**Quantifying the Reduction in Potential Infection Risks from Non-O157 Shiga Toxin
Producing *E.coli* in Strawberries by Low Dose Electron Beam Processing**

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Abstract

Strawberries are vulnerable to harboring microbial pathogens because they are generally not washed due to their perishable nature. The focus of this study was to quantify the reduction in infection risks associated with non-O157 Shiga toxin producing *E.coli* serotypes contaminated strawberries if the strawberries are exposed to low doses ~ 1 kGy (kiloGray) of electron beam (eBeam) irradiation. A cocktail of six serotypes of non O157 *E.coli* namely, O26:H11, O45:H2, O103:H2, O111:NM, O121:H19, and O145 was employed. Strawberry puree rather than whole strawberries were used in this study to ensure dose uniformity that is critical for accurate interpretation of microbial reduction. The results show that when these serotypes are exposed to ≤ 1 kGy eBeam dose, there is approximately 4-log reduction in their numbers when they are present within a strawberry matrix (puree). Quantitative microbial risk assessments suggest that if a typical strawberry serving (150 g) was heavily contaminated ($\sim 10^5$ CFU/serving size), 2 out of 10 susceptible individuals (20%) would get sick (without eBeam treatment). However, if these contaminated strawberries had been treated with 1 kGy of eBeam dose, the infection risks would have been significantly reduced to approximately 4 out of every 100,000 individuals (0.004%). Similarly, even at low levels of contamination ($\sim 10^2$ CFU/serving), the infection risks would be reduced from 6 out of 10000 susceptible individuals to approximately 4 out of 100 million susceptible individuals.

Keywords: electron beam, non-O157 *E.coli*, strawberries, infection risks, microbial risk assessment

1. Introduction

Strawberries are considered healthy and therefore popular because they are not only tasty but contain an abundance of antioxidants which have demonstrated anticancer properties (*Folmer et al., 2014*). The US is among the world's leading producers of strawberries accounting for about 30% of the world's production (*FAO STAT, 2015*). Approximately 1.3 billion metric tons of strawberries were produced in 2012 with an estimated market value around \$2.2 billion. Given their highly perishable nature, strawberries are, however, neither washed nor a validated pathogen kill-step employed to remove or eliminate microbial pathogens that they may harbor. This inability to adequately wash strawberries increases the likelihood of them being linked to foodborne illnesses. Berries such as strawberries have been attributed to disease outbreaks all around the world involving viral, protozoan, and bacterial pathogens (*CDC, 2012, Miller et al., 2013; Niu et al., 1992*). Infection rates of non-O157 Shiga toxin-producing *E.coli* (non O157 STEC) strains are reported to be as high as that of O157 STEC strains (*Gould et al. 2013*). Non O157 *E.coli* strains were responsible for a number of deaths in Germany when they had entered the food supply chain through contaminated sprouts (*Mora et al., 2011*). The "Big Six" non O157 serotypes namely, O26, O45, O103, O111, O121, and O145 have been identified to be the key disease-causing non O157 strains (*FSIS, 2012*).

Electron beam (eBeam) irradiation is a FDA approved non-thermal ionizing radiation based food processing technology. We and others have already shown that this technology is applicable to increase the shelf-life and inactivate microbial pathogens on fresh produce such strawberries (*Predmore et al., 2015; Espinosa et al., 2012; Sanglay et al., 2011*). The use of ionizing radiation technology is stymied in the US because the FDA has approved the use of ionizing radiation for microbial pathogen reduction only for spinach and lettuce. However, the FDA has

allowed the use of ionizing radiation such as eBeam technology for extending the shelf life of fresh produce, provided that the delivered dose does not exceed 1 kGy (FDA, 2015). We have previously shown that even at low doses (~ 1 kGy), eBeam processing results in extending the shelf life of strawberries when stored under refrigerated conditions (Smith, 2015). Our goal in this study was to obtain empirical evidence about the reduction of infection risks associated with non O157 Shiga toxin producing *E.coli* serotypes on strawberries at a dose already approved by the FDA for “delaying maturation” (i.e., extending shelf life) (FDA, 2015). The FDA does not

2. Material and methods

2.1. Bacterial cultures

The bacterial pathogen serotypes O26:H11, O45:H2, O103:H2, O111: NM, O121:H19, and O145, were obtained from the culture collection of the Food and Feed Safety Research Unit (USDA-ARS FFSRU) in College Station, Texas. These cultures were grown on either Trypticase Soy Agar (TSA) plates or Trypticase Soy Broth (TSB) liquid media at 37 °C for 24 hours. Prior to each experiment, a loop of each strain was individually transferred to TSB and shake incubated at 37°C overnight. The overnight culture was washed using Phosphate-Buffered Saline (PBS) by three consecutive rounds of centrifugation ($3000 \times g$ for 10 min) using a floor-mounted high speed centrifuge. The optical density of the washed cells was measured (using 620 nm absorbance) and standardized to approximately 10^9 CFU/ml. A cocktail of the six non-O157 serotypes were prepared by combining equal aliquots of the six strains. The cell density in the cocktail was adjusted to yield approximately 10^9 CFU/ml.

2.2 Sensitivity of non O157 *E.coli* strains to varying eBeam doses in phosphate buffered saline solution

The objective was to calculate the D-10 value (dose required to achieve 90% reduction in titers) of the different strains. The serotypes O26:H11, O45:H2, O103:H2, O111: NM, O121:H19 were used in this experiment to determine the sensitivity of these strains to eBeam irradiation. Defined concentrations of the different bacterial serotypes were individually exposed to varying eBeam doses. The measured doses ranged from 0.17 kGy to 0.96 kGy. The surviving bacterial concentrations after eBeam exposure (log CFU/mL) were plotted as a function of the measured eBeam dose (kGy). The inactivation of the bacterial pathogens was assumed to be linear (*Hieke & Pillai, 2015*). Linear regression analysis was performed and the negative reciprocal of the slope was calculated to be the D-10 value. The Student's t-test was performed to determine whether there was any statistically significant ($p < 0.05$) difference between the D_{10} values.

2.3. Inoculation of strawberry samples

Fresh strawberries were purchased at a local farmer's market to reduce the likelihood that they were treated with antimicrobial sprays or other disinfectants. These samples were refrigerated prior to the experiments. Preliminary studies showed that attempting to inoculate intact strawberries on the surface or internally were not reproducible. Also, inoculating the surfaces of the strawberries would not be realistic since it is possible that pathogens may be internal to the fruits. Thus, to simulate natural contact of the pathogen to the fruit matrix we used a strawberry "puree". The puree was prepared as follows: twenty five grams of strawberries were placed in sterile Whirl-Pak bags (Whirl-Pak, NASCO, Fort Atkinson, WI) and kneaded by hand to obtain a homogenous puree. One milliliter aliquots of the pathogen cocktail were added to these samples. The bags were sealed and samples were further kneaded to achieve a uniform mixing of the bacterial cells with the fruit matrix. To comply with the university biosafety

regulations, all pathogen -spiked samples were placed in heat-sealed double-bagged Whirl Pak® bags (Nasco, New York, NY). These heat-sealed bags were then placed inside a “specimen transport” bags that were rated up to 95 kPa (Thermosafe, Arlington Heights, IL). Only such triple-bagged samples were permitted to be treated at the commercial scale eBeam facility on campus.

2.4. Electron beam processing

The eBeam processing was performed at the National Center for Electron Beam Research at Texas A&M University using a 10 MeV, 18 kW, linear accelerator. To verify the actual eBeam dose received by the samples, alanine (L- α -alanine pellet) dosimeters (Harwell Dosimeters, Oxfordshire, UK) were used. The alanine dosimetry system that was employed was traceable to international standards. The dosimeters were measured using the Bruker E-scan spectrometer (Bruker, Billerica, MA) to measure the delivered eBeam dose. The target dose was 1.0 kGy. A number of preliminary trials were performed to ensure that the dose was ≤ 1 kGy. The measured doses in these experiments ranged between 0.80 kGy to 1.12 kGy (Table 1). All treatments were conducted in triplicate and repeated three times on separate days. Control (0 kGy) samples were prepared similarly, but were not exposed to eBeam dosing.

2.5. Enumeration of non O157 strains after eBeam exposure

To estimate the numbers of surviving non-O157 strains, the entire content of the eBeam processed sample bags were mixed with 225 ml of PBS in stomacher bags and mixed for 1 minute in a “stomacher” at the medium setting. The sample was serially diluted in PBS and aliquots were plated on TSA plates as well as *E.coli* specific media namely, modified m-TEC agar (m-TEC Agar) (Difco). We chose m-TEC agar and TSA agar rather than relying on non-O157 selective media to avoid possible errors arising from potentially injured cells (from eBeam

exposure) not growing on the selective media. Moreover, m-TEC agar is a standard *E.coli* media approved by the US EPA for isolating and enumerating *E.coli* in environmental samples (EPA, 2002). The plates were incubated for 24 hours at 37 °C. The red/magenta colonies characteristic of *E.coli* cells were enumerated and reported as CFU/g.

2.6. Quantitative microbial risk assessment

We estimated the infection risks that would arise from exposure to non O157 serotype - contaminated strawberries. The reduction in the titers of the non-O157 cocktail when exposed to eBeam dose (≤ 1 kGy) used in this study was used as the basis for calculating the reduction in risks. We assumed a standard strawberry serving size of 150 g (Ashfield-Watt, P.A. 2004). Reduction in infection risks associated with various levels of non O157 serotype contamination loads (on 150 g serving sizes) with and without eBeam irradiation was estimated. The initial non -O157 pathogen titers (per serving size) were assumed to be 10^2 CFU, 10^3 CFU, 10^4 CFU and 10^5 CFU. The infection risks were estimated using the beta-Poisson (modified exponential model) where the defined parameters were $N_{50} = 2.11 \times 10^6$, $\alpha = 0.155$ and serving size = 150 g (CAMRA, 2015; Dupont et al., 1971). We assumed that all the bacterial pathogens were infectious and that all of the exposed individuals were also susceptible to infection.

3. Theory

The underlying hypothesis of this study was that the application of low (~ 1 kGy) eBeam doses on strawberries results in a defined reduction of non O157 *E.coli* strains which translates to a reduction of potential infection risks associated with these pathogens. The objectives of this study were three-folds. The first objective was to determine the sensitivity of selected non-O157 *E.coli* strains to high energy (10 MeV) eBeam irradiation. The second objective was to determine

the reduction of these pathogens in a strawberry matrix; the third objective was to quantify the reduction in infection risks achievable if contaminated strawberries were processed using eBeam irradiation at the low dose (1 kGy). We employed laboratory inoculations of a cocktail containing the following Shiga toxin producing *E.coli* strains namely, O26:H11, O45:H2, O103:H2, O111: NM, O121:H19, and O145.

4. Results

The D-10 values for the five non O157 *E.coli* strains (O26:H11, O111:NM, O45:H2, O101:H2, and O121:H19) when exposed to eBeam irradiation in phosphate buffered saline solution were 0.119 ± 0.005 , 0.074 ± 0.005 , 0.071 ± 0.006 , 0.006 ± 0.002 , and 0.142 ± 0.012 respectively. Based on the Student's t test ($\alpha = 0.05$), there was no significant difference (in the D-10 value among the five strains. Table 1 shows the reduction of the non-O157 *E.coli* strains in the strawberry puree after exposure to 1 kGy eBeam dose. Over 4-log reduction (average 4.23 log reduction based on inactivation observed using the two media) of non-O157 serotype cocktail was observed at this low eBeam dose. Table 2 shows the reduction of infection risks if strawberries contaminated with non-O157 *E.coli* serotypes are processed at low (~ 1 kGy) eBeam doses. If the strawberries were contaminated at 100 CFU per serving size, the infection risks without eBeam irradiation would be approximately 6 persons out of every 10,000 susceptible individuals (0.06%). However, if these same strawberries are treated with ~ 1 kGy eBeam dose, the infection risks are significantly reduced to only approximately 4 persons out of every 100 million individuals. Table 2 also shows that if the strawberries are heavily contaminated (~ 10^5 CFU/serving size), 2 out of 10 susceptible individuals (20%) would get sick (without eBeam treatment). However, if these heavily contaminated strawberries are treated with 1kGy of eBeam

dose, the infection risks would be significantly reduced to approximately 4 out of every 100,000 individuals (0.004%).

5. Discussion

Strawberries are of significant economic value to US agriculture with an estimated value of around \$ 2.4 billion. However, this commodity is highly perishable and therefore no traditional pathogen kill step can be employed. Given their growing practices, they are therefore vulnerable to microbial contamination and since no wash step or pathogen kill-step is employed they are prime suspects in a number of foodborne illness outbreaks (*Olaimat and Holley, 2012*). Non-thermal technologies such as eBeam processing are suitable for highly perishable commodities such as lettuce and spinach (*Espinosa et al., 2012*). The FDA has approved the use of eBeam and other ionizing radiation technologies for use with fresh foods such as strawberries (*FDA, 2015*).

To make this study relevant to the commercial strawberry industry we focused at the FDA approved dose of 1 kGy (maximum). The primary reason we employed strawberry puree rather than intact strawberries was that it was critical that the dose be uniform in this experiment. If whole strawberries were employed, there would have been differences in the dose distribution on the berries and this difference could have significantly skewed the interpretation of the results. During commercial processing, however, the expected reduction of the pathogen should be based on the minimum dose measured within the package of intact strawberries rather than the maximum (1 kGy) dose. The eBeam facility on the Texas A&M University campus routinely treats whole fresh fruits like guavas and mangoes with doses between 400 Gy and 1kGy to meet phytosanitary regulations and to delay maturation. We have recently reported that that eBeam at ~ 1 kGy can extend the shelf-life of strawberries without negatively impacting its sensory of

consumer acceptability (*Smith et al., 2015*). The D-10 value of non O157 *E.coli* strains have been reported previously (*Li et al., 2015; Kundu et al., 2014*). They reported values ranging between 0.090 kGy and 0.127 kGy. In this study we obtained a D-10 value of 0.068 kGy in phosphate buffered solution. This should have translated to greater than 10 log reduction in strawberries. The reason we observed only a 4.23 log reduction of these pathogens in the strawberry puree reflects the differences in response of microorganisms to ionizing radiation depending on the surrounding matrix. It is well known that the presence of free water molecules enhances the inactivation kinetics. A number of different hypotheses have been proposed for the reduced inactivation of microorganisms in matrices that contain non aqueous compounds as compared to pure water or buffer solutions. These include the possible free radical scavenging effect of organic compounds (*Shenoy et al., 1975*), reduced radiolysis of water molecules (*Song et al., 2009*) and antioxidant activity of phenolic compounds present in strawberries (*Wang & Lin, 2000; Heinonen et al., 1998*).

The FDA has regulations in place currently for labeling irradiated foods such as fresh strawberries. Presently, if this technology is used for strawberries, all retail packages (at point of sale) should display the radura symbol with the phrase, “treated by irradiation for food safety” or “treated by irradiation for shelf-life extension” clearly indicated. Even though this study has shown that 1 kGy eBeam dose results in significant collateral reduction of pathogenic non-O157 *E.coli* strains, the labeling cannot state, “treated by irradiation for food safety” since the FDA has permitted the use of doses up to 1 kGy for “delay of maturation” purposes only. Nevertheless, this delay of maturation (ie., extension of shelf life) will be accompanied by a defined reduction in public health risks if this technology is adopted.

6. Conclusions

This study has shown that even at a low eBeam dose such as 1 kGy, at least a 4-log reduction of non O157 Shiga toxin producing *E.coli* serotypes can be achieved in a strawberry matrix. The significance of achieving this level of bacterial pathogen reduction in fresh produce such as strawberries is that it translates to significant reduction in potential infection risks.

Demonstrating the reduction in infection risks with 1 kGy eBeam dose allow decision makers to manage public health risks and in communicating the value of this technology to consumers as well as decision makers the in fresh produce industry or government.

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References

- Ashfield-Watt, P. A., Welch, A. A., Day, N. E., & Bingham, S.A. (2004). Is 'five-a-day' an effective way of increasing fruit and vegetable intakes?, Public Health Nutrition, 7(2): 257-261.
- CAMRA, Center for Advancing Microbial Risk Assessment. (2015). http://qmrawiki.canr.msu.edu/index.php?title=Dose_Response_
- Centers for Disease Control and Prevention (CDC), (2012). Multistate Outbreak of Shiga Toxin-producing *Escherichia coli* O26 Infections Linked to Raw Clover Sprouts at Jimmy John's Restaurants, <http://www.cdc.gov/ecoli/2012/O26-02-12/index.html>
- DuPont, H. L., Formal S. B., Hornick, R.B., Snyder, M.J., Libonati, J.B., Sheahan, D.G., LaBrec, E.H. & Kalas, J.P. (1971). Pathogenesis of *Escherichia coli* diarrhea. *New England Journal of Medicine*, 285, 1-9.

259 EPA Method, (2002). Method 1603: *Escherichia coli* (*E. coli*) in water by membrane filtration
 260 using modified membrane-thermotolerant *Escherichia coli* Agar (Modified mTEC), Washington
 261 DC, EPA-821-R-09-007.

262 Espinosa, A. C., Jesudhasen, P., Arredondo, R., Cepeda, M., Mazari-Hiriart, M., Mena, K. D., &
 263 Pilai, S. D. (2012). Quantifying the reduction in potential health risks by determining the
 264 sensitivity of Poliovirus type 1 chat strain and Rotavirus SA-11 to electron beam irradiation of
 265 iceberg lettuce and spinach. *Applied and environmental microbiology*, 78, 4, 988.

266 FAO STAT, (2015). <http://faostat3.fao.org/home/E>. Accessed May 14, 2015

267 FDA, (2015). Federal Register, CFR 179.26 [http://www.ecfr.gov/cgi-bin/text-](http://www.ecfr.gov/cgi-bin/text-idx?SID=2c4e58481ca8b6ba26e94304f940150c&node=pt21.3.179&rgn=div5)
 268 [idx?SID=2c4e58481ca8b6ba26e94304f940150c&node=pt21.3.179&rgn=div5](http://www.ecfr.gov/cgi-bin/text-idx?SID=2c4e58481ca8b6ba26e94304f940150c&node=pt21.3.179&rgn=div5). Accessed May
 269 14, 2015

270 Folmer, F., Basavaraju, U., Jaspars, M., Hold, G., El-Omar, E., Dicato, M., & Diederich, M.
 271 (2014). Anticancer effects of bioactive berry compounds. *Phytochemistry Reviews*, 13, 295–322.

272 FSIS, (2012). Food Safety and Inspection Service, Risk Profile for Pathogenic Non-O157 Shiga
 273 Toxin-producing *Escherichia coli*, Office of Public Health Science, Office of Policy and
 274 Program Development, Food Safety and Inspection Service, United States Department of
 275 Agriculture, Washington, DC.

276 Gould, L. H., Mody, R. K., Ong, K. L., Clogher, P., Cronquist, A. B., & Garman, K. N. (2013).
 277 Increased recognition of non-O157 Shiga toxin-producing *Escherichia coli* infections in the
 278 United States during 2000-2010: epidemiologic features and comparison with *E.coli* O157
 279 infections. *Foodborne Pathogens and Disease*, 10, 435-460.

280 Heinonen, I. M., Meyer, A. S., & Frankel, E. N. (1998). Antioxidant activity of berry phenolics
 281 on human low-density lipoprotein and liposome oxidation. *Journal of Agricultural and Food*
 282 *Chemistry*, 46, 4107–4112.

283 Hieke, A. S. C., & Pillai, S. D. (2015) Attenuation of 10 MeV electron beam energy to achieve
 284 low doses does not impact *Salmonella* spp. Inactivation kinetics. *Radiation Physics and*
 285 *Chemistry*, 110, 38-41.

286 Kundu, K., Gill, A., Lui, C., Goswami, N., & Holley, R. (2014). Use of low dose e-beam
 287 irradiation to reduce *E. coli* O157:H7, non-O157 (VTEC) *E. coli* and *Salmonella* viability on
 288 meat surfaces. *Meat Science*, 96, 1, 413-418.

289 Li, S., Kundu D., & Holley, R. A. (2015). Use of lactic acid with electron beam irradiation for
 290 control of *Escherichia coli* O157:H7, non-O157 VTEC *E. coli*, and *Salmonella* serovars on fresh
 291 and frozen beef. *Food Microbiology*, 46, 34-39.

292 Miller, B. D., C. E. Rigdon, T. J. Robinson, C. Hedberg, & K. E. Smith. (2013). Use of global
 293 trade item numbers in the investigation of a *Salmonella* Newport outbreak associated with
 294 blueberries in Minnesota, 2010. *Journal of Food Protection*, 76, 5, 762–769.

295 Mora, A., Herrera, A., López, C., Dahbi, G., Mamani, R., Pita, J. M., Alonso, M. P., Llovo, J.,
 296 Bernárdez, M. I., Blanco, J. E., Blanco, M., & Blanco, J. (2011). Characteristics of the Shiga-
 297 toxin-producing enteroaggregative *Escherichia coli* O104:H4 German outbreak strain and of
 298 STEC strains isolated in Spain. *International Microbiology*, 14, 3, 121-41.

299 Niu, M. T., L. B. Polish, B. H. Robertson, B. K. Kanna, B. A. Woodruff, C. N. Shapiro, M. A.
 300 Miller, J. D. Smith, J. K. Gedrose, M. J. Alter, & H. S. Margolis. (1992). Multistate outbreak of
 301 hepatitis A associated with frozen strawberries. *The Journal of Infectious Diseases*, 166, 3, 518–
 302 524.

303 Olaimat, A. N., & Holley, R. A. (2012). Factors influencing the microbial safety of fresh
 304 produce: a review. *Food Microbiology*, 32, 1–19.

305 Predmore, A., Sanglay, G.C., DiCaprio, E., Li, J., Uribe, R. M., & Lee, K. (2015).
 306 Electron beam inactivation of Tulane virus on fresh produce, and mechanism of inactivation of
 307 human norovirus surrogates by electron beam irradiation. *International Journal of Food*
 308 *Microbiology*, 198, 28-36.

309 Sanglay, G. C., Li, J., Uribe, R. M., & Lee, K. (2011). Electron-beam inactivation of a norovirus
 310 surrogate in fresh produce and model systems. *Journal of Food Protection*, 74, 7, 1155-1160.

311 Shenoy, M. A., Asquith, J. C., Adams G. E., Michael, B. D., & Watts, M. E. (1975). Time-
 312 resolved oxygen effects in irradiated bacteria and mammalian cells: a rapid-mix study. *Radiation*
 313 *Research*, 62, 498–512.

314 Smith, B. R. (2015). Electron beam processing of hospital foods. In S. D. Pillai, & S. Shayanfar
315 (Eds.), *Electron beam pasteurization and complementary food processing technologies*, Elsevier,
316 (pp. 221—229). Woodhead Publishing.

317 Song, H. P., Kim, B., Jung, S., Choe, J. H., Yun, H. J., Kim, Y. J., & Jo, C. (2009). Effect of
318 gamma and electron beam irradiation on the survival of pathogens inoculated into salted,
319 seasoned, and fermented oyster. *LWT - Food Science and Technology*, 42, 1320-1324.

320 Wang, S.Y., & Lin, H.S. (2000). Antioxidant activity in fruit and leaves of blackberry, raspberry,
321 and strawberry varies with cultivar and developmental stage. *Journal of Agricultural and Food*
322 *Chemistry*, 48, 140–146.

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Table 1: Inactivation of a cocktail of non O157 *E.coli* serotypes (O26:H11, O45:H2, O103:H2, O111: NM, O121:H19, and O145) on strawberries and exposed to 1 kGy electron beam (eBeam) dose. The samples were plated on either Trypticase Soy Agar or m-TEC media

Measured	TSA	m-TEC
eBeam Dose (kGy)	(Log CFU/g)*	(Log CFU/g)*
Control (0 kGy)	9.34± 0.15	9.48 ± 02
0.95 kGy**	5.23± 0.23	5.14± 0.10
Mean reduction	4.23 log	

*The values shown are mean ± standard deviation based on n=3 independent trials with each trial having 3 replications

**Mean of the 3 measured dose obtained during the experiments

Table 2. Risks of infection associated with consuming strawberries contaminated with non O157 Shiga toxin producing *E.coli* with and without eBeam (≤1 kGy) processing

Initial <i>E.coli</i> Concentration CFU/serving (before treatment)	Infection Risks Without eBeam Irradiation	Final <i>E.coli</i> Concentration CFU/serving (after 1.0 kGy treatment*)	Infection Risk Reduction With eBeam Irradiation
100,000	2.2×10^{-1}	5.89	3.7×10^{-5}
10,000	5.2×10^{-2}	0.589	3.7×10^{-6}
1,000	6.2×10^{-3}	0.0589	3.7×10^{-7}
100	6.3×10^{-4}	0.00589	3.7×10^{-8}

Assuming *E. coli* exposure; strawberry serving size = 150 grams

*Log-reduction of 4.23 assumed