

Evaluation of Chemical and Photochemical Oxidation Processes for Degradation of Phosmet on Lowbush Blueberries (*Vaccinium angustifolium*)

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Chemical and photochemical oxidation processes were evaluated for their ability to degrade residual phosmet on lowbush blueberries and for their role in the conversion of phosmet to phosmet oxon—a toxic metabolite of phosmet. Chemical processes included 1 ppm of aqueous ozone, 1% hydrogen peroxide, 100 ppm of chlorine, and UV, whereas photochemical processes included hydrogen peroxide/UV, chlorine/UV, and ozone/hydrogen peroxide/UV. Phosmet applied as Imidan 2.5EC under laboratory conditions resulted in a mean residual concentration of 44.4 ppm, which was significantly degraded ($p < 0.05$) by ozone and chlorine, yielding reductions of 57.7 and 46%, respectively. Interaction between phosmet (Imidan 2.5EC) and any chemical or photochemical treatment did not result in conversion to phosmet oxon. Residual analysis of commercially grown blueberries revealed mean phosmet (Imidan 70W) levels of 10.65 ppm and phosmet oxon levels of 12.49 ppm. Treatment of commercial blueberries resulted in significant reductions in phosmet regardless of treatment type; however, only UV, hydrogen peroxide/UV, and ozone treatments degraded phosmet (Imidan 70W) to less toxic metabolites and reduced phosmet oxon levels. Treatment-induced conversion of phosmet to phosmet oxon was noticeably influenced by variations between phosmet formulations. Acceleration of photochemical degradation by UV was not observed. Selective oxidation by ozone represents a significant postharvest process for degrading residual phosmet on lowbush blueberries.

KEYWORDS: Organophosphorous insecticides; hydrogen peroxide; ozone; UV; blueberries

1. INTRODUCTION

The use of pesticides in commercial agriculture has contributed to the widespread distribution of quality agricultural commodities to a global market; however, at the price of these advantages, environmental and public health concerns are the emerging disadvantages resulting from the use of agricultural chemicals.

Preharvest application of phosmet, a phosphorodithioate organophosphate insecticide, is common in blueberry cultivation to control blueberry maggot, spanworm larvae, and flea beetles. Because application can occur as close as 7 days preharvest, it is common to find residues near tolerance levels (10 ppm) on unprocessed fruit. Furthermore, due to the relative toxicity of phosmet oxon, one of the primary degradation products of phosmet, concern exists over the presence of both the parent and the oxygen analogue on unprocessed blueberries. **Figure 1** details the molecular structures of phosmet and phosmet oxon. Although chemical sanitizers are not applied for the purpose of degrading pesticide residues, residual reductions should be a

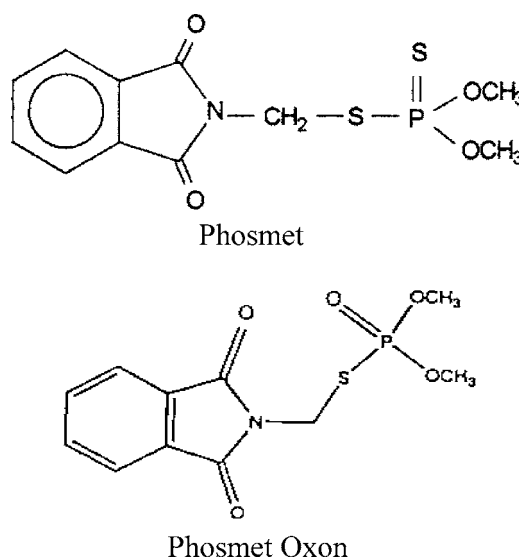


Figure 1. Structural formulas of phosmet (*O,O*-dimethyl *S*-phthalimido-methyl phosphorodithioate) and phosmet oxon (*O,O*-dimethyl *S*-phthalimidomethyl phosphorodithioate).

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secondary benefit of postharvest treatments applied to improve the microbial safety of agricultural commodities.

Oxidation processes based on the use of ozone (O_3), hydrogen peroxide (H_2O_2), and UV irradiation are currently employed for wastewater treatment as chemical oxidation processes (O_3/H_2O_2 , O_3 , H_2O_2/Fe^{2+}) or photochemical oxidation processes (H_2O_2/UV , O_3/UV) (1). On the basis of the proven effectiveness of these methods for pesticide removal in wastewater, several of these processes are currently under consideration for use in postharvest agricultural processing as pesticide degradation treatments and as antimicrobial agents. Industrial application of these treatments is based on the oxidation potential of each oxidant as well as their ability to generate highly reactive intermediates, namely, the hydroxyl radical. Pesticide degradation by chemical oxidants has been achieved under the following applications: hydrogen peroxide for the removal of organochlorine and organophosphorous pesticides from potatoes (2), ozone for the removal of diazinon and mancozeb in aqueous solutions (3, 4), ozone for the removal of azinphos-methyl, captan, and formetanate hydrochloride on apples and in aqueous solutions (5), and ozone alone and in combination with hydrogen peroxide for the degradation of organochloride compounds (6). In addition to ozone and hydrogen peroxide, chlorine has also been investigated for its efficacy in pesticide degradation as reported by Hwang et al. (7) for the removal of mancozeb in solution, by Zhang and Pehkonen (8) for the oxidation of diazinon in aqueous solution, by Ong et al. (5) for the removal of pesticides in solution and from apples, and by Hazen et al. (9) for the degradation of phosmet on blueberries; however, the effectiveness of chlorine is limited by its reactivity with organic compounds to form toxic byproducts. Trihalomethanes (THMs) and haloacetic acids (HAA5s), two major classes of disinfection byproducts, are mutagenic and carcinogenic compounds formed in abundance following chlorination of organic-laden water. Consequently, these chlorine byproducts adversely affect public health and the environment (10, 11).

As with most oxidation treatments, complete mineralization is not typically accomplished. Thus, formation of various byproducts appears to be unavoidable, especially due to the fact that different intermediates and final products often result from different oxidation processes (1). In addition, degradation metabolites of certain pesticides, in this case phosmet oxon, are equally as toxic as the parent compound; therefore, research is needed to thoroughly evaluate the role of chemical and photochemical oxidation processes in degradation of the parent compound and its toxic metabolites prior to utilization in postharvest processing of fruits and vegetables.

The supplementation of chemical treatments with UV can assist in mineralization of pesticides based on UV absorption by organic compounds in the range of 200–300 nm. Once absorbed, UV assists in decomposition through direct photolysis or excitation of the molecules to become more reactive with chemical oxidants or the resulting hydroxyl radicals (12). Currently, the majority of the literature on chemical and photochemical oxidation processes is aimed at reporting the role of these treatments in degrading pesticides in aqueous solutions. Application studies evaluating the degradation capacity of these oxidants on fruit and vegetable commodities are scarce. Furthermore, the vast majority of applied research investigating pesticide degradation is limited by experimental protocol in applying the pesticide as a pure analytical standard; however, pesticides applied to agricultural commodities are applied as proprietary formulations with numerous inert ingredients, which would be expected to alter the effectiveness of oxidation

treatments and the degree of degradation leading to formation of toxic byproducts. For this reason, the objectives of this research were to evaluate the degradation capacity of chemical oxidants (H_2O_2 , Cl_2 , O_3) versus photochemical oxidation processes (H_2O_2/UV , Cl_2/UV , $O_3/H_2O_2/UV$) in degrading phosmet applied as Imidan 70W and 2.5EC on lowbush blueberries and to assess the influence of these treatments on the oxidation of phosmet to phosmet oxon.

2. MATERIALS AND METHODS

2.1. Materials. Lowbush blueberries were raked from five different plots on a commercial blueberry field in Deblois, ME, during the week prior to harvest. Berries from each plot were pooled to obtain a representative field sample from which subsamples were removed for evaluation of postharvest oxidation treatments to degrade phosmet in the form of Imidan 70W applied during the agricultural growing season. To evaluate the effectiveness of oxidation treatments on degrading higher residual concentrations of phosmet, organic lowbush blueberries obtained from a local organic farm in Stockton Springs, ME, were sprayed with 45 ppm of Imidan 2.5EC sourced from Gowan Chemicals (Yuma, AZ). Phosmet and phosmet oxon standards were obtained from the EPA Repository (Fort Mead, MD). All organic solvents used in the extraction and analysis of phosmet and phosmet oxon were of HPLC grade from Fisher Scientific Co. (Fair Lawn, NJ).

2.2. Application of Phosmet (Imidan 2.5EC) to Organic Blueberries. Phosmet solutions were prepared using Imidan 2.5 EC (Gowan Chemicals) diluted in distilled water to a final concentration of 45 ppm. The applied concentration was selected on the basis of residual levels on field berries analyzed immediately after the restricted entry period of 3 days for phosmet. Phosmet was applied to organic blueberries using a Burkhard computer-controlled sprayer (Burkhard Manufacturing Co. Ltd., Rickmansworth, U.K.) operating at 10 psi and an atomizer click-stop setting of six. Immediately following phosmet application, samples were allowed to dry under ambient temperature for 1 min in a laminar flow hood prior to experimentation.

2.3. Chemical and Photochemical Treatment Application. Application of single oxidation treatments included 1% hydrogen peroxide, 100 ppm of chlorine, 1 ppm of aqueous ozone, and UV and photochemical combinations of 1% hydrogen peroxide/UV, 100 ppm of chlorine/UV, and 1 ppm of ozone/1% hydrogen peroxide/UV. Prior to experimentation, 1% hydrogen peroxide was prepared from 30% reagent grade hydrogen peroxide (Fisher Scientific Co.), and 100 ppm chlorine solutions were prepared from 6% sodium hypochlorite adjusted to pH 6.25 with hydrochloric acid (HCl).

Aqueous ozone treatments were generated using ambient air as the feed gas in a SGC11-22 ozone system (Pacific Ozone Technology Inc., Benicia, CA). The ozone unit was connected to the industrial conveyor system using food-grade PVC flex tubing. The dissolved ozone sensor was calibrated using the indigo colorimetric method for ozone determination in water (13), and aqueous ozone concentrations generated during processing were determined using an ozone Accuvac test kit (Hach Co., Loveland, CO). Concentrations were monitored before and after each treatment to ensure a mean concentration of 1 ppm of ozone in aqueous sprays.

UV treatments were administered using a UV light hood (RGF Environmental, West Palm Beach, FL) fitted with four low-pressure mercury arc bulbs (RGF 75W, $\lambda = 254$ nm, 30.5 in) suspended 8 in. over the conveyor belt. The UV intensity on the sample surface (4.38 mW/cm²) was measured using a J-225 BLAK-RAY UV intensity meter (UVP, Inc., Upland, CA).

Aqueous treatments were administered to 50 g samples using an overhead spray conveyor system designed and fabricated by the Advanced Manufacturing Center at the University of Maine. To closely simulate industrial blueberry processing parameters, unit operations were calibrated to deliver 0.11 gal/min (GPM) per pound of blueberries at a belt speed of 40 ft/min. Treatments were allowed a contact time of 60 s prior to blast freezing at -25 °C for 10 min. Frozen samples were stored at -20 °C for 48 h prior to analysis. Contact time was selected to facilitate current processing parameters for blueberries. All

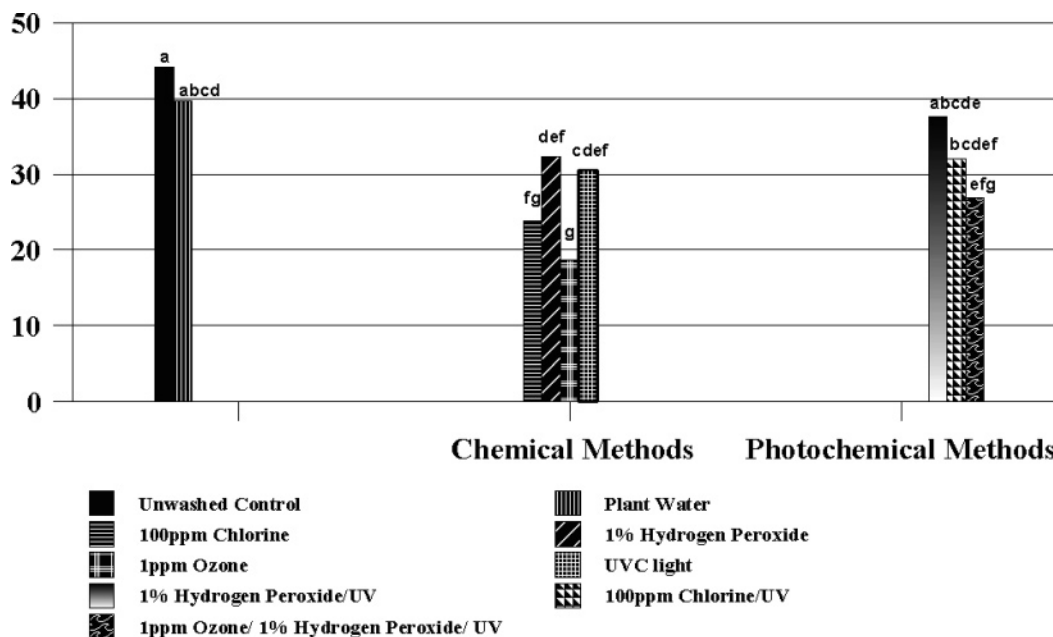


Figure 2. Spray application study. Residual phosmet (ppm) in the form of Imidan 2.5EC was determined on lowbush blueberries in response to 60 s of exposure to chemical and photochemical treatments. Phosmet levels represent the mean of three replicates per treatment with extractions performed in duplicate. Columns not sharing similar letters are significantly different at $p < 0.05$ according to analysis by ANOVA and Tukey's HSD multiple comparison.

treatments were performed in triplicate and administered in random order to alleviate sources of error in sampling and application.

2.4. Phosmet and Phosmet Oxon Residue Analysis. The concentrations of phosmet and phosmet oxon were determined by HPLC (Hewlett-Packard 1050, Hewlett-Packard Co., Palo Alto, CA) equipped with a photodiode array detector and a phenyl-hexyl column (3 μm , 150 \times 4.6 mm, Phenomenex). HPLC conditions for analysis included the use of two mobile phases operating under the following gradient profile: mobile phase A, 70:30 (water/acetonitrile), 0–11 min, 100% mobile phase A; and mobile phase B, 30:70 (water/acetonitrile), 11–21 min, 100% mobile phase B. Additional conditions were as follows: 1.0 mL/min flow rate, 5 μL injection volume, and 5 min post-time run. Under these parameters, the retention time and peak absorption for phosmet were 14.5 min at 224 nm and those for phosmet oxon, 5.1 min at 210 nm. Extraction of phosmet and phosmet oxon from blueberries was achieved using HPLC grade acetonitrile. Samples of 5 g were homogenized in acetonitrile and centrifuged prior to direct injection of the supernatant. Standard stock preparations of each compound were prepared using HPLC grade acetonitrile and diluted within range using an organic blueberry matrix.

2.5. Statistical Analysis. All data were subjected to one-way analysis of variance (ANOVA) and Tukey's HSD multiple comparison to assess significant differences ($p < 0.05$) in residual phosmet and phosmet oxon resulting from chemical and photochemical treatments. Statistical analysis was performed using Systat Analytical Software, version 11.0 (Chicago, IL). Percent reductions were calculated using residual levels of phosmet and phosmet oxon before and after treatment.

3. RESULTS

3.1. Treatment-Induced Degradation of Phosmet Applied as Imidan 2.5EC on Organic Blueberries. Application of phosmet in the form of Imidan 2.5EC to organic blueberries resulted in a mean residual concentration of 44.4 ppm of phosmet. According to HPLC analysis of phosmet and phosmet oxon standards in the blueberry matrix, the detection limits were determined as 1.39 ppm for phosmet and 0.5 ppm for phosmet oxon. Chemical treatment methods resulted in significantly lower ($p < 0.05$) residual phosmet levels compared to unwashed controls or water-washed samples (Figure 2). Hydrolytic degradation resulting from water sprays yielded only minimal

reduction in phosmet residues (9.8%). In comparison to chemical treatment methods, oxidation of phosmet by chlorine and ozone yielded reductions of 46 and 57.7%, respectively. Oxidative degradation of phosmet by chlorine and ozone was significantly greater than reductions achieved by other chemical oxidants. UV and 1% hydrogen peroxide treatments degraded phosmet by 31.2 and 23.2%, respectively, although results were not significantly different ($p < 0.05$) from hydrolytic degradation of phosmet resulting from water sprays.

Phosmet oxidation resulting from photochemical treatments was not significantly enhanced ($p < 0.05$) by the addition of UV irradiation to chemical treatments. Among photochemical methods, the combination of ozone/hydrogen peroxide/UV resulted in the greatest residual reduction of phosmet (39.4%), although results were not significantly different ($p < 0.05$) from oxidation of phosmet resulting from chlorine or ozone as single chemical treatments.

All treatments degraded phosmet to intermediates other than phosmet oxon as evidenced by the lack of phosmet oxon residues detected by HPLC analysis (data not shown).

3.2. Treatment-Induced Degradation of Phosmet and Conversion to Phosmet Oxon on Commercial Blueberries. Analysis of phosmet residues on commercially grown blueberries revealed mean residual phosmet and phosmet oxon levels of 10.65 and 12.49 ppm, respectively, 1 week prior to harvest. According to phosmet application records, phosmet was applied in the form of Imidan 70W 3 weeks prior to sampling.

All treatments resulted in significant degradation of phosmet ($p < 0.05$) below the 1.3 ppm level of detection as illustrated in Figure 3; however, phosmet oxon levels detected in samples following exposure to chemical and photochemical treatments revealed incomplete degradation of phosmet to less toxic metabolites (Figure 4). Significant differences ($p < 0.05$) in residual oxon levels were not observed among treatments and unwashed controls regardless of the fact that some treatments induced conversion of phosmet to phosmet oxon and others reduced oxon levels present at the time of harvest. Despite the

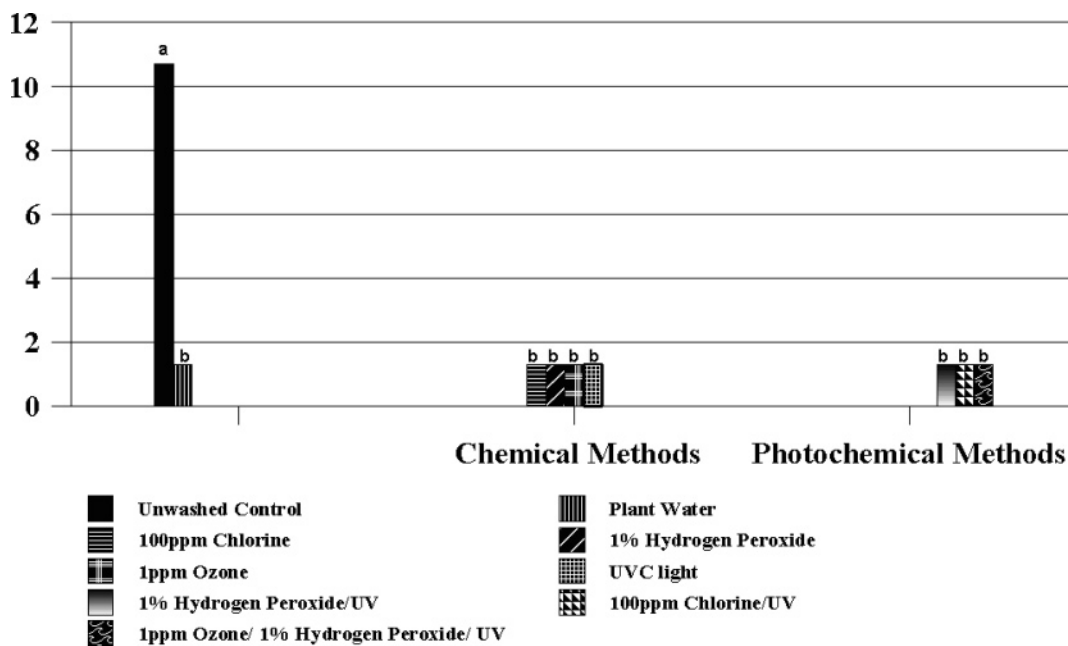


Figure 3. Field study with Imidan 70W. Residual phosmet levels (ppm) were determined on lowbush blueberries in response to 60 s of exposure to chemical and photochemical treatments. Phosmet levels represent the mean of three replicates per treatment with extractions performed in duplicate. Columns not sharing similar letters are significantly different at $p < 0.05$ according to Tukey's HSD multiple comparison. Residual phosmet levels resulting from all treatments were below the 1.39 ppm level of detection.

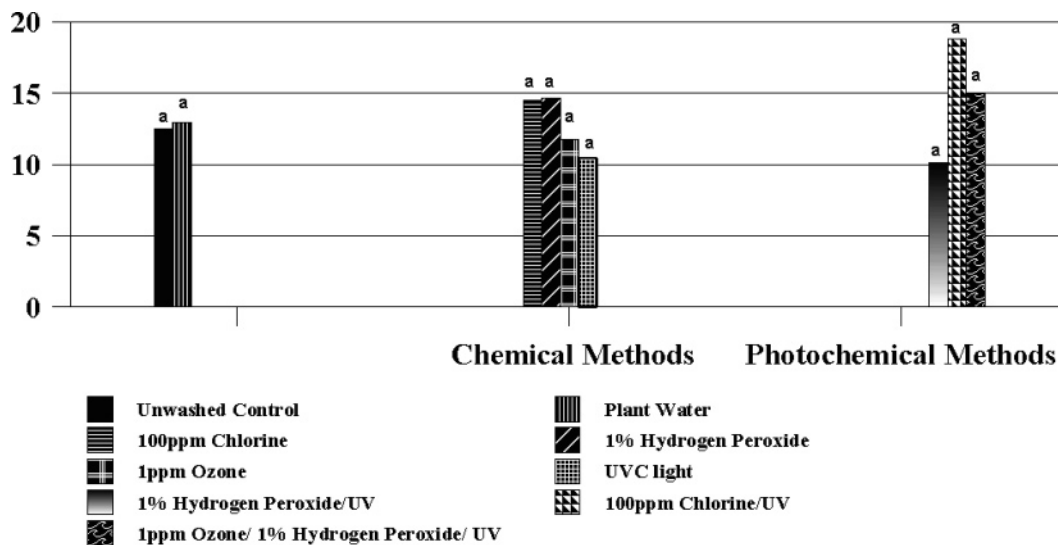


Figure 4. Field study with Imidan 70W. Residual levels (ppm) of phosmet oxon were determined on lowbush blueberries in response to 60 s of exposure to chemical and photochemical treatments. Phosmet oxon levels represent the mean of three replicates per treatment with extractions performed in duplicate. Columns not sharing similar letters are significantly different at $p < 0.05$ according to Tukey's HSD multiple comparison.

lack of statistical significance, only 1 ppm of ozone, UV, and 1% hydrogen peroxide/UV treatments yielded reductions in residual oxon levels by 6.3, 16.1, and 19.1%, respectively. Although 1% hydrogen peroxide/UV treatment was the only photochemical treatment to degrade oxon residues, it appears that the oxidation of phosmet oxon by this treatment was primarily dependent on the action of UV irradiation alone as evidenced by UV-induced reduction in oxon residues. All other chemical and photochemical treatment methods induced conversion of phosmet to phosmet oxon as reflected in oxon level increases of 3.6 to 50.9%. Treatment-induced conversion of phosmet to phosmet oxon was greatest on blueberries treated with chlorine/UV.

4. DISCUSSION

Many factors govern the degradation of phosmet in the field, resulting in numerous degradation pathways and different final products. Of the primary degradation products identified by U.S. EPA fate assessment studies, phosmet oxon is the only degradate identified for toxicological concern (14). For this reason, selection of a chemical or photochemical method for use in postharvest blueberry processing should be capable of not only degrading pesticide residues but also converting the parent compound to less toxic analogues. Maximum degradation of phosmet applied as Imidan 2.5EC was observed on samples treated with 1 ppm of aqueous ozone followed by reductions induced by 100 ppm of chlorinated water sprays. Ong et al. (5)

reported degradation of azinphos-methyl, also an organophosphorous insecticide, on apples and in solution by aqueous ozone. Ozone-induced reductions were greatest at pH 4.5 and decreased with increasing pH. These results support the role of molecular ozone over hydroxyl radicals formed in the decomposition of ozone at high pH in the degradation of the organophosphate insecticide azinphos-methyl. Degradation of phosmet was also accelerated in the presence of molecular ozone as compared to degradation resulting from photochemical treatment methods, which rely on hydroxyl radicals to elicit oxidation. According to Laplanche et al. (15), molecular ozone reacts with phosphorodithioate organophosphate compounds, under experimental conditions, in a successive manner by cycloaddition on the P=S double bond and by electrophilic attack of the additional S atom. For example, ozone-induced degradation of malathion, also a phosphorodithioate organophosphorous compound, resulted in direct oxidation of the P=S bond by molecular ozone followed by a successive attack on malathion oxon, leading to secondary and tertiary metabolites of the parent compound. Thus, molecular ozone appears to play a selective role in the degradation kinetics of organophosphorous compounds to less toxic metabolites.

In the spray application study, exposure of samples to UV irradiation resulted in a 31.2% reduction in phosmet residues, although results were not significantly different ($p < 0.05$) from reductions induced by hydrogen peroxide, chlorine, or water sprays (Figure 2). Due to the limited exposure of UV to the commodity surface, typical UV reactions, such as the formation of radical species, would be expected to be inhibited. For example, the spherical nature of blueberries prevents complete coverage by UV, and according to Bank et al. (16), the bactericidal effectiveness of UV is limited to areas directly exposed. Moreover, degradation of phosmet residues on blueberries would also be limited to those areas directly exposed to UV. Diminished UV coverage could explain the lack of synergy exhibited by photochemical treatment methods in reducing residual phosmet, with the majority of phosmet degradation resulting from these treatments dependent upon the oxidizing potential of the chemical oxidant employed in combination with UV.

Residual analysis of phosmet as Imidan 70W on field samples revealed significant reductions ($p < 0.05$) in phosmet as a result of all chemical and photochemical treatments, although significant differences did not exist among treatments. Despite the degradation of phosmet, conversion of phosmet to phosmet oxon was enhanced as a result of all treatments except ozone, UV, and hydrogen peroxide/UV. These treatments did not induce conversion of phosmet to phosmet oxon but rather reduced oxon levels present at the time of harvest. Application of chlorine, the current industrial sanitizer used by the blueberry industry, resulted in increased levels of phosmet oxon above levels present at the time of harvest; furthermore, the production of phosmet oxon was greater by chlorine than by hydrolysis alone. The increased conversion of phosmet to its oxon form may be explained by the differences in activation energy for each reaction. According to data by Zhang and Pehkonen (8), the oxidation of diazinon, an organophosphorous insecticide, in aqueous systems to diazoxon by chlorine exhibited much lower activation energy than that necessary for the hydrolysis of diazinon. Increased conversion of phosmet to phosmet oxon by chlorine and some photochemical treatments could be explained by the reaction kinetics of hypochlorous acid and hydroxyl radicals. Both hypochlorous acid and hydroxyl radicals attack organic compounds nonselectively with reactions by hydroxyl

radicals involving hydrogen abstraction or electrophilic addition to double bonds (1). Regardless of the oxidant, a nonselective attack of phosmet resulted in oxidation of phosmet to phosmet oxon instead of degradation to less toxic secondary and tertiary metabolites of the parent compound. Hydrogen peroxide/UV induced degradation of phosmet oxon by 19.1% on commercial blueberries; however, reductions were not significantly different ($p < 0.05$) from those resulting from UV alone, which resulted in 16.1% reduction of phosmet oxon. Overall, decreased synergism was exhibited by photochemical processing methods in degrading phosmet and phosmet oxon.

Differences in the degree of oxon formation varied among samples from both studies. Residual oxon levels on unwashed controls and treatment berries were not detected as a result of phosmet applied under laboratory conditions as Imidan 2.5EC; however, residual oxon was detected on all samples to which phosmet was applied as Imidan 70W in the preharvest period. Initially, these differences can be explained by the fact that the organic blueberries to which Imidan 2.5EC was applied did not undergo environmental degradation under field conditions. Thus, environmental degradation pathways that may typically result in oxon formation were prevented; however, this explanation is limited only to the assessment of initial oxon levels and does not explain the differences in oxon formation based on exposure to postharvest treatments. In this study, phosmet residues were present as a result of spray application with two different formulations—Imidan 2.5EC and Imidan 70W. Imidan 2.5EC, an emulsifiable concentrate, was selected as the phosmet formulation for the spray application study due to its physical characteristics and ease of application by the computer-controlled sprayer. Commercially grown blueberries typically receive aerial application of Imidan 70W, a wettable powder. Both formulations produced by Gowan Chemicals, Inc., are similar in active ingredients, yet the distinct physical differences of these compounds and their inert ingredients would be expected to modify adsorption, retention, and degradation of phosmet on biologically active crops. Although inert ingredients are regarded as proprietary information, research has shown that inert ingredients in pesticide formulations may include many types of additives and adjuvants such as surfactants, emulsifiers, dispersants, solubilizers, antifoam/defoamers, solvents, carriers/diluents, preservatives, thickeners/suspending agents, wetting agents, pH buffers, polymeric adhesion promoters, film formers, alcohols, mineral oils, and modified vegetable oils (17). Therefore, due to the physicochemical differences between Imidan 2.5EC and Imidan 70W, it is quite probable that the differences in oxon formation may be the result of variations in inert ingredients between the formulations and the role of these ingredients in adsorption and metabolite formation upon exposure to postharvest oxidants. For example, physicochemical differences between the two phosmet formulations most likely influenced the degree of oxon formed from hydrolysis reactions upon exposure to water sprays. Differences in the inert ingredients including surfactants, film formers, pH buffers, etc., would be expected to influence the hydrolytic pathways for phosmet, yielding direct hydrolysis of phosmet to less toxic metabolites and/or indirect hydrolysis in which the P=S bond may be oxidized first followed by hydrolysis of the oxygen analogue. As evidenced in Figures 2–4, hydrolytic degradation of phosmet resulted in the reduction in phosmet residues on samples receiving application of Imidan 2.5EC, yet in blueberries receiving preharvest application of Imidan 70W, hydrolytic degradation of phosmet resulted in the reduction in the parent compound with some conversion of phosmet to its oxygen

analogue. Thus, it appears that phosmet applied as an emulsifiable concentrate underwent direct hydrolysis upon exposure to water, whereas residues of phosmet applied as a wettable powder hydrolyzed along two distinct pathways. Although the exact role played by formulation is not clearly understood, results of this study are consistent with the findings of Cabras et al. (18) and Krol et al. (19), who reported no correlation between pesticide degradation on olives by water washing and the water solubility of the individual pesticides evaluated. Therefore, although phosmet oxon has a greater solubility in water than the parent compound, its degradation is not mediated by its solubility. Nevertheless, regardless of the phosmet formulation applied to blueberries, ozone treatments substantially degraded phosmet and phosmet oxon without inducing conversion of phosmet to phosmet oxon.

Although different oxidants typically lead to different final products (1), the selection of an oxidation treatment for postharvest processing should take into account the formation and type of metabolites resulting from oxidation of the parent compound. In the selection of a postharvest oxidant for lowbush blueberries, application of aqueous ozone has proven to be the most effective method in degrading phosmet to less toxic metabolites and degrading phosmet oxon residues present at the time of harvest. Furthermore, ozone represents an effective postharvest oxidation treatment capable of degrading phosmet regardless of the formulation of phosmet applied in the preharvest period. With application in the aqueous state, ozone yields several advantages over other oxidants for incorporation into postharvest processing facilities: its precursors are abundant, and it leaves no residues postcontact. In addition, application of ozone to postharvest processing represents an environmentally benign process when used in conjunction with ozone destruct systems to break down unreacted ozone molecules into diatomic oxygen.

5. SAFETY

Phosmet is a class II nonsystemic organophosphate insecticide, which elicits effectiveness as a cholinesterase inhibitor. Phosmet is moderately toxic to mammalian species upon acute exposure of >113 mg/kg of body weight (14). As with any pesticide, special precautions should be taken its handling including the use of a fume hood and personal protective equipment.

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