

CENTER FOR MEAT PROCESS VALIDATION

Jerky Test Results – Test A – Not Effective

Steve Ingham, Dennie Buege and Gina Searls, February 2005

Test A (No. 1: 10-15-04)

This test was an attempt to duplicate a cooperating plant's process – targeted their DB (dry bulb) and WB (wet bulb) at prescribed time intervals.

- S strips dipped for 2 seconds in pH 5.0 marinade – no holding period before processing
- S gradual DB and WB rise over 2.5 hours to 142 DB and 113 WB
- S at 2.5 hours, DB and WB spike for 15 minutes (target 170 DB - - 40% RH)
- S this late spike was followed by 2 hours of increasing DB (165 6 185); falling WB/% RH
- S high fan speed and steam wet bulb control

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count						(7.8 logs)	(7.8 logs)
After marinade dip						+ 0.1 log	- 0.2 log
0 minutes	84	69	42	68			
30	105	97	77	95			
60	131	106	50	115			
90	139	109	50	127			
120	142	113	42	131			
Sample - 120 minutes						- 0.6 log	- 3.0 logs
160***	160	133	50	141			
185	167	114	20	158			
225	170	111	16	165			
255	185	122	14	185			
Sample - 255 minutes						0 - 0.54 (.41 - .77)	- 4.0 logs

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

***Middle of 15 minute spike.

Comments: In processing jerky, early in the process while the moisture content of the product is still relatively high, the product temperature follows (acts like) the wet bulb (see 30 minutes). After the product has dried to an extent, evaporative cooling of the strips diminish and the product temperature begins to rise above the wet bulb temperature (see measurements at 60 minutes and beyond).

This process was **not very effective** in destroying pathogens. We believe this is because the dry and wet bulb come-up were too slow. Wet bulb temperature was less than 115°F for the first two hours - not effective for killing pathogens. Product temperature did not reach 130°F until 120 minutes into the process. By that time the sub-lethal drying may have "toughened" the bugs to heating, and the drier product conditions presented a less

lethal environment for the bugs. Although a minor humidity spike was applied at that time, it appears to be a case of "too little - too late." This slow come-up affected the two pathogens differently, allowing *Salmonella* to survive better than *E. coli* O157:H7.

For more information on this project or the work of the University of Wisconsin Center for Meat Process Validation contact: Steve Ingham, Extension Food Safety Specialist (608) 265-4801, scingham@wisc.edu or Dennis Buege, Extension Meat Scientist (608) 262-0555, drbuege@ansci.wisc.edu March, 2005.

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Jerky Test Results – Test B - Effective

Steve Ingham, Dennie Buege and Gina Searls, February 2005

Test B (No. 6: 11-10-04)

(repeated as tests 7 and 8 with similar procedures/schedules/results)

- S strips mixed with pH 4.2 marinade for 4 minutes
- S marinated strips held at 40°F for 48 hours
- S high temperature (up to 195°F) and short time (90 minutes) process
- S DB and WB temperatures followed actual in-plant conditions
- S low fan speed used to control drying rate

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count						(8.0 logs)	(8.2 logs)
After marinade addition						- 0.3 log	- 0.4 log
After 48 hour hold						- 0.9 logs	- 0.4 logs
15 minutes	139	105	32	106			
30	152	115	34	119			
45	181	123	18	129			
60	185	126	18	137			
Sample - 60 minutes					0.88	- 4.1 logs	- 3.7 logs
75	196	132	17	150			
90	193	136	21	159			
Sample - 90 minutes					0.80	- 7.1 logs	- 7.2 logs

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

- same process was repeated 3 times, with very similar pathogen reductions.
- addition of acidic marinade and holding provided a small reduction in pathogens.

Comments: This process is targeted to produce a rapid increase in dry bulb temperature. The house starts out with a 185°F dry bulb setting. Our house settings mimicked what actually happens in the commercial settings. By 45 minutes the product temperature was approaching 130°F and pathogen destruction should have started. By using "slow" fan speeds in our processing oven, we were able to dry the test product at virtually the same rate as the commercial product. In the latter stage of processing the dry bulb went to the mid 190's, the product temperature approached 160°F, and after 90 minutes we attained a 7-log reduction of both pathogens (Effective).

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Jerky Test Results – Test C - Effective

Steve Ingham, Dennie Buege and Gina Searls, February 2005

Test C (No. 3: 10-21-04)

S strips tumbled for 15 minutes in pH 4.0 marinade

S constant 170°F dry bulb was target throughout the test

S after initial 30 minutes with no added humidity, wet bulb was then set at 142°F for 60 minutes

S then returned to no added humidity in house for remainder of process

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count						(8.2 logs)	(8.1 logs)
After 15 minutes of tumbling						- 1.1 logs	0.0 logs
0 minutes	96***	68	33	64			
30	89***	63	33	63	(start of humidity spike)		
45	154	142	72	142	(15 min. into humidity spike)		
60	166***	142	51	142	(30 min. into humidity spike)		
75	158***	140	60	140	(45 min. into humidity spike)		
Sample - 90 minutes		(end of humidity spike)			0.95/0.95	- 7.1 logs	- 7.2 logs
120	171	112	26	121			
150	173	111	21	143			
180	173	101	12	154			
210	173	99	8	158			
Sample - 210 minutes					0.62/0.74	- 7.1 logs	- 7.2 logs
240	174	97	6	161			
270	174	97	5	162			
Sample - 270 minutes					0.50/0.67	- 7.1 logs	- 7.2 logs

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

***Smokehouse was initially improperly set such that DB did not operate at desired 170°F at start of cycle. However, during 1 hour elevated humidity spike WB was at proper setting (140°F), and dry bulb approached desired setting (170°F).

Comments: The rationale for this test was to dry the product for 30 minutes for quality reasons, then apply a moderate humidity spike (142°F) for 60 minutes. This produced greater than a 6.5 log kill of both pathogens immediately after the humidity spike. With that accomplished, the product then can be dried to desired Aw. (Note that 15 minutes of tumbling with a pH 4.0 marinade produced a 1-log reduction in *Salmonella*, but had no effect on *E. coli* O157:H7.) (Effective)

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Jerky Test Results – Test D - Effective

Steve Ingham, Dennie Buege and Gina Searls, February 2005

Test D (No. 4: 10-22-04)

S strips tumbled for 15 minutes in pH 4.0 marinade

S constant 170°F dry bulb throughout test

S after 30 minutes of drying, wet bulb was set at 160°F for 15 minutes for a short elevated humidity spike

S after spike, no humidity was added to house for remainder of process

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count						(8.2 logs)	(8.2 logs)
After 15 minutes of tumbling						- 1.3 logs	- 0.1 log
5	143	103	26	94			
25	170	106	15	107			
35	175	159	66	161	(5 min. into humidity spike)		
45	171	160	76	158	(end of 15 min. humidity spike)		
60	172	119	21	119			
90	173	101	9	131			
Sample - 90 minutes					0.76/0.81	- 7.2 logs	- 7.2 logs
120	173	102	7	143			
150	174	102	5	151			
180	174	102	5	156			
Sample - 180 minutes					0.54/0.64	- 7.2 logs	- 7.2 logs
270	174	103	3	162			
Sample - 270 minutes					0.44/0.53	- 7.2 logs	- 7.2 logs

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

Comments: Same rationale as test C (#3), except humidity spike was higher (160°F dry bulb) but shorter (15 minutes). These conditions were **effective** in producing a greater than 6.5 log kill for both pathogens (determined here at 45 minutes of processing after end of humidity spike). (Effective)
(Note that tumbling inoculated strips for 15 minutes in an acid marinade produced a greater than one log reduction in *Salmonella*, but had little effect on *E. coli* O157:H7.)

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Jerky Test Results – Test E - Effective

Steve Ingham, Dennie Buege and Gina Searls, February 2005

Test E (No. 15: 1-19-05)

- S strips were slightly thicker than used in previous tests (average = 0.26 inch)
- S massaged with non-acid, nitrite containing marinade for 5 minutes/held 22 hours @ 40°F
- S marinade pickup was 15% of meat weight (2% ingoing salt and 2% ingoing sugar; spices included)
- S "warm" winter day = 35°F (not excessively dry)
- S 170 DB setting throughout run
- S 30 min. @ 170 DB x 110 WB
- S 15 min. @ 170 DB x 140 WB (target humidity spike)
- S dry to finished product @ 170 DB x 00 WB
- S pans of water in house/low fan speed / steam used to control WB
- S product Awet@ after 15 minute humidity spike

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count							(8.01)	(7.99)
After 22 hours of marination							- 0.2	- 0.2
15	150	126	49	113				
30	163	123	31	123	(WB turned up)			
32	166	148	62	142	(15 min. spike begins)			
47	166	139	47	141	(15 minute spike ends)			
Sample - 47 minutes (after spike)					.97/.97		- 7.1	- 7.0
60	170	114	19	120				
75	166	123	28	124				
90	166	123	28	125				
105	166	122	27	125				
120	166	121	26	126				
135	166	119	25	127				
150	166	119	25	130				
Sample - 150 minutes (yield)						55.9		
165	167	115	21	132				
180	167	117	22	139				

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
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Sample - 180 minutes (yield)						50.9		
195	167	115	21	140				
210	167	117	22	146				
Sample - 210 minutes					.83/.85	47.5	- 7.1	- 7.0

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

(Effective)

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Jerky Test Results – Test F - Effective

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Test F (No. 16: 1-20-05)

- S 170°F DB setting throughout run
- S 30 min. drying (no humidity added)
- S 60 min. WB target = 130°F (when humidity addition was called for at beginning of spike, WB initially overshot 130°F, and slowly drifted downward to 126°F during the 1 hour spike period)
- S finish drying with no added humidity
- S non-acid, nitrite-containing marinade added at 15% of meat wt.
- S targeted to provide 2% salt, 2% sugar, spices present
- S marinade massaged into meat for 5 minutes; held 22 hours @ 40°F
- S day moderately cold (20°F); humidity in smokehouse room = 17% upon entry
- S after 130 WB spike, product was dry to the touch (no standing moisture) and had good color
- S low fan speed; WB controlled by steam; pans of water in house

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count							(8.04)	(7.93)
After 22 hours of marination							- 0.3	- 0.1
15	143	121	52	121				
30	167	126	30	126	(start of A130 WB@ period)			
45	169	136	40	137	(15 min. into spike)			
60	169	133	36	134	(30 min. into spike)			
75	169	128	31	130	(45 min. into spike)			
90	169	126	29	128	(end of A130 WB@ period)			
Sample - 90 minutes					0.94	70.2	- 6.9	- 3.8
105	173	110	15	107				
120	169	115	20	119				
135	169	119	23	126				
150	170	119	22	132				
Sample - 150 minutes (yield only)						56.7		
165	170	116	20	137				
180	171	121		143				

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
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Sample - 180 minutes (yield only)						51.0		
195	172	119		147				
210	169	121		149				
Sample - 210 minutes					0.81/0.88	47.3	- 7.1	- 7.0

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

S 60 minutes of 130°F wet bulb target was more lethal to *Salmonella* than *E. coli* O157:H7.

S at conclusion of test without product being fully dried, 7 log kills of both pathogens were attained.

(Effective)

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Jerky Test Results – Test G - Effective

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Test G (No. 17: 1-27-05)

overall perspective: 170 DB/98 WB - 30 min. (pre-dry)
 170 DB/130 WB - 60 min. (lethality)
 170 DB/00 WB - final lethality and dry

- S cold dry day (10% RH in processing room/10°F outside)
- S non-acid marinade - 15% pick-up, to deliver 2% salt, 2% sugar, spices
- S massage marinade into inoculated strips for 5 min.; hold strips for 22 hours @ 40°F
- S product had good color after 130°F WB spike step; dry to touch
- S pans of water placed in house; humidity addition controlled by water spray; low fan speed

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Yield (%) ***	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count							(8.0)	(8.0)
After 22 hours of marination							- 0.2	-0.3
15	137	111	44	102				
30	163	117	25	116				
38****	161	130	41	129	(start of 130°F WB period)			
53 (+15*****)	162	131	41	130				
68 (+30)	162	132	42	130				
83 (+45)	163	132	41	130				
98 (+60)	165	130	36	131	(end of 130°F WB period)			
Sample - 98 minutes					0.92/.93	68.9	- 3.9	- 2.1
113	169	125	28	127				
128	166	121	26	128				
143	166	123	28	131				
158	166	122	27	135				
Sample - 158 minutes (yield only)						55.3		
173	164	116	23	137				
188	166	119	25	142				

Process Time (minutes)	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
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Sample - 188 minutes (yield only)						50.3		
203	165	117	24	142				
218	166	124	29	148				
Sample - 218 minutes					0.84/0.91	46.7	- 6.9	- 7.0

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

***Based upon total weight of meat and marinade

****It took 8 minutes to slowly bring WB to 130°F

***** A+15" = 15 minutes into 60 min. lethality period @ 130 WB

S 60 minutes of 130°F wet bulb target was more lethal to *Salmonella* than *E. coli* O157:H7.

S at conclusion of test without product being completely dried, greater than 6.5 log kills of both pathogens was attained.

(Effective)

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Jerky Test Results – Test H – Not Effective

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Test H (No. 12: 12-15-04)

- S strips marinated with solution of salt, sugar, spices, nitrite, water (pH = 5.3)
- S marinade massaged into meat for 5 minutes; strips held 22 hours @ 40°F
- S strips picked up 15% of their weight as marinade, to provide 2% ingoing salt and 2% ingoing sugar
- S this was a straight 140°F run, with a moderate dry bulb come up over 30 minutes to simulate a full house
- S no humidity was added, cold, clear low RH day
- S fan speed was "low"; pans of water in house

Process Time	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Average Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count							(8.0)	(8.0)
After 22 hours of marination							- 0.1	- 0.1
15	110	85	32	88				
30	122	91	29	95				
45	138	97	23	104				
60	138	99	26	110				
75	138	99	26	113				
90	138	99	26	116				
Sample - 90 minutes					0.71/0.75	39.4	- 4.3	- 3.8
105	140	99	24	125				
120	140	99	24	129				
Sample - 120 minutes					0.64	34.5	- 4.2	- 3.4

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

Comments:

- ! the strips appeared thinner than previous trials. Supposedly they were cut to the same thickness as in trials 2-5. However, the marinade used was much lower in sugar (2% ingoing here vs 15% in trials 2-5), and the total marinade pick-up in this test was 15%, vs 37% for tests 2-5.
- ! weather conditions were cold and dry - would contribute to accelerated drying rate.
- ! this could be viewed as a worst case test:
 - ! low climate humidity
 - ! thin strips/minimum marinade pick-up non-acid marinade
 - ! fast rate of drying (less "kill time" when product was moist)
- ! while this low temperature process provided substantial kill at the realistic Aw values of 0.71/0.75 (90 minutes into process), the lethality was substantially less than for the 180°DB in test #11 (1-log less kill of *Salmonella*; 2-logs less kill of *E. coli* O157:H7). **(Not Effective)**

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Jerky Test Results – Test I – Not Effective

Steve Ingham, Dennie Buege and Gina Searls, February 2005

Test I (No. 13: 12-17-04)

- S strips marinated with solution of salt, sugar, spices, nitrite, water (pH = 5.3)
- S marinade massaged into meat for 5 minutes; strips held 22 hours @ 40°F
- S strips picked up 15% of their weight as marinade, to provide 2% ingoing salt and 2% ingoing sugar
- S this was a straight 160°F run, with a moderate dry bulb come up over 30 minutes to simulate a full house
- S no humidity was added, cold, clear, low RH day
- S fan speed was "low", pans of water in house

Process Time	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Average Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count							(8.1)	(8.1)
After 22 hours of marination							- 0.1	- 0.3
15	122	99	42	99				
30	143	107	31	109				
45	156	115	28	118				
60	158	118	29	124				
Sample - 60 minutes					0.86/0.88	51.6	- 4.0	- 3.3
75	158	115	27	127				
Sample - 75 minutes					0.80	42.5	- 4.7	- 4.0

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

Comments:

- ! the strips appeared thinner than previous trials. Supposedly they were cut to the same thickness as in trials 2-5. However, the marinade used was much lower in sugar (2% ingoing here vs 15% in trials 2-5), and the total marinade pick-up in this test was 15%, vs 37% for tests 2-5.
- ! weather conditions were cold and dry - would contribute to accelerated drying rate.
- ! this could be viewed as a worst case test:
 - ! low climate humidity
 - ! thin strips/minimum marinade pick-up non-acid marinade
 - ! fast rate of drying (less "kill time" when product was moist)

(Not Effective)

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Jerky Test Results – Test J – Not Effective

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Test J (No. 11: 12-14-04)

- S strips marinated with solution of salt, sugar, spices, nitrite, water (pH = 5.3)
- S marinade massaged into meat for 5 minutes; strips held 22 hours @ 40°F
- S strips picked up 15% of their weight as marinade, to provide 2% ingoing salt and 2% ingoing sugar
- S this was a straight 180°F run, with a moderate dry bulb come up over 30 minutes to simulate a full house
- S no humidity was added, cold, clear, low RH day
- S fan speed was "low"; pans of water in house

Process Time	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Average Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count							(8.0)	(8.1)
After 22 hours of marination							- 0.2	- 0.1
15	124	92	29	94				
30	148	102	22	108				
45	171	112	17	130				
60	173	112	16	148				
Sample - 60 minutes					0.68/77	43.1	- 5.2	- 4.6
75	173	111	15	162				
Sample - 75 minutes					0.79	37.9	- 5.1	- 5.6

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

Comments:

- ! the strips appeared thinner than previous trials. Supposedly they were cut to the same thickness as in trials 2-5. However, the marinade used was much lower in sugar (2% ingoing here vs 15% in trials 2-5), and the total marinade pick-up in this test was 15%, vs 37% for tests 2-5.
- ! weather conditions were cold and dry - would contribute to accelerated drying rate.
- ! this could be viewed as a worst case test:
 - ! low climate humidity
 - ! thin strips/minimum marinade pick-up non-acid marinade
 - ! fast rate of drying (less "kill time" when product was moist)
 - ! processing this jerky to a realistic mean Aw of 0.79 produced a 5+ log kill of both pathogens

(Not Effective)

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Jerky Test Results – Test K – Theoretically Effective

Steve Ingham, Dennie Buege and Gina Searls, February 2005

Test K (No. 14: 12-21-04)

- S run conducted with 6 full screens of jerky in house (no pathogens)
- S 160°F DB throughout test; no humidity added
- S purpose was to observe what DB temperatures would be attained when running a moderately full house
- S no humidity was added; clear cold dry (provides fast drying)
- S low fan speed
- S 15% pick-up of non-acid marinade; to deliver 2% salt, 2% sugar, spices, nitrite into product
- S marinade massaged 5 minutes into strips; strips held 22 hours @ 40°F

Process Time	DB (°F)*	WB (°F)*	% RH	Product Temp. (°F)	Aw	Yield (%)	Log <i>Salmonella</i> Reduction**	Log <i>E. coli</i> O157:H7 Reduction**
Initial Count								
15	144	110	34	108				
30	152	121	39	119				
45	158	126	39	124				
60	155	124	39	123				
Sample - 60 minutes					0.96	71.6		
75	155	118	32	118				
90	157	122	34	123				
105	159	119	30	121				
120	160	116	26	122				
135	161	108	19	127				
150	162	108	18	139				
Sample - 150 minutes					0.72	39.2		

*Actual temperatures measured within the smokehouse.

**Mean of 3 samples.

Comments: This test can be compared to Test I (No. 13: 12-17-04). Both were run at 160°F, with no added humidity, on cold dry winter days. The difference was that this test had 6 screens of jerky in the house, while Test I had one screen. The presence of more product in the house had the effect of raising the wet bulb about 10°F higher in this test (into the mid 120's) than in Test I. This increased wet bulb effect due to greater amount of product in the house would have increased the kill in the process (Test I with lower wet bulb values provided a 4.7 log kill of *Salmonella* and a 4.0 kill of *E. coli* O157:H7). **(Theoretically Effective)**

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