



Critical Limit Summary for Attaining Enough Process Lethality When Making Whole-Muscle Beef Jerky

The USDA-FSIS updated guidance for manufacture of ready-to-eat products, including a revised Appendix A, in June 2017. This summary was updated to reflect those updates and interpretation of earlier research conducted by the University of Wisconsin-Madison.

Background: Research has shown that two phenomena can decrease lethality during cooking of **whole muscle beef jerky**: 1) evaporative cooling may keep meat strips from getting hot enough to kill bacteria, and 2) cooking in dry air may make pathogens more heat-resistant and less likely to be killed.

Appendix A Processes use USDA-FSIS lethality performance standards for process validation. Product is **cooked** to a validated internal temperature/time combination **while humidity** is maintained.

CCP1: Cooking To use Appendix A as validation for your cook step, you must: 1) monitor the **internal temperature of a strip** – the strip can be cut thicker than normal, and 2) **monitor and maintain humidity in the oven**.

Select: 1) a target temperature/time combination, and 2) a relative humidity option using the following information.

Appendix A Lethality Performance Standards – June 2017 (USDA-FSIS)

Temperature* (°F)	Time	RH* option	Temperature* (°F)	Time	RH* option
130	112 minutes	Option 4	145	4 minutes	Option 1,2,3
131	89 minutes	Option 4	146	182 seconds	Option 1,2,3
132	71 minutes	Option 4	147	144 seconds	Option 1,2,3
133	56 minutes	Option 4	148	107 seconds	Option 1,2,3
134	45 minutes	Option 4	149	85 seconds	Option 1,2,3
135	36 minutes	Option 4	150	67 seconds	Option 1,2,3
136	28 minutes	Option 4	151	54 seconds	Option 1,2,3
137	23 minutes	Option 4	152	43 seconds	Option 1,2,3
138	18 minutes	Option 4	153	34 seconds	Option 1,2,3
139	15 minutes	Option 4	154	27 seconds	Option 1,2,3
140	12 minutes	Option 4	155	22 seconds	Option 1,2,3
141	9 minutes	Option 4	156	17 seconds	Option 1,2,3
142	8 minutes	Option 4	157	14 seconds	Option 1,2,3
143	6 minutes	Option 4	158+	0 seconds**	Option 1,2,3
144	5 minutes	Option 4			

***Temperature** = Internal product temperature (measured/recorded)

***Relative Humidity (RH) options:**

Option 1: **Steam injection**** for 50% of cooking time, or 1 hour (whichever is longer)

Option 2: **Sealed oven**** for 50% of cooking time, or 1 hour (whichever is longer)

**Wet bulb at least 125°F for at least 1 hour.

Option 3: At least **90% RH** for at least 25% of the cooking time, or 1 hour (whichever is longer)

Option 4: At least **90% RH** for at least 25% of the cooking time, or 1 hour (whichever is longer)

--At all times, **if total cooking time is less than 1 hour**, at least 90%RH for the entire cooking time.

[Continued]

IMPORTANT NOTE: A process exceeding a given temperature or held for a longer time at the target temperature, is considered validated as long as humidity requirements are met. Processor must maintain records showing the oven temperature (dry bulb) and the length of the cook cycle. In addition, wet bulb temperature or %RH is monitored and recorded throughout the cook cycle.

CCP2: Drying Once lethality is achieved in cooking, **the product is dried** at 150°F or higher, dry bulb temperature, to a water activity of 0.85 or lower. A water activity of this level will ensure that no pathogens can grow on the finished product (it is shelf-stable). **Note that the product still must have a Moisture:Protein Ratio (MPR) of 0.75 or lower for you to label it as jerky.**

Additional information:

- *Compliance Guideline Meat and Poultry Jerky Produced by Small and Very Small Establishments* (2014)
- *Salmonella* Compliance Guidelines for Small and Very Small Meat and Poultry Establishments that Produce Ready-to-Eat (RTE) Products and Revised Appendix A (June 2017)

What would it look like if a processor uses Appendix A to validate a beef jerky cook step?

EXAMPLE: - smokehouse/oven operating set at 170°F:

CCP1: Cooking (lethality). **Critical limits** and notes related to monitoring:

• Oven 170°F (dry bulb), or higher.	SOP* states dry bulb reaches 170°F within 25 minutes of start
• 27% RH/ wet bulb temperature 125°F, or higher, for at least 1 hour	SOP states steam injection used to achieve wet bulb (Option 1) SOP states monitoring begins once dry bulb reaches 170°F
• Product internal temperature at least 145°F for at least 4 minutes.	SOP states that product internal temperature/time is met with DB 170°F/ WB 125°F SOP states length of this step is at least 1 hour

*SOP – Standard Operating Procedure for smokehouse/oven operation

CCP2: Drying (shelf stability). **Critical limits** and notes related to monitoring:

• Oven 150°F (dry bulb), or higher.	SOP states that steam injection ends. Dry bulb setting reduced to 150°F.
• Drying ends when a_w reaches 0.85, or lower	SOP [^] for relating product yield to a_w

[^]An SOP which tells how to **correlate yield and water activity** can be found here:

http://www.meathaccp.wisc.edu/prerequisite_programs/assets/SOP%20Packaging.pdf

Research-Tested Alternative Validated Processes. Researchers at University of Wisconsin-Madison and the USDA Eastern Regional Research Center have established alternative processes that achieve at least a 5-log reduction in *Salmonella* and *E. coli* O157:H7. These validated processes are published as scientific journal articles; a summary of each process follows. **These processes rely on monitoring of the smokehouse/oven temperature**, not on product internal temperature monitoring. **The Critical Limits for these processes are the times, temperatures, and % RH values within the oven.** These processes establish minimum standards for lethality. To avoid deviations, processors are encouraged to establish oven/smokehouse settings which exceed minimum values. Supporting research is noted at the end of this document. **Marination** of strips or strip pH is **not** considered a critical factor in these validated processes. **Strips** must be at least 0.25" thick to avoid reaching dryness prior to lethality being achieved.

In each case, **there are multiple heating stages** which may require minimum dry-bulb and/or wet-bulb temperatures.

Type 1-A Process: 4 Heating stages – oven settings

- Stage 1 - dry-bulb temperature 170°F (or higher) reached and held
- Stage 2 – dry-bulb 170°F held while wet-bulb temperature (125-140°F) held for a given time
- Stage 3 – dry-bulb temperature at 170°F.
- Stage 4 – dry bulb at 145°F or higher until shelf stability is reached, $a_w \leq 0.85$.

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)		Time for this stage (minutes)		Cumulative Time (minutes)
1	170°F (oven must reach 170°F <u>within</u> 20 min)	Not Applicable (NA)		30*		30
2	170°F	Choose one combination of wet-bulb and time:	125°F	60		90
			130°F	60		90
			135°F	30		60
			140°F	10		40
3	170°F	NA		125°F [^]	30	120
				130°F	90	180
				135°F	90	150
				140°F	90	130
4	145°F or higher	NA		As necessary to achieve dryness		As necessary to achieve dryness

*Note: A higher dry-bulb in Stage 1, a higher dry-bulb or wet-bulb or longer time in Stage 2, or a higher dry-bulb or longer time in Stage 3, are considered validated **as long as dry bulb reaches 170°F (minimum) within 20 minutes of start and holds for at least 10 minutes** (30 minutes total). Wet bulb temperature must be monitored during entirety of Stage 2.

[^]Additional heating time at 170°F (dry bulb) in Stage 3. For example if Stage 2 heating is at 170°F dry bulb and 125°F wet bulb (60 minutes), in Stage 3, oven is held at 170°F **for an additional 30 minutes (minimum). Cumulative times (minimum) must be met.**

Dry-bulb may drop to 145°F while product is dried to a_w 0.85 or less. Cumulative time (minimum) must be met. **Validated lethality:** 6.5 log reduction *Salmonella*; 7.0 log reduction *E. coli* O157:H7

Type 1-B Process: 4 Heating stages – oven settings

- Stage 1 - dry-bulb temperature 150°F OR 190°F reached and held
- Stage 2 – dry-bulb temperature 150°F, wet-bulb temperature 130°F held for 60 minutes
- Stage 3 – dry-bulb temperature at 150°F for 60 minutes.
- Stage 4 - dry bulb at 135°F or higher until shelf stability is reached, $a_w \leq 0.85$.

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)	Time for this stage (minutes)	Cumulative Time (minutes)
1 Choose one dry-bulb temperature:	150°F (oven must reach 150°F <u>within</u> 20 min)	Not Applicable (NA)	30*	30
	190°F (oven must reach 190°F <u>within</u> 20 min)			
2	150°F	130°F	60	90
3	150°F	NA	60	150
4	135°F or higher** OR NA	NA	As necessary to achieve dryness	As necessary to achieve dryness

*Note: A higher dry-bulb in Stage 1, a higher dry-bulb or wet-bulb or longer time in Stage 2, or a higher dry-bulb or longer time in Stage 3, are considered validated **as long as dry bulb reaches target (150°F/190°F) (minimum) within 20 minutes of start and holds for at least 10 minutes** (30 minutes total). Wet bulb temperature must be monitored during entirety of Stage 2.

Drying. If dry bulb at 150°F (Stage 1), heat to dryness at 135°F (minimum); if dry bulb at 190°F (Stage 1), **no minimum drying temperature. **Validated lethality:** 6.5 log reduction *Salmonella*; 7.0 log reduction *E. coli* O157:H7

Type 2 Process: 3 Heating stages – oven settings

- Stage 1 - dry-bulb temperature 145°F and wet bulb temperature 105°F reached and held
- Stage 2 – dry-bulb temperature 170°F; wet-bulb temperature 112°F, or higher, after 120 minutes. Wet bulb must read 105°F, or higher, within 10 minutes and 112°F, or higher, after 120 minutes.
- Stage 3 – dry-bulb 145°F or higher until shelf stability is reached; $a_w \leq 0.85$.

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)	Time for this stage (minutes)	Cumulative Time (minutes)
1	145°F (oven must reach 145°F <u>within</u> 10 min)	105°F (once 145°F reached)	15*	15
2	170°F (oven must reach 170°F <u>within</u> 10 min)	112°F (at 120 minutes)	105	120
3	145°F or higher	NA	As necessary to achieve dryness	As necessary to achieve dryness

Type 2 Process (continued): *Note: A higher dry-bulb or wet-bulb temperature in Stage 1 or a higher dry-bulb or wet-bulb temperature or longer time in Stage 2 are considered validated **as long as dry bulb**

and wet bulb temperatures reach minimum target within 10 minutes of start and hold for at least 5 minutes (15 minutes total). At a minimum, wet bulb temperature must be monitored/recorded at start, when 145°F dry bulb reached, and after 120 minutes (cumulative time).
Validated lethality: 6.0 log reduction *Salmonella*; 6.0 log reduction *E. coli* O157:H7

Type 3 Process: 3 Heating stages – oven settings

- Stage 1 - dry-bulb temperature 145°F and wet bulb temperature 116°F reached and held
- Stage 2 –dry-bulb temperature 170°F; wet-bulb temperature 117°F, or higher, after 180 minutes. Wet bulb must read 116°F, or higher, within 10 minutes of start and 117°F, or higher, after 180 minutes.
- Stage 3 – dry-bulb temperature 150°F or higher until shelf stability is reached; $a_w \leq 0.85$.

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)	Time for this stage (minutes)	Cumulative Time (minutes)
1	145°F (oven must reach 145°F <u>within</u> 10 min)	116°F (once 145°F reached)	90*	90
2	170°F (oven must reach 170°F <u>within</u> 20 min)	117°F (at 180 minutes)	90	180
3	150°F or higher	NA	As necessary to achieve dryness	As necessary to achieve dryness

*Note: A higher dry-bulb or wet-bulb temperature in Stage 1 or a higher dry-bulb or wet-bulb temperature or longer time in Stage 2 are considered validated **as long as dry bulb and wet bulb temperatures reach minimum target within 10 minutes of start and hold for at least 80 minutes** (90 minutes total). At a minimum, wet bulb temperature must be monitored/recorded at start, when 145°F dry bulb reached, and again after 180 minutes (cumulative time).

Validated lethality: 5.5 log reduction *Salmonella*; 5.6 log reduction *E. coli* O157:H7

Type 4 Process: This process can not be adequately controlled in a plant to ensure safety.

Type 5 Process: Withdrawn. Sufficient data **do not exist to support the safety of the Type 5 process**.

Type 7 Process: 5 Heating stages –

- Stage 1 - dry-bulb 120°F; wet bulb 98°F within 10 minutes –60 minutes total this stage
- Stage 2 –dry-bulb 130°F held for 60 minutes
- Stage 3 – dry bulb 140°F held for 60 minutes
- Stage 4 – dry bulb 170°F; wet bulb 109°F after 240 minutes total processing time
- Stage 5 – dry-bulb 150°F or higher until shelf stability is achieved; $a_w \leq 0.85$.

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)	Time this stage (minutes)	Cumulative Time (minutes)
1	120°F (120°F <u>within</u> 10 min)	98°F (once 120°F reached)	60	60
2	130°F (130°F <u>within</u> 20 min)	NA	60	120
3	140°F (140°F <u>within</u> 20 min)	NA	60	180
4	170°F (170°F <u>within</u> 20 min)	109°F (after 240 minutes)	60	240
5	150°F or higher	NA	Until dryness	Until dryness

For stages 2-4, each time the temperature setting is increased, **the new dry bulb target must be met within 20 minutes; the dry bulb temperature can also gradually ramp-up during each stage.** The RH in the smokehouse must be **at least 43%** at the start of the process (98°F wet-bulb) and at least 15% after 240 minutes of total processing time (109°F wet-bulb).

Lethality: 6.0 log reduction *Salmonella*; 5.6 log reduction *E. coli* O157:H7

Type 8 Process: 3 Heating stages – oven settings. Addition of hickory smoke during Stage 1 & 2 is considered a critical factor.

- Stage 1 - dry-bulb 180°F; wet bulb 142°F within 24 minutes – 30 minutes total this stage
- Stage 2 –dry-bulb 180°F; wet-bulb 123°F, or higher, after 180 minutes – 150 minutes total this stage. Wet bulb must read 142°F, or higher, within 24 minutes of start and 123°F, or higher, after 180 minutes.
- Stage 3 – dry-bulb 150°F or higher until shelf stability is reached; $a_w \leq 0.85$.

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)	Time for this stage (minutes)	Cumulative Time (minutes)
1	180°F (oven must reach 180°F <u>within</u> 24 min)	142°F (once 180°F reached)	30*	30
2	180°F	123°F (at 180 minutes)	150	180
3	150°F or higher	NA	As necessary to achieve dryness	As necessary to achieve dryness

*Note: A higher dry-bulb temperature in Stage 1 or 2, or higher wet-bulb temperatures at the start of heating and after 180 minutes are considered validated **as long as the oven reaches the minimum process temperature as outlined.**

REFERENCES. published peer-reviewed scientific articles on which these summaries are based.

For Processes 1-A, 1-B, 2, 3 and 7:

Buege, D.R., G. Searls, and S.C. Ingham. 2006. Lethality of commercial whole-muscle beef jerky manufacturing processes against *Salmonella* serovars and *Escherichia coli* O157:H7. *Journal of Food Protection*. 69: 2091-2099. <http://www.meathaccp.wisc.edu/validation/assets/Jerky%20JFP%2069.pdf>

For Process 8:

Porto-Fett, A.C.S., J.E. Call, and J. B. Luchansky. 2008. Validation of a commercial process for inactivation of *Escherichia coli* O157:H7, *Salmonella* Typhimurium, and *Listeria monocytogenes* on the surface of whole muscle beef jerky. *Journal of Food Protection*. 71:918-926. Available online: www.meathaccp.wisc.edu/validation/assets/Jerky%20JFP%2071.pdf

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