

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. Appendix A was additionally updated in 2021. 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. 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](https://foodsafety.wisc.edu/wp-content/uploads/sites/1026/2024/01/SOP_Yield_aw.pdf):
https://foodsafety.wisc.edu/wp-content/uploads/sites/1026/2024/01/SOP_Yield_aw.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 during the **Cook** cycle/step. **These processes rely on monitoring smokehouse/oven temperature and time as critical factors.**

USDA-FSIS requires that processors verify that product has achieved the desired lethality during the Cook step and prior to Drying. At least initially, verification can be achieved by cutting a thicker piece of meat and inserting a temperature probe or by wrapping a piece of meat around a probe. Once sufficient data are gathered, USDA FSIS allows oven temperature to be used in place of product temperature. Supporting research is noted at the end of this document.

NOTE: Marination of strips/ strip pH is **not** considered a critical factor in these validated processes.

NOTE: A processor **must meet** all settings for a particular process, e.g. Type 1-A; a deviation **can not be addressed** by re-starting a process or using an alternative Wisconsin process, i.e. Type 1-B. Consult a processing authority to determine if a deviation can be addressed by switching to Appendix A process.

Temperature recording. Temperatures were recorded with calibrated dataloggers accurate to within ± 1 degree (F). There is normal and inherent variability in datalogger accuracy and in temperature during a run due to oven/smokehouse cycling. Processors should consider the temperatures described as **minimum setting** and set the oven a bit higher than the minimum or hold a setting slightly longer than necessary to avoid even the appearance of a deviation.

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

- Stage 1 - dry-bulb temperature 170°F
- Stage 2 – dry-bulb 170°F, wet-bulb temperature at 125 to 140°F and held for specified time at target temperature
- 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 within 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. In Stage 1, dry bulb must reach 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.

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Type 1-A (continued)

^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.**

In Stage 4, 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 for this process: 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
- Stage 2 – dry-bulb temperature 150°F, wet-bulb temperature 130°F 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 ≤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 20 min</u>)	Not Applicable (NA)	30*	30
	190°F (oven must reach 190°F <u>within 20 min</u>)			
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. In Stage 1, dry bulb must reach minimum target (150°F/190°F) within 20 minutes of start and hold for at least 10 minutes (30 minutes total). Wet bulb temperature must be monitored during 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 for this process: 6.5 log reduction *Salmonella*; 7.0 log reduction *E. coli* O157:H7

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Type 2 Process: 3 Heating stages – oven settings

- Stage 1 - dry-bulb temperature 145°F and wet bulb temperature 105°F
- Stage 2 – dry-bulb temperature 170°F; wet-bulb temperature 112°F, or higher, **at 120 minutes**.
- Stage 3 – dry-bulb 145°F or higher until shelf stability is reached; aw <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	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

*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. In Stage 1, dry bulb must reach minimum target within 10 minutes of start and hold for at least 5 minutes (15 minutes total).

Wet bulb temperature must be monitored/recorded **15 minutes into the process** when it must read at least 105°F and **after 120 minutes** when wet-bulb must read at least 112°F.

Validated lethality for this process: 6.0 log reduction *Salmonella*; 6.0 log reduction *E. coli* O157:H7

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Type 3 Process: 3 Heating stages – oven settings

- Stage 1 - dry-bulb temperature 145°F, wet bulb temperature 116°F
- Stage 2 –dry-bulb temperature 170°F; wet-bulb temperature 117°F, or higher, after 180 minutes.
- Stage 3 – dry-bulb temperature 150°F or higher until shelf stability is reached; a_w ≤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	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. In Stage 1 **dry bulb** temperature must reach minimum target within 10 minutes of start and holds for at least 80 minutes (90 minutes total).

Wet bulb temperature must reach minimum for Stage 1 once dry bulb is stabilized; 116°F wet bulb. In Stage 2, wet bulb must read at least 117°F after 180 minutes (cumulative time).

Validated lethality for this process: 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	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). In Stage 1, wet bulb must be monitored/recorded as soon as dry bulb has stabilized.

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

Type 8 Process: 3 Heating stages. Addition of hickory smoke (Stage 1 & 2) is a critical factor.

- Stage 1 - dry-bulb 180°F; wet bulb 142°F – 30 minutes total this stage
- Stage 2 –dry-bulb 180°F; wet-bulb 123°F after 180 minutes – 150 minutes total this stage.
- 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	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. In Stage 1, dry bulb must reach 180°F within 24 minutes; wet bulb must reach at least 142°F at 30 minutes (cumulative time).

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.

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.

All research articles are posted to this web page: <https://foodsafety.wisc.edu/meat-haccp/>