Efficacy of a UV-C Device to Control Environmental Contamination in a Meat Processing Facility

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Objective: Determine the efficacy of a UV-C Device to Control Environmental Contamination in a Meat Processing Facility with different exposure times.

Introduction: Food processing companies invest significant resources into controlling environmental contamination. With manufacturers of ready-to-eat (RTE) foods, an important concern is the control of *Listeria monocytogenes*. Both the US Food and Drug Administration and the USDA Food Safety and Inspection Service have a "zero tolerance" for *L. monocytogenes* in RTE foods. That is, if a regulatory sample tests positive for the bacterium, the product must to be recalled.

L. monocytogenes is well documented as an environmental bacterium. It is easily destroyed by common sanitation practices and chemicals, but is capable of growing and surviving in environments which can be difficult to clean. Because of this, the food industry is always looking at better ways of controlling environmental contamination in processing areas, especially in those which handle RTE foods. Although there is no regulatory standard for surviving microbial populations on food processing equipment after sanitation, the food processing industry often uses a standard of either 100 or 60 ($\log_{10}$ 2.0 or $\log_{10}$ 1.78) colony forming units/cm^2. The disinfecting properties of Ultraviolet light are well known, but the practical application of the technology in food processing environments has often been difficult. This study evaluates the efficacy of a small UV instrument to reduce environmental contamination in a meat processing environment.

Methods:

Cultures and Inoculation: Ground beef was mixed with sterile buffered peptone water (BPW) in a 1:2 ratio (1 part meat, 2 parts BPW). The mixture was allowed to incubate overnight at ambient temperature, approximately 22^{o}C. After incubation, a foam paint brush was used to apply the broth to a section of floor tile, 30 x 30 cm, in the Experimental Meat Processing laboratory. The inoculated broth was allowed to dry overnight at 10^{o}C. Two hours prior to the application of the UV intervention, a second layer of the inoculated broth was applied to the same area and allowed to dry.

UV Application: The UVC instrument was positioned at approximately 2 meters directly above the inoculated floor tile. The distance from the light source to the inoculated floor tile was 2 meters. The unit was operated following the manufacturer's instructions for 30, 60 and 120 minute exposure periods.

Sample Analysis: Prior to operating the unit, a 10 cm x 10 cm area of the floor was swabbed with a sterile sponge moistened with BPW, to establish a control sample. When the exposure time was completed, a second 10 x 10 cm area was swabbed, separate from the original area. The samples were analyzed by pour plating on trypticase soy agar and incubating at room temperature for 72 hours.

Statistical Analysis: The experiment was independently replicated twice with two technical replications within each independent replication. The populations were transformed to $\log_{10}$, and the $\log_{10}$ reductions were calculated by subtracting the $\log_{10}$ population after treatment from the initial $\log_{10}$ population prior to treatment (control sample). The reductions were then analyzed with Winks SDA ver. 7.0 (Texasoft, Cedar Hill, TX). The data were modeled using the analysis function of SigmaPlot ver 13 (San Jose CA).

Results and Discussion:

The $\log_{10}$ reductions in colony forming units/cm^2 are summarized in Table 1, and the original experimental data is given in Appendix 1. Increasing the exposure time increased the $\log_{10}$ reduction, although the magnitude of reduction was greatest between the 30 and 60 minute exposure times. Increasing the exposure time from 60 to 120 minutes resulted in an increased $\log_{10}$ reduction, but of a smaller magnitude than seen between 30 and 60 minutes.

Once graphed, the results indicated that the curve generally followed a two parameter Exponential Rise to Maximum (Fig. 1). Although not a perfect fit, the resulting mathematical model could be used to estimate the necessary exposure time, if the initial population was known. For example, if it was known that the environmental contamination did not exceed 1000 cfu/cm^2 ($\log_{10}$ 3.0), then the exposure time required to achieve a minimum 3 $\log_{10}$ reduction could be calculated. In this example, approximately 55 minutes.

The reductions are consistent with the effects of UV irradiation on a mixed microbiome. Many bacteria are sensitive to UV irradiation, and are destroyed rapidly. This accounts for the large increase observed between the 30 and 60 minute exposure times. However, as the most sensitive bacteria are eliminated from the population, the surviving population is of course more resistant. Because the most sensitive bacteria are eliminated after a 60 minute exposure, the surviving population shows a smaller reduction between 60 and 120 minutes, as it consists of bacteria which are inherently more resistant to UV.

Table 1. Log_{10} reductions and percentage reductions of aerobic bacteria on inoculated floor tile as affected by exposure time.

Exposure Time (minutes)	Log_{10} Reduction ($cfu/cm^{2)}$	Percent Reduction
30	1.70[A] (0.42)	98.00
60	3.69 (0.89)	99.98
120	4.42 (0.20)	99.99

A Mean (standard deviation)

Figure 1. Reduction of aerobic bacterial populations on floor tiles inoculated with ground beef broth as effected by exposure time.

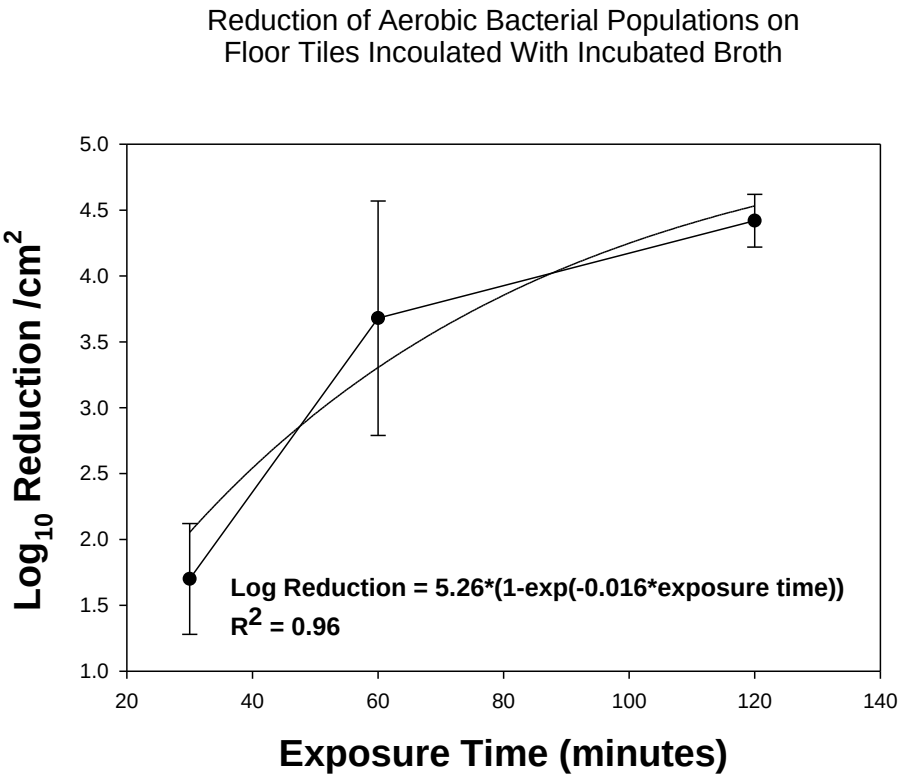
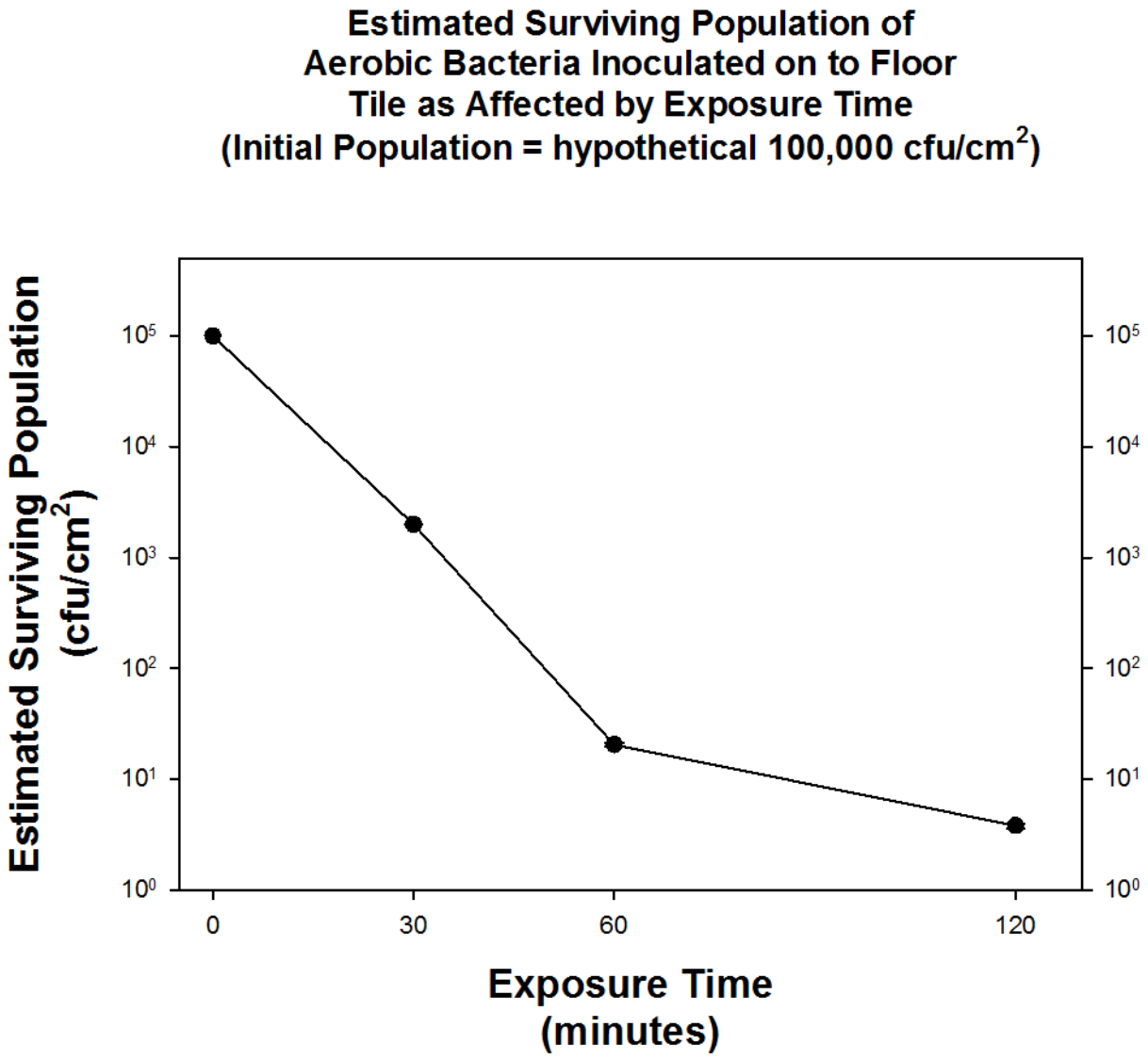


Figure 2. Estimated Surviving population of aerobic bacterial populations on floor tiles inoculated with ground beef broth as effected by exposure time, with a hypothetical initial population of 100,000 (log_{10} 5.0) colony forming units/cm^2.



Appendix 1. Experimental data of $\log_{10}$ reductions of aerobic bacteria on inoculated floor tile as affected by exposure time.

Replication	Exposure Time	Initial Population	Difference initial - final
1	30	3.1	1.4
1	30	4.7	2.0
4	60	6.3	4.8
4	60	5.7	4.0
5	60	6.1	2.8
5	60	5.9	3.2
5	120	7.1	4.3
5	120	6.8	4.6
6	120	5.6	4.6
6	120	5.5	4.2

Appendix 2. Statistical analysis of log10 reductions of aerobic bacteria on inoculated floor tiles.

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WINKS 7.0.9 PROFESSIONAL Edition                          January 15,2017
   ------------------------------------------------------------------------
-
   Independent Group Analysis                C:\Users\dicks\Desktop\temp.SDA
   ------------------------------------------------------------------------
-

   Grouping variable is VAR3
   Analysis variable is VAR5

   Group Means and Standard Deviations
   ----------------------------------
   30.00:  mean = 1.7            s.d. = .4243            n =  2
   60.00:  mean = 3.6925         s.d. = .8956            n =  4
   120.00:  mean = 4.42          s.d. = .202             n =  4


   Analysis of Variance Table

   Source              S.S.        DF             MS      F         Appx P
   ------------------------------------------------------------------------
-
   Total              12.65        9
     Treatment         9.94         2           4.97   12.85        0.0045
     Error             2.71        7          .38695

   Error term used for comparisons = .39 with 7 d.f.

                                                                   Critical q
   Newman-Keuls Multiple Comp.        Difference   P     Q          (.05)
   ------------------------------------------------------------------------
   Mean(120.00)-Mean(30.00) =              2.72   3      7.14       4.165 *
   Mean(120.00)-Mean(60.00) =            0.7275   2     2.339       3.344
   Mean(60.00)-Mean(30.00) =             1.9925   2     5.231       3.344 *

   Homogeneous Populations, groups ranked

   Gp  1  refers to VAR3=30.00
   Gp  2  refers to VAR3=60.00
   Gp  3  refers to VAR3=120.00

                 Gp Gp Gp
                  1  2  3
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   This is a graphical representation of the Newman-Keuls multiple
comparisons
   test. At the 0.05 significance level, the means of any two groups
   underscored by the same line are not significantly different.
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Simultaneous 95% Confidence Limits

Significant comparisons based on Conf. Limits indicated by ***.
CI uses Tukey-Kramer procedure. P-values reflect a Bonferroni adjustment.
Error term used = .39 with 7 d.f.

Group Comparison	Difference	p-value	Simultaneous 95% Confidence Limits	
Mean(120.00)-Mean(30.00) =	2.72	0.004	(1.1335, 4.3065)	***
Mean(120.00)-Mean(60.00) =	0.7275	0.426	(-0.3126, 1.7676)	
Mean(60.00)-Mean(30.00) =	1.9925	0.023	(0.7187, 3.2663)	***

Note: Because different multiple comparisons procedures are based on different
methods, they may not completely agree for marginally significant comparisons.