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A review of postharvest disinfestation technologies for selected fruits and vegetables

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This report has been prepared by The New Zealand Institute for Plant and Food Research Ltd (Plant & Food Research), which has its Head Office at 120 Mt Albert Rd, Mt Albert, AUCKLAND. This report has been approved by:

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Executive Summary

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The growth of New Zealand horticultural exports ($2.9 billion in 2008) is dependent upon effective quarantine procedures. Postharvest insect control is an important aspect of this process and must, as much as possible, not reduce the quality of the treated produce. Disinfestation treatments may be either pre-shipment, in-transit, or applied on arrival if specified phytosanitary requirements have not been met.

Current disinfestation treatments are heavily dependent on the use of the fumigant methyl bromide (MeBr), which is an ozone-depleting substance and whose use is under continual pressure. Clearly, identification of opportunities for research into alternatives is required. The advantages of MeBr are its low cost, ease of application, and broad spectrum. Future solutions are unlikely to have all three of these properties. Rather, they are likely to be specific to individual crops, cultivars, pests, markets and even growing regions. This therefore requires a much higher level of knowledge on the treatment, pests, product and how and where these fit into the supply chain for each market. New solutions are also being increasingly targeted to be "soft" solutions which leave no residues, and in some cases even reduce agrichemical resudues that were applied preharvest.

There are a wide range of postharvest disinfestation treatments available:

- Physical treatments:
  - Temperature; cold (e.g. coolstored), heat (hot air or water)
  - Controlled/modified atmospheres
  - Physical removal (brushes, air, or waterblasting)
  - Pressure/vacuum)
  - Irradiation
  - Radio/microwave frequencies

- Chemical treatments:
  - Fumigation treatments with Generally Recognised As Safe (GRAS) compounds (i.e. ozone, ethyl formate)
  - Fumigation treatments with higher risk fumigants (i.e. phosphine, sulphuryl fluoride, carbonyl sulphide, ethane dinitrile)
  - Insecticidal dips

- Segregation:
  - Image recognition systems are reaching the point where removing infested fruits at grading may be possible.
  - Other methods of detection may be possible (spectral or volatiles).

Aim: This project sought to review all available literature possible and provide:

1) An overview of each of the various disinfestation treatments
2) For each crop:
   a. An overview of the crop (size, markets)
   b. A review of current disinfestation procedures
   c. Future directions for disinfestation research.

Overall Recommendations

Each industry should consider its individual requirements, but there is potential for research synergies in many situations. We recommend research programmes should be developed in the following areas:

- Development of low-temperature phosphine treatment
- Extension of cold disinfestation for cold-susceptible species (e.g. mealybugs, lightbrown apple moth (LBAM), possibly thrips)
- Determination of the efficacy of waterblasting on specific crops
- Investigating the impact of various formulations of ethyl formate on pests and fruit quality
- Determination of the efficacy of hot water treatments on specific crops
- Investigating the potential of GRAS compounds for fumigation
- Investigating the efficacy of a short low-oxygen atmosphere treatments as part of dynamic controlled atmosphere (CA) storage regimes
- Development of detection methods for grading out pests
- Development of high-temperature controlled atmosphere (HTCA), controlled atmosphere cold storage (CACS), standard cold storage SCS treatment combinations to take advantage of species susceptibilities for organic producers
- Investigating the impact of metabolic stress disinfestation and disinfection (MSDD) (vacuum/pressure and ethanol treatment) on pests
- Development of an irradiation acceptance analysis and research programme
- Expand of this report to include major vegetable crops such as capsicum, onions, potatoes, tomatoes and update as a 'living' document.

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Introduction

New Zealand horticultural exports were valued at $2.9 billion in 2008 (2008). Trade in horticultural products is dependent upon effective quarantine procedures that minimise the movement of pests and diseases across quarantine boundaries and prevent the accidental introduction of exotic pests and diseases in imported countries.

Postharvest insect control is an important aspect of this process. Disinfestation treatments may be either pre-shipment, in-transit, or applied on arrival if specified phytosanitary requirements have not been met.

Current disinfestation treatments, especially post-entry quarantine, are heavily dependent on the use of the fumigant methyl bromide (MeBr). Although this chemical is broadly effective against many pests, it is an ozone-depleting substance, extremely toxic to humans and results in the loss of any organic status of the export crop. In 1992 the availability of methyl bromide was restricted by the Montreal Protocol to Quarantine and Pre-Shipment (QPS) use only. Identification of opportunities for research into alternatives is required.

The advantages of MeBr are its low cost, ease of application, and broad spectrum. Future solutions are unlikely to have all three of these properties. Rather, they are likely to be specific to individual crops, cultivars, pests, markets and even growing regions. This therefore requires a much higher level of knowledge on the treatment, pests, product and how and where these fit into the supply chain for each market. New solutions are also being increasingly targeted to be “soft” solutions that leave no residues, and in some cases even reduce agrichemical resudues that were applied preharvest.

Restrictions on residues are increasing in many markets and there has been renewed interest in utilising postharvest disinfestation treatments that do not leave residues, to control pests that have previously been controlled by residue-contributing preharvest measures, and even to decrease residues after harvest (e.g. waterblasting or hot water treatments).

Postharvest insect control treatments may include physical treatments (such as cold, heat, controlled/modified atmospheres, removal, irradiation, radio/microwave frequencies, pressure/vacuum), fumigation treatments with either Generally Recognised As Safe (GRAS) compounds (i.e. ozone, ethyl formate), or higher risk fumigants (i.e. phosphine, sulphuryl fluoride, carbonyl sulphide, ethane dinitrile) or insecticidal dips. Some postharvest practices currently used, such as coolstorage, can be utilised as a disinfestation treatment (or part thereof) if efficacy can be demonstrated. In addition, computing power and visual and spectral systems have now reached the point where insects can be detected “in line” (during packing), and thus fruits with insects might be excluded during packing.

Export crops

The major fresh produce horticultural exports from New Zealand are kiwifruit and apples, which were worth over $1.2 billion in 2008 and have been the dominant fresh produce horticultural export crops for many years. Onion, potato, buttercup squash and avocado exports were worth >$50 million each, while capsicums, cherries, tomatoes and blueberries exports earned more than $10 million each in 2008.

The horticultural industries involved in this review include apple, asparagus, avocado, blueberries, citrus, feijoa, kiwiberry, kiwifruit, nashi, passionfruit, persimmon, summerfruit, strawberry and tamarillo.

Organic produce

Since the late 1990s there has been a strong and steady growth in the sales of organic foods. Data detailing the volume of accredited organic products have to rely on unofficial reports because of failure

of official trade data to distinguish between organic and conventional products. Organic foods typically command a price premium over conventionally produced foods because of higher production costs and the tendency for demand to exceed supply. For fruit and vegetable markets in the EU, a price premium between 20-40% is common. Strict quarantine requirements put on organic products by importing countries like Japan, Korea, Taiwan, the USA and Australia mean that if insects are found, consignments are treated with methyl bromide, which cancels the organic status of the product. Alternative treatments that meet organic certification as well as phytosanitary requirements are necessary to develop supply chains for organic products.

Market Access Pests

Market access pests are those that can occur on the exported part of the plant and whose presence can result in market access restrictions. The pests that occur on the horticultural crops at harvest can be grouped in the following broad groups: thrips, scale insects, mites, mealybugs, caterpillars, aphids, weevils, beetles, bugs, hoppers and psyllids. Most of these pests are surface dwelling, therefore readily exposed to disinfestation treatment. However, and some are internal pests that require an effective postharvest disinfestation treatment to penetrate the commodity.

Treatment efficacy can vary with the susceptibility of the target species/life stage, the treatment application method and the environmental conditions that prevail before, during and after treatment.

All quarantine pests can cause market access restrictions; however, often non quarantine pests cannot be readily identified from their quarantine pest relatives, and thus also cause difficulties when intercepted. Eggs and juvenile stages of pests (especially thrips, mealybugs and mites) are often intercepted and unidentifiable, and therefore quarantine regulators must assume that they are the quarantine species and treat accordingly. In the future, rapid identification using molecular markers may offer a solution to this problem. Also, although dead pests should not be a quarantine concern, it is often difficult to determine if eggs, pupae and sessile insects are live or dead. A biochemical test has been developed by AgResearch that shows a colour change when an insect is alive and this is currently being developed further and patented.

A list of pest species, common names and order and family referred to in this report is in provided in Appendix 1.

Export Markets

Five destinations (Austrialia, Japan, United Kingdom, European Union and the USA), all exceed $300 million fob value of New Zealand fruit and vegetable exports. Expanding markets include Taiwan, Hong Kong, Malaysia, Thailand, United Arab Emirates, Canada, Russia, Mauritius, Saudi Arabia, South Africa and India. Each importing country has its own quarantine pest list and different phytosanitary requirements. Information about the conditions to export plant products, including fruit and vegetables, is published on the MAF website (http://www.biosecurity.govt.nz/regs/exports/plants/icpr). This includes the requirement for import permits, phytosanitary cerificates, additional declarations and/or treatments and also any other relevant export information and documentation. The information is a guide only and exporters should make their own enquiries in relation to importing countries' requirements, as the information is liable to change.

Maintenance, and even more so expansion of access to markets, requires a substantial commitment to research and development. It generally takes a number of years to develop an effective and robust disinfestation treatment, and commercialisation requires commitment and co-ordination of industry bodies, packhouses, technical providers, fumigators, exporters, regulator bodise and researchers. Finally, market opportunities, actionable pests, residue limits and politics all change on a year-to-year basis.

Process for Developing of Disinfestation Treatments for Market Access

Ministry of Agriculture and Forestry, Biosecurity New Zealand (MAF BNZ) has the responsibility of negotiating with the overseas authorities responsible for control of imports and biosecurity to determine new or improved conditions of entry for New Zealand products and the removal of unjustifiable phytosantitary barriers to trade. Negotiating access to new markets is a lengthy process involving many steps and often takes 5-10 years.

The process by which a postharvest disinfestaion treatment is developed usually involves determining the following:

1. Efficacy against a range of life stages of target pest/s found on exported commodity (time and/or dose response trials) to determine effective treatment parameters and the order of tolerance for each life stage tested
2. Tolerance of the fresh produce to a range of the treatment parameters that have been demonstrated to cause a high level of pest mortality
3. Acceptability of the treatment in the target market (includes determining if a Maximum Residue Limit (MRL) is required)
4. Collection of efficacy data for protocol negotiation (and registration/residue analysis if required)
5. Protocol negotiation
6. Industry investment in infrastructure
7. Commercialisation.

It is important to note that some importing countries require disinfestation research to follow a more intensive and formal experimental procedure. For example, Japan requires more traditional extensive disinfestation research to demonstrate Probit 9 mortality level and satisfy the following steps:

- Life stages found on fruit at the time of harvest
- Cultivar chemical/fumigant sorption test
- Susceptibility of each life stage found on fruit at harvest to treatment
- Identification of the cultivar associated with the lowest mortality
- Large-scale mortality test (0 live out of 30,000 of most tolerant life stage)
- Confirmation trial using semi-commercial treatment equipment
- Phytotoxicity in fruit after treatment
- Gas penetration, sorption and desorption under standard disinfestation treatment
- Residue analysis.

Markets such as Australia and Taiwan have a newer “systems approach” that involves methods of quantitative pest risk analysis, which includes:

- Mode of trade
- Volume of trade
- Probability of infestation at each step of the pathway:
    - Probability of pest being on fruit at harvest
    - Probability of pest being viable (as opposed to dead or parasitized)
    - Likelihood that clean fruit are contaminated during picking and transport to packhouse
    - Probability of viable pest remaining on fruit during packing
    - Likelihood that clean fruit are contaminated by pest during processing in packhouse
    - Likelihood that pest survives palletisation, quality inspection, containerisation and transport to market
    - Likelihood that clean fruit are contaminated by pest during palletisation, quality inspection, containerisation and transport to market
- Probability of entry, establishment and spread
- Assessment of consequences.

If the final probability remains below an ‘acceptable allowable limit’, then after being through a defined process, the commodity is allowed entry.

In summary, it is clear that market access is highly complex area requiring both short- and long-term perspectives. An integrated approach by many teams and industry groups, and therefore good communication and information exchange is a prerequisite to success and effective utilisation of resources. This SFF review is a good springboard for development of effective research programmes across the horticultural industry.

Summary

Current disinfestation treatments are heavily dependent on the use of the fumigant methyl bromide (MeBr), which is an ozone-depleting substance and whose use is under continual pressure. Clearly, identification of opportunities for research into alternatives is required. The advantages of MeBr are its low cost, ease of application, and broad spectrum. Future solutions are unlikely to have all three of these properties. Rather, they are likely to be specific to individual crops, cultivars, pests, markets and even growing regions. This therefore requires a much higher level of knowledge on the treatment, pests, product and how and where these fit into the supply chain for each market. New solutions are also being increasingly targeted to be “soft” solutions which leave no resudues, and in some cases even reduce agrichemical resudues that were applied preharvest.

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