USE OF CA FOR QUARANTINE CONTROL OF INSECTS ON FRESH FRUITS AND VEGETABLES

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The purpose of this presentation is to try to stimulate interest in conducting research on the use of controlled atmospheres (CA) for quarantine control of insects on fresh fruits and vegetables. A brief discussion on the events leading to an interest in CA for use for quarantine treatments will follow, including a review of some research indicating the potential of CA for this use. Some drawbacks and roadblocks for using this method will also be discussed. Currently no CA treatment is approved for use as a quarantine treatment, but there is a definite need for this type of treatment.

The Animal and Plant Health Inspection Service (APHIS) is the regulatory agency of the U.S. Department of Agriculture concerned with protecting United States agriculture against exotic pests and disease. The Plant Protection and Quarantine (PPQ) division of the agency has the mission of protecting U.S. agriculture from the ravages of plant pests and pathogens. PPQ is concerned with preventing the introduction of plant pests into the U.S. as well as preventing interstate and intrastate dissemination of these organisms.

Many of the dangerous plant pests located throughout the world are hitchhikers and can be artifically spread long distances from their habitats. Plant pests are often disseminated throughout the world because of inadequate controls applied in the country of origin. Since controls are lacking in many countries or the controls are not adequate for quarantine purposes, destination countries must depend on laws and regulations to protect against outside pests and to retard pest spread within their borders.

In countries where there is a recognized risk of introducing a pest or pathogen it is essential to have control over the introduction of the plant material and plant products involved. The form of control will vary according to the circumstances and will take cognizance of the quarantine risk involved. Certain plant products which are prohibited importation except by permit, may be admitted provided the commodity, when released on the market, does not constitute a quarantine risk In some cases a commodity treatment may be prescribed to eliminate any possible infestation with insects.

In the early days of plant quarantine, few treatments were available to control undesirable pests and thus permit importation of infested agricultural commodities. At present, many of these are permitted entry subject to some type of treatment. These treatments include the use of chemicals, cold treatment or heat treatment. Irradiation also may be available for use in the future. Such treatments can be carried out in the country of origin under PPQ supervision, intransit, as in the case of cold treatment of certain fruits on-board vessels, or upon arrival in this country.

PPQ policy is that treatments will be required only in situations of actual infestation, in any situation of imminent dissemination of an agricultural pest or pathogen or when prescribed as a condition of entry in the U.S. Code of Federal Regulations. The treatment program not only eliminates pest and pathogen hazards that may accompany international trade but also allows and encourages international trade in commodities that would otherwise be prohibited entry or be unsuitable for export. Our Agency's role is to to assist importers and exporters in meeting quarantine requirements of our country and of countries of import or export. Since there is a strong market for fresh fruit in this country, thousands of cases of fresh fruit are imported especially in the winter months. This assures an abundance of high quality fruit in the market place during all months of the year.

For over 30 years EDB has been use to fumigate a variety of fruits and vegetables. It was found to be especially effective against fruit flies. Since fruit flies have been among the most important and troublesome quarantine pests, EDB fumigations found extensive practical use. The short treatment time, low dosage, and wide commodity tolerance were important advantages of this fumigant. One drawback in the use of this chemical was the dosages effective against fruit flies were not effective against most other insects.

In 1984 EDB was banned for most agricultural uses including fumigation of fruits and vegetables for quarantine control. Under this ruling, certain fruits could still be fumigated for export, primarily Florida grapefruit and Hawaiian papaya, under very strict requirements if the host country was agreeable to the treatment.

Few substitutes for EDB are available. Methyl bromide, the other available fruit fumigant has shown to cause damage to many fruits and vegetables including citrus, when used at dosages necessary to kill fruit flies. In addition millions of cases of fruit are imported every year which require fumigation with methyl bromide because they harbor insects other than fruit flies. Due to increased concern for possible contamination of food stuffs with pesticide residues and other restrictions being passed involving the use of pesticides, even methyl bromide may not be available in the future for quarantine fumigations of fresh commodities.

Since the early 1900's, sustained cold treatment has been employed as an effective method for the control of the Mediterranean and certain other tropical fruit flies. Exposing infested fruit to temperatures of 36°F or below for definite periods results in the complete mortality of the various life stages. Under prescribed conditions, this treatment can be used on vessels while the cargo is in transit.

Cold treatment or fumigation-cold treatment has also been used for the control of the Apple Maggot, False Codling Moth and for the Light Brown Apple Moth. In the United States last season, over two million cartons of fresh fruit were imported and over one million cartons of exported fruit were cold-treated either on vessels in transit to or in warehouses located in the United States and Canada. This amount does not include the fruit that was cold-treated in other countries before shipment. In addition much of the imported fruit is fumigated for the control of other insects.

Our Agency faces two basic problems in the near future in the area of disinfesting fruit for quarantine purposes. One is the loss of effective chemical fumigants, and the other is the length and severity of present cold treatments. These treatments are at temperatures ranging from 31-36°F and can be as long as 22 days. Some fruit are not tolerant or are marginally tolerant to the treatment at these conditions. What is needed are treatments which leave no toxic residues, will not damage the commodities, and are of relatively short duration. The short treatments would be especially useful in opening up export markets such as from Central and South American countries and Mexico and in the movement of fresh commodities interstate during pest outbreaks where the long cold treatment schedules are not practical due to the shorter distances involved.

Currently CA is used to disinfest grains from stored product insects and to extend the shelf-life of fruits and vegetables. The atmospheres and environment to be used for these purposes are quite different and are limited by the commodity's ability to tolerate each set of conditions.

The feasibility of disinfesting grain from insects using CA has been demonstrated. The application of CA treatment to grain kills stored product pests and offers advantages over widely used pesticide treatments which leave potentially dangerous residues and create pest resistance problems. CA treatment of grain involves the alteration of the proportions of the normal atmospheric gases (nitrogen, carbon dioxide, and oxygen) to give atmospheres lethal to the stored grain pests involved.

High CO_2 atmospheres and low oxygen atmospheres have been shown to be insecticidal. Atmospheres below 2% oxygen are lethal to most stored product pests (2). High levels of CO_2 are also toxic to stored grain pests. The optimum CO_2 levels for high or complete kill of grain insects is about 60% CO_2 in air (9).

The time taken to achieve a certain level of insect kill is dependent on the composition of the atmospheres and on the temperature and humidity of the environment. The period required for high insect motality at high storage temperatures (e.g. 35°C) is only a few days but this is extended to several weeks at less than 15°C. High CO_2 atmospheres in general have been found to be less temperature dependent than low oxygen systems (4).

Controlled atmospheres are also used in combination with low temperature storage to extend the shelf-life of many fruits and vegetables (10). However, the insecticidal environment used to disinfest grain - that is, prolonged periods of storage at high temperatures, low humidity, and high carbon dioxide levels - is often detrimental to commodity quality and therefore inapplicable to fresh fruits and vegetables. Some research has investigated exposure of insects infesting fruit and vegetables to high levels of CO_2 for short periods of time, and has shown limited lethal effect which may have a practical application as a quarantine treatment.

High levels of CO_2 caused 100% mortality of the Western Flower Thrips (*Frankliniella occidentalis*) on strawberries held for 48 hours at 2.5°C (1). This treatment also reduced decay without visible injury to the berries, but flavor was slightly affected. Eggs and young larvae of the Caribbean fruit fly (*Anastrepha suspensa*) were particularly susceptible to 40% and 100% CO_2 after exposure for 48 hours at 10°C and 22-23°C respectively (6). Aphids (Myzus persicae) and cabbage loopers found on lettuce were not significantly affected by CO_2 levels to 70% combined with 5% oxygen levels when held at 2.5°C for 7 days (11). Exposure of San Jose scale (Quadraspidiotus perniciosus) on apples to 90% CO_2 and less than 1% O_2 for 2 days at 12°C or greater or 22°C at 96% CO_2 for one day was completely effective without affecting the quality of some apple varieties (15). Standard cold storage is also effective but the apples must be stored for 2 or more months to obtain complete mortality (13 ,14). Storage of apples for at least 16 weeks at 2°C in a controlled atmosphere of 3% O_2 and 3% CO_2 or standard cold storage has been proposed as a quarantine treatment for San Jose scale on infested apple exports from Italy to Germany (7).

There have been a few reports of the effects of CA on lepidopterous pests. Codling moth larvae (Cydia pomonella) were not completely controlled at 132 days in normal CA storage (8). However, complete kill was obtained at 95% CO_2 at 27°C after 48 hours of exposure. A study by Moffit (12) showed that a minimum of 60 days CA or standard cold treatment after fumigation was required to kill all live larvae. Investigations in New Zealand with apples on three leaf roller insects have shown that the three insect species could be completely eliminated in 90 days under standard CA atmospheres of 3% O_2 and CO_2 and a temperature of about 1°C (5). These results indicate that a quarantine inspection for leafroller species on apples from New Zealand may be unnecessary if the consignment has been cold stored under CA conditions for at least 90 days.

Development of quarantine treatments for agricultural commodities must follow a set of specifications that can be obtained from APHIS. These specifications are intended to encourage other agencies, States, private cooperators, and foreign governments to prepare their protocols and design specific experiments to provide information and data relating to their proposed new regulatory treatment systems. The information provided would be used by APHIS in evaluating and approving useful regulatory treatment systems. Scientists who are responsible for the development of new regulatory treatment systems should plan their programs and conduct their experimental work to conform with these specifications.

One of the difficult problems in developing quarantine system treatments and quarantine systems is using appropiate statistics that will guarantee quarantine security. For some years probit 9 has been the established standard (3). Probit 9 is a statistical statement that infers that no more than 3 quarantine pests from a population of 100,000 will survive a quarantine treatment or system at the 95% confidence level, which is a mortality rate of 99.997%. The use of probit 9 statistics in the research of quarantine treatments or systems dictates that the sum of the treated population must equal 100,000 or more target organisms in three or more tests with no more than three survivors. Probit 9 has been used regardless of the normal infestation rates or the volume of the commodity treated. The probit 9 concept has come under increased scrutiny because it does not take into consideration the actual level of infestation of the host commodity by the quarantine pest at harvest or the potential for culling infested commodities during processing at the packing house, poor versus good hosts, and other factors. Other statistical alternatives to probit 9 are being studied for potential use in quarantine treatment research and development.

If quarantine treatments were developed using CA, where would they take place? The obvious place would be at storage warehouses designed for CA either in this country or at the country of origin. Another possibility, using the shorter treatments, would be to conduct the treatments in transit in holds of refrigerated vessels or in self refrigerated containers specifically modified to utilize CA.

The development and use of containers in recent years has revolutionized the physical distribution of perishable goods. Containerization allows door-to-door delivery with a minimum of handling, pilferage and transit time. The standard refrigerated containers are 20 or 40 feet in length and can be transported by container ships and large cargo planes.

Some container companies offer the option of using CA during transportation of perishables. The CA is achieved by altering or displacing the oxygen in the natural atmosphere inside the trailer body with a concentration of one or several gases. The use of CA, fumigation plus CA or CA plus cold treatment in refrigerated containers offers the most practical application of this technology for quarantine treatments.

In summary, preliminary research has been conducted on the use of CA for eliminating quarantinable insects. Further research is needed to expand on this knowledge and integrate it into workable quarantine systems. Many hurdles would have to be overcome in order to use CA as a practical treatment. However, it could prove to be an important treatment for some pests on certain fruits, one that is unlikely to be challenged as a source of food contamination or environmental pollution.

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