High Hydrostatic Pressure and UV Light Treatment of Produce Contaminated with *Eimeria acervulina* as a 
*Cyclospora cayetanensis* Surrogate

KALMIA E. KNIEL,1* ADRIENNE E. H. SHEARER,1 JENNIFER L. CASCARINO,2 GARY C. WILKINS,2 AND 
MARK C. JENKINS1,2

1Department of Animal and Food Sciences, University of Delaware, 531 South College Avenue, Townsend Hall, Newark, Delaware 19716; and 
2Animal Parasitic Diseases Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705-2350, USA

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ABSTRACT

The prevalence, size, genome, and life cycle of *Eimeria acervulina* make this organism a good surrogate for *Cyclospora cayetanensis*, a protozoan that causes gastroenteritis in humans, including recent outbreaks in the United States and Canada associated with contaminated raspberries and basil. Laboratory studies of *C. cayetanensis* are difficult because of the lack of readily available oocysts and of infection models and assays. UV radiation and high-hydrostatic-pressure processing (HPP) are both safe technologies with potential for use on fresh produce. Raspberries and basil were inoculated with sporulated *E. acervulina* oocysts at high (10⁶ oocysts) and low (10⁴ oocysts) levels, and inoculated and control produce were treated with UV (up to 261 mW/cm²) or HPP (550 MPa at 40°C for 2 min). Oocysts recovered from produce were fed to 3-week-old broiler chickens, which were scored for weight gain, oocyst shedding, and lesions at 6 days postinoculation. Oocysts exhibited enhanced excystation on raspberries but not on basil. Birds fed oocysts from UV-treated raspberries had reduced infection rates, which varied with oocyst inoculum level and UV intensity. Birds fed oocysts from UV-treated raspberries (10⁶ oocysts) were asymptomatic but shed oocysts, and birds fed oocysts from UV-treated basil (10⁴ oocysts) were asymptomatic and did not shed oocysts. Birds fed oocysts from HPP-treated raspberries and basil were asymptomatic and did not shed oocysts. These results suggest that UV radiation and HPP may be used to reduce the risk for cyclosporiasis infection associated with produce. Both treatments yielded healthy animals; however, HPP was more effective, as indicated by results for produce with higher contamination levels.

*Cyclospora cayetanensis* is a foodborne and waterborne protozoan parasite that infects the upper small intestine of humans and can cause severe diarrhea, stomach cramps, and nausea, which may be accompanied by fever (14, 44). *Cyclospora* oocysts have a strong outer membrane surrounding two sporocysts, which contain the infective life stage, with four sporozoites in each sporocyst. Cyclosporiasis has been associated with fresh fruits, vegetables, and herbs likely contaminated by water, soil, or handlers. In particular, raspberries, basil, parsley, snow peas, and leafy greens have been implicated as probable transmission vehicles in outbreaks of cyclosporiasis in the United States (8, 14, 30, 44). During the summer of 2005, outbreaks of cyclosporiasis occurred in the states of Florida and Connecticut, and in Canada, *C. cayetanensis*-contaminated basil was identified as the source of infection (9, 10, 48). Although contamination can occur both preharvest (soil, feces, irrigation water, dust, insects, or animals) and postharvest (human handling, equipment, or transport containers) (5), no direct transmission route has been identified. The water used to mix pesticides was previously identified as a possible source of contamination in the outbreaks of cyclosporiasis associated with contaminated raspberries (23, 24). Because of the sensitive nature of this illness concerning mostly imported produce and the unknown reservoir or route of contamination, alternative treatment methods for produce are needed. The use of nonthermal treatments on minimally processed fruits and vegetables is attractive to both industry and consumers (6). High-hydrostatic-pressure processing (HPP) and UV radiation are nonthermal treatments currently being used to reduce microbial contamination in foods and water.

Cyclosporiasis has not been associated with heat-treated produce, and *C. cayetanensis* is reportedly sensitive to heat, cold, microwaves, freezing, and desiccation (14, 34, 45). However, methods for removing or inactivating *C. cayetanensis* on produce while maintaining fresh product attributes have not been established. HPP is an emerging food-processing technology utilized to inactivate deleterious vegetative bacteria, viruses, fungi, and enzymes without decreasing the nutritive and sensory attributes of foods (36). HPP has been successfully commercialized for guacamole, oysters, and refrigerated meats and has been explored for numerous other foods, including fruit and vegetable products. The potential application of HPP for fresh produce is generally promising. Midrange pressures of 300 to 450 MPa have been reported to inactivate some yeasts, molds, and bacteria on a variety of fruits and vegetables without affecting their fresh qualities (2, 11). Very high pressure (700 MPa) applied at an elevated temperature re-
portedly does not compromise the aroma, color, or major flavor compounds of fresh basil. Color retention of pressure-treated red raspberries varies, with low (200 MPa) and high (800 MPa) pressures providing the most pigment stability. HPP also does not appear to compromise several beneficial factors in various fruits, including antimutagenic and antioxidative factors.

UV radiation is another nonthermal treatment that has been studied for its effectiveness in inactivating protozoa, viruses, and bacteria without negatively affecting the fresh produce. The documented antimicrobial effects of UV light were first recognized by Downs and Blunt in 1877. Short wavelength light of 254 nm, generated from low-pressure mercury lamps, is generally known as germicidal radiation and damages the nucleic acids of organisms. Light at 200 to 280 nm is called UVC light and causes cross-linking between neighboring pyrimidine nucleoside bases in the same nucleic acid strand. The resulting thymidine or uracil dimers in DNA and RNA, respectively, effectively prevent replication. Microorganisms, such as bacteria, may be killed by a lethal dose of UV light or may be inactivated to some degree by a sublethal dose with the possibility of reactivation by a repair process. Photoreactivation is the means by which UV-inactivated microorganisms recover activity through the repair of pyrimidine dimers under near-UV light (310 to 400 nm) with the use of enzymes such as photolyase. Although these repair processes have been observed in bacteria, they have not been well documented in protozoa. Although Cryptosporidium oocysts exposed to fluorescent light are capable of repairing pyrimidine dimers, the infective ability of the oocysts is lost. For successful infection to occur, both the sporozoite genetic material and the oocyst wall must be functional. In all protozoa, the membrane is a strong structure necessary to survive the acidity and enzymes of the stomach and small intestine and to provide stability in the environment.

C. cayetanensis is difficult to study in the laboratory because humans are its only known host, making access to oocysts and methods of evaluating viability difficult and limited. Previous studies have been focused on only oocyst sporulation as a measure of inactivation. Recent attempts to determine the infective dose of C. cayetanensis were not successful. Eimeria species are poultry coccidian parasites and are closely related to C. cayetanensis, bearing similarities in morphology, life cycle, and genetics. Phylogenetic analysis supports the conclusion that Eimeria and Cyclospora could belong to the same family, and one author suggested that Cyclospora should be considered a member of the genus Eimeria based on small subunit rRNA gene alignment. Although there are differences in the infectivity and host susceptibility of these two organisms, the use of Eimeria as a model for Cyclospora is justified. Eimeria acervulina has been utilized as a surrogate for C. cayetanensis previously and was used in the present study.

Studies on the resistance of E. acervulina to HPP have previously been conducted in our laboratory. Sporulated oocysts of E. acervulina suspended in laboratory media were rendered nonpathogenic in their natural host by treatment with HPP and mild heat, although pressure at cold temperatures was less effective and mild heat alone had no effect. Food constituents can be baroprotective; therefore, the resistance of coccidia in food cannot be assumed to be equivalent to that determined in laboratory media. To our knowledge, there is no information currently available describing the inactivation of Cyclospora or Eimeria oocysts by either of the nonthermal treatments used in the present study on fresh produce or by UV radiation in any laboratory media. The objective of the present study was to evaluate the efficacy of HPP and UV radiation for inactivation of E. acervulina, used as a surrogate for C. cayetanensis, on foods recently involved in foodborne outbreaks, specifically raspberries and basil.

**MATERIALS AND METHODS**

**Oocyst propagation.** E. acervulina (originally obtained from Auburn University and propagated at the U.S. Department of Agriculture Agricultural Research Service [USDA-ARS] for more than 30 years) was collected from the feces of Sex-Sal chickens (Moyer’s Hatchery, Quakertown, Pa.). Oocysts were suspended in 2.5% potassium dichromate and sporulated by forced aeration for 48 to 72 h at 25.6 to 27.8°C. Sporulated oocysts were further cleaned with 10% bleach (30 min) followed by repeated water washes. The treated oocysts were stored in Dulbecco’s modification of Eagle’s medium with 4.5 g/liter glucose and L-glutamine and sodium pyruvate (DMEM; Mediatech, Inc., Herndon, Va.) at 4°C and used within 6 months.

**Inoculation and recovery.** Raspberries imported from Chile were purchased from a local grocery store in Newark, Del. Average raspberry weight was 4.79 ± 2.31 g. Basil was grown locally in Newark, Del. Leaves of about the same size (5 cm long and 2 cm wide) were used in each experiment, and average leaf weight was 0.36 ± 0.10 g. Raspberries and basil leaves were inoculated individually with oocysts using a droppwise method to simulate spot contamination from water droplets, soil, or human handlers. Two concentrations of oocysts were studied for each food type: 2 × 10⁶ and 2 × 10⁷ oocysts. Inoculated samples were air dried for 15 to 30 min before treatment. After treatment, each produce sample was washed with 10 ml of water in a 15-ml conical tube (Fisher Scientific International, Inc., Hampton, N.H.) to loosen the oocysts, the raspberry or basil leaf and wash water were passed through cheesecloth, and the oocysts were recovered by centrifugation. Concentration efficiencies of >99% of the inoculated oocysts were determined by counting oocysts with a hemacytometer. Oocysts were stored in Hanks balanced salt solution (HBSS; Mediatech, Inc., Ormond Beach, Fla.) at 4°C until used.

**UV light treatments.** UV light of 254 nm (G36T6 model 4136 germicidal light) was generated with a low-pressure lamp contained within an enclosed chamber (Fuller Ultraviolet, Franklin, Mass.) (47). Light intensity is measured with a calibrated dosimeter (Spectronics, Westbury, N.Y.) before each use. To increase the UV intensity and decrease the potential for shadowing, the chamber interior was covered with a highly reflective material (Solar Bright, Fuller Ultraviolet). Each raspberry and basil leaf was treated individually and placed on a piece of Solar Bright during treatment. Intensity (2.9 to 261 mW/cm²) was controlled by the distance between the raspberry or basil leaf and the light source.
High-hydrostatic-pressure treatments. Inoculated berries and basil leaves were transferred to sterile polypropylene pouches (VWR International, West Chester, Pa.), with three berries or one basil leaf per pouch. The samples were double bagged and heat sealed. Pressure treatments were applied in an PT-1 hydrostatic press (Avure Technologies, Kent, Wash.). Oocysts were treated at 550 MPa with a 2-min hold time (exclusive of come-up time of approximately 30 s with instantaneous depressurization), and the surrounding water bath was kept at 40°C, as previously determined effective for oocysts alone (43).

Permeability. The effect of treatment on oocyst membrane permeability was examined by uptake of methylene blue dye (43). E. acervulina alone in HBSS or recovered from raspberries, as previously described, were centrifuged (16,060 X g for 10 min at 4°C), and the pellet was resuspended in 1 ml of methylene blue (Poly Scientific, Bay Shore, N.Y.) for 30 min at 4°C. Untreated E. acervulina served as a negative control. For a positive control, E. acervulina in DMEM was exposed to three freeze-thaw cycles (~80°C for 30 min and immersion in a 41°C water bath for 10 min), pelleted, and resuspended in methylene blue. The number of oocysts permeable to methylene blue was enumerated with a hemacytometer.

Excystation. During the first step of this assay, the exterior oocyst wall is broken by mechanical force. Oocysts (1.25 ml of 10⁶ oocysts per ml) were added to 1.5-ml microcentrifuge tubes containing 0.18 g of 1-mm-diameter glass beads. Oocysts and beads were vortexed at a speed setting of 2,000 on a Deluxe Digital Vortex Mixer (Fisher Scientific), and samples were withdrawn after 6 min of bead beating. After the oocyst membrane was broken, sporocysts were washed in cold saline A (0.14 M sodium chloride, 0.005 M potassium chloride, 0.004 M sodium bicarbonate, and 0.006 M dextrose in deionized water) and then treated with excystation solution (0.25% trypsin and 0.014 M taurocholic acid in saline A) for 45 min at 41°C to release sporozoites. Excystation fluid was removed by washing three times with cold saline A followed by centrifugation at 16,060 X g for 10 min at 4°C (AccuSpin Micro R, Fisher Scientific). Remaining sporocysts, sporocyst ghosts (empty sporocyst shells), and sporozoites were resuspended in HBSS. Suspensions were examined microscopically (X400, Motic BA300, Motic Instruments, Inc., Richmond, British Columbia, Canada) in 25 nonoverlapping fields; counts were conducted in duplicate. Intact sporocysts and sporocyst ghosts were enumerated, and percent excystation was calculated: [sporocyst ghosts/sporocysts + ghosts] X 100.

In vivo infection. Three-week-old White Plymouth Rock commercial broiler chickens (Moyer’s Hatchery) were fed a commercial feed diet and were used to determine the infectivity of untreated, pressure-treated, and UV-treated E. acervulina. For parts of the UV study on raspberries, oocysts were treated and then shipped overnight, and the birds were inoculated and assessed at the USDA-ARS Animal Parasitic Diseases Laboratory. For the other UV-treated raspberry and basil samples and the HPP study, the birds were inoculated and assessed at the University of Delaware College of Agriculture and Natural Resources farm. Birds were handled and processed identically at each location. Oocysts were used within 48 h of treatment. Up to 10 birds were used per treatment group, and groups were maintained in separate houses. Control groups included a negative control, in which birds were sham inoculated with sterile HBSS, and a positive control group, in which birds were given untreated E. acervulina oocysts by oral gavage. Six days postinoculation, birds were evaluated for weight gain and intestinal lesions (26). Birds were killed by cervical dislocation, and the intestine from the duodenal loop to the end was cut lengthwise to evaluate color, lesions, and diarrhea. The entire intestine was assessed; however, E. acervulina causes lesions primarily in the upper intestine from the duodenal loop to Meckel’s diverticulum. Fecal droppings were collected from the last 24 h and processed for E. acervulina oocysts. Fecal material was suspended in an equal volume of water, stomached for 2 min, mixed with an equal volume of sucrose, and centrifuged at 3,500 X g. The top layer in the tube was removed and washed three times with water, and the concentrated oocysts were enumerated with a hemacytometer.

RESULTS AND DISCUSSION

Permeability and excystation. Eimeria and Cyclospora oocysts are shed unsporulated and sporulate outside the host within 7 to 10 days under favorable environmental conditions (35). The oocyst wall comprises two layers of resistant material, which is protective against external environmental conditions. Both Eimeria and Cyclospora have sporocysts that contain the infective sporozoites within the oocyst. When the sporocysts reach the intestinal tract of the host, the sporocyst wall breaks down and the sporozoites are released. Coccidian oocyst membranes respond to the acidic pH of the stomach or, in the case of Eimeria, the mechanical action of the bird gizzard.

Neither HPP nor UV radiation increased the permeability of the oocyst membrane to methylene blue dye, as observed by microscopy. Less than 4% of UV- or HPP-treated oocysts included methylene blue compared with >90% of heat-killed or freeze-thawed oocysts.

There was no difference in excystation of E. acervulina oocysts in liquid medium treated with HPP (43) or UV light as compared with untreated oocysts. Excystation rates ranged from 85% ± 8% for untreated oocysts alone and 89% ± 8% for oocysts recovered from untreated raspberries or basil. Excystation rates were not significantly different after UV treatment (0 to 261 mW/cm²) and ranged from 94% ± 2% for oocysts treated on the berry or basil leaf and 88% ± 5% for oocysts treated alone at ±116 mW/cm².

Slight differences were observed in oocysts recovered from raspberries; however, this difference was not observed during excystation but rather in the number of sporozoites present before bead beating (Fig. 1). This phenomenon was obvious by microscopy because there was no clumping of sporozoites. There was a visual increase in the number of sporozoites recovered from raspberries compared with oocysts in suspension or those recovered from basil. This phenomenon also was observed upon excystation of HPP-treated raspberries, where >2.2 times the number of sporozoites were recovered from raspberries compared with oocysts in suspension or those recovered from basil. This phenomenon may also be observed upon excystation of HPP-treated raspberries observed after interactions with raspberries may be a combination of factors including pH, flavanoids, and plant phenols. The greater release of sporozoites in the presence of raspberries as compared with other matrices may influence the apparent infectivity of oocysts. This phenomenon may have played a role in the high infectivity associated with ingestion of contaminated raspberries (25). It was previously suggested that the infective dose of C.
**FIGURE 1.** Visible E. acervulina sporocysts before bead beating in samples treated alone or recovered from raspberries. Of 100 fields counted per sample (n = 5), more sporocysts were visible before excystation in samples recovered from raspberries (solid bars) than in samples treated alone (open bars).

C. cayetanensis was low or the number of oocysts per berry was high or both (23); the efficient release of sporocysts may be an additional possibility. This phenomenon may be influenced by the acidity of the raspberries (pH 3.4 ± 0.2).

**In vivo infectivity study.** E. acervulina is the most frequently encountered coccidian in commercial poultry in North and South America (31). The prevalence, size, genome, and life cycle make *E. acervulina* a good surrogate for *C. cayetanensis,* whose oocysts are not readily available and whose evaluation in the laboratory is difficult because of the lack of infection models and assays. The severity of coccidiosis infection can vary with the isolate and with the number of oocysts ingested (31). Ingestion of ≥1,000 oocysts results in lesion scores of 1 or greater on a scale of 1 to 4 (41).

Data from inoculation of UV- and HPP-treated *E. acervulina* are presented in Tables 1 and 2, respectively. The pathogenicity of the oocysts is measured by weight gain and lesion scoring, as first described in 1970 by Johnson and Reid (26). Infection of *F. acervulina* is heaviest at the beginning of the intestine, near the duodenal loop, but all parts of the intestine were evaluated. This lesion pattern is similar to that associated with *Cyclospora* infection in humans (3). Lesions occur at the point of infection. Lesions were scored from 1 to 4, where 4 indicated the most severe lesions based on numbers and size, bleaching of intestinal wall, and other clinical signs (26).

**TABLE 1. Effect of UV treatment of raspberries on the pathogenicity of *E. acervulina***

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Mean wt gain (% of control)</th>
<th>Mean lesion score (scale 1–4)</th>
<th>Fecal oocyst sheddinga</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inoculum, 2 × 10⁶</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HBSS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated oocysts, no raspberries</td>
<td>10</td>
<td>100</td>
<td>0b</td>
<td></td>
</tr>
<tr>
<td>Untreated oocysts recovered from raspberries</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>++</td>
</tr>
<tr>
<td>30 mW/cm², recovered from raspberries</td>
<td>8</td>
<td>51</td>
<td>3</td>
<td>+</td>
</tr>
<tr>
<td>80 mW/cm², recovered from raspberries</td>
<td>5</td>
<td>56</td>
<td>2</td>
<td>+</td>
</tr>
<tr>
<td>160 mW/cm², recovered from raspberries</td>
<td>5</td>
<td>62</td>
<td>2</td>
<td>+</td>
</tr>
<tr>
<td>160 mW/cm², recovered from basil</td>
<td>8</td>
<td>48</td>
<td>2.5</td>
<td>++</td>
</tr>
<tr>
<td>160 mW/cm², no raspberries</td>
<td>5</td>
<td>51</td>
<td>1.5</td>
<td>++</td>
</tr>
<tr>
<td>Inoculum, 2 × 10⁴</td>
<td></td>
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<td></td>
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<tr>
<td>HBSS</td>
<td>10</td>
<td>100</td>
<td>0b</td>
<td></td>
</tr>
<tr>
<td>Untreated oocysts, no raspberries</td>
<td>10</td>
<td>101</td>
<td>3</td>
<td>++</td>
</tr>
<tr>
<td>160 mW/cm², no raspberries or basil</td>
<td>15</td>
<td>85</td>
<td>0b</td>
<td>+d</td>
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<tr>
<td>160 mW/cm², recovered from raspberries</td>
<td>5</td>
<td>108</td>
<td>1.3</td>
<td>+</td>
</tr>
<tr>
<td>160 mW/cm², recovered from basil</td>
<td>8</td>
<td>94</td>
<td>0b</td>
<td>−</td>
</tr>
<tr>
<td>261 mW/cm², recovered from raspberries</td>
<td>8</td>
<td>86</td>
<td>1.75</td>
<td>+</td>
</tr>
<tr>
<td>261 mW/cm², recovered from basil</td>
<td>8</td>
<td>77</td>
<td>0.1</td>
<td>+e</td>
</tr>
</tbody>
</table>

a ++, >10⁵ oocysts per ml; +, <10⁴ oocysts per ml; −, no oocysts detected.
b Healthy gut.
c One bird had a heavier infection and a score of 3, whereas the other three birds had a score of 1.
d Five of these birds shed oocysts, but the other eight birds in a second experiment did not.
e One bird had small lesions, but the other birds showed no signs of infection and <10 oocysts per ml was observed in the fecal sample.
Birds that received HBSS had no signs of infection, did not shed oocysts, and had normal weight gain. Birds that received untreated oocysts had signs of severe infection, including intense coalesced lesions along the intestinal wall and depressed weight gain. The birds received a high dose (2 × 10^6 oocysts) or a low dose (2 × 10^4 oocysts). The low dose allowed better interpretation of lesions because they were observed as individual plaques. In at least one other study (13), lesion scores did not increase linearly with oocyst dose, and low levels of inocula produced high lesion scores. This finding is consistent with our findings in that a lesion score of 3 was observed with the lower challenge dose (Table 2). Light infections may produce little effect on weight gain (31), as seen in the present study. Birds that received UV-treated oocysts had fewer to no lesions and reduced shedding of oocysts, depending on the oocyst inoculum level, UV dose, and food matrix (Table 1). The presence of moderate clinical signs may be due to previous findings that oocysts on raspberries are not all inactivated because of shadowing and the fact that oocysts can be masked by the irregular nature of the raspberry surface (27). UV radiation is effective on outer surfaces; however, oocysts in crevices or in damaged plant tissues would not likely be inactivated by this treatment. Conversely, HPP provides uniform treatment throughout the food matrix regardless of shape and size and may be more consistently reliable for treating contaminated produce. Birds that received HPP-treated oocysts had no lesions, had weight gain comparable to HBSS control birds, and did not shed oocysts. The same pressure conditions used previously to inactivate E. acervulina in laboratory media (43) were also sufficient for inactivation of this organism in raspberries and basil.

Although no formal sensory experiments were conducted in this study, previous research suggests that HPP conditions used to inactivate E. acervulina would not be detrimental to the quality of basil. Pulse-pressure treatment of fresh basil at 700 MPa and 65°C, more extreme conditions than those used to inactivate E. acervulina in the present study, did not compromise fresh basil aroma, color, or major flavor compounds (28). The storage quality of treated raspberries needs to be evaluated because previous research indicated that midrange pressures of 400 and 600 MPa were the least effective for retaining anthocyanin pigments (46), and these same treatment conditions were reported to yield incomplete inactivation of enzymes responsible for anthocyanin degradation (19). UV light has been studied for its use as an alternative to fungicide treatment and as a means to delay microbial spoilage of fruits and vegetables (20). In previous work, UV radiation of plants induced a weak stress response, which in turn enhanced the biosynthesis of phenol compounds (18, 20). Although this reaction could improve the antimicrobial activity of UV light, marked improvement is unlikely at relatively low doses such as those used in this study.

In today’s global economy, much produce is imported into the United States, including the basil and raspberries that were involved in outbreaks of cyclosporiasis (42). Protozoa such as Cyclospora are endemic in many parts of the world, including in the Latin American countries where many herbs, fruits, and vegetables are grown and exported to the United States (21, 24). The sources of contamination in those outbreaks were never identified, but contaminated water may have played a role in some of the cases (4, 24). We do not know the prevalence of coccidia on produce; however, Cyclospora oocysts have been identified on various fruits and vegetables in Peru (36) and in irrigation water and soil from Egypt (15). Foodborne outbreaks have become increasingly more common since the mid-1990s.

The advice given to those individuals who wish to avoid contamination from oocysts on produce is to wash the produce thoroughly before eating it; however, washing might decrease but not eliminate the risk for transmission of Cyclospora (8). Vigorous washing also may damage the integrity of a delicate product such as raspberries. The nonthermal treatments described in this study can help eliminate the risk but still maintain the majority of the fresh qualities of the foods. Although raspberries, basil, and snow peas have been implicated in recent outbreaks, these items were consumed as parts of more complex foods such as pasta salad (8), Italian dipping oil, pesto sauce (22), and raspberry sauces served with slices of cake or lemon tart (24). These food products are examples of how minimally processed produce can easily be included because the textural integrity of the whole berry or leaf is not critical to the quality of the finished products. HPP may decrease the risk of cyclosporiasis infection associated with consumption of basil and raspberries used in sauces and salads. There is a clear need for both postharvest control measures, such as hydrostatic pressure and UV light, and consumer control methods, including limiting cross-contamination, washing produce items, and good personal hygiene.

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