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WHITE PAPER

VALIDATING OVEN PERFORMANCE FOR PRODUCT UNIFORMITY

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INTRODUCTION

The primary objectives during thermal processing are to achieve lethality requirements and desired finished product characteristics. Any inefficiency in smokehouse or oven performance can have a negative impact on the quality, yield and safety of ready-to-eat (RTE) processed meat and poultry products. All too often the smokehouse controls system is used as the sole source to determine performance metrics. However, it is equally important to periodically validate both the oven and product performance to ensure that the equipment is functioning as intended and that it is capable of achieving the thermal processing parameters outlined in the cook cycle. Validating for process uniformity can serve as a viable means to not only ensure safety but also to provide insight for areas of process improvement that may result in a higher quality product with better yields and increased profitability. This white paper is designed to give a brief overview of practical mapping methods that can be used to critically assess the performance of an oven to confirm that safe, high quality products are produced with minimal variation.

PRINCIPLES OF OVEN DESIGN

It is important to have a basic understanding of oven design when determining the ideal location to probe product for performance evaluation. Heated air from the supply cabinet is forced into the oven via the supply ducts, discharged throughout the chamber and removed through the return plenum in the center of the oven. There are two thermocouples in the return plenum that are utilized for temperature and humidity control of the oven. The dry-bulb measures the ambient air temperature determined by the thermocouple and control system while the wet-bulb measures the temperature of air that is affected by the cooling of evaporating water via a wet sock that is placed over the wet-bulb thermocouple. The wet sock is cotton material used to absorb water to encase the sensing element on the thermocouple with moisture. This allows the controls to receive a temperature reading for the purpose of humidity control. The temperature difference between the dry-bulb and wet-bulb determines the amount of relative humidty in the oven.

Figure 1 – Wet-bulb and dry-bulb controls

PRINCIPLES OF OVEN DESIGN (continued)

As the wet-bulb and dry-bulb temperatures move closer to each other, the relative humidity (moisture present) increases which allows for more aggressive heating as a result of greater heat energy present. On the contrary, a lower level of heat energy is present as the two move farther apart resulting in a more gentle cooking process. Maintaining the humidity level is critical for not only heat transfer, but for smoke application, color development and "skin" formation. It is important for processors to understand that a hot, dry (low humidity) process will result in more temperature variation in the product than a higher humidity process. Furthermore, it is critical that the final wet-bulb temperature is higher than the targeted internal product temperature to minimize variation in the oven.

Ovens are designed to alternate airflow from the discharge of a single fan via rotating dampers. Alternating airflow and fan speed is important and is acknowledged to be a primary factor in oven performance as it creates constant turbulence, resulting in more uniform processing conditions throughout the oven. The airflow of a two lane batch oven is depicted below in figure 2.

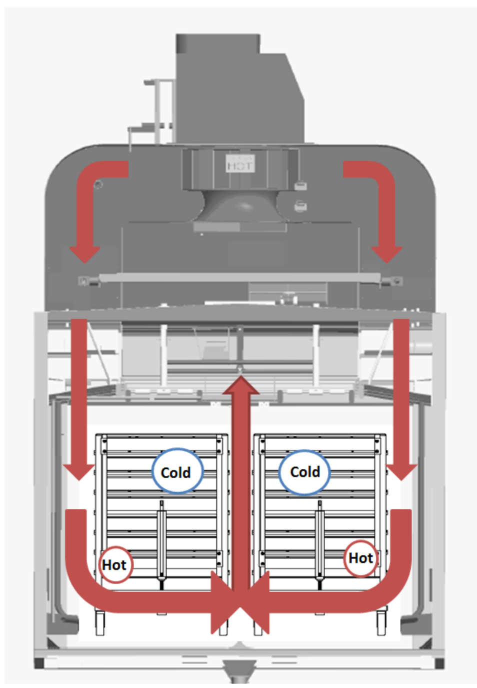

Figure 2 – Simulated batch oven airflow and temperature variation

Depending on the design, each batch oven may offer specialized approaches to thermal processing (humidity control, etc.); however, it does not mean the operating range and control of important heating elements (wet-bulb, dry-bulb, air velocity, etc.) are the same from oven to oven. Therefore, an understanding of equipment parameters is essential to determine true performance capabilities. Every house will not perform exactly the same, so it is important to evaluate product performance across all ovens to ensure processing uniformity from batch to batch and from oven to oven.

DESIGNING A PRODUCT PERFORMANCE VALIDATION STUDY

It is important to understand that large ovens are all custom designed, so they will have some level of temperature variation due to the design/functionality of the smokehouse as well as variation in the product being produced. In general, in a properly balanced oven, internal product temperatures will be ±2.5°F. In order to reduce variation from oven to oven, it is important to consider all product attributes especially during a temperature/process analysis. Processed meat products can vary in size/shape, species, moisture level, fat content, ingredients and casing type, just to name a few. For optimum performance, an oven should be fully loaded with products of similar size and shape as well as casing type, and this product should be loaded on meat trucks of the same design from batch to batch. Each casing type (e.g. natural, edible collagen, plastic, or fibrous) is a unique barrier with specific oxygen and moisture transmission rates which will perform differently under the same processing conditions and may provide conflicting results. Furthermore, the meat and non-meat ingredients should all be consistent throughout the entire load.

A wide variety of digital temperature probes are available to analyze the performance of an oven. All will yield acceptable results when they are calibrated and placed in the appropriate locations so data can be analyzed accordingly. First, a baseline must be established to determine what, if any variation exists from the control settings on the smokehouse. One probe should be placed next to the oven's dry-bulb and one should be placed inside the wet-bulb sock next to the wet-bulb controls (see figure 1). Because it is often overlooked, it is important to mention that the wet-bulb sock should be moist and free from buildup that occurs from long cooking processes. Wet-bulb socks should be replaced on a daily basis to ensure the most accurate reading possible, especially if natural or liquid smoke is used during the smoke cycle. Always use a new wet sock when validating your ovens. The readings obtained from these two probes will be used not only to confirm oven performance, but also to plot the data collected from the product and various locations throughout the house.

It is important to measure in both the hot and cold zones of the smokehouse when mapping an oven to evaluate product/process performance. In general, when process temperatures (dry-bulb and wet-bulb) are being measured in the return plenum, the coldest part of the oven is measured. Because of this, the supply air is much warmer than the return air, but this insures that all product is exposed, at a minimum, to the set point. As such, in a properly balanced oven, the warmest product will always be the bottom outside corners of the meat truck and the coldest product will be in the center upper portion of the meat truck as shown in Figure 2. Monitoring both temperatures will ensure that adequate drying steps are implemented for color development as well as the temperatures necessary for process lethality.

When designing a study to evaluate oven performance, monitoring not only the ambient (dry-bulb) temperature of both the hot and cold zones is recommended, but also the internal temperature as well as the surface temperature of the product. The driving force for heat transfer is the difference between the surface and core temperature. When measuring core or internal temperature, it is crucial that the thermometer probe be placed as centrally as possible in the product. When variations in the size or diameter of the products exist (i.e., bone in hams), place the thermometer probe in the largest product on the smokehouse truck to ensure food safety and lethality parameters are achieved.

DESIGNING A PRODUCT PERFORMANCE VALIDATION STUDY (continued)

Measuring surface temperature, as shown in Figure 3, is the most accurate method to determine the presence of cold or hot spots in the oven as the temperature on surface of the product is very similar to measuring the wet-bulb temperature in these locations. The surface temperature of the product can provide valuable information about the product performance and it can also offer insight for areas of product improvement. To monitor surface temperature, the probe should be placed directly under the casing or below a thin layer of the whole muscle meat product. In this example, the internal temperature is probed in the snack stick on the left while the surface temperature is probed in the product on the right.

Figure 3 – Comparison of internal measurement and surface measurement in snack sticks

Three phenomena occur simultaneously during thermal processing: protein is shrinking, fat is expanding and moisture is evaporating. Moisture will evaporate from the product surface at the wet-bulb temperature. Thus, the surface temperature of the product is much like a wet-bulb reading. Understanding where in the thermal processing step the product surface temperature is higher than the wet-bulb reading (where drying is occurring) can provide insight to color development, skin formation, bite characteristics and peel-ability of the product. Furthermore, the speed at which the surface temperature of a product moves through a temperature zone where protein denaturation occurs (140°F-150°F) can significantly impact cook yields. Figure 4 demonstrates a mapping of frankfurters where variations in color development occurred. By mapping the surface temperature of the frankfurter, we can see that the surface of the product with the green line never broke away from the house wet-bulb temperature, indicating that drying conditions were not present and color development did not occur before the high humidity in the finishing step took place. On the other hand, the surface of product where the purple line broke away from the wet-bulb temperature much earlier in the cycle allowed adequate drying to occur before the high humidity step begins.

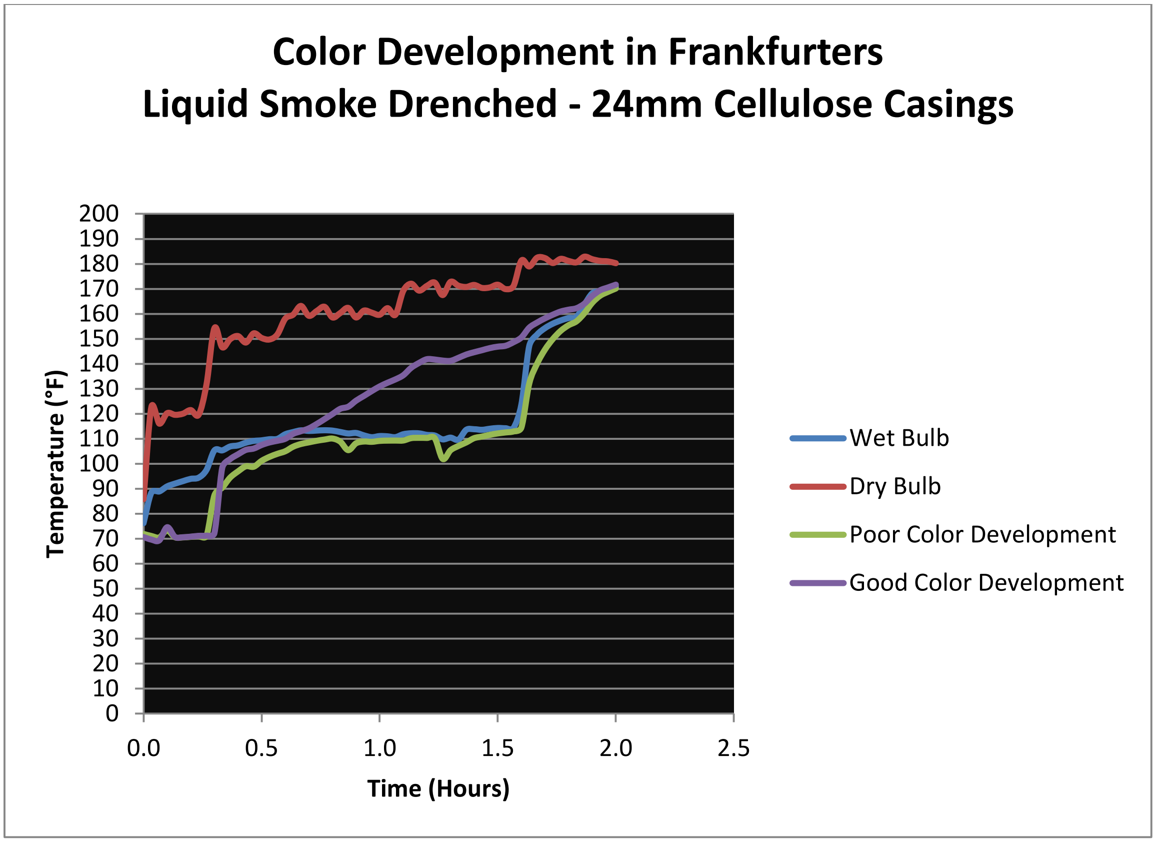

Figure 4 – Oven mapping to troubleshoot color development in liquid smoke drenched frankfurters

SUMMARY

Having a visual understanding of what is occurring behind the smokehouse doors can provide accurate changes in the thermal processing schedule to create ideal conditions and eliminate processing failures. Valuable information can be obtained with periodic oven validation studies to troubleshoot product failures or confirm that the product, process and equipment are working in harmony to achieve the desired results from a quality and yield basis. Wet-bulb, dry-bulb, relative humidity and air velocity are considered the “cornerstones of cooking” and when properly understood, can be used to improve the quality and yield of a processed meat product. Just as it is important to keep a stringent oven maintenance plan to ensure all components are properly functioning and operating as they should, it is equally important to monitor the product and confirm it is being processed under the appropriate conditions for desired finished product characteristics.

About Kohl Schrader, Ph.D.
Dr. Kohl Danielle Schrader holds a Ph.D. in Meat Science from Iowa State University and has extensive experience in the production of sausage and processed meats including fresh, smoked, “naturally cured” and dry and semi-dry meat products. She has been a featured speaker at a number of meat industry-related conferences, university courses, and workshops, including the American Association of Meat Processors Convention, American Meat Science Association Reciprocal Meat Conference, University of Wisconsin-Madison’s meat processing workshops, and Iowa State University’s meat science processed meat short courses.

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