THE FEASIBILITY OF USING HOUSEHOLD STEAM CLEANERS TO CONTROL MICROBIAL QUALITY OF ANIMAL CARCASSES IN SMALL AND VERY SMALL MEAT PROCESSING PLANTS

A Final Progress Report to USDA FSIS

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Phase I - Laboratory Studies

Methodology

Three different commercial household steam or steam/vacuum cleaning systems, S1, S2, and S3 (Figure 1), were purchased from two different suppliers (Table 1). Each cleaning system differed from the others in their technical parameters (Table 1). System-1 (S1) was a household steam cleaner with a high steam capacity power of 1,500 W. System-2 (S2) used a combination of steam (1,000 W) and vacuum (800 W), producing a high temperature steam (248^{o}F) at 58 psi (4 bars), whereas, system-3 (S3) was a vapor cleaning system with the highest capacity of 1,600 W, producing low moisture steam at high pressure (85-95 psi).

A

B

C

FIGURE 1: Household steam cleaners used in the study. A). Cleaner S1- Steam Fast SF 275; B). Cleaner S2 – Steam Fast SF850; and 3). Cleaner 3 – Super Vapor 6.

Table 1. Detailed information on the household steam cleaners used in the study.

Steam Cleaner	Supplier	System	Specification	Cost	Meat Surface Temperature after 30 sec	Meat Surface Temperature after 180 sec
S1 SF 275	Top Innovations	steam	1,500W	$149.99	45^{o}C	87^{o}C
S2 SF 850	Top Innovations	steam vacuum	1, 000W & 248^{o}C 800 W & 58 psi	$899.99	33^{o}C	71^{o}C
S3 Super vapor 6	Vapor Systems	vapor	1,600W &85-95 psi	$1495.00	27^{o}C	66^{o}C

Blocks of pork skins (7 X 3.5 cm^2), inoculated with a 5 strain-mixture of *Escherichia coli* O157:H7 or *Listeria monocytogenes* at 10^7 and 10^5 CFU/10 cm^2, respectively, were divided into three groups with 12 inoculated pork skin pieces in each group. Each group of the pork skin blocks was treated with S1, S2, or S3 for 30, 60, 90, 120, 150, and 180 sec, respectively, and the treatment was duplicated at each time interval. Each trial was conducted twice and during each trial, two inoculated pork skin pieces were run as positive controls which were not subjected to any steam or steam/vacuum treatment. Additionally, two skin pieces not inoculated with the pathogens were run as negative controls. All of the samples were transferred, following the steam treatment, to a bucket of ice for immediate chilling.

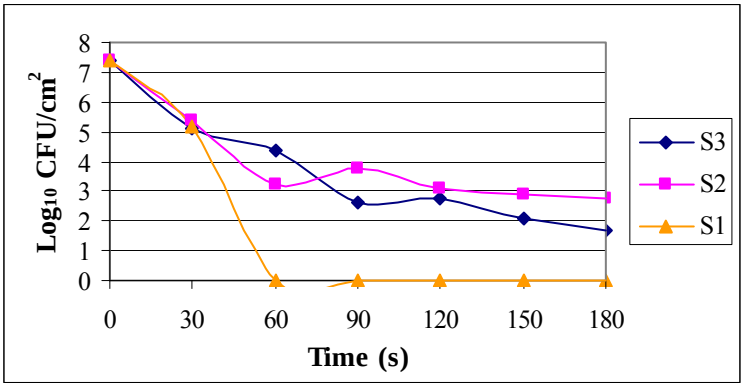
The treated pork skins were sampled by aseptically excising the 5 X 2 cm^2 inoculated area with a sterile pair of scissors. Each of the skin samples were aseptically transferred to a sterile sampling bag containing 10 ml of sterilized maximum recovery diluent (MRD). The contents of the bag were subjected to stomaching for 1 min at normal speed using a Stomacher 400 lab blender. Serial dilutions were prepared using sterilized MRD. A 50 µl of appropriate dilutions was plated in duplicate onto sorbitol MacConkey agar (SMAC) with Cefixime-Tellurite (CT) supplement (Dynal biotech, Oslo, Norway; CT-SMAC), Oxford medium base with modified Oxford antimicrobial supplements (MOX), tryptic soy agar (TSA), and MacConkey (MAC) agar plates, respectively for the enumeration of *E. coli* O157:H7, *L. monocytogenes*, total aerobes, and thermoduric bacteria, respectively, using the Autoplate® 4000 automated spiral platter. The inoculated plates were incubated under appropriate conditions before colonies were counted using the **Q***COUNT*™ automatic colony counter (**Q***COUNT*™ software, Spiral Biotech, Bethesda, MD, USA). All media used in the study were purchased from Difco Laboratory (Sparks, MD) unless otherwise specified. Data obtained was analyzed statistically based on a 95% confidence level.

The surface temperatures of the pork skin pieces, while receiving the steam treatment from S1, S2, or S3, were recorded using a traceable dual channel thermometer with offsets (Fisher Scientific). Each channel was connected *via* K-type beaded probes which are designed to measure the surface temperature. Both probes were attached to the pork skin surfaces and temperature readings were recorded for each treatment time and for all three steam systems. The temperature readings were plotted as a function of steam time.

Results

The application of steam and steam/vacuum generated by S1, S2, and S3, respectively caused a reduction in the populations of *E. coli* O157:H7 up to 7.38, 4.85, and 5.79 Log_{10} CFU/cm^2 (P<0.05), respectively, with a treatment time of 60, 180, or 180 sec at the 10^7 CFU/10 cm^2 inoculation level (Figure 2A). Whereas, at the 10^5 CFU/10 cm^2 inoculation level, the reduction in *E. coli* O157:H7 populations caused by S1, S2, and S3, respectively, was 5.70, 5.70, and 5.45 Log_{10}CFU/cm^2 (P<0.05), respectively, with a treatment time of 150, 150, or 180 sec (Figure 3A).

A



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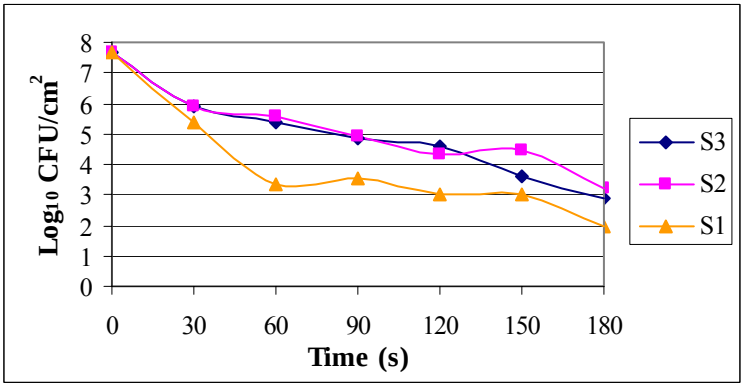

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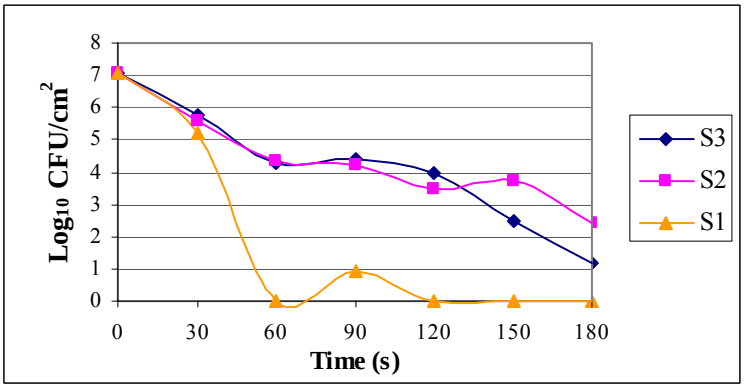
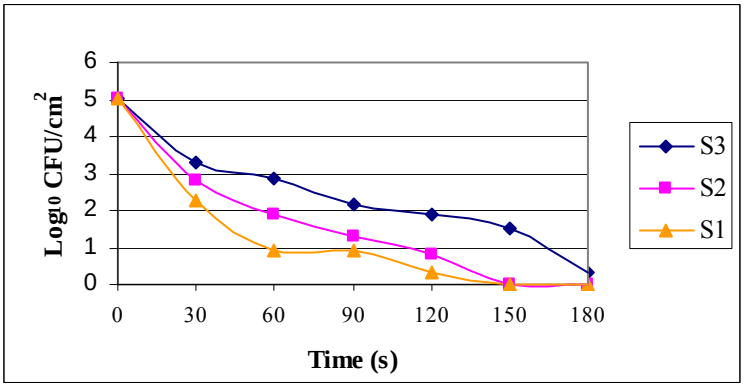


FIGURE 2. Survival of *E. coli* O157:H7 (A), total aerobes (B), and thermoduric bacteria (C) on pieces of pork skins (5 X 2 cm^2), inoculated with approximately 7 Log_{10} CFU/10 cm^2 of *E. coli* O157:H7, as influenced by 30, 60, 90, 120, 150, or 180 sec of steam or steam/vacuum treatment with the household cleaning system S1 (▲), S2 (■), and S3 (♦).

A



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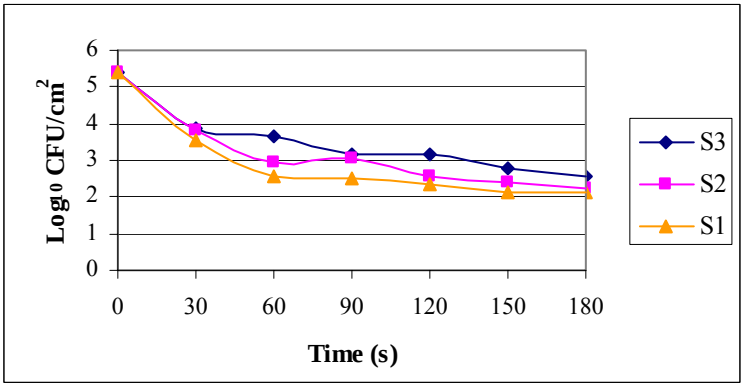

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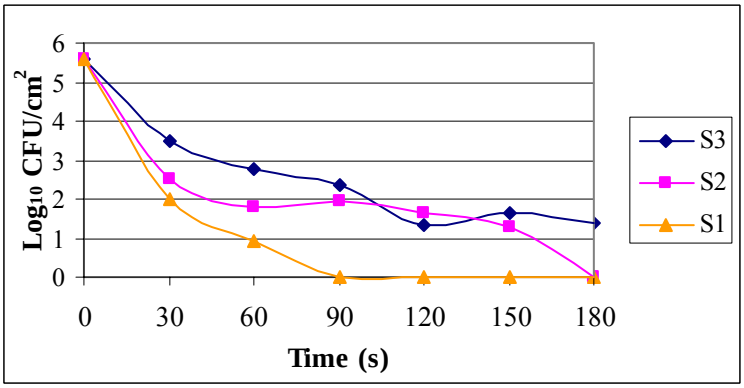

FIGURE 3. Survival of *E. coli* O157:H7 (A), total aerobes (B), and thermoduric bacteria (C) on pieces of pork skins (5 X 2 cm^2), inoculated with approximately 5 Log_{10} CFU/10 cm^2 of *E. coli* O157:H7, as influenced by 30, 60, 90, 120, 150, or 180 sec of steam or steam/vacuum treatment with the household cleaning system S1 (▲), S2 (■), and S3 (♦).

The application of steam, generated by the three household cleaners, for 180 s caused a reduction in the populations of *L. monocytogenes* up to 7.61, 6.91, and 5.78 $Log_{10}CFU/cm^2$, respectively, from the initial level of inoculation of 10^7 CFU/10 cm^2 (Figure 4A). The same treatment resulted in a reduction of 5.75, 4.04, and 3.23 $Log_{10}CFU/cm^2$, respectively, on the pork skin samples having an initial *Listeria* population of 10^5 CFU/10 cm^2 (Figure 5A).

A similar reduction trend was observed with total aerobic and thermoduric bacteria counts on pork skin inoculated with *E. coli* O157:H7 (Figure 2B, 2C, 3B and 3C) and *L. monocytogenes* (4B, 4C, 5B and 5C) at both 10^7 and 10^5 CFU/10 cm^2 inoculation levels. Significant differences were observed between different inoculation levels (10^7 and 10^5 CFU/10 cm^2), treatment times (30, 60, 90, 120, 150, and 180 sec), and types of cleaning systems (S1, S2, and S3) used in the study ($P<0.05$). These results indicated that the evaluated household cleaning systems effectively reduced the levels of both pathogenic and spoilage microorganisms under the tested laboratory conditions.

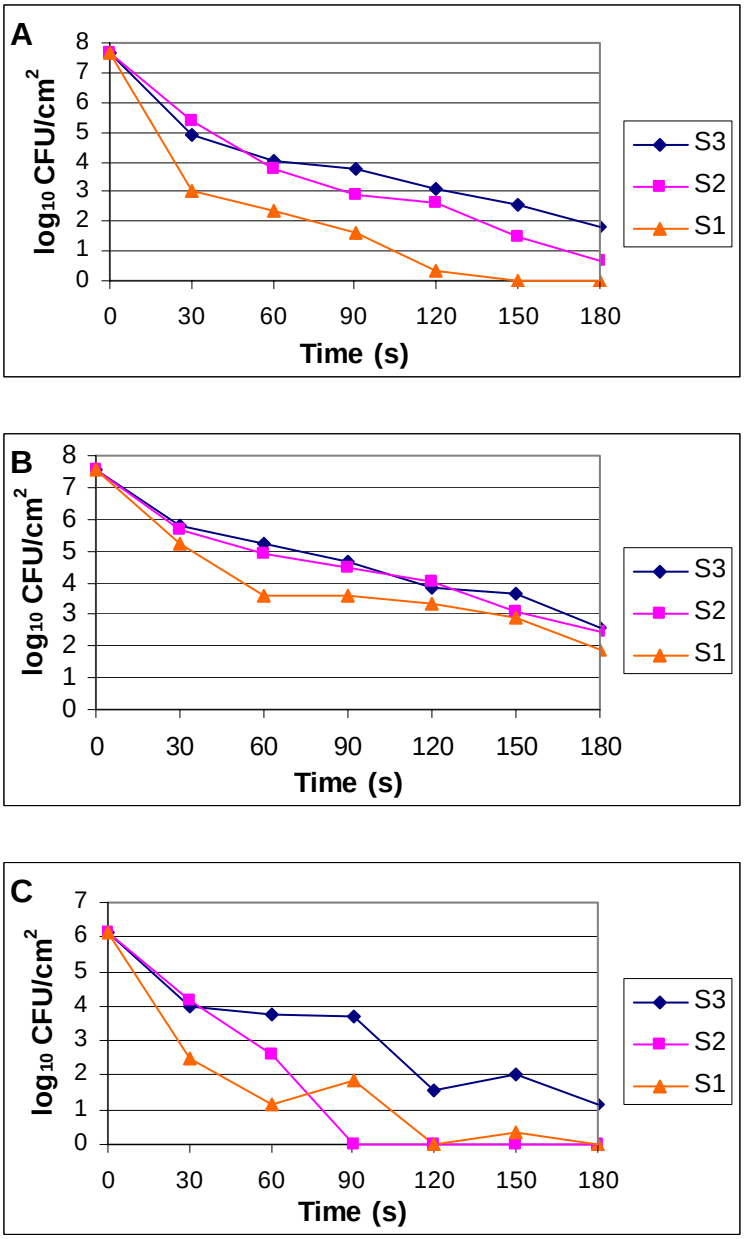

FIGURE 4. Mean populations of (A) *L. monocytogenes*, (B) total aerobes, and (C) thermoduric bacteria recovered from pork skin samples, inoculated with 7 Log_{10} CFU/10 cm^2 of *L. monocytogenes*, after treatment with steam or steam/vacuum for 0, 30, 60, 90, 120, 150, or 180 sec using three household cleaning systems S1(▲), S2(■) or S3(♦).

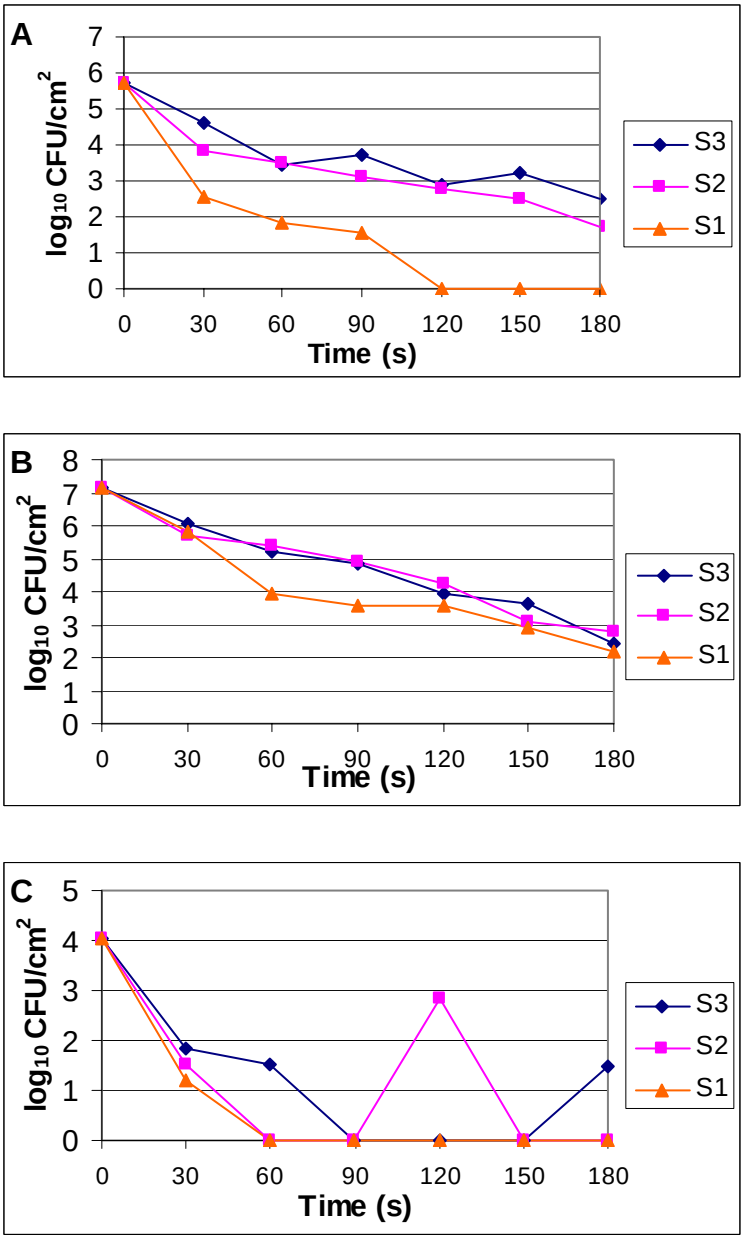

FIGURE 5. Mean populations of (A) *L. monocytogenes*, (B) total aerobes, and (C) thermoduric bacteria recovered from pork skin samples, inoculated with 5 Log_{10} CFU/10 cm^2 of *L. monocytogenes*, after treatment with steam or steam/vacuum for 0, 30, 60, 90, 120, 150, or 180 sec using three household cleaning systems S1(▲), S2(■) or S3(♦).

The surface temperatures of the pork skin while receiving treatment of steams generated by the three cleaning systems are summarized in Figure 6. The skin samples treated by S1 had relatively higher surface temperatures in comparison to the samples treated by S2 and S3, and the samples treated by S2 had relatively higher surface temperatures than the samples treated by S3. The surface temperatures of pork skin samples correlated with the results of microbial inactivation studies, in which S1 had superior performance to the other two cleaning systems. The increases in pork skin surface temperatures obtained by S1, S2, and S3 were in order of 45°, 33° and 27°C, respectively in the first 30 sec of steam treatment (Figure 6). At the end of the 180 sec treatment, the surface temperatures of the pork skin samples treated by S1, S2, and S3 elevated to 87°, 71°, and 66°C, respectively. Because of its better ability in raising meat surface temperatures, S1 was selected for inactivation of pathogenic and spoilage microorganisms on animal carcasses in small and very small meat processing plants.

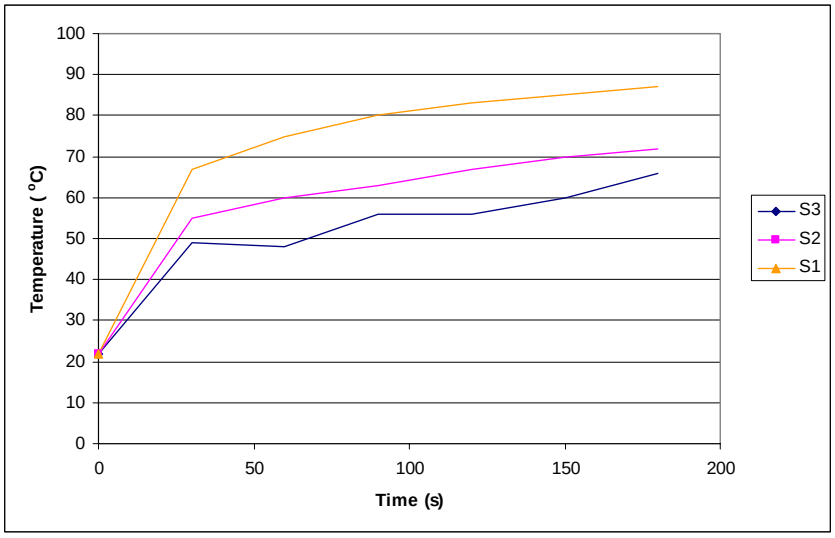

FIGURE 6. Surface temperature of pork skin samples treated by household steam cleaner S1 (▲), S2 (■), and S3 (♦) for 30, 60, 90, 120, or 180 sec.

Phase II - In Plant studies

Methodology

The effectiveness of the household steam cleaners in reducing the levels of total aerobes, coliforms, and enterobacteriaece was evaluated using a total of 70 beef, and 70 hog carcasses from 4 different small or very small meat processing plants in Georgia. The left side of a beef or hog carcass was used as controls whereas, the right side of the same carcass was treated for 180 sec with the steam generated by cleaner S1, which has been proven to be the most effective cleaner in laboratory studies. The levels of total aerobes, coliforms, and enterobacteriaece on three different anatomical locations of the beef (neck, midline, and rump) and hog (ham, belly, and jawl) carcasses were determined before and immediately after the stream treatment.

Results

The overall statistical analysis of the results from the 420 samples of the 140 animal carcasses revealed that the 180 sec steam treatment by S1 significantly reduced the populations of total aerobes, coliforms, and enterobacteriaece ($P<0.05$) (Table 2). The results in Table 3 showed that, after the steam treatment, the populations of total aerobes, coliforms, and enterobacteriaece on the neck, midline and rump areas of the beef carcasses as well as on the jawl, belly and ham areas of the hog carcasses were significantly lower ($P<0.05$) than the populations of the same types of microorganisms on the respective anatomical areas of each type of animal carcass evaluated in the studies.

Table 2. Overall mean populations (Log_{10} CFU/cm^2) of total aerobes, coliforms, and enterobacteriaece recovered from the three anatomical locations of beef and hog carcasses, before and immediately after the steam treatment using a commercial household cleaning system (n=420).

Sampling time	Total aerobes	Coliforms	Enterobacteriaece
Before	2.19 a	2.15 a	1.62 a
After	0.75 c	0.83 c	0.36 b

* Means in the same column followed by the same letter are not significantly different.

Table 3. Mean populations (Log_{10} CFU/cm^2) of total aerobes, coliforms, and enterobacteriaece recovered from the three anatomical locations of beef and hog carcasses, before and immediately after steam treatment using a commercial household cleaning system.

	BEEF (n=70)			HOG (n=70)		
	Rump	**Midline**	**Neck**	**Ham**	**Belly**	**Jawl**
Total aerobes						
Before	1.83 a	1.94 a	1.87 a	2.06 a	2.91 a	2.52 a
After	0.79 b	1.15 b	1.06 b	0.24 b	0.59 b	0.67 b
Coliforms						
Before	1.53 d	2.02 d	2.11 d	1.95 d	2.94 d	2.34 d
After	0.38 e	0.84 e	0.92 e	0.82 f	1.30 f	0.70 e
Enterobacteriaece						
Before	1.27 g	1.47 g	1.35 g	1.34 g	2.19 g	2.12 g
After	0.20 h	0.71 h	0.65 h	0.08 h	0.28 h	0.26 h

* Means in the same column followed by the same letter are not significantly different.