



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

Background: Processing **whole-muscle** beef into jerky involves heating and drying to attain the desired texture and shelf-stability. However, the drying of the product may keep the heat in the process from adequately killing pathogens on the surface of the beef. This may happen in two ways: 1) evaporative cooling may keep the beef strip surface from getting hot enough to kill bacteria, and 2) dry conditions during the early heating stages may make pathogens more heat-resistant so that they survive the later stages of the process. To avoid these problems, there are several processes that can attain the required destruction of pathogens while still producing an acceptable product.

“Appendix A” Process. This **2-step process** requires you to have either a wet-bulb thermometer (best) or a relative humidity (RH) meter in your smokehouse. The process is based on achieving enough lethality early in the process with a first step (heating) that has at least 90% RH and the corresponding wet-bulb and dry-bulb temperatures, and achieves a high product internal temperature. The **high-humidity heating must begin within 30 minutes of starting your process**. Once the high-humidity heating is done, **you may then dry the product at a dry-bulb temperature of 150°F or hotter**.

CCP1: Heating To be sure that you achieve enough lethality, you must **monitor two things**: 1) the internal temperature of a strip – the strip can be cut thicker than normal, and 2) the wet-bulb temperature or %RH of the oven. Make sure that the wet-bulb temperature or %RH meets one of the temperature/%RH/time combinations in the table below. Also make sure that the product internal temperature meets one of the combinations listed below.

Lethality Table

Internal Temperature of Product (°F)	Wet-Bulb Temperature of Smokehouse (°F)	% Relative Humidity of Smokehouse	Time
130	126	90	112 minutes
131	127	90	89 minutes
132	128	90	71 minutes
133	129	90	56 minutes
134	130	90	45 minutes
135	131	90	36 minutes
136	132	90	28 minutes
137	133	90	23 minutes
138	134	90	18 minutes
139	135	90	15 minutes
140	136	90	12 minutes
141	137	90	9 minutes
142	138	90	8 minutes
143	139	90	6 minutes
144	140	90	5 minutes
145	141	90	4 minutes
146	142	90	182 seconds

Internal Temperature of Product (°F)	Wet-Bulb Temperature of Smokehouse (°F)	% Relative Humidity of Smokehouse	Time
147	143	90	144 seconds
148	144	90	107 seconds
149	145	90	85 seconds
150	146	90	67 seconds
151	147	90	54 seconds
152	148	90	43 seconds
153	149	90	34 seconds
154	150	90	27 seconds
155	151	90	22 seconds
156	152	90	17 seconds
157	153	90	14 seconds
158	154	90	Instantaneous

CCP2: Drying Once lethality is achieved in the first part of the process, the product is dried at a temperature of at least 150°F 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.**

Alternate Appendix A Process based on USDA-FSIS 2014 Compliance Guideline. The USDA-FSIS issued a *Compliance Guideline for Meat and Poultry Jerky Produced by Small and Very Small Establishments* (2014). This Compliance document allows processors to use less than 90% humidity required in Appendix A if relative humidity/wet-bulb temperature is maintained for a sufficient period of time: *Establishments have the flexibility to use the options in Appendix A that utilize less than 90% relative humidity; that is, the options of: Heating roasts of any size to a minimum internal temperature of 145°F (62.8°C) in an oven maintained at any temperature if the relative humidity of the oven is maintained either by continuously introducing steam for 50 percent of the cooking time or by use of a sealed oven for over 50 percent of the cooking time, or if the relative humidity of the oven is maintained at 90 percent or above for at least 25 percent of the total cooking time, but in no case less than 1 hour.* The 2012 Compliance Guidelines further state: *The literature review has shown that at least 27-32% relative humidity should be present during the cooking process to ensure that adequate lethality is attained. In addition, the wet bulb temperature should reach at least 125-130°F for an hour or more during the lethality process (Buege, 2006a; Harper, 2009).*

Alternative Appendix A process:

1) Maintain the relative humidity of the ovens at least 27-32% for at least 50% of lethality step by **continuously introducing steam or by use of a sealed oven**; this time to be **at least 1 hour**,
OR

Maintain the relative humidity of the ovens of at least 90% for at least 25% of lethality step (humidity maintained with a sealed oven or by continuously introducing steam); this time must be **at least 1 hour**, ...**AND**

2) During the lethality stage, achieve a **product internal temperature/time combination** of at least 145° F for at least 4 minutes and maintain a wet bulb setting of 125-130°F for at least 1 hour.

Once lethality is met, the product is dried to achieve shelf stability. **As an example**, for a standard smokehouse/oven schedule operating set at 170°F, critical limits would be as follows:

CCP1: Cooking (lethality)

Critical limits (must be monitored):

- Oven temperature setting 170°F.
- Relative humidity at least 27% for at least 1 hour.
- Wet bulb at least 125°F for at least 1 hour.
- Product internal temperature at least 145°F for at least 4 minutes.

CCP2: Drying (shelf stability)

Critical limits (must be monitored):

- Oven temperature setting 170°F.
- Dry to water activity of 0.85 or lower (shelf stability).

A document which correlates yield and water activity can be found here:

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

Note, your critical limits do not include dampers being opened or closed, nor do they list the continuous injection of steam into the oven, this is covered in an SOP for Oven/Smokehouse Operation. The Guidelines **do require** that humidity is achieved with either introducing steam or closing the dampers.

Research-Tested Alternative Validated Processes. Researchers at University of Wisconsin-Madison and the USDA’s Eastern Regional Research Center (ERRC) have studied the lethality of eight alternative processes for making whole-muscle beef jerky that have enough lethality. The results of these studies have been published in peer-reviewed scientific journal articles and **are considered validated processes for the manufacture of whole muscle beef jerky**; a summary of each process follows. **The Critical Limits for each of the processes summarized below are the smokehouse temperatures (dry-bulb and /or wet-bulb), process times and % RH values. Supporting research documentation can be found at the end of this document.**

Type 1-A Process: This process has 3 stages. In Stage 1 a high-dry-bulb temperature is achieved in the smokehouse, in Stage 2 the wet-bulb temperature is raised enough to get lethality, and in Stage 3 the product is dried.

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)	Time for this stage (minutes)	Cumulative Time (minutes)	
1	170°F (oven must reach 145°F within 10 min and 170°F within 25 min)	Not Applicable (NA)	30	30	
2	170°F	Choose one	125°F	60	90
		combination of wet-bulb and time:	130°F	60	90
			135°F	30	60
			140°F	10	40
3	170°F	NA	Until desired dryness	Until desired dryness	

*Note that Type 1-A processes with a higher dry-bulb temperature in Stage 1, a higher dry-bulb or wet-bulb temperature or longer time in Stage 2, or a higher dry-bulb temperature in Stage 3, can also be considered validated **as long as the oven reaches the minimum process temperature as outlined in Stage 1.**

Type 1-B Process: This process also has 3 stages. The only differences between this process and the Type 1-A process are that the Stage 1 dry-bulb temperature target is different, there is only one choice for wet-bulb temperature and time in Stage 2, and the Stage 3 dry-bulb temperature is different.

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 145°F <u>within 10 min and 150°F within 25 min</u>)	Not Applicable (NA)	30	30
	190°F (oven must reach 145°F <u>within 10 min and 190°F within 25 min</u>)			
2	150°F	130°F	60	90
3 Choose one dry-bulb temperature:	150°F	NA	Until desired dryness	Until desired dryness
	190°F	NA	Until desired dryness	Until desired dryness

*Note that processes with a higher dry-bulb temperature in Stage 1, a higher dry-bulb or wet-bulb temperature or longer time in Stage 2, or a higher dry-bulb temperature in Stage 3 can also be considered validated **as long as the oven reaches the minimum process temperature as outlined in Stage 1.**

Type 2 Process: This is a 2-stage process in which the dry-bulb temperature is set at 145°F to begin the process and this temperature is achieved **within the first 10 minutes**. At the 15-minute point in the process, the dry-bulb temperature setting is **increased** to 170°F. The dry-bulb temperature should reach 170°F **within 10 minutes**, and this temperature is held at least another 95 minutes (longer if necessary to achieve desired dryness). The **RH** in the smokehouse must be at least 27% at the start of the process and at least 17% after 120 minutes total processing time. The corresponding wet-bulb temperatures are 105°F and 112°F at the start and after 120 minutes, respectively. *Note that processes reaching higher dry-bulb or wet-bulb temperatures at either time-point can also be considered validated **as long as the smokehouse reaches the processing temperature within the time allowed.**

Type 3 Process: This is a 2-stage process in which the dry-bulb temperature is set at 145°F to begin the process and this temperature is achieved **within the first 10 minutes**. At the 90-minute point in the

process, the dry-bulb temperature setting is increased to 170°F. The dry-bulb temperature should reach 170°F **within 10 minutes**, and this temperature is held at least another 90 minutes (longer if necessary to achieve desired dryness). The **RH** in the smokehouse must be at least 41% at the start of the process and at least 21% after 180 minutes total processing time. The corresponding wet-bulb temperatures are 116°F and 117°F at the start and after 180 minutes, respectively. *Note that processes reaching higher dry-bulb or wet-bulb temperatures at either time-point can also be considered validated **as long as the smokehouse reaches the processing temperature within the time allowed.**

Type 5 Process: This process involves setting the dry-bulb temperature at 180°F, achieving this temperature **within 10 minutes**, and maintaining this temperature for at least 65 additional minutes (75 minutes total processing time). The **RH** in the smokehouse must be at least 29% at the start of the process and 15% after 75 minutes of processing (corresponding wet-bulb temperatures are 136°F and 117°F, respectively). *Note that processes reaching higher dry-bulb temperatures, or higher relative humidity, at either time-point can also be considered validated **as long as the smokehouse reaches the processing temperature in the time allowed.**

Type 7 Process: This is a 4-stage process in which the dry-bulb temperature is increased at hourly intervals. **In this step-wise process, each time the temperature setting is increased, the new temperature must be achieved within 10 minutes; the temperature can also gradually ramp-up during each stage.** The final product drying is done at 170°F. 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).

Stage	Dry-Bulb Temperature (°F)	Wet-Bulb Temperature (°F)	Time for this stage (minutes)	Cumulative Time (minutes)
1	120°F (oven must reach 120°F <u>within</u> 10 min)	98°F, or higher (must be 98°F (43% RH) at start of process)	60	60
2	130°F (oven must reach 130°F <u>within</u> 10 min)	NA	60	120
3	140°F (oven must reach 140°F <u>within</u> 10 min)	NA	60	180
4	170°F (oven must reach 170°F <u>within</u> 10 min)	109°F, or higher, after 240 minutes of processing (15% RH)	60 min, or longer (add more time for further drying)	240 min, or longer (add more time for further drying)

Critical Limits (see next page):

Critical Limits:

- Dry bulb at least 120°F—stage 1, 130°F—stage 2, 140°F—stage 3, and 170°F—stage 4.
- Wet bulb at least 98°F (43% RH) at the start of the process.
- Wet bulb at least 109°F (15% RH) after 240 minutes.
- Process time of 240 minutes (4 hours) or longer.

Type 8 Process: In this process the dry-bulb temperature must be at least 180°F for the **entire process**. **Hickory smoke is applied throughout the process.** The dry-bulb temperature of 180°F must be achieved in the oven within the first 24 minutes and maintained for at least 150 minutes. The RH in the smokehouse must be at least 36% at the end of the come-up time (142°F wet-bulb temperature). After 150 minutes the RH in the smokehouse must be at least 19% (123°F wet-bulb temperature).

Critical Limits:

- Dry bulb at least 180°F for at least 150 minutes
- Oven reaches 180°F, or higher, within 24 minutes of the start
- Wet bulb at least 142°F (36% RH) when the oven reaches 180°F and at least 123°F (19%) after 150 minutes of processing.

To view the published peer-reviewed scientific journal articles on which these summaries are based, please go to the links listed below.

For Processes 1-A, 1-B, 2, 3, 5, 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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