FSIS Compliance Guideline for Meat and Poultry Jerky Produced by Small and Very Small Establishments

2012 Updated Compliance Guideline

This guidance document is designed to help very small meat and poultry establishments that manufacture jerky identify:

- The key steps in the jerky process needed to ensure safety; and
- The scientific support documents available to help develop a safe process and product.

This Compliance Guideline articulates how industry can meet FSIS expectations regarding jerky processing. It is important to note that this Guideline represents FSIS's current thinking on this topic and should be considered usable as of its issuance. Guidelines will be continually updated to reflect the most current information available to FSIS and its stakeholders.

Request for comments:

FSIS is seeking comments on this guidance document as part of its efforts to continuously assess and improve the effectiveness of policy documents. All interested persons may submit comments regarding any aspect of this document, including but not limited to: content, readability, applicability, and accessibility. The comment period will be 60 days and the document will be updated in response to the comments.

Comments may be submitted by either of the following methods:

Federal eRulemaking Portal Online submission at regulations.gov: This Web site provides the ability to type short comments directly into the comment field on this Web page or attach a file for lengthier comments. Go to http://www.regulations.gov and follow the online instructions at that site for submitting comments.

Mail, including - CD-ROMs, and hand- or courier-delivered items: Send to Docket Clerk, U.S. Department of Agriculture (USDA), FSIS, Patriots Plaza 3, 1400 Independence Avenue SW, Mailstop 3782, 8-163A, Washington, DC 20250-3700.

All items submitted by mail or electronic mail must include the Agency name, FSIS, and document title: FSIS Compliance Guideline for Meat and Poultry Jerky Produced by Small and Very Small Establishments. Comments received will be made available for public inspection and posted without change, including any personal information, to http://www.regulations.gov.

Compliance Guideline for Meat and Poultry Jerky Produced by Small and Very Small Establishments

Table of Contents

Compliance Guideline for Meat and Poultry Jerky Produced by Small and Very Small Establishments

Purpose

This guidance document is designed to help very small meat and poultry establishments that manufacture jerky identify:

- The key steps in the jerky process needed to ensure safety; and
- The scientific support documents available to help develop a safe process and product.

This guidance document is not intended to set any regulatory requirements. This document replaces previous versions of the guidance that was last updated in 2007.

Background

Meat or poultry jerky is a ready-to-eat (RTE), dried product that is considered shelf-stable (i.e., it does not require refrigeration after proper processing). Following a 2003 salmonellosis outbreak from *Salmonella* Kiambu in jerky produced in New Mexico, FSIS published the first version of the Compliance Guideline for Meat and Poultry Jerky Produced by Small and Very Small Establishments. The Compliance Guideline provided guidance for small and very small meat and poultry establishments on the critical steps for jerky processing and the controls needed at each of these steps to ensure a safe product was produced.

One potential cause of the 2003 *Salmonella* Kiambu in jerky outbreak was the very slow drying process under low humidity conditions (1% RH - 82°C dry bulb, 30°C wet bulb), which allowed *Salmonella* organisms to dehydrate during drying and become resistant to heat[1]. Therefore, the first version of the jerky compliance guidelines emphasized the need for high levels of humidity during jerky processing. Since 2003, a number of journal articles have been published that has increased scientific understanding of the critical factors during jerky processing including the role of humidity.

One potential cause of the 2003 *Salmonella* Kiambu in jerky outbreak was the very slow drying process under low humidity conditions

This document updates and replaces the 2007 version of the guidance to reflect the most up-to-date science and understanding of jerky processing. In addition, through recent Food Safety Assessments (FSAs), FSIS has found that producers of meat and poultry jerky may still not be adequately processing jerky to achieve the lethality necessary to produce a safe product. Therefore, this guidance also addresses recent concerns identified through FSAs.

[1] http://www.promedmail.org/direct.php?id=20031003.24887

Step-by-Step Guide for Jerky Processing

Below is a summary of the seven (7) general or common processing steps used in jerky production. Although an establishment's process may not include all these steps, **the lethality treatment and drying should be utilized to produce a safe product**. Other steps such as the intervention and post-drying steps may be utilized for those processes that do not achieve an adequate lethality. Further descriptions of the key steps in the jerky process including the microbial interventions that can be applied to ensure safety, are reviewed on the following pages.

- **Step 1 - Strip preparation**: Whole muscle is sliced or ground; ground product is formed into strips (some jerky is formed).

- **Step 2 – Marination**: The strips are then marinated in a solution that often contains salt, sugar, and flavoring ingredients.

- **Step 3 – Interventions**: Antimicrobial interventions, before and after marinating the strips of raw product, may be added to increase the level of pathogen reduction beyond that achieved by heating alone.

- **Step 4 – Lethality**: The lethality treatment is defined as the process step or steps used to destroy pathogenic microorganisms on or in a product to make the product safe for human consumption and is considered to include the time when the product is placed in the heated oven until the product reaches the desired lethality time/temperature combination (also referred to as the cooking time).

  In order to achieve adequate lethality, it is important that an establishment's actual process adheres to the following critical operational parameters (see key definitions on page 7) in the scientific support documentation:
  - Product time/temperature combination
  - Relative humidity

  The purpose of the lethality step is to apply a lethality treatment to kill or reduce the level of microorganisms. Drying the jerky ensures the final product reaches a sufficient water activity to prevent the growth of microorganisms, especially toxigenic microorganisms, such as *Staphylococcus aureus*.

- **Step 5 – Drying:** Drying is the process during which water (moisture) is removed from the product. After the lethality treatment, jerky is dried to meet a water activity level sufficient for food safety purposes.

- **Step 6 – Post-drying heat step**: A post-drying heat step may be added to increase the level of pathogen reduction beyond that achieved by heating alone.

- **Step 7 – Handling**: Product is often handled after the lethality and drying steps and prior to packaging.

Each step in the jerky process is reviewed in more detail below. Please note that each process is unique, so some processors may not utilize all 7 steps or some may perform the steps below in different orders.

- **Step 1 - Strip preparation**: Whole muscle is sliced or ground; ground product is formed into strips (some jerky is formed).

It is critical for establishments to use source materials prepared under good manufacturing practices (GMPs) designed to minimize contamination and the presence and growth of pathogens of public health concern so that the initial pathogen load is not higher than what the process is designed to reduce. Establishments that choose to purchase source materials known to be contaminated with pathogens of public health concern, such as *Salmonella* or shiga toxin-producing *Escherichia coli* (*E. coli)* (STEC) organisms such as *E. coli* O157:H7 or *E. coli* O45, should have controls in place to ensure cross-contamination between raw and RTE product does not occur.

- **Step 2 – Marination**: The strips are then marinated in a solution that often contains salt, sugar, and flavoring ingredients.

- **Step 3 - Interventions**: Antimicrobial interventions, before and after marinating the strips of raw product, have been shown to increase the level of pathogen reduction beyond that achieved by heating alone.

Some heating processes may not deliver an adequate lethality and, thus, may require an additional intervention step to ensure product safety. Examples of interventions that may increase the lethality of the process are:

- Preheating the meat or poultry jerky strips in the marinade to a minimum internal temperature of 160°F will provide an immediate reduction of *Salmonella* (Harrison and Harrison, 1996). Heating in marinade may produce unacceptable flavors for some products; however, other liquids such as water could be used. The times and temperatures in FSIS Appendix A: Compliance Guidelines For Meeting Lethality Performance Standards For Certain Meat and Poultry Products (referred to throughout the document as Appendix A) could be used for preheating in the liquid, although the product internal temperature should be monitored to ensure adequate lethality is achieved).

- Dipping the product in 5% acetic acid for 10 minutes before placing it in the marinade can augment the log reduction effects of drying but not enough to eliminate pathogens (Calicioglu, 2002 & 2003). This intervention may also result in an undesirable flavor.

- Dipping the product in 1:2 or 1:3 mixtures of calcium sulfate (Mionix Safe$_2$O™) and water for 30 seconds can better reduce the level of *Salmonella*, *Listeria monocytogenes (Lm)*, and *E. coli* O157:H7 compared with no pretreatment. Pretreatment with acidified sodium chlorite (Keeper®) at concentrations between 500 and 1,200 ppm was also effective. These pretreatments were effective in both dehydrators and smokehouse processing (Harrison et al., 2006).

- **Step 4 - Lethality treatment**:

The establishment needs to control, reduce, or eliminate the biological hazards identified in its hazard analysis. For meat and poultry jerky, these hazards will most likely include microbiological hazards from *Salmonella* spp., *Lm*, and *Staphylococcus aureus*. For beef jerky, *E. coli* O157:H7 may also be a hazard reasonably likely to occur. In recent years, several jerky products have been found to be adulterated with *Salmonella* and *E. coli* O157:H7.

The lethality treatment of poultry jerky must achieve at least a 7.0 log reduction of *Salmonella* spp. as required in 9 CFR 381.150. The lethality treatment of meat jerky should achieve at least a 5.0 log reduction of *Salmonella* spp. and should also achieve sufficient reductions in the other bacterial pathogens of public health concern (e.g., at least a 5.0 log reduction for *E. coli* O157:H7 for products containing beef as recommended in the *Salmonella* Compliance Guidelines for Small and Very Small Meat and Poultry Establishments that Produce Ready-to-Eat (RTE) Products). In addition, the lethality treatment of meat and poultry jerky should achieve at least a 3.0 log reduction in *Lm* although a 5.0 log reduction or greater is desirable for providing an even greater safety margin for ensuring that *Lm* doesn't grow during cold storage to detectable levels. However, establishments are not expected to validate that their process achieves reduction in *Lm* if it achieves sufficient reductions in *Salmonella* because *Salmonella* is considered an indicator of lethality.

In addition, an official establishment should have sound decisions in the hazard analysis that support that source materials were prepared using GMPs and other process controls such that adequate reduction results in the production of a safe product.

Official establishments choosing to use cooking to achieve lethality before drying may consider a number of different types of scientific documents to support the time/temperature/humidity combination used in the actual process. Such types of scientific support documents include:

- Compliance Guidelines (e.g., Appendix A)
- Journal articles
- Challenge studies
- In-plant data

KEY DEFINITIONS

The **lethality treatment** is defined as the process step or steps used to destroy pathogenic microorganisms on or in a product to make the product safe for human consumption and is considered to include the time when the thermal processing begins (e.g., the product is placed in the heated oven) until the product reaches the desired lethality time/temperature combination (also referred to as the cooking time).

Critical operational parameters are those parameters of an intervention that must be met in order for the intervention to operate effectively and as intended. Such parameters include but are not limited to time, temperature, water activity, concentration, relative humidity, and type of equipment.

An in-depth discussion of considerations for each of these types of scientific support documents, along with examples, is discussed in the section titled: **Scientific Support Documents for Jerky Processing**.

Critical Operational Parameters during the Lethality Treatment

Regardless of the scientific support document utilized, it is important that an establishment's actual process and procedures relate and adhere to the critical operational parameters in the scientific support in order to achieve adequate lethality. There are several critical operational parameters that are important for jerky processing that will be reviewed.

Product time/temperature combination

It is important that the jerky product achieve the temperature shown to be effective in the Appendix A guidelines or other scientific support documents. Most often the temperatures used during the lethality treatment that are reported in scientific support documents are the temperatures that the product should reach.

FSIS has found through FSAs that many establishments often use temperatures from support documents to set critical limits for the oven temperature; however, setting the oven temperature to the temperature in the support does not ensure that the product will reach the same internal temperature which is critical to ensuring adequate lethality is achieved. FSIS has also found through FSAs that some establishments do not measure or verify that the product has achieved the desired internal lethality temperature until after drying. FSIS does not recommended verifying product temperatures only after drying because the product may have dried out before the lethality temperature was reached resulting in lower than expected pathogen reduction.

Product internal temperature can be measured by inserting a thermocouple probe into the geometric center of a beef strip. Proper insertion may be difficult because the product is so thin; therefore, FSIS recommends that establishments slice one piece of jerky twice as thick as normal so that the probe can be inserted. If this thicker piece reaches the lethality temperature, the thinner pieces should as well. In addition, to accurately measure the product temperature, the establishment should also have an understanding of factors that could affect the temperature of the product. These factors include having an understanding of the cold spots in the oven, as well as understanding of the variation in temperature of the oven during different seasons. Although monitoring product temperature is encouraged, establishments can use the oven temperature in place of the product temperature provided that the establishment has a consistent product and process and has sufficient data correlating the oven temperature with the product temperature.

In addition to the product temperature, the amount of time the product is held at this temperature is also critical to ensuring that adequate lethality is achieved. It is important for the establishment to understand how the actual temperature of the product was taken, the time it takes the product to reach the target temperature (known as the come-up time or CUT), and the amount of time the product is held at the target temperature compared to the scientific support documentation. If the product is held at

the target lethality treatment for less time than what was used in the scientific support then adequate lethality may not be achieved.

Relative Humidity

In addition to the product time/temperature combination, the relative humidity (e.g., steam) in the oven is also critical for achieving adequate lethality in jerky. It is important that the establishment maintains humidity according to Appendix A or other supporting documents. Relative humidity around a product during the lethality treatment promotes lethality in two ways:

- First, the humidity reduces surface evaporation and the energy or heat that evaporation removes from the product during heating. If sufficient relative humidity surrounding the product is not maintained during the lethality treatment, undesirable evaporative cooling at the surface will occur, and the product will not reach the desired temperature. Producing products under conditions of high humidity early in the cooking process reduces evaporative cooling allowing products to reach higher product surface temperatures which results in a greater reduction in microorganisms.

- Second, the humidity keeps the product surface (and any pathogens) more moist and prevents unwanted concentration of solutes (e.g., sugar and salt) as a result of drying. Research has demonstrated that bacteria can become more heat resistant as their moisture level decreases, and increased concentrations of solutes, especially sugars, increase the heat resistance of bacteria. Therefore, drying of the product surface before the pathogens are destroyed will increase pathogen heat resistance and allow them to survive the heating process. By incorporating humidity to minimize evaporation, the D values (time at a constant temperature necessary to destroy 90% or 1 $\log_{10}$ of the target organism) that are the basis for Appendix A and other scientific support documents remain valid (Goepfert, 1970; Goodfellow and Brown, 1978; Faith, N.G. et al. 1998).

KEY DEFINITIONS

Relative Humidity is defined as the degree of saturation of the air by water (vapor), expressed as a percentage. Relative humidity describes the relation of the existing vapor pressure at a given temperature to the maximum vapor pressure at that temperature. Air at a given temperature can absorb vapor until its saturation (100%). The difference between the dry and wet bulb temperature is the relative humidity at that temperature. The following website http://home.fuse.net/clymer/water/wet.html contains a function for calculating the relative humidity given the wet and dry bulb temperatures.

Without sufficient humidity the product surface may dry too quickly, and the bacteria may become more heat resistant.

For these reasons, it is crucial that the processor prevent drying of the product until a lethal time-temperature combination is attained. Therefore, in order to be most effective,

the humidity should be applied during the lethality treatment and before the drying step occurs. It is also recommended that establishments treat the lethality and drying steps as separate stages to ensure that lethality is achieved before the product dries out. This is why FSIS recommends that the desired product temperature be measured or verified prior to the drying stage. One way for an establishment to know that the product has not dried out before a lethal time-temperature combination is attained is to measure the water activity of the product after the lethality treatment but before drying. Some published articles (for example, Buege et al., 2006a) may report the water activity at the point in the process for comparison. Another way is for the establishment to monitor the wet-bulb temperature early in the process, because it provides a good indication of product surface temperature, which strongly influences lethality (Buege, 2006). Further explanation and directions for making a wet-bulb thermometer are in Attachment 2.

Some simple and practical measures that can be used to aid in meeting the humidity level utilized in the scientific support documents include:

- Seal the oven: Close the smokehouse doors and oven dampers to provide a closed system and prevent moisture loss.

- Add humidity:
    - Place one or more shallow, wide pans of hot water in the oven to increase the humidity in the system. Conduct a test run to determine whether the water evaporates.
    - Injecting steam or a fine water mist in the oven can also add humidity.

In either case, the use of a humidity sensor or the use of wet-bulb and dry-bulb thermometers (to measure relative humidity) would enable the operator to determine whether adequate humidity is being applied.

In order to ensure adequate humidity is attained, the establishment should monitor the humidity throughout the lethality treatment. The process should be monitored using wet and dry bulb thermometers (used to determine relative humidity) or a humidity sensor.

NOTE: A 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**

KEY DEFINITIONS

The **dry-bulb** temperature refers to the ambient air temperature. It is called "dry-bulb" because the air temperature is indicated by a thermometer not affected by the moisture in the air or as a result, evaporative cooling. The dry-bulb temperature is most commonly measured by jerky-makers.

The **wet-bulb** temperature is the temperature indicated by a moistened thermometer bulb exposed to the air flow. A wet-bulb thermometer measures the extent of cooling that happens as moisture dries from a surface, a process also known as evaporative cooling. The wet-bulb temperature is always lower than the dry-bulb temperature except when there is 100% relative humidity, when they will be identical. Because evaporative cooling occurs on the surface of thin jerky strips, the wet-bulb temperature is more accurate measurement of product surface temperature.

A **Sealed oven** is generally defined as one in which the smokehouse doors and smokehouse oven dampers are closed to prevent moisture loss.

125-130°F for an hour or more during the lethality process (Buege, 2006a; Harper, 2009). See page 16 for more information.

The following website http://home.fuse.net/clymer/water/wet.html contains a function for calculating the relative humidity given the wet and dry bulb temperatures. A basic wet bulb thermometer can be prepared by fitting a wet, moisture-wicking cloth around a dry bulb thermometer. To maintain a wet cloth during the process, submerse an end of the cloth in a water supply. The cloth must remain wet during the entire lethality treatment especially if smoke is applied. The establishment should inspect the wet-bulb sock prior to thermal processing and should be changed as necessary depending on the sock's condition. Attachment 2 contains more details for creating a wet-bulb thermometer.

The use of a wet bulb thermometer is especially important for production at high altitudes or areas of low humidity. In fact, processing failures in the manufacture of jerky have occurred in establishments located at high altitudes. Establishments located at higher altitudes will generally have a lower atmospheric pressure. This leads to lower boiling points and faster evaporation from the product surface, which can lead to undesirable evaporative cooling and drying of the product surface. Furthermore, at high altitudes, the relative humidity can be less at the higher altitude due to the lower air pressure (if the temperature at sea level and the high altitude is the same). As a result, at high altitudes, the amount of moisture added to the smokehouse chamber necessary to achieve a given log reduction of bacteria may need to be increased to account for lower levels of humidity in the ambient air. Adjustments to the amount of humidity added to the smokehouse chamber to account for changes in humidity in the ambient air at high altitudes will need to be made by establishments on a case-by-case basis as part of the initial design of the system to ensure that the humidity in the actual process matches the level in the scientific supporting documentation.

Establishments should also take into account variability in relative humidity in the ambient air throughout different times of year.

- **Step 5 – <u>Drying</u>**:

Drying is the process during which water is removed from the product. After the lethality treatment, jerky is dried to meet a finished product water activity level that is sufficient for food safety purposes. After drying is complete, the establishment should monitor or verify the water activity to demonstrate that the product has attained the critical limit for shelf-stability. It is important that the establishment achieves the water activity of the finished product identified in its supporting documentation.

FSIS is aware that some manufacturers rely upon the maximum moisture protein ratio (MPR), rather than water activity, for determining whether their process adequately dries the jerky to produce a shelf-stable product. MPR is an inappropriate indicator of shelf-stability. Water activity (also referred to as a_w), however, as measured by an instrument such as a water activity meter, is the more appropriate indicator to verify jerky is properly dried for food safety. This is because water activity is a better measure of available water (or water that is not bound by other components) for microbial growth than MPR. Minimizing available water (e.g., achieving a water activity of 0.85 or less) is critical for controlling growth of pathogens. However, an MPR of 0.75:1 or less remains part of the standard of identity for jerky (for labeling purposes only). Thus, an MPR of

0.75:1 or less is necessary to label the product "jerky," but it is not always sufficient to ensure safe jerky products. In addition, in order to label a product "jerky" it should be shelf-stable. Although FSIS does not define jerky as shelf-stable in the regulatory standards of identity (9 CFR part 319), consumers consider and expect jerky to be shelf-stable.

A water activity critical limit of 0.85 or lower should control growth of all bacterial pathogens of concern as well as mold for products stored in an aerobic or oxygen containing environment such as in ambient air; however, if the product is vacuum packaged in an oxygen impervious packaging (creating an anaerobic environment where no oxygen is present), the water activity critical limit could be 0.91 or lower. These limits are based on the growth and toxin production limits for *Staphylococcus aureus* under optimal conditions with and without oxygen present (ICMSF, 1996). Establishments that choose to use these limits as support for the shelf-stability of their product may cite this guideline as supporting documentation for these limits and are not expected to provide additional scientific support.

NOTE: Vacuum packaged products with a water activity level > 0.85 and ≤ 0.91 should be kept refrigerated once the package is opened because the product would no longer be considered shelf-stable once it is exposed to oxygen. Lack of shelf-stability once the product is exposed to oxygen is mainly a concern for products that would not be consumed within a single serving as these products are not likely to be vacuum packaged by the consumer between servings. Therefore, unless the establishment has support that the product is likely to be consumed in a single serving, vacuum packaged products with a water activity in the range of > 0.85 and ≤ 0.91 should be labeled with a statement such as "Refrigerate After Opening" (as described in 9 CFR 317.2(k)).

KEY QUESTION

Question: Should an establishment use the MPR to determine whether its process produces a shelf-stable product?

Answer: No. Establishments should use water activity to demonstrate that the product has attained the critical limit for shelf-stability.

KEY DEFINITIONS

Shelf-stable is the condition achieved when meat and poultry products can be stored under ambient temperature and humidity conditions, and if the package integrity is maintained during storage, shipping, display at retail, and in the home, will not become unsafe throughout the manufacturer's specified shelf-life.

Water activity, also referred to as a_w, is a measure of the concentration of moisture (i.e., water) **and** its availability in a food. The amount of water available in a food depends on the total concentration of all dissolved substances in the product because they bind water. Thus, if ingredients such as salt or sugar are added to food, they compete with the bacteria for available water.

Moisture-protein-ratio (MPR) expresses the percent moisture divided by the percent protein. MPR is commonly used in the U.S. to classify dried sausages and other meat products. Although MPR values indicate the degree of product drying, they are not necessarily indicative of microbial safety or product shelf-stability because they do not take into account availability of the water.

- **Step 6 – <u>Post-drying heat step</u>**: A post-drying heat step may be added to increase the level of pathogen reduction beyond that achieved by heating alone.

This step may be needed for processes that do not result in an adequate reduction of *Salmonella* through the initial heating process. Adding a post-drying heat step has the potential to reduce *Salmonella* levels by approximately 2 logs from the level of reduction achieved during initial heat step. One example of a post-drying heat step that has been found to reduce *Salmonella* levels by approximately 2 logs is to heat the dried product in a 275°F oven for 10 minutes (Harrison et al., 2001).

- **Step 7 – <u>Handling</u>**: Product is often handled after the lethality and drying steps and prior to/during packaging.

Establishments should control their processes to prevent contamination of product with pathogens from product handling after the lethality and drying steps. Such controls should include ensuring that cross-contamination of product is minimized prior to packaging, and ensuring that the product is packaged in such a way that cross-contamination of product post-packaging is also minimized (e.g., with a good seal to maintain package integrity throughout storage, shipment and display).

Cross-contamination of product can occur from situations such as the following:

- Use of the same equipment (e.g., grinders, mixers, or packaging equipment) for both raw and cooked products without complete cleaning and sanitizing of the equipment between production lots.

- Placing cooked product on the same surface (e.g., cutting table) as raw product without complete cleaning and sanitizing of the surface before reuse.

- Using the same utensils or containers (e.g., scoops or buckets) for both raw and cooked product without complete cleaning and sanitizing of the surface before reuse.

- Condensation, aerosolization, or dusting of dry ingredients into the processing environment.

The establishment is required to maintain sanitation in the ready-to-eat (RTE) area to ensure that food contact surfaces are free of contamination from *Lm* and other pathogens, such as *Salmonella*, in accordance with 9 CFR part 430. The establishment is also required to develop and implement Sanitation SOPs (9 CFR 416) to ensure that contamination and adulteration of the product is prevented after the lethality treatment.

Further guidance on post-processing handling and sanitation for ready-to-eat products including jerky can be found in the Salmonella Compliance Guidelines for Small and Very Small Meat and Poultry Establishments that Produce Ready-to-Eat (RTE) Products and the Compliance Guidelines to Control Listeria monocytogenes in Post-Lethality Exposed Ready-to-Eat Meat and Poultry Products.

Scientific Support Documents Available for Jerky Processing

Establishments have numerous options for the types of scientific documents that can be used to support that the process achieves adequate lethality. Examples of the scientific support documents available to help develop a safe jerky process and product are discussed below along with considerations for each type of support. Product sampling results, based on historical data alone, should not be used as scientific support for a jerky process because they do not provide information on the level of pathogen reduction that is achieved for the process.

Compliance Guidelines

FSIS has issued a number of different compliance guidelines that have application to jerky processing. It is important to note that, while FSIS considers these documents to be guidelines, if followed precisely they are considered as validated process schedules because the guidelines contain processing methods already accepted by the Agency as effective in safely cooking meat and poultry products.

Some considerations for each of these compliance guidelines are outlined below.

- **FSIS Appendix A: Compliance Guidelines For Meeting Lethality Performance Standards For Certain Meat and Poultry Products**

For meat jerky, use of the time-temperature combinations provided in Appendix A, including those temperatures above 158°F in which the desired lethality is instantaneous, should help to ensure the safety of the product. These time-temperature combinations are based on experiments that were done with products without added salt or sugar. Added salt, sugar, or other substances that reduce water activity will increase the heat resistance of bacteria in a product. However, time and experience have shown that the time-temperature combinations in the lethality compliance guidelines have been sufficient to produce safe products even with both salt and sugar added, but the **humidity during heating is a critical factor**. The humidity options in the Appendix A guidelines that are applicable to jerky processing are as follows:

- 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; or

- Heating roasts of any size in an oven maintained at any temperature that will satisfy the internal temperature and time combinations [from the chart provided in Appendix A] 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 relative humidity may be achieved by use of steam injection or sealed ovens capable of producing and maintaining the required relative humidity.

Key Considerations for Options in the Appendix A guidelines that utilize < 90% humidity

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.

If an establishment can not apply these humidity options for equal to or more than one hour, then the humidity of the oven should be maintained at 90% or above throughout the lethality treatment.

If an establishment chooses to use one of the options that require less than 90% relative humidity, then only those time/temperature combinations of equal to or greater than 145°F for 4 minutes apply. This option is included in the Appendix A guidelines but is often overlooked. It is also important to note again that the temperature values in the Appendix A correspond to product temperatures, not oven temperatures.

NOTE: The "continuously introducing steam" option is meant to refer to the use of live steam although it may also apply to establishments that spray water onto hot heating elements which creates steam that in turn produces humidity in the smokehouse. "Continuous" does not mean that the steam is injected for at least one hour during one stage; rather, steam could be injected during stages or time intervals during the lethality as long as the total amount of time the steam is introduced for adds up to over 50% of the cooking time.

It is FSIS's expectation that establishments using any of the options in the Appendix A guidelines as their supporting documentation will maintain the humidity level in the oven for at least the percentage of cooking time specified by the method, but in no case less than one hour. It is critical that humidity is maintained during cooking to ensure a safe product. Guidance for maintaining humidity is provided here. In addition, prudent establishments using any of the options in the Appendix A guidelines will either: 1) monitor the humidity level of their ovens (e.g., by use of dry and wet bulb thermometers to calculate the relative humidity or use of a humidity sensor that provides a direct measurement), or 2) provide documentation that supports that, when the oven dampers are closed, humidity is maintained in the ovens, or that supports that steam is being continuously injected.

It is important that establishments maintain and monitor the humidity levels in the oven.

Moreover, it is also expected that establishments using the sealed oven method will have a procedure for checking that the dampers are properly working. This procedure could include a review of records from a computerized system that contains documentation of the time at which the oven dampers were open and were closed, along with a maintenance program to periodically monitor that the seals are intact and functional, and that when the oven dampers are closed, a tight seal is obtained that prevents a significant loss of humidity. Establishments should

also consider whether there are other openings, particularly in older smokehouses, such as drain valves or air intake valves; that need to be closed in order to ensure a seal is obtained. Finally, some older ovens may have a stack or other opening that can't be closed. For those establishments with older ovens that can not be completely closed, the sealed oven method should not be used. However, the establishment may choose to close what they are able and to add moisture in the system either by continuously introducing steam or another validated method.

Establishments using the option to continuously inject steam should also have a procedure or mechanism in place to ensure that steam is in fact being continuously injected. Such a mechanism could include the monitoring of the time that steam is continuously introduced into the oven during the cooking time or use of temperature charts, with wet and dry bulb temperatures, that show that the wet bulb temperature is rising for 50% of the cooking time based upon a letter from the manufacturer stating that when the relative humidity is rising it is because of live steam injection.

FSIS recommends that establishments monitor the humidity levels in the oven even when using one of the options that requires < 90% humidity because the literature suggests that **at least 27-32% relative humidity** should be present during the cooking process to ensure that adequate lethality is attained. In addition, the literature suggests that the wet bulb temperature should reach at least 125-130°F for an hour or more during the lethality process. Wet bulb temperature is generally a strong indicator of product internal temperature early in the process. Therefore, maintaining the wet bulb at a high enough level to cause lethality (125-130°F) is recommended (Buege, 2006a; Harper, 2009), although achieving a specified relative humidity or wet bulb is not a requirement for all of the humidity options in the Appendix A guidelines. Finally, although FSIS recommends that establishments monitor the humidity levels in the oven or provide documentation that supports that the oven is sealed, or steam is continuously injected for each batch or lot produced, the establishment is required to list the procedures and the monitoring frequency chosen for each CCP (9 CFR 417.2(c)(4)).

The humidity parameters in the Appendix A guidelines cannot be maintained in a home-style dehydrator. However, processes that can achieve an adequate reduction of *Salmonella* and *E. coli* O157:H7 in dehydrators are described in the studies by Buege et al. (2006), and Harrison et al. (2006).

NOTE: Establishments that choose a monitoring frequency less than each batch or lot should consider how they will support product safety in the event of a deviation if documentation is not available to support that batches or lots of product produced since the last monitoring were processed with adequate humidity.

- **FSIS Guidance on Safe Cooking of Non-Intact Meat Chops, Roasts, and Steaks for time/temperature combinations**

For meat jerky, the use of the time-temperature combinations provided in the FSIS guidance on the safe cooking of non-intact meat chops, roasts, and steaks should also help to ensure the safety of the product. Humidity should also be considered when using this time/temperature table; therefore, the same options for humidity in Appendix A should also be used with this guidance. In addition, the same expectations regarding

maintaining and monitoring humidity for Appendix A apply for establishments that use the FSIS Guidance on Safe Cooking of Non-Intact Meat Chops, Roasts, and Steaks for time/temperature combinations.

- **Time-Temperature Tables For Cooking Ready-To-Eat Poultry Products**

For poultry jerky, to produce a safe product, establishments can use the minimum internal temperatures listed in Appendix A of 160°F for uncured poultry or 155°F for cured and smoked poultry.

NOTE: If highly pathogenic avian influenza (HPAI) virus H5N1 is identified as a hazard reasonably likely to occur, cured and smoked poultry should be cooked to at least 158°F or a time and temperature combination that achieves a 7-log$_{10}$ reduction of *Salmonella*.

The required reduction of *Salmonella* can also be achieved by using one of the time-temperature combinations listed in the Time-Temperature Tables for Cooking Ready-to-Eat Poultry Products. Regardless of whether Appendix A or the Time-Temperature tables are used, **humidity during heating is a critical factor**. As with meat jerky, the time-temperature combinations would be sufficient to produce safe products with both salt and sugar additives if the processor uses the humidity parameters applicable to beef as described in Appendix A. The same expectations regarding maintaining and monitoring humidity for Appendix A apply for establishments that use the Time-Temperature Tables for Cooking Ready-to-Eat Poultry Products.

Key Considerations for Journal Articles in Attachment 1

Attachment 1 contains a summary of published studies that have been found to achieve adequate lethality for jerky and the critical operational parameters. The Attachment is provided to help establishments identify alternatives to the Appendix A guidelines.

This Attachment is not considered adequate support on its own because it does not provide the details of each study that an establishment needs to determine if the study is representative of the actual process.

For this reason, if an establishment chooses to use one of the articles provided in Attachment 1, FSIS expects that the establishment will have a full copy of the original article on file.

Journal articles

Journal articles are a primary type of support used for jerky processes as a number of studies have been conducted to determine time/temperature/humidity combinations that result in adequate lethality for jerky. Attachment 1 contains a summary of time/temperature/humidity combinations, along with other critical operational parameters from published studies that have been found to result in adequate lethality.

If an establishment chooses to utilize a journal article as scientific support, it should ensure that the critical operational parameters used in the study match those used in the actual process. If one or more of the parameters are not addressed or do not match the level used in the support, then the establishment's process may not achieve the same level of lethality as cited in the journal article. In that case, the establishment

should document a justification as to why that parameter does not need to be met or measured or why it differs from the support. The establishment should consider whether it is using the same:

- Product (e.g., species, type-whole muscle or ground)
- Product formulation
- Product time/temperature combination
- Relative humidity at each stage (including, if reported, using the same humidity levels at the beginning and end of each stage)
- Type or pH of marination (if applicable)
- Smoke (if applicable)

as used in the article. The establishment should also ensure that the composition of the product (% salt, % fat) used in the study is the same as the composition of the actual product being produced. A prudent establishment should have knowledge of the products it produces. Because meeting the critical operational parameters is essential to achieving lethality in the product, the parameters used or measured in the article should be addressed in the process.

KEY QUESTION

Question: Can an establishment's process use a different level of a critical operational parameter (for example, a higher concentration of an antimicrobial or a higher processing temperature) than what was used in the support document?

Answer: Generally, establishments should use the same critical operational parameters as those in the support documents. In some circumstances, establishments may be able to support using critical operational parameters that are different from those in the support documents (e.g., higher concentrations of antimicrobials or higher thermal processing temperatures). In these cases, establishments should provide justification supporting that the levels chosen are at least as effective as those in the support documents. This justification is needed because higher levels of a critical operational parameter may not always be equally effective. For example, antimicrobial agents may only be effective within a range of concentrations, after which point efficacy may decrease. Similarly, higher processing temperatures may result in the surface of the product drying out before adequate lethality is achieved. In addition to ensuring that the levels chosen are at least equally as effective as those in the support documents, establishments should ensure the levels are also safe and suitable (http://www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/7120.1.pdf).

Challenge Studies

In cases where an establishment's process does not match available scientific support documents, such as a Compliance Guideline or published journal article, establishments may decide to conduct an inoculation challenge study to support that their processes achieve adequate lethality (e.g., for poultry jerky at least a 7.0 log reduction of *Salmonella* spp. and for meat jerky at least a 5.0 log reduction of *Salmonella* spp. and at least a 5.0 log reduction for *E. coli* O157:H7 for products containing beef as well as sufficient reduction for *Lm*). The challenge study should be designed to closely match the critical operational parameters in the establishment's actual process. In addition, it is important that the challenge study is conducted using the pathogen of interest, and that the inoculation level is sufficient to show adequate log reduction of the target pathogens.

At a minimum, a study for a microbiological food safety hazard should identify:

- The hazard (biological, physical, and chemical),
- The expected level of hazard reduction or prevention to be achieved,
- The processing steps that will achieve the specified reduction or prevention,
- All critical operational parameters or conditions (e.g., time, temperature, and humidity) necessary to achieve the reduction,
- How these processing steps/parameters can be monitored,
- The critical ingredients (e.g., salt, sugar, and cure), and
- The critical product characteristics (e.g., pH, water activity, and fat content).

Challenge studies conducted using pathogens such as *Salmonella* spp. and *E. coli* O157:H7 should be conducted in a testing laboratory and not in the processing plant environment. FSIS considers all *Salmonella* and *E. coli* O157:H7 serotypes to be pathogens of public health concern. If an establishment chooses to conduct a challenge study in a plant environment, to best represent actual processing conditions for example, then the establishment should choose surrogate organisms that have been found to respond similarly to the pathogens of interest (e.g., *Salmonella* and if applicable, *E. coli* O157:H7). For example, the University of Wisconsin has conducted research with ground-and-formed jerky and found that two *Pediococcus* strains (*Saga 200* and *Biosource*) have similar heat-resistance to *Salmonella* and can be used in in-plant validation studies (Borowski et al., 2009). FSIS has identified four surrogate organisms that have been shown to respond similarly to *E. coli* O157:H7 during cooking (see the following askFSIS Q&A for more information) for use in in-plant validation studies.

Challenge studies should be equivalent to peer-reviewed scientific literature. All of the critical elements previously listed for a study above need to be included to permit evaluation or confirmation of the results. For more information on conducting challenge studies please review the article published by the National Advisory Committee on Microbiological Criteria for Foods in the Journal of Food Protection in 2010.

References

Borowski, A.G., Ingham, S.C., Ingham, B.H. 2009. Validation of ground-and-formed beef jerky processes using commercial lactic acid bacteria starter cultures as pathogen surrogates. J. Food Prot. 72(6): 1234-1247.

Buege, D. R., Searls, G. Ingham, S.C. 2006a. Lethality of commercial whole-muscle beef jerky manufacturing processes against *Salmonella* serovars and *Escherichia coli* O157:H7. J. Food Prot. 69(9): 2091-2099.

Buege, D.R., Searls, G., Mohanan, S., Buege, D.R. 2006b. Survival of *Staphylococcus aureus* and *Listeria monocytogenes* on vacuum-packaged beef jerky and related products stored at 21°C. J. Food Prot. 69(9) 2263-2267.

Calicioglu, M., Sofos, J.N., Samelis, J., Kendall, P.A., Smith, G.C. 2002. Destruction of acid-adapted and non-adapted *Salmonella* during drying and storage of beef jerky treated with marinade. Animal Sciences Research Report. Colorado State University.

Calicioglu, M., Sofos, J.N., Samelis, J., Kendall, P.A., Smith, G.C. 2003. Effects of acid adaptation and modified marinades on survival of postdrying *Salmonella* contamination on beef jerky during storage. J. Food Prot. 66(3):396-402.

Eidson, M., Sewell, C. M., Graves, G, Olson, R. 2000. Beef jerky gastroenteritis outbreaks. Environ. Health. 62:9-13.

Faith, N.G., Le-Coutour, N.S., Alvarenga, M.B., Calicioglu, M., Buege, D.R., Luchansky, and J. B. 1998. Viability of *Escherichia coli* O157:H7 in ground and formed beef jerky prepared at levels of 5 and 20% fat and dried at 52, 57, 63, or 68 degrees C in a home-style dehydrator. Int. J. Food Microbiol. 41(3):213-221.

Getty, K.J.K., Boyle, E.A.E., Roberts, M.N., Lonneker, S.M. 2006. Jerky Validation for Small and Very Small meat and Poultry Businesses: Final Report. Available at: http://www.fsis.usda.gov/PDF/C-12_New_Technology_FY2004_Final_Report.pdf. Accessed 25 January 2012. **Note**: the full study for this report can be found in the Harper et al. (2009) reference below.

Goepfert, J.M., Iskander, I.K., Amundson, C.H. 1970. Relation of the heat resistance of *Salmonellae* to the water activity of the environment. Appl. Microbiol. 19(3):429-33.

Goodfellow, S.J., Brown, W.L.. 1978. Fate of *Salmonella* inoculated into beef for cooking. J. Food Prot. 41(8):598-605.

Harper, N.M., Roberts, M.N., Getty, K.J.K., Boyle, E.A.E., Fung, D.Y.C., Higgins, J.J. 2009. Evaluation of two thermal processing schedules at low relative humidity for elimination of *Escherichia coli* O157:H7 and *Salmonella* Serovars in chopped and formed beef jerky. J. Food Prot. 72: 2476-2482.

Harrison, J.A. Harrison, M.A. 1996. Fate of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* Typhimurium during preparation and storage of beef jerky. J. Food Prot. 59(12):1336-8.

Harrison, J.A. Harrison, M.A., Rose-Morrow, R.A., Shewfelt, R.L. 2001. Home-style beef jerky: effect of four preparation methods on consumer acceptability and pathogen inactivation. J. Food Prot. 64(8):1194-98.

Harrison, M. A., Singh, R.K., Harrison, J.A., Singh, N. 2006. Antimicrobial intervention and process validation in beef jerky processing. Final Report. Available at: http://www.fsis.usda.gov/PDF/C-17_New_Technology_FY2004_Final_Report.pdf. Accessed 25 July 2011.

International Commission on Microbiological Specifications for Foods (ICMSF). 1996. Microorganisms in Foods 5: Characteristics of Microbial Pathogens. London: Blackie Academic & Professional. 524 p.

National Advisory Committee on Microbiological Criteria for Foods. 2010. Parameters for determining inoculated pack/challenge study protocols. J. Food Prot. 73(1): 140-202.

Porto-Fett, A.C.S., Call, J.E., Luchansky, J.B. 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. J. Food Prot. 71(5): 918-926.

Swayne, D. E. and Beck, J.R. 2005. Experimental study to determine if low-pathogenicity and high-pathogenicity avian influenza viruses can be present in chicken breast and thigh meat following intranasal virus inoculation. Avian. Dis. 49:81-85.

Thomas, C. and Swayne, D.E. 2007. Thermal inactivation of H5N1 high pathogenicity avian influenza virus in naturally infected chicken meat. J. Food Prot. 70(3):674-680.

Helpful Web Resources

Dry Bulb, Wet Bulb, and Dew Point Temperature

Background on 2003 *Salmonella* Kiambu jerky outbreak

Compliance Guidelines to Control Listeria monocytogenes in Post-Lethality Exposed Ready-to-Eat Meat and Poultry Products

Food Safety Regulatory Essentials (FSRE) Processing Procedures: Dried Meats

FSIS Appendix A: Compliance Guidelines For Meeting Lethality Performance Standards For Certain Meat and Poultry Products

FSIS Guidance on Safe Cooking of Non-Intact Meat Chops, Roasts, and Steaks for time/temperature combinations

Making Your Own Wet Bulb Thermometer

Salmonella Compliance Guidelines for Small and Very Small Meat and Poultry Establishments that Produce Ready-to-Eat (RTE) Products

Time-Temperature Tables For Cooking Ready-To-Eat Poultry Products

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Attachment 1: Time, temperature, and humidity combinations reported in the literature for beef jerky that achieve at least a 5 log reduction in *E. coli* O157:H7. NOTE: All processes reported in this Attachment achieved at least a 5 log reduction of *Salmonella* in addition to *E. coli* O157:H7.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven Temperature (°F)	Time (min)	Humidity (%)	Log Reduction (*E. coli* O157:H7)
Buege et al. (2006a) [2]	Whole muscle beef jerky	Yes – pH 5.3	No	Type 1-A* Stage 1 – 145 170 Stage 2 – Choose either: Dry-bulb at 170 and wet-bulb at 125 OR Dry-bulb at 170 and wet-bulb at 130 OR Dry-bulb at 170 and wet-bulb at 135 OR Dry-bulb at 170 and wet-bulb at 140 for at least Stage 3- Dry at 170 dry-bulb	 15 15 at least 60 at least 60 at least 30 10 to targeted doneness	 27 32 37 43	≥5

[2] Buege, D.R., Searls, G., and Ingham, S.C. 2006a. Lethality of commercial whole-muscle beef jerky manufacturing processes against *Salmonella* Serovars and *Escherichia coli* O157:H7.

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven Temperature (°F)	Time (min)	Humidity (%)	Log Reduction (*E. coli* O157:H7)
Buege et al. (2006a)	Whole muscle beef jerky	Yes – pH 5.3	No	Type 1-B* Stage 1 – 145 Then choose either: Stage 2 – Dry-bulb at 150 THEN dry bulb at 150 and wet bulb at 130; THEN dry bulb at 150 OR Stage 2- Dry-bulb at 190 THEN dry bulb at 190 and wet bulb at 130; THEN dry bulb at 190	 15 15 60 to targeted doneness 15 60 to targeted doneness	 56 19	≥5
	Whole muscle beef jerky	Y – pH 5.3	No	Type 2** 145 170	 15 to targeted doneness	 27-31(start)*** 17-21(end)	≥5

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven Temperature (°F)	Time (min)	Humidity (%)	Log Reduction (*E. coli* O157:H7)
Buege et al. (2006a)	Whole muscle beef jerky	Yes – pH 5.3	No	Type 3** 145 170	90 to targeted doneness	41(start)*** 21(end)	≥5
	Whole muscle beef jerky	Yes – pH 5.3	No	Type 5** 180	to targeted doneness	29(start)**** 15(end)	≥5†

*Type 1-A and Type 1-B processes with a higher dry-bulb temperature in Stage 1, a higher wet-bulb temperature or longer time in Stage 2, or a higher dry-bulb temperature in Stage 3, as long as other parts of the process are not changed, can also be considered validated because they should have greater lethality.

**Processes reaching higher dry-bulb temperatures in either stage can also be considered validated because they would have greater lethality.

***Humidity values are from Table 3 in Buege et al. (2006a).

****Humidity values are from Table 5 in Buege et al. (2006a).

Oven: Pans of water were placed on the lowest rack in the smokehouse, and a low fan speed was used. Humidity (steam or water) was introduced in Type 1-A and 1-B processes. Study did not indicate whether dampers were open or closed.

† Finished product water activity level was ≤ 0.85

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven Temperature (°F)	Time (min)	Humidity % (%)	Log Reduction (*E. coli* O157:H7)
Buege et al. (2006a)	Whole muscle beef jerky	Yes – pH 5.3	No	Type 7**			
				120	60	43***	≥5
				130	60		
				140	60		
				170	60	15	

**Processes reaching higher dry-bulb temperatures in either stage can also be considered validated because they would have greater lethality.

***Humidity values are from Table 3 in Buege et al. (2006a).

Oven: Pans of water were placed on the lowest rack in the smokehouse, and a low fan speed was used. Humidity (steam or water) was introduced in Type 1-A and 1-B processes. Study did not indicate whether dampers were open or closed.

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven/Product Temperature (°F)*	Time (hours)	Humidity (%) (Start/End)	Log Reduction (cfu/strip) (*E. coli* O157:H7)
Porto-Fett et al. (2008)[3]	Whole muscle beef jerky	Yes – ~pH 5.5	Yes	178	1.5	63.4 21.9	≥7
	Whole muscle beef jerky	No	Yes	178	1.5	63.4 21.9	≥7
	Whole muscle beef jerky	Yes – ~pH 5.5	Yes	178.3	2.5	63.8 21.5	≥7†
	Whole muscle beef jerky	No	Yes	178.3	2.5	63.8 21.5	≥7
	Whole muscle beef jerky	Yes – ~pH 5.5	Yes	178.5	3.5	62.3 19.2	≥7†
	Whole muscle beef jerky	No	Yes	178.5	3.5	62.3 19.2	≥7†

*Oven temperatures are average of continuous readings taken every 30s after CUT.
Oven: Dampers were completely open.

†Finished product water activity levels were ≤ 0.85

[3] Porto-Fett, A.C.S., Call, J.E., and Luchansky, J.B. 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(5): 918-926.

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven Temperature (°F)	Time (min)	Humidity (%)*	Log Reduction (*E. coli* O157:H7)
Harper et al. (2009),[4] Getty et al. (2006)[5]	Chopped and formed beef jerky	No	No (smoke flavor was added)	Stage 0 –			
				Stage 1 – 132	14	32.6	≥5[†]
				Stage 2 – 132	16	52	
				Stage 3 – 132	14	14.5	
				Stage 4 – 172	16	22	
				Stage 5 – 172	14	22	
				Stage 6 – 172	16	22	
				Stage 7 – 172	14	22	
				Stage 8 – 172	16	22	
				Stage 9 – 172	14	22	
				Stage 10 – 172	16	22	
				Stage 11 – 172	14	22	
				Stage 12 – 172	5 h	22	

*Humidity levels were calculated from actual dry and wet-bulb temperatures reported in Getty et al. (2006): http://www.fsis.usda.gov/PDF/C-12_New_Technology_FY2004_Final_Report.pdf. Although the report states that humidity remained at less than 10% throughout the entire smokehouse cycle, humidity levels calculated from dry and wet-bulb temperatures in the report were higher, as indicated in the table. This was verified through personal communication with the author [April 2011].
Oven: Automated dampers and steam injection.

[†]Finished product water activity level was ≤ 0.85

[4] Harper, N.M., Roberts, M.N., Getty, K.J.K., Boyle, E.A.E., Fung, D.Y.C., Higgins, J.J. 2009. Evaluation of two thermal processing schedules at low relative humidity for elimination of *Escherichia coli* O157:H7 and *Salmonella* Serovars in chopped and formed beef jerky. Journal of Food Protection. 72: 2476-2482.
[5] Getty, K.J.K., Boyle, E.A.E., Roberts, M.N., Lonneker, S.M. 2006. Jerky Validation for Small and Very Small meat and Poultry Businesses: Final Report. Available at: http://www.fsis.usda.gov/PDF/C-12_New_Technology_FY2004_Final_Report.pdf. Accessed 25 January 2012.

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven Temperature (°F)	Time (min)	Humidity (%)**	Log Reduction (*E. coli* O157:H7)
Borowski et al. (2009)[6]	Ground-and-formed beef jerky	No*		Type 2-A			
			No	170	30	57	7.35†
			No	130	120	22	
			No	170	90	28	
	Ground-and-formed beef jerky	No*		Type 3-A			
			No	170	30	7	6.8†
			No	170	15	23	
			No	170	130	ND	
	Ground-and-formed beef jerky	No*		Type 4-A			
			No	135	90	67	8.11†
			No	185	150	9	

*A spice rub mix was used. Two types of spice mixes (Colorado and BBQ) were used in the study. Results for one type of spice mix (Colorado) are reported here. Variability in lethality was found due to spice mix type. See Borowski et al. (2009) for details on the spice mixes used including pH and a_w values and results for products prepared with the BBQ spice mix.
**%RH values are approximate based on an average of the range of actual dry and wet bulb temperatures provided in the article. RH values reported as ND were not determined.

NOTE: All processes reported here used a commercial oven-smokehouse.
Oven: Dampers were open for processes without smoke added.

†Finished product water activity levels were ≤ 0.85

[6] Borowski, A.G., Ingham, S.C., Ingham, B.H. 2009. Validation of ground-and-formed beef jerky processes using commercial lactic acid bacteria starter cultures as pathogen surrogates. Journal of Food Protection. 72(6): 1234-1247.

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Temperature (°F)	Time (min)	Humidity (%)**	Log Reduction (*E. coli* O157:H7)
Borowski et al. (2009)	Ground-and-formed beef jerky	No*		Type 2-B			
			Yes	170	30	32	7.42
			Yes	130	120	ND	
			Yes	170	90	ND	
	Ground-and-formed beef jerky	No*		Type 3-B			
			No	170	30	7	7.41
			No	170	15	39	
			Yes	170	130	ND	
	Ground-and-formed beef jerky	No*		Type 4-B			
			Yes[7]	135	90	68	7.46
			Yes[8]	185	150	ND	

**A spice rub mix was used. Two types of spice mixes (Colorado and BBQ) were used in the study. Results for one type of spice mix (Colorado) are reported here. Variability in lethality was found due to spice mix type. See Borowski et al. (2009) for details on the spice mixes used including pH and a_w values and results for products prepared with the BBQ spice mix.
**%RH values are approximate based on an average of the range of actual dry and wet bulb temperatures provided in the article. RH values reported as ND were not determined.

NOTE: All processes reported here used a commercial oven-smokehouse.
Oven: Dampers were open until smoke was added at which point dampers were closed.

[7] Smoke added after 30 min.
[8] Smoke discontinued after 90 min.

This Attachment is not considered adequate support on its own because it does not provide the details of each study an establishment needs to determine if the study is representative of the actual process.

Reference	Product	Marinated (Yes/No)	Smoke Added (Yes/No)	Oven Temperature (°F)	Time (hours)	Humidity (%)	Log Reduction (*E. coli* O157:H7)
Harrison et al. (2006)[9]	Beef jerky strips	Yes	No	143.6	8-9	33	>6[†]

NOTE: The process reported here used a commercial oven-smokehouse.
Oven: No humidity control. Study did not indicate whether dampers were open or not.

[†]Finished product water activity level was ≤ 0.85

[9] Harrison, M. A., R. K. Singh, J. A. Harrison and N. Singh. 2006. Antimicrobial intervention and process validation in beef jerky processing. Final Report. Available at: http://www.fsis.usda.gov/PDF/C-17_New_Technology_FY2004_Final_Report.pdf. Accessed 25 July 2011.

Attachment 2: Making Your Own Wet Bulb Thermometer (Reprinted with permission)

By G. Burnham, S.C. Ingham and B.H. Ingham
University of Wisconsin-Madison Center for Meat Process Validation

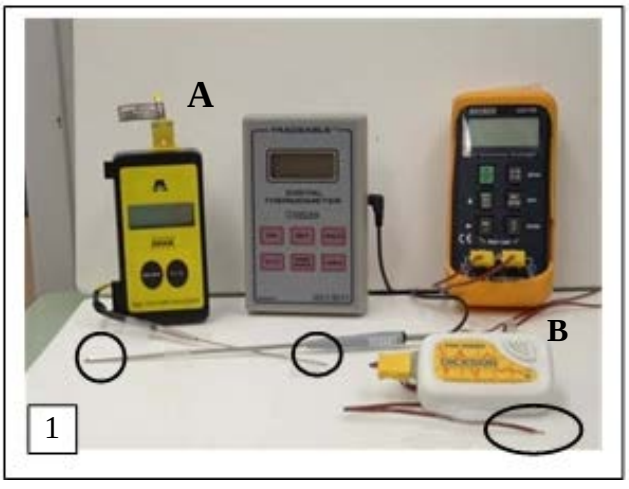
If you are smoking or drying meat, there are several parameters to monitor which will help you control your process: **dry bulb temperature**, **wet bulb temperature**, and **relative humidity**. Research at the University of Wisconsin Center for Meat Process Validation has shown that **monitoring wet bulb temperature is even more important (and much easier!) than monitoring product temperature** during your process. Since wet bulb temperature is critical to process monitoring, this document describes how to easily, and perhaps inexpensively, construct a wet bulb thermometer.

Dry bulb temperature, usually referred to as air temperature, is the smokehouse/oven property that is most commonly measured by jerky-makers. When people refer to the temperature (heat content) of the air, they are normally referring to the dry bulb temperature. It is called "dry bulb" because the air temperature is indicated by a thermometer that is not moistened and will not be affected by evaporative cooling.

Wet bulb temperature is the temperature indicated by a moistened thermometer bulb exposed to air. A wet bulb thermometer measures the extent of cooling that happens as moisture dries from a surface (evaporative cooling). The wet bulb temperature is always lower than the dry bulb temperature except when there is 100% relative humidity. **Because evaporative cooling occurs on the surface of thin jerky strips, the wet bulb temperature is more accurate measurement of product temperature**.

We developed a **wet bulb thermometer (WBT)** which is easy to assemble and economical for a meat processor to use.

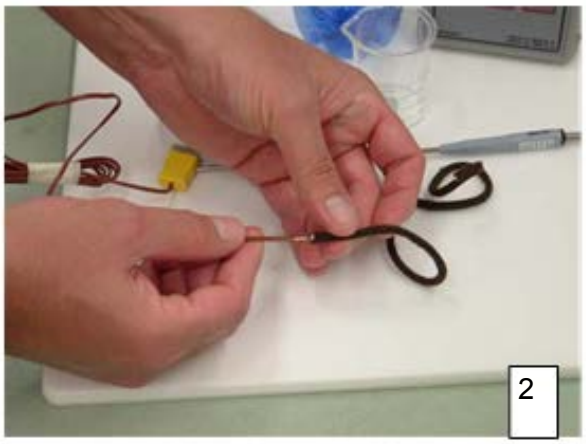
To begin assembling a wet bulb thermometer, you will need to determine what type of **temperature measuring device** you will use. You will need to use a temperature recorder with a "tip reading" probe/wire/stem. Either an **instant read** or a **data-logging temperature measuring device** will work; both are pictured in image 1.



A - 3 styles of 'instant read' temperature measuring device
B - a data logger-style of temperature measuring device
In each case, the 'tip reading' probe/wire is circled.

Instant read temperature recorders. **(A)** An instant read temperature Recorder will offer immediate feedback, with the temperature displayed on the front of the unit. However, data may not be recorded with this type of unit; the processor must record the data periodically. See page 34 for more information on ordering instant-read temperature recorders.

A data logger-style temperature recorder. (B) This type of device keeps track of, or 'logs' temperature over a period of time. An inexpensive data logger usually does not offer immediate readout of data. A processor must connect the data logger to a computer to view the temperature data. A data logger does, however, offer a continuous record of temperature history which can be important for HACCP documentation. See page 34 for information on ordering a standard data logger.

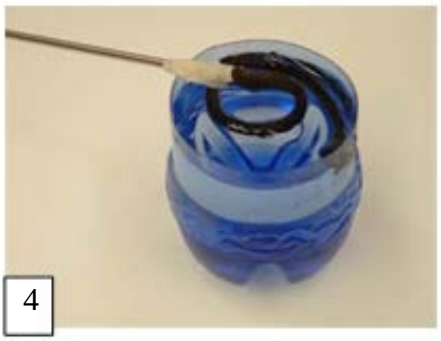

2

Once you have your temperature recorder, you will need to choose material to serve as the **"wick"** to cover the tip probe. Water evaporating from the wick will reduce the temperature recorded, giving an indication of evaporative cooling. The wick should be made from an absorbent material, preferably cotton. It should also be constructed of **two phases**: a loose, absorbent interior, and an exterior that is of an absorbent tighter meshing material. The exterior keeps the inner absorbent material around the sensing portion of the temperature probe and prevents the sensing portion of the recorder from being exposed to direct ambient conditions. You may wish to purchase wicks commercially, such as from an online supplier (http://www.wickstore.com/wetbulbwick.html), or a good substitute is a round cotton bootlace (image 2). See page 34 for more information on supplies for a wet bulb thermometer.

There are several simple steps to setting up a **wet bulb thermometer**.

1. **Gather materials.** You will need a **vessel for holding water** which must either be refilled during processing, or must be sufficiently large to hold enough water (allowing for evaporation) to keep the water level close to the temperature probe. Choosing a vessel with a small diameter opening will reduce evaporation. Once a water vessel has been chosen, simply fill it with water. You will also need a **temperature measuring device** and material to serve as a **wick**. In image 3, the bottom of a soda bottle and a glass beaker are pictured as vessels. Both an instant read and a data logger are shown for measuring temperature and pieces of brown cotton shoelace serve as the wick.


3

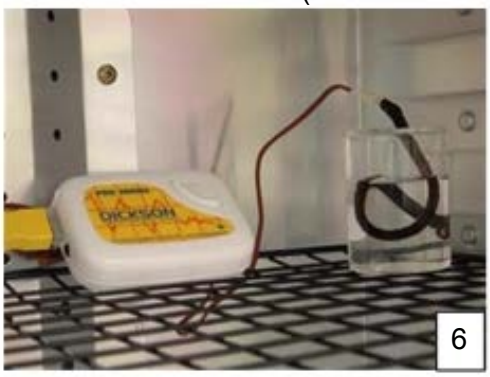

4

2. **Assemble the wet bulb thermometer. Cut** a portion of the wicking material (it should be long enough to reach the bottom of the water vessel and than some). **Connect** the sensing portion of your temperature recorder to the wick by inserting the probe/wire/stem into the center of the wick (image 2). **Secure the end** of the wick to the probe/wire/stem using tape. **Place the wick** in the water-containing vessel. **Make sure** the wick is completely

saturated with water, then position the wick-covered sensing portion of your temperature recorder so that it is completely exposed to ambient conditions, yet as close as possible to the water source (image 4). This will ensure adequate wicking of the water to the sensing portion of the temperature recorder. If exposure to ambient conditions is too great, such as when the wick is too long or the recorder too far from the water surface, the wick may dry out, and evaporative cooling will not be recorded.

3. **Place the wet bulb thermometer inside the chamber.** If you are using an instant reading temperature measuring device to make process adjustments, place the wet bulb thermometer for easy access and readability, such as near a door or window (image 5). If immediate feedback is not a consideration (image 6), place the device where the ambient conditions of your process are least likely to give you optimum conditions - hence a "worst case" reading. Position the wet bulb thermometer in a flow of air (such as in a stream of incoming air), but away from fans which will cause excessive evaporation and drying of the wick.

5



6

4. **Record wet bulb temperature.** Establish a regular schedule of recording or down-loading wet bulb temperature. Check water level in the vessel periodically, and also check the position of the wick. The portion of the wick above the water must remain moist for accurate temperature measurement. The wet bulb temperature can be used to adjust your process conditions, as needed.

Supplies for Making a Wet Bulb Thermometer*

Instant Read Temperature Recorders
Fisher Scientific (800-766-7000)
- Part 15-078-38; price $131.49 plus shipping
- Part 15-077-14; price $111.15 plus shipping

Data Logger-Type Temperature Recorders
Dickson Company (800-323-2448)
- Part SM325 (LCD Display Temperature Data Logger w/ 2 K-thermocouple probes); price $399 plus shipping
- Also order software to download information to computer ($79)

Wick Material
- Round cotton bootlace (pictured in this document) - available at many general stores • Wet-bulb wick ($50-$60 per spool http://www.wickstore.com/wetbulbwick.html)

- Wet-bulb sock: Alkar, part #50040; price $127.00 for bundle of 100 (608-592-4865)

**The items and suppliers listed here are suggestions only, based on price and availability. The mention of particular suppliers is not meant to exclude others from consideration.*

For more information contact:
Steve Ingham, Extension Food Safety Specialist (608) 265-4801, scingham@wisc.edu
May, 2006

The University of Wisconsin-Madison Center for Meat Process Validation provides science-based HACCP support to small meat processors in meeting state and federal mandates for safe food processing and handling. For more information on the Center contact Dr. Steve Ingham, 1605 Linden Drive, UW-Madison, Madison, WI 53706 (608) 265-4801 Email: scingham@wisc.edu