Pears (Conference)	2	<1	-0.5
Onions	3	5	0
Strawberries	-	15	0
Bananas	3	3	14

With CA fumigation techniques requiring oxygen at 0.5% and lower it can be seen that the established measuring and control techniques widely used in the produce CA industry can be readily used for de-infestation.

OXYGEN SENSORS

With the low oxygen levels required in these applications it is important to use accurate and stable analysers to make the measurements. There are 3 different sensor principles that have been used in this industry; their characteristics are summarised in table 2.

Table 2. Comparison of oxygen sensors

Principle	Minimum reading O_2	Typical sensor cost €	Typical sensor life Years	Comments
Paramagnetic	0.2%	1500	20+	Sensitive to flow and vibration
Zirconia	10 ppm	600	6	Sensor heated to 300+ C, Logarithmic output
Electrochemical cell	0.02%	60	2	Life reduced when CO_2 high

ICA design and manufacture a range of oxygen analysers used both in ICA equipment and incorporated as OEM analysers by many CA equipment manufacturers. In recent years we have exclusively used electrochemical sensors due to the high quality of their performance and their cost effectiveness. The bi-annual replacement of the cells is a disadvantage but is a quick and simple procedure.

CARBON DIOXIDE SENSORS

Sensors using the principle of Infra-Red adsorption are the only practical choice for carbon dioxide measurement. Infra-red radiation in the specific band that is adsorbed by CO_2 is generated and passed through a chamber containing the flowing gas sample to be measured

The amount of radiation adsorbed by the CO_2 is measured and converted to a measurement of CO_2 concentration. High quality and accurate sensors are readily available with ranges from of 0-1000ppm to 0-20%. Surprisingly the availability of sensors with the range 0-100% CO_2 is more difficult with limited choices and at a higher cost.

GAS SAMPLING

It is important that care is taken over sampling the storage room atmosphere and that the analyser is presented with a representative sample of the room content. The prevention of leaks and blockages are essential for long term successful operation. Samples can be satisfactorily obtained through tubes of over 100m in length if the correct precautions are taken.

The tube should be robust and if fitted outside not subject to UV degradation. Black UV stabilised nylon tubing is the most satisfactory. The tube should be run in a single length from the inside of the room to the analyser manifold as tube fittings can easily be a point of leakage.

If the contents of storage room are stored at a higher dew point than the minimum ambient temperature then condensation will occur in the sampling line. To prevent this condensation causing blockage the internal tube diameter should be at least 6mm and the tube installed with a constant slope and without dips that can cause a water trap. If ambient temperatures are expected to be below zero then blockage by freezing can occur.

In de-infestation applications a leakage in the sampling line is fail safe in that the oxygen will be reading higher on the analyser that it is in the room. In fresh produce storage this error can cause severe damage to the stored crop if the oxygen falls below the anaerobic level.

AUTOMATION

Gas measurement, room sampling and machinery control can all be automated with computer based control systems. Features of these systems should include data recording, alarms, automatic analyser checking and calibration. It is common for the room environment to be maintained at the required Oxygen and CO_2 level with the automatic operation of the atmosphere generating machinery. Temperature measurement and recording can also be incorporated to maintain the complete record for audit purposes. The ICA6000 system is designed for this purpose and is independent of any machinery manufacturer. It has excellent communication facilities, includes build in analysers and sampling systems and is very simple to install and operate.

ROOM SEALING AND TESTING

The construction of storage rooms for controlled atmosphere produce storage is a specialist area that needs close attention to detail. Because these rooms require to be refrigerated they are commonly made from sectional insulating panels. All the panel joints are taped and sealed with a flexible elastomeric coating. The doors have to be specially designed and made for Low Oxygen use and include all round gaskets or pneumatic seals.

An essential part of the specification for a new room is a pass on a standard leak test. It is good and normal practice that this test is repeated every year before the storage season.

The standard UK test is to pressurise the room using a small blower to a pressure of 200 Pa (20mm water). The blower is then sealed off and the time taken for the pressure to fall to 130 Pa is recorded. An acceptable time for low oxygen rooms is 10 minutes but in practice a good room would hold up for 30 minutes or more. In N America the standard is slightly different in that the time is measured for the pressure to fall to half the original value which should be longer than 30 minutes for a low oxygen room.

CONCLUSIONS

The need for lower oxygen levels, easier operation and more cost effectiveness is common in both the Produce Storage and Crop Protection applications of Controlled Atmosphere. A sharing of expertise and common equipment supply should be able to help achieve these objectives.