*CBC-funded Final Research Report*

# POSTHARVEST FUMIGATION: OPPOURTUNTIES & CHALLLENGES

***Expanding export opportunities for California fresh blueberries***

Spencer Walse

## Project Summary

*The overarching goal of this research is to develop postharvest treatments to facilitate the movement of California blueberries through trade and marketing channels. Particular attention is paid to the expansion into export markets. This research critically supports compliance with domestic quarantine regulations related to the protection and distribution of fresh blueberries, international regulations on ozone-depleting substances per the Montreal Protocol via the development of postharvest methyl bromide alternatives, and dealings with governments regarding insect-related phytosanitary issues that have the potential to serve as trade barriers. The balancing/melding of regulatory concerns with agriculture and industrial requirements to develop and utilize functional and economical postharvest treatments, including fumigation, requires specific analyses for each applied scenario where methyl bromide has to be replaced and/or contemporary infrastructure has to be retrofitted to accommodate safe usage of the alternative. Here we briefly outline efforts by CBC-funded researchers to develop postharvest fumigation as a tool that will enhance the global prominence of California blueberries.*

With the ever-increasing demand in both domestic and international markets for food quality, safety, and security, there also comes the critical need to control horticultural pests in the safest and most economical ways possible. Whenever horticultural crops traverse political boundaries, pest-related trade barriers can ensue. Frequently, but not always, these barriers are mitigated with the aid of scientific contribution. The Crop Protection and Quality Research Unit (CPQRU) of the USDA-ARS San Joaquin Valley Agricultural Sciences Center (SJVASC) in Parlier, California, has a team of scientists dedicated toward this end, with particular attention given to postharvest pest control strategies that enhance the competitiveness of United States agriculture.

As a member of the CPQRU research team, chemist Dr. Spencer Walse leads a program focused on trade barrier issues, with the major goals of 1) the retention and expansion of domestic and/or international markets for US growers and 2) the protection of US growers from the agricultural, ecological, and economic threat posed by horticultural pests. With a research scope that encompasses a variety of key technical and regulatory issues, such as Maximum Residue Levels (MRL)[1], pesticide registrations, food safety, and IPM strategies, arguably the greatest effort is given toward the development of novel theories and treatments for postharvest insect pest control.

As would be expected, Dr. Walse teams with many in academia and industry to tackle postharvest insect control issues for the California blueberry industry. Dr's Adaskaveg (UCR), Xiao (USDA-ARS-SJVASC), and Smilanick (USDA-ARS retired) continue to provide invaluable collaborative expertise owing to their years of blueberry (and table grape) experience. Industry organizations, specifically the California Blueberry Commission and the United State Highbush Blueberry Council, provide key support to the coordinated research effort, as the scientific aspects of a project must meld with political, regulatory, and economic nuances.

Relative to treatments applied during production, whether that be GMO-plantings, conventional insecticide applications, or any IPM strategy for that matter, postharvest opportunities allow for greater synchronization of the treatment with the logistical and infrastructural constraints that funnel into the marketing channel. While efforts continue across the gamete of postharvest possibilities, which include cold-treatments, heat-treatments, irradiation, controlled atmosphere, fogging, etc., fumigation continues as an invaluable postharvest treatment option.

Postharvest fumigation is a critical element of the ~$18 billion per year California specialty crop industry, as it provides a biological safeguard against pests and, in many scenarios, is the only available tool for governments, regulators, and industry to guarantee pest-free security and food safety. One fumigant, methyl bromide, has dominated the postharvest applications in California and beyond. Methyl bromide quickly penetrates commodity loads and has, in general, non-discriminating efficacy against insect and microbiological pests (Bond, 1984). As such, methyl bromide has been used successfully for quarantine[2] and preshipment[3] (QPS) disinfestations over the last four decades; in fact, its routine use has left the specialty crop industry, producers and port facilities alike, with infrastructural capabilities that are almost exclusively geared toward postharvest chambers designed specifically for methyl bromide use.

There are many dynamics involved with the continued use of methyl bromide by the specialty crop industry as a whole, several of which are currently poignant to the California blueberry industry. Methyl bromide use is regulated via international legislation under the Montreal Protocol[4]. The Protocol (Article 2H) *recognizes that QPS methyl bromide is an important remaining use of this ozone-depleting substance that is not controlled*, a clear acknowledgment by the international community that methyl bromide is critically important and will continue as the "tool of first choice" due to its internationally accepted efficacy and regulatory status. However, (decision XI/13) urges *Parties to implement procedures to monitor the QPS uses of methyl bromide by commodity and* (decision VII/5) *urges Parties to refrain from using methyl bromide and to use non-ozone-depleting technologies.* This "urging of the Parties" away from QPS methyl bromide use creates a myriad of challenges for regulatory, agricultural, and industry entities with a stake in postharvest chamber fumigation, a technology that literally evolved around QPS methyl bromide use. The situation is further complicated by the fact that continued QPS uses are at the discretion of the importing nation per FAO standards (ISPM, 2007).

One of the key export markets targeted by California blueberries, Australia, is a nation with reciprocal, albeit limited, blueberry production and a GDP purchasing power ranked 19th in the world. The key insect pest of concern to Australia, as related to California and all other states, is the spotted wing drosophila (SWD). Since 2010, Australia has accepted postharvest methyl bromide fumigation as a means to control SWD in (listed in order of acceptance): table grapes, sweet cherries, raspberries, peaches & nectarines, plums, and apricots. From a technical perspective, the acceptance of efficacy data for fresh blueberries, which was funded by CBC and provided to APHIS in 2014, is nothing more than a regulatory formality. Yet, California (Washington and Oregon) blueberry growers continue to wait because Australia is requesting that market access be granted for the entire US, including fruit sourced from Eastern states where blueberry maggot (BBM) (*Rhagoletis mendax*) is a key concern. Using resource at UC Davis's Quarantine Research Facility as well as Michigan State University, Dr. Walse's team has nearly completed the research to establish a methyl bromide fumigation schedule to control BBM, which is likely to require parameters identical to those required for SWD control. The expectation is to submit the completed research for BBM to APHIS, for transmission to Australia by fall of 2019.

With respect to market access for California blueberries to Korea, it is difficult to rationalize the lack of progress from a technical perspective, meaning political and regulatory factors are driving this issue. Oregon blueberries have market access under a "systems approach", while California and Washington blueberries are sidelined. Adding to the frustration, the methyl bromide treatment for BBM will likely satisfy Korean quarantine requirements, thereby potentially opening market access for fresh blueberries from the Eastern states. Notably, Korea has been pushing to move away from methyl bromide use at its ports of arrival due to worker exposure issues, meaning the BBM treatment will have to be done stateside, pre-departure, causing Eastern shippers to 1) put fumigated fruit on the water for a ~14 day container voyage or 2) burden the expense of air freight. Those with knowledge of the impact on fruit quality of pre-departure methyl bromide treatments of Chilean fruit for European Grapevine Moth (EGVM) and/or Mediterranean fruit fly (Medfly) should understand the inherent risk of the former option.

The following paragraphs will summarize efforts made by the CPQRU research team, as well as seminal University of California and industry collaborators, toward the development of postharvest MB alternatives for the California blueberry industry.

Since the US government became a signature of the Montreal Protocol in 1988, researchers and industry, near and afar, have been diligently working – some would call it struggling mightily- to find technically and economically viable postharvest alternatives to methyl bromide. Foremost, the alternative must have a domestic food tolerance[5], which can cost a registrant a capital investment of greater than one million USD and take five years for USEPA to review, and not necessarily approve. Secondarily, the alternative must have MRLs in the target market, which essentially means the registration/approval process must repeat itself in the foreign regulatory realm.

Incomprehensible to most, or at least the author, only a single “stand-a-lone” postharvest methyl bromide alternative, phosphine, can currently be used to treat fresh fruit stateside, and currently the treatment of blueberries is not allowed on the phosphine label. However, this should change within a year, as a proposed inclusion of “all fresh fruit and vegetables” on the labels of the two formulations of cylinderized phosphine, Ecofume and Vaporphos, are currently being reviewed by the USEPA. Owing to the pioneering work of Dr. Fransiskus Horn in the late 1990’s, phosphine is now used to treat fresh fruit at cold-storage temperature and MRLs of 10 ppb are established in nearly all key exports markets targeted by California blueberries, with those in Australia (and New Zealand) currently pending. MRLs of 10ppb, consistent with a “no detection” per international food standards of Codex Alimentarius, are used across the globe and are essentially a regulatory formality because they “acknowledge” a treatment that would otherwise be undetected during residue analysis. The rapid off-gassing of phosphine from fresh fruit, including blueberries, during the USEPA mandated 48-hour lag (under cold-storage) between fumigation aeration and consumption enables compliance with such a low food tolerance, with the chance of non-compliance in a foreign market being essentially nil. Moreover, the rapid off-gassing of phosphine during aeration minimizes worker exposure concerns, relative to methyl bromide which takes > 20-fold longer to off-gas from a given type of fruit. Another advantage of phosphine is that it generally enhances quality of fruit, as evidenced by a CBC-funded project began to thoroughly benchmark the quality of phosphine-treated blueberries relative to that treated with methyl bromide.

There are key features, however, that differentiate phosphine and methyl bromide. Whereas methyl bromide works on the timescale of 2 to 4 hours at treatment temperatures above 40°F, phosphine is typically used on the timescale of 12 to 72 hours at “cold-storage” temperatures spanning ca. 31 to 45°F. With respect to SWD, growers/packers should expect at treatment lasting 48 h at fruit temperature above 32°F. It will likely require 5 d under these conditions to control BBM, not a very attractive option for industry, so work continues to try to shorten the duration.

The necessity to treat for such a long duration, relative to that required for methyl bromide, requires compensatory scaling of fumigation structures so as to accommodate pack-house throughput requirements, particularly for larger export markets. Chile fresh fruit packers and shippers have overcome this logistical complication, primarily, by conducting phosphine fumigation in large controlled-atmosphere rooms or banks of modified reefer containers. Whether it be used as a stand-a-lone postharvest fumigation, or as a final mitigation step as part of a systems-approach to pest control, phosphine is an available tool for the California blueberry industry and the extent of its usage will depend on industry drivers and considerations.

With respect to the anti-fungal fumigant, sulfur dioxide, there is a full-court-press toward federal and state registration of both the cylinderized fumigant as well as sodium metabisulfite products (pads, liners, etc.), which slowly emit sulfur dioxide during storage and shipping. Essentailly, CBC and USHBC are pushing for the blueberry industry to have the same opportunities as the table grape industry, with respect to sulfur dioxide use. Registration of the cylinderized fumigant will allow users to quickly apply up to 10,000ppmv sulfur dioxide for 30 min to incoming fruit at pulp temperature greater than 60°F. Known as the "insect treatment" this application controls black widow spiders (if present), other surface pests, and considerably impacts SWD levels. In fact, when this fumigation is followed by 6 day of cold storage at 31.7°F, or alternatively 12 day storage at 33.7°F, levels of SWD control are achieved to meet the standards of Australia. Clearly, being able to use 10,000ppmv sulfur dioxide for 30 min, followed by a 6 d cold treatment, would be a great opportunity for the blueberry industry and would result in fruit of much higher quality relative to the use of methyl bromide. Two other scenarios for the cylinderized fumigant are being pursued. The first will hopefully allow 2,500ppmv sulfur dioxide to be applied via "total utilization" once a week for at least 5 consecutive weeks. The second will hopefully allow 400ppmv sulfur dioxide to be applied via "total utilization" thrice a week for at least 5 consecutive weeks. The blueberry industry has a significant amount of exploration ahead as it learns how to best optimize the use of sulfur dioxide, tailored to specific logistical needs and/or varieties.

With respect to the sodium metabisulfite products, Dr. Chang-lin Xaio and Dr. David Obenland of CPQRU have studied evaluated the effectiveness of pads, liners, and bags alone or in combination with modified atmosphere packaging bags (MAP) for control of gray mold and other diseases and for maintenance of fruit quality. Dual-stage $SO_2$-emitting pads ($SO_2$ is initially released up to 10 ppm and then declined and stabilized at a low concentration), slow-release $SO_2$-emitting pads ($SO_2$ is released at a low and constant concentration), or MAP bags significantly reduced fruit rots during cold storage compared to nontreated controls. The dual-stage $SO_2$ pad in combination with MAP or slow-release $SO_2$ pad in combination with MAP provided even better control, but the dual-stage $SO_2$ pad can cause bleaching on blueberry fruit due to $SO_2$ injuries. Results indicate that the combination of slow-release $SO_2$-emitting pad and a MAP bag is a promising method for control of fruit rots while maintaining blueberry fruit quality during storage. Current efforts are conducted in close collaboration with manufacturers to design use-patterns and labels for registration of sulfur dioxide fumigation as well as $SO_2$ -emitting sodium metabilsulfite products (liners, pads, bags) for blueberries.

Two other alternative fumigants, ethyl formate and propylene oxide, are currently being investigated by the CPQRU research team for insecticidal efficacy, residue characteristics, and impacts on fruit quality. While it is unlikely that ethyl formate and propylene oxide will provide control of SWD and BBM at doses that do not harm fruit, following fumigations lasting less than 2 hours, interestingly, both ethyl formate and propylene oxide are highly effective against external feeding insects, including mites, psyllid, and thrips. Stay tuned for research outcomes regarding technical aspects of these methyl bromide alternatives as well as feedback from the regulatory front as we push to establish food tolerances and labels for the blueberry industry.

If any blueberry growers, packers, and shippers wish to learn more about postharvest treatments, including fumigation, please reach out to the CPQRU team. We are always willing to conduct fumigations in Parlier, California so that folks have an opportunity to observe the treatment and evaluate fruit quality on their own terms/criterion – drop the fruit off, we will treat it, and then return the fruit for evaluation.

[1]**Maximum Residue Levels (MRL):** the highest level of a pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly per label instructions (Good Agricultural Practice).

[2]**Quarantine**: treatments to prevent the introduction, establishment and/or spread of quarantine pests (including diseases), or to ensure their official control, where:(i) Official control is that performed by, or authorized by, a national plant, animal or environmental protection or health authority;(ii) Quarantine pests are pests of potential importance to the areas endangered thereby and not yet present there, or present but not widely distributed and being officially controlled;

[3]**Preshipment**: treatments applied directly preceding and in relation to export, to meet the phytosanitary or sanitary requirements of the importing country or existing phytosanitary or sanitary requirements of the exporting country.

[4]**Montreal Protocol:** International treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion. It has been ratified by 197 parties, which includes 196 states and the European Union, making it the first universally ratified treaty in United Nations history.

[5]**Food tolerance:** Limits on the amount of pesticides that may remain in or on foods marketed in the USA (referred to as MRLs in many other countries); set by the USEPA and enforced by USDA (just meat & poultry) and FDA (other foods).

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***Spencer Walse, Ph.D., is a Research Chemist at the United States Department of Agriculture, Agricultural Research Service, San Joaquin Valley Agricultural Sciences Center as well as an Adjunct Professor in the Environmental Toxicology Department at the University of California, Davis.***

For additional information, please contact spencer.walse@ars.usda.gov