

QUALITY ATTRIBUTES DURING 160 DAYS REFRIGERATED SHELF LIFE OF A  
SMOKED, FULLY COOKED SAUSAGE FORMULATED WITH A NITRITE CONTAINING  
PORK PREBLEND

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## Abstract

Pork preblends held for 0, 4 or 7 d were formulated into smoked sausages and analyzed for cook yield, instrumental external color, pH, salt content, proximate analysis, Warner-Bratzler shear force (WBSF), thiobarbituric acid reactive substances (TBARS), sensory analysis and purge percentage during 0, 110, 131 and 160 d display at an average 2.65 °C under fluorescent lighting.

One preblend × day of display interaction was found for  $b^*$  values. On display d 0, preblend d 7 was more yellow ( $P < 0.05$ ) than preblend d 0 and 4; however, no differences ( $P > 0.05$ ) were found for any preblends on d 110 or 160. On display d 131, preblend d 0 was more ( $P < 0.05$ ) yellow than preblend d 4 but similar ( $P > 0.05$ ) to preblend d 7. There was no preblend effect ( $P > 0.05$ ) on any of the other attributes measured. Display day did not affect ( $P > 0.05$ ) purge, pH, proximate analysis, WBSF, juiciness, saltiness or off-flavor. For color,  $a^*$  and saturation index values decreased ( $P < 0.05$ ) and  $L^*$  increased ( $P < 0.05$ ) between d 0 and 110 as well as d 110 and 131, while  $L^*$ ,  $a^*$ ,  $a^*/b^*$  ratio and saturation index values were similar ( $P > 0.05$ ) from d 131 to 160. Hue angle value decreased from d 0 to 110 but was similar for the remaining display. A reduction ( $P < 0.05$ ) in  $a^*/b^*$  ratio was shown from d 0 and 110 (average 0.85) to d 131 and 160 (average 0.78). There was a reduction in salt content by 0.43% and an increase in TBARS values by 0.46 mg malonaldehyde/100 g sample from d 0 compared to d 110, 131 and 160 ( $P < 0.05$ ). Inconsistent differences were found for sensory panel traits bite and flavor intensity and a reduction in mouthfeel coating was found from d 0, 110 and 131 compared to 160 ( $P < 0.05$ ). Therefore, preblending could be implemented without any detrimental outcome on quality or sensory attributes of skinless smoked sausage; however, as day of display increases product may become lighter, less red and more oxidized.

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# Chapter 1 - Literature Review

## Sausage

### *Description*

Sausage is a comminuted meat product that must at least include ground meat and salt (Hui, 2012). Comminuted meat products are those which have been reduced to a smaller particle size typically through the result of cutting, grinding, chopping, emulsifying or another form of processing. Among comminuted meat products, sausage remains to be the most common. Generally, additional ingredients such as cure and spices are included, depending on the sausage classification (Hui, 2012).

According to the United States Department of Agriculture (USDA) Food Standards and Labeling Policy Book (2005), there are four main classifications of sausage, which include: fresh sausage, uncooked smoked sausage, cooked sausage/and or smoked sausage, and dry and semi-dry sausage. The main classification that is most relevant for this project, however, is cooked sausage/ and or smoked sausage. This sausage class is differentiated by being chopped or ground, seasoned, cooked and/or smoked with an added water limitation of 10 percent of finished product, with the utilization of cure being a requirement for certain sausages and the addition of meat byproducts may be used when permitted. Furthermore, this sausage category is limited to a maximum of 30 percent fat and 156 ppm nitrite. Examples of cooked sausage and/or smoked sausage examples are wieners, bologna, liver sausage and cotto salami. According to Hui (2012), cooked and smoked sausage makes up approximately 85% of all sausage production today. Additional specific information on what can legally be added to the different classes of sausage can be found in the Code of Federal Regulations Title 9 Chapter III Subchapter A Part 319.

### *History of Sausage*

Sausage is known to have a deep history being traced back thousands of years. Although the exact origin of sausage processing remains unknown, the description of meat in stomach casings being cooked is found documented in the eighth century B.C. Homer's Greek poem, "The Odyssey". The name sausage is derived from the Latin term "salsus," meaning salted or

preserved in salt (Hui, 2012). Prior to the era of refrigeration and electricity, the process of sausage making was primarily used as a method of preservation. Sausage was comprised of pieces of diced meat mixed with salt and seasonings that were stuffed into animal intestine casings. From these casings the characteristic cylindrical link shape was formed and continues to influence the general sausage link shape to this day (Pearson & Gillett, 1996).

In some instances, sausages were produced and dried during the winter season for warmer, summer season consumption. Through this concept, some sausages were given the name “summer sausage” and classified as semi-dry sausages by USDA (USDA Food Standards and Labeling Policy Book, 2005). The incorporation of salt and the process of drying were, and still remain, key contributing factors to meat preservation.

There is a wide array of sausages worldwide that are comprised of various combinations of meat species, moisture content, color and spices. While many factors influenced sausage development over time, a few major components included the culture and climate of the region, ethnicity and supply of spices available. Warmer climates such as those found in Italy and southern France led to the processing of dryer sausages while cooler German and northern European climates tended to produce sausages with a higher moisture content or simply more fresh (Rust, 1975). The various types of sausages being made in particular regions were often given a distinct name of the city in which the sausage originated from. Some examples include: bologna from Bologna, Italy; genoa salami from Genoa, Italy; frankfurters from Frankfurt, Germany; and braunschweiger from Brunswick, Germany (Rust, 1975).

American sausage consumption began to grow during the Civil War era (1861-1865) and even more so with the addition of refrigerated rail cars in 1878 (Hui, 2012). Additionally, the types of sausage produced increased due to emigration from Europe and as a result, the majority of these sausage recipes were European. These new sausages were welcomed as U.S. ethnicity grew (Pearson & Gillett, 1996). Following the influx of immigrants and sausage expansion, the meat industry was faced with change and increased government regulation. In 1905, Upton Sinclair published “The Jungle” as a serial form novel where he exposed the working conditions within the meat packing industry. The novel explains how unidentified ingredients such as offal products were added to sausage products without labeling (Hui, 2012). The government quickly responded with the implementation of the Federal Meat Inspection Act (FMIA) in 1906 that provided foundational guidelines for the industry to follow. This form of regulation assured the

public that meat products would be safe and sanitary for human consumption and that the products would be labeled truthfully and accurately.

Throughout history from a meat processing and efficiency standpoint, the production of sausage has resulted as a way of adding value to meat trim and in some instances, when labeled, been a successful way to utilize variety meats and animal byproducts. From a consumer's perspective, there are several reasons for the continued consumption of sausage. According to Pearson and Gillett (1996), these motives consist of convenience, variety, economy and nutritional value.

Modern-day sausage processing is quicker, more efficient and economical primarily due to automation of machinery, packaging technology, well-engineered equipment, functional processing plants and availability of refrigerated transportation. Meat industry production from 1971 to 1976 showed an increase in sausage growth with frankfurters having the highest numbers and the second highest amount alternating between fresh sausage and bologna. In 1971, 563,671,980 kg of frankfurters were produced and in 1976 that number increased more than 23% to 696,240,247 kg (Rust, 1975). In 1981, total sausage production was 2,284,463,994 kg. In 1981 frankfurter numbers dropped slightly from 1976 values, however, with 643,480,197 kg produced (AMI, 1982). From the ten-year time span of 1979 to 1989, the sausage industry (frankfurters, sausages and other sausage products) generated an average 21% increase in consumer expenditures. In 1979, consumer expenditures for frankfurters, sausage and other sausage products were \$4,833 million while 1989 showed an increase in expenditures to \$5,842 million (AMI, 1991). More current industry numbers from Hillshire Brands Company data reported an 8 percent increase in dinner sausages sold in U.S. retail stores from 2012 to 2014 (Pellegrini, 2015). In September 2014, Mintel, a market reporter, reported retail sales of \$8.7 billion for the hot dog and sausage category which was an 18 percent growth from 2009 to 2014 (Pellegrini, 2015). Throughout history, many changes have been made in the sausage industry including growth and industry expansion.

### ***Functionality of Sausage***

From a processing standpoint, the functionality of sausage is imperative to produce successful products. Functionality can be described as the potential of the meat proteins to perform desirably (Whiting, 1988). By understanding the many facets that contribute to sausage

functionality, the processor should be able to potentially optimize yields, enhance palatability and increase product shelf life and ultimately increase profitability of the sausage product. A few of these influential factors are state of rigor, age of animal, muscle type and protein used, processing conditions, along with amounts and types of ingredients used.

The state of rigor in a carcass will impact the functionality of a sausage. Pre-rigor meat is the period 45 min to an hour after slaughter and prior to the onset of rigor mortis or stiffening of the carcass. Due to a higher pH and adenosine triphosphate content in the pre-rigor phase, myosin is easily extracted; this results in much higher water holding capacity and higher emulsifying capacity (Hamm, 1960; Xiong, 2007). The pre-rigor state is considered a crucial functional period of the meat because it is much easier to extract the contractile proteins using salt before they become firm (Rust, 1975). In order to reap the benefits of pre-rigor meat, the meat has to be boned out, ground and salted before rigor onset. Rust (1975) stated that emulsifying capacity could increase by at least 25 percent if pre-rigor meat is used. Claus and Sørheim (2006) found that using pre-rigor meat for beef patties resulted in much lower cooking losses, a more cohesive texture and an increase in protein solubility.

Another component to consider is the biological age of the animal at harvest. The age of a beef animal can drastically affect the bind value of raw material used in sausage. The bind scale is an index where 100 constitutes maximum bind and 0 represents little to no bind. According to Hickey and Brant (1974), cow and bull meat have a bind value of 100. Also, when compared to other species, these particular meats are higher than any pork or chicken values. Beef trimmings, 75% (lean) have a bind value of 80 compared to bull and cow meat. Increasing the lean percentage also will increase the binding ability of meat. Bull and cow meat are high binding meats due to the fact that they are quite lean.

There are three different muscle tissue types: skeletal, smooth and cardiac. Skeletal muscle is voluntary and multinucleated. This muscle is responsible for support and movement of the body. The other two muscle types, smooth and cardiac, are both involuntarily controlled, and contain a single nucleus in each cell. Smooth muscle is found in many organs such as the stomach, urinary tract, reproductive tract and circulatory system while cardiac muscle is found in the heart. Among these three, skeletal muscles have the highest binding ability and non-skeletal muscles have low to no bind. Additionally, there are two main types of protein that affect product bind. Myofibrillar or contractile protein is known to have high binding capabilities as

this protein is salt soluble and heat-coagulable (Rust, 1975). The second protein, stromal, is more likely to have a detrimental effect on bind. Stromal protein includes collagen and elastin. When heated, collagen can become gelatinized. This gelatin form has binding capabilities when chilled but is much less effective when not chilled as it transforms to a liquid (Rust, 1975). Without heating and chilling, however, collagen as well as elastin contains little to no binding ability.

In addition to these biological factors, processing conditions play a major role in emulsion stability of sausage batters. Without a stable emulsion, quality issues such as fat separation can occur during thermal processing. Rust (1975) stated several processing factors that influence emulsion stability. These include temperature, time, particle size and thermal processing rate. The ideal temperature for optimal protein extraction is 4.4° - 7.2°C, according to Rust (1975). Rust (1975) recommended that final emulsion temperature for frankfurters should not exceed 21°C. Temperatures higher than 21°C typically result in a less stable emulsion and more fat separation. The amount of time between forming an emulsion and thermal processing also affects emulsion stability. Holding a batter for a shorter time between the two processes allows the product to withstand higher temperatures and is less likely to breakdown. Particle size is an additional factor to consider. Smaller particle sizes require a greater amount of soluble protein than coarser ground product (Rust, 1975). If the emulsion does not contain enough contractile protein, then the emulsion stability will deteriorate. Overchopping leads to smaller fat globules and subsequent greasing out during thermal processing (Pearson & Gillett, 1996). Lastly, the rate of thermal processing has an effect on emulsion stability. Fat separation can occur especially in weaker formulations if the heating rate is too sudden (Rust, 1975).

Nonmeat ingredients contribute to sausage product functionality. Nonmeat ingredients are added for many practical reasons such as flavor, shelf life extension, yield enhancement and food safety. Arguably, one of the most critical ingredients added in sausage processing is salt (NaCl). This compound solubilizes protein, which creates bind, adds flavor and acts as a preservative (Romans, Costello, Carlson, Greaser, & Jones, 2001). When salt is applied at approximately 2% or more, the ionic strength of the sarcoplasm will increase above 0.5, permitting a breakdown of myosin filaments and the swelling of myofibrils, ultimately resulting in a higher water-holding capacity (Hamm, 1986). Water is another functional ingredient as it operates as a solvent for the other added dry ingredients, can reduce product temperature during processing, contributes to enhancing cook yield, is economical to use and adds juiciness to the

product. Sodium nitrite ( $\text{NaNO}_2$ ) utilized at the comminuted legal amount (156 ppm of meat green weight) is also a very crucial ingredient added in cured sausage products due to its ability to add flavor, color, and bacteriostatic properties (Romans et al., 2001). Furthermore, this compound is an effective antioxidant. Food safety is taken as a serious priority in the meat industry and with the utilization of sodium nitrite, the outgrowth of *Clostridium botulinum* is inhibited in vacuum packaged products. Phosphate is an ingredient with functional properties. Used at the legal limit (0.5% of finished product weight), phosphates increase water-holding capacity ultimately optimizing yields, but also helps develop cure color, stabilizes flavor and solubilizes proteins (Romans et al., 2001). There are many other nonmeat ingredients that contribute to product functionality like the addition of spices adding to product flavor and appearance, erythorbates acting as reducing agents of cure and antimicrobials improving shelf life. Without all of these nonmeat ingredients, sausage products would not be capable of reaching optimum functional capacity.

### **Preblending**

Preblending consists of the grinding and mixing of separate meat ingredients with part or all of the cure (salt and nitrite and/ or nitrate) in proportion to the amount of meat (Pearson & Gillett, 1996). Following the mixing process, the preblend is generally held for a period of time prior to being added to the remaining meat product ingredients. Within the meat processing industry, preblending may vary in length of storage time, ingredients and also fat and lean percentages. Romans et al. (2001) stated the cooler storage time to be from 8 to 72 hours. For many years, preblending has been used in industry to increase the functionality of the product. Incorporating a preblend into a meat product allows processors the ability to increase the salt concentration within the preblend meat block and ultimately provides a more optimal condition for water retention. Kenney and Hunt (1990) found that a 4% NaCl beef preblend held for 12 h produced the greatest protein-water interactions, but that providing more water to interact with muscle proteins is of little impact unless the proper ionic strength is provided. In order for the functionality of the preblend to improve, protein-salt interactions must be increased (Ockerman & Crespo, 1982). Also, Lamkey, Mandigo, and Calkins (1991) found that smaller particle sizes used in a 24 h beef preblend increased the bind between particles of a cooked product (Lamkey et al., 1991).

Various fat percentages are used in preblends where cooked sausage formulations target the end product to have no more than 30% fat (CFR 319.180, 2011). A study done by Gumpen and Sørheim (1987) used either pork (23% fat) or beef (18% fat) for their preblends. Another study by Hand, Mandigo, and Calkins (1992) used a fat level for a pork and beef preblend of 27%. In the literature, when fat is reduced and water is increased, generally phosphate is included into the sausage formulation (Andres, Garcia, Zaritzky, & Califano, 2006; Chin, Lee, & Chun 2004). A study done by Eilert and Mandigo (1996) used six different beef preblend treatments to formulate a frankfurter with a target 15% fat, 25% water, 2% salt and 0.5% phosphate. The preblend treatments included a control = no salt or phosphate, NOPHOS = salt but no phosphate, BK-PYRO3 = salt + neutral pyrophosphate, BK-STP = salt + sodium tripolyphosphate, BK-414 = salt + blend of sodium pyrophosphate and sodium tripolyphosphate and BK-512 = salt + blend of sodium polyphosphate and sodium hexametaphosphate. The authors found the preblends containing phosphate had higher levels of soluble protein and greater cooking stability.

Pearson and Gillett (1996) explained that preblending has several advantages including control of composition by adjusting the final blend to a known fat content and stabilization of meat by the addition of cure. Additionally, preblends can be prepared using hot boned meat where addition of cure results in the maximum amount of salt-extractable protein, allows for efficient use of equipment, and retards oxidation of the raw materials (Pearson & Gillett, 1996). Conversely, Hand, Hollingsworth, Calkins, and Mandigo (1987) evaluated the effects of preblending, reduced fat, and salt levels on frankfurter characteristics. They found that 24 hour preblending had very little effect on frankfurter color and texture. There are many comminuted meat products in which the preblending process has been incorporated. A few of those main meat products include bologna, frankfurters, luncheon meats and various sausages.

### ***History of Preblending***

According to the Pearson and Gillett (1996), preblending first achieved prominence in the mid-1960s. Terrell (1974) stated that preblending began in the late 1950s. He declared that the foundation for preblending was made through a patent by Kielsmeier and Gara (1962) that described preparation and compositional control of sausage materials. Historical literature describes preblending as a similar process to current industry procedures; however, there are

various time frames in which preblended salt, meat and nitrite are held (Webb, 1968; Pearson & Gillett, 1996). Hand et al. (1987) described the preblending time period to be 12 or more hours while Ockerman and Crespo (1982) found there to be an increase in water holding capacity in beef preblends after 24 hours. Additionally, within 14-24 hours of preblending, Acton and Saffle (1969) found an increase in soluble protein levels and emulsifying capacity. Various terms such as preformulation and presalting (typically just salt added to meat) have been used in the past interchangeably with the term preblending. Currently, preblending is used within the meat industry due to its advantages in functionality and cost-optimization (Pearson & Gillett, 1996; Romans et al., 2001).

### ***Functionality of Preblending***

#### ***Preblend***

Incorporating a preblend into a sausage formulation is known to enhance the functionality of the meat product by increasing cook yield and the overall bind of the product. These functionality characteristics have been attributed to the excess time provided for salt to extract protein, which allows protein molecules to have an open structure; this in turn contributes to an increase in the overall water holding capacity (Shannon, 1983).

The importance of examining solely the preblend's functionality prior to incorporation into the final product is substantial, as this information will help contribute to determining how beneficial preblend processing is for a process. There are numerous factors that can affect the variability in functionality of preblends. A few main examples include: postmortem age of meat (pre- and postrigor), species type, particle size, salt concentration, fat percentage levels and phosphate use (Pearson & Gillett, 1996; Eilert & Mandigo, 1996; Gumpen & Sørheim, 1987).

The effect postmortem age and rigor state have on preblend functionality was researched by Abu-Bakar, Reagan, Wynne, & Carpenter (1982) evaluating functional characteristics of pre- and postrigor beef preblends for frankfurters. They found a higher pH value and a greater concentration of salt-extractable protein for prerigor beef preblends. Even though these differences were found, the smokehouse yield of the final product was not affected. In addition, changes in species and chopping time have shown to affect meat batter water retention in presalted pork and beef (Gumpen & Sørheim, 1986). When comparing presalted pork to presalted beef species, Gumpen and Sørheim (1986) found that pork retained water more

effectively than beef and that coarser chopped pork batters also had higher water retention or a lower cooking loss. A study done by Hand et al. (1987) evaluated beef and pork frankfurters where the use of beef and pork mixed preblends with various salt levels (1.5, 2.0, or 2.5%) was used. They found that salt positively affected emulsion stability of raw frankfurters and salt coupled with a low-fat formulation increased the texture and made the product more firm instrumentally. Hand et al. (1987) also found that an increase in fat content resulted in a softer, less firm texture. Eilert and Mandigo (1996) conducted a study where phosphate was added to beef preblends and found that preblends made with 0.5% phosphate showed higher soluble protein levels and higher cooking stability (% yield) than control formulations without salt or phosphate or controls with salt only. They stated that phosphate preblends could be used as a way to increase the functionality of low-fat/high-moisture products. Integrating a pork and beef preblend with mechanically separated poultry showed positive, increased ( $P < 0.05$ ) instrumental firmness textural results on smoked sausage product (Jantawat & Carpenter, 1989).

### ***Non-preblend***

Non-preblended meat products or products that do not include a preblend also have functional characteristics. However, the salt and meat ingredients are not held to allow for extensive protein extraction; therefore, non-preblended meat products are thought of as having less functionality than a preblended meat product (Pearson & Gillett, 1996; Romans et al., 2001).

### ***Finished product***

Acton and Saffle (1969) and Shannon (1983) found that preblending enhances finished product protein bind, color and water holding capacity. According to Hand et al. (1992), textural advantages were found when coarse ground pork and beef preblends were used with shorter preblending storage times of 16 hours and no textural benefits were discovered with long, 2-10 d, preblending storage times. Within the industry, mechanically separated poultry (MSP) also known as mechanically deboned poultry meat (MDPM) is used in many comminuted products such as frankfurters, bologna and smoked sausage. A study done by Jantawat and Carpenter (1989) was conducted where the effect of preblending with the incorporation of MDPM was evaluated. They found an increase ( $P < 0.05$ ) in instrumental firmness and chewiness in preblended smoked sausage with the incorporation of MDPM. When evaluating beef frankfurters preblended with pre- or postrigor meat, Abu-Bakar et al. (1982) found no differences in the final

product for smokehouse yield, despite a higher pH and greater concentration of salt-extractable protein in prerigor beef preblends. They did find, however, that frankfurters made with prerigor meat were more acceptable in appearance and sensory characteristics of flavor and juiciness.

## **Shelf Life of Cooked Sausage**

### *Attributes affecting sausage quality and functionality*

#### ***Cook yield***

Meat is cooked for important reasons including food safety and preservation, appearance, and palatability. Through cooking, the moisture content is decreased particularly on the surface, which in turn aids in peelability and shelf life extension (Pearson & Gillett, 1996). During the cooking process of sausage, the majority of the cook loss is attributed to moisture (water) although there can potentially be a small loss of fat and a very slight loss of water-soluble vitamins, minerals and sarcoplasmic proteins (Bender, 1992). The purpose of cook yield percentages is to determine how much product weight loss is a result of the thermal process. Cook yield percentage is calculated as the cooked product weight divided by the raw product weight; the result is then multiplied by 100. This number is imperative for processors to monitor as it directly affects the economics of their business. Many different components influence product cook yield.

The addition of phosphate is known to help increase cook yields. Frye (1990) added sodium tripolyphosphate to 20 h pork preblends for a fine-cut sausage and a coarse ground sausage. This study showed no differences ( $P > 0.05$ ) in smokehouse yields among preblends with or without phosphate for fine-cut sausage. However, smokehouse yield declined ( $P < 0.05$ ) by 2.1% for coarse-ground sausages made with a preblend without phosphate when compared to coarse-ground sausages made with preblend (65% lean/35% fat) formulated with phosphate (sodium tripolyphosphate- STPP). However, no differences ( $P > 0.05$ ) were found between the coarse-ground sausages formulated with either 65% lean/35% fat STPP added preblend, 50% lean/50% fat STPP added preblend, or control where STPP was added to sausage batching step.

Another factor that can impact cook yield is the moisture and fat content of a sausage and processing temperature. In a Korean study conducted by Chin et al. (2004), they investigated how pork sausage was affected by fat and moisture levels ranging from 2% - 26% and 55% -

78%, respectively. They found no differences ( $P > 0.05$ ) in percent cooking loss between treatments. As fat content increased from 0 to 25% and moisture content decreased, percent cooking loss decreased from 16.00% to 9.47%. Another study evaluating the effects of percent fat / percent added water (10/30, 15/25, 20/20 and 30/10) on beef frankfurters was done by Hensley and Hand (1995). Three different chopping temperatures, 9, 12, or 15°C, were used. No differences ( $P > 0.05$ ) in percent processing yield among treatments ( $89.8\% \pm 1.83$ ) were found.

The type of meat used in a sausage can also affect the cook yield percentage. A variety of different sausages today include MSP, which can negatively influence cook yield if used in large amounts. Jantawat and Carpenters (1989) studied a 3:1 pork:beef smoked sausage made with various amounts of MDPM: 10, 30, 50 and 70% by weight. These meat combinations were also preblended 24 h prior to stuffing. Results from this study showed as MDPM increased from 10% to 50% or more, a decrease ( $P < 0.05$ ) in cook yield from 95.9% to 94.4%, respectively, occurred. Among the preblend and conventional processing methods, however, no differences ( $P > 0.05$ ) were found for percent cook yield.

### ***Warner-Bratzler Shear Force***

Warner-Bratzler shear force (WBSF) values are used by the meat industry to determine the maximum force (kg) required to shear through a sample. According to AMSA's Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat (2015), WBSF measurements are the most common form of objective measurements for meat tenderness. There are exact specifications for a V-notched WBSF blade that must be met in order to be a valid WBSF value. By using this value, the sausage industry is able to better evaluate how different factors can impact sausage texture. There are several various factors that can impact the texture of sausage like phosphate, grind type, fat and moisture content, and chopping temperature.

Frye (1990) measured WBSF values on sausage prepared by coring so that the outer protein of the skin was removed. He found the 50% fat with phosphate preblend treatment used to formulate fine cut sausage had a lower ( $P < 0.05$ ) WBSF than the treatment without phosphate. The coarse-ground sausage without phosphate had lower ( $P < 0.05$ ) WBSF values than lean (80% lean and 20% fat) and lean/fat (80% and 20% fat + 50% lean and 50% fat) preblends with phosphate. Frye (1990) also found coarse-ground sausage containing a lean, phosphate added preblend exhibited the highest ( $P < 0.05$ ) WBSF values.

Hensley and Hand (1995) evaluated textural attributes of beef frankfurters using a Kramer shear. Frankfurters were prepared by chopping to different endpoint temperatures and four fat and moisture content treatments with these ratios (%fat / %added water): 10/30, 15/25, 20/20 and 30/10 (control). Frankfurters were sheared on the short axis of a link at ambient temperature. They found the 15/25 frankfurters had the highest ( $P < 0.05$ ) Kramer shear peak force at 0.21 N. The optimal chopping temperature for the highest ( $P < 0.05$ ) Kramer shear force value was 12°C.

Conflicting results of the effect preblending has on WBSF values were found. Abu-Bakar et al. (1982) conducted a study on beef prerigor and postrigor preblends for wiener production. They found no differences ( $P > 0.05$ ) between preblend d 0, 14, 21 and 28 holding times. Those WBSF values were 2.7, 2.1, 2.6 and 2.5 kg, respectively. Rigor state, however, affected tenderness where prerigor meat type had a greater ( $P > 0.05$ ) WBSF value at 2.7 kg than wieners formulated with postrigor meat with a WBSF value at 2.2 kg. Hand (1986) reported no differences ( $P > 0.05$ ) in Kramer shear force values between pork and beef preblend holding times 0, 4, 8, 12, 16, 48, 96, 144, 192 and 240 hours on coarse ground sausage. However, Instron compression tests that assess cohesiveness or binding among meat particles showed greater texture for preblends held between 0-16 h but no change was noted from 48-240 h. Furthermore, Hand (1986) found no differences ( $P > 0.05$ ) in Kramer shear force values for preblending times 0, 4, 8, 12, 16, 20, 24, 48 or 72 hours on fine ground sausages. Reagan, Pirkle, Campion, and Carpenter (1981) completed a study on sausage formulated with a prerigor beef preblend and found length of storage (d) affected single blade shear force (kg) values where preblending hold time d 7 and 14 resulted in a greater ( $P > 0.05$ ) shear force value than d 21 by 0.2 and 0.3 kg, respectively.

### ***Purge***

Purge is defined as product exudate or juice within a package that consists of primarily free water and water-soluble proteins. For cooked sausage products, purge can also be comprised of solubilized non-meat ingredients. Even though purge has nutritional value due to solubilized protein, the accumulation of purge in a package is undesirable to consumers. Therefore, the meat industry invests time and resources into monitoring purge loss percentage of products. The quality of a product's juiciness is affected if purge loss is severe (Aberle, Forrest, Gerrard, & Mills, 2001). Purge loss is directly related to a product's ability to bind to water, which may be

influenced by postmortem changes such as production of lactic acid, loss of ATP, onset of rigor mortis and cell structure changes (Aberle et al., 2001).

Additional factors that impact purge loss are fat and moisture content, chopping temperature and storage time. Hensley and Hand (1995) evaluated purge loss of beef frankfurters over an 8-week storage period. They found as storage time progressed, the amount of purge became greater ( $P < 0.05$ ). Among all fat/moisture combinations, frankfurters containing 10% fat and 30% moisture had the greatest amount of percentage purge loss during storage time. Conversely, the highest fat and lowest moisture combination of 30% fat and 10% moisture had the least amount of purge. When the interaction of chopping temperature and fat/moisture content was evaluated, the 30% fat and 10% moisture content formulation had the least purge loss at 9°C while the highest moisture content formulation exhibited the least purge loss at 15°C. Another study evaluating reduced fat beef frankfurters revealed similar results, finding 17% fat frankfurters had less ( $P < 0.05$ ) purge loss than < 3% fat frankfurters (Candogan & Kolsarici, 2003). However, an extension of refrigerated storage time from 0 d to 42 d resulted in an increase ( $P < 0.05$ ) in purge loss for both 17% fat and < 3% fat beef frankfurters. When low-fat chicken sausage was evaluated over a 45 d period, similar results were found for both fat content and storage factors (Andres et al., 2006). Andres et al. (2006) found a 5% increase in fat resulted in a lower ( $P < 0.05$ ) difference in purge loss compared to 0% and 2% added fat. Carballo, Mota, Barreto, and Jimenez Colmenero (1995) found that protein content positively influenced the reduction of purge loss on pork bologna while research by Colmenero, Carrascosa, Barreto, Fernandez, and Carballo (1996) found similar results on the effect of fat content and chopping temperature on purge loss of pork bologna.

During a 30 d refrigerated shelf-life study of cooked pork sausage, phosphate was added at 0.1 - 0.5% to three meat types: prerigor, chilled postrigor, and previously frozen for 30 d (Wang, Xu, & Zhou, 2009). Wang et al. (2009) found no differences ( $P > 0.05$ ) for percent purge loss on d 0 or 30 for any of the meat types or phosphate levels, demonstrating that phosphate was not effective at reducing purge loss over time.

### ***Packaging***

The fundamental purpose of packaging is to effectively provide a desirable product to the consumer. Packaging also helps to prevent product damage, aids in containment of product and assists in product protection from contamination of biological, chemical and physical hazards

while facilitating product marketing and convenience of use to consumers (Yam, Takhistov, & Miltz, 2005). Previously, packaging was thought of in a “passive” manner or simply as an inactive barrier shielding against oxygen. More recently, a concept referred to as “active” packaging has been developed. “Active” is determined as a more proactive approach to packaging by considering the properties of the product, package and environment and how they can work simultaneously to extend shelf life, improve food safety and maintain food quality (Miltz, Passy, & Mannheim, 1995; Vermeiren, Devlieghere, Van Beest, de Kruijf, & Debevere, 1999). There are several types of packaging aimed towards the “active” concept and each of these packaging types is utilized to cater to certain characteristics of the meat product.

Three main types of packaging are used in the meat industry: tray and overwrap, vacuum packaging and controlled atmosphere packaging (CAP) (Aberle et al., 2001). Among these, vacuum packaging, CAP, gas-flushing and naturally-respiring products with distinct permeable films are considered types of modified atmosphere packaging (MAP), which is referred to as product stored in a regulated atmosphere (Farber, 1991). At retail stores, a large portion of self-service fresh meat is packaged using a tray and oxygen-permeable polyvinyl chloride overwrap (Aberle et al., 2001).

One major type of packaging is vacuum. This type of packaging is generally less accepted for packaging fresh meat by consumers, as the cherry red bloom in beef and reddish-pink color in pork is unattainable due to lack of oxygen (Aberle et al., 2001). Although vacuum packaging may be still widely less accepted among consumers for fresh meat, it is valuable within the meat industry due to its contribution to shelf life extension and its ability to maintain product quality, especially in cured meat products. Sebranek and Fox (1985) stated that vacuum packaging is very valuable to cured meat products due to its ability to reduce oxygen contact with meat, resulting in less product fading and oxidative rancidity. Laminates, which are composite polymer films, are used in vacuum packaging due to low water vapor and oxygen transmission rates. Good barrier films to water vapor comprise of polyethylene and oriented polypropylene while barrier films to oxygen consist of polyvinylidene chloride and ethylene vinyl alcohol. A vacuum package is comprised of both film barrier types, ultimately providing an excellent barrier to oxygen and moisture (Aberle et al., 2001). Both fresh and processed meat utilize MAP. The atmosphere within the package is modified to an optimal percentage of various gasses determined by the type of meat product and whether or not the product is cured.

The main commercial gasses used in packaging include oxygen, nitrogen and carbon dioxide, while traces of carbon monoxide, nitrous oxide and sulphur dioxide may potentially be used (Farber, 1991). Each of these gasses provide a vital function, whether that be decreasing spoilage, enhancing food safety or influencing meat color. Oxygen (O<sub>2</sub>) facilitates formation of oxymyoglobin, which results in desirable fresh meat color; however, oxygen also supports growth of aerobic bacteria (Farber, 1991; Sørheim, Nissen, & Nesbakken, 1999). Carbon dioxide (CO<sub>2</sub>) displays a bacteriostatic effect and can inhibit product respiration while nitrogen (N<sub>2</sub>) is an inert tasteless gas described as being a filler among the main gasses, which helps in suspending oxidative rancidity (Farber, 1991; Devlieghere, Debevere, & Van Impe, 1998; Sørheim et al., 1999).

Cured meats can quickly discolor when exposed to residual oxygen and light, which can occur in vacuum and modified atmosphere packaging (Rikert, Bressler, Ball, & Stier, 1957). Møller, Jensen, Olsen, Skibsted, and Bertelsen (2000) reported that 0.1% or less of residual oxygen in MAP prevents discoloration in cured ham under fluorescent lighting at 5°C for 27 d. Additional deterioration of product quality from oxygen can include oxidative rancidity. In a study done by Parra et al. (2012), where dry-cured ham was either vacuum packaged or MAP with different gas mixtures of N<sub>2</sub> or argon, they found lower ( $P < 0.05$ ) lipid oxidation in vacuum packaged ham on d 60. They also found that vacuum packaging better-maintained ham lean and fat color intensity for the 60 d refrigerated shelf study. Cilla, Martinez, Beltran, and Roncales (2006) found vacuum packaging maintained quality of dry-cured ham cuts and slices better over an 8-mo period than MAP packaged with 80% N<sub>2</sub> and 20% CO<sub>2</sub>. Fernandez-Fernandez, Vazquez-Oderiz, & Romero-Rodriguez (2002) also found vacuum packaging to be more effective in maintaining quality of chorizo sausage during a 29-wk room temperature study. Additionally, Pexara, Metaxopoulos, & Drosinos (2002) found that vacuum packaging maintained the quality of cured, cooked and sliced turkey fillets and cooked pork sausage for 28 d refrigerated shelf life.

Conversely, a study conducted by Garcia-Esteban, Ansorena, and Astiasaran (2004) found only minor differences between packaging types. Cured ham was vacuum or MAP (100% N<sub>2</sub>, or 20% CO<sub>2</sub> and 80% N<sub>2</sub>) packaged and stored refrigerated for 8-wk. They found no differences ( $P > 0.05$ ) in packaging type or storage time for redness; lightness was slightly higher ( $P < 0.05$ ) for vacuum packaged ham and yellowness increased ( $P < 0.05$ ) over time for vacuum packaged ham. Ultimately, it is imperative to have extensive sanitation and hygiene in a

packaging room in order to increase shelf life, as the initial contamination will greatly affect the length of shelf life, regardless of storage time and packaging type (Samelis & Georgiadou, 2000). Furthermore, packaging is capable of only maintaining product quality and cannot improve the quality (Aberle et al., 2001).

### ***Chemical Attributes***

#### ***pH***

Meat product quality can dramatically be influenced by pH since there is a direct relationship between pH and water holding capacity (WHC). The ability for a meat product to hold water is crucial as it affects yield, product color and texture. Processors desire most ready-to-eat (RTE) products to have an optimal WHC, which means formulating the product so the pH is above the isoelectric point. Microbial growth is another important quality factor influenced by pH. Microorganisms have a pH range for optimum growth near 7.0 (neutral) while meat pH, typically around 5.6, is favorable to yeast, mold and acidophilic bacteria growth. Within the RTE category, generally the most monitored pathogen is *Listeria monocytogenes*, which can grow at a pH range of 4.39-9.4 (Aberle et al., 2001; Food Safety and Inspection Services (FSIS), 2014).

When evaluating storage time for beef and pork preblends in refrigerated storage from 0 to 4 d, Waldman, Westerberg, and Simon (1974) found no differences in pH for raw or cooked frankfurters. In another refrigerated storage study, Andrés et al. (2006) found no differences in pH with low-fat cooked chicken sausages stored to 50 d. Puolanne, Ruusunen, and Vainionpaa (2001) observed that when salt is reduced in cooked pork and beef sausages, high-pH raw materials and/or alkaline phosphates should be used to raise pH enough to have a more optimal WHC.

#### ***Lipid Oxidation (TBARS)***

Lipid oxidation is a principal cause of quality issues within processed meats, especially with frozen products over time (Olsen, Vogt, Veberg, Ekeberg, & Nilsson, 2005). There are many factors that influence the rate of oxidation. Following slaughter, certain aspects that affect lipid peroxidation are species, anatomical location, diet, sex and age as well as phospholipid composition and content (Gray & Pearson, 1987). Additional factors that occur during and after

processing that impact lipid peroxidation are processing and storage temperature, packaging, composition and post-mortem age of raw material, chopping, flaking, emulsification deboning and adding compounds like salt, nitrite and spices (Kanner, 1994). Factors that increase lipid oxidation rate are called pro-oxidants, and major ones include: metal ions, heat, ultraviolet light and low pH (Aberle et al., 2001). On the contrary, there are also compounds which hold antioxidant properties and work as a retardant to lipid oxidation. A few antioxidants include nitrite, ascorbate, phosphate, sage, rosemary, butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA).

Certain types of lipids are more susceptible to oxidizing. The more double bonds a fatty acid contains, the more likely it is to oxidize. Even an increase in just one double bond results in an oxidizability increase of 40 times (Olsen et al., 2005). Therefore, polyunsaturated fatty acids become rancid much quicker than monounsaturated and saturated fatty acids (Aberle et al., 2001). Within unsaturated fatty acids, there are three that mainly contribute to increasing oxidation rate, which are: oleate, linoleate and linolenate (Gray, 1978). There are three main steps to the lipid oxidation mechanism: initiation, propagation and termination. A free radical or very unstable and highly reactive molecule will either go through this 3-step mechanism or be mediated by other oxidants or enzyme systems. In primary oxidation, hydroperoxides are formed, which are the product of fatty acids and oxygen. Following this initial reaction are the reactions responsible for reaction rate and they form secondary compounds that are thought to be responsible for off-flavors (Gray, 1978).

In order to gauge lipid oxidation or product rancidity, the meat product can be evaluated subjectively by sensory or objectively by chemical analysis. A common and extensively used way to chemically measure lipid oxidation in meat products is by the 2-thiobarbituric acid (TBA) test. This method uses a spectrophotometer to measure pink chromogens, which form when TBA reacts with secondary products from lipid oxidation. Malondialdehyde (MDA) is used as a calibration standard (Sørensen & Jørgensen, 1996). When measuring TBA, the threshold for consumers to notice oxidized odor is 0.5 to 1.0 mg/kg MDA (Tarladgis, Watts, & Younathan, 1960) and the threshold where consumers are able to detect oxidized off flavor is 0.6 to 2.0 mg/kg MDA (Greene & Cumuze, 1981). However, Zipsler, Kwon, and Watts (1964) reported the sensory threshold to be 1.0 mg/kg MDA. According to AMSA (2012) there are two methods of measuring thiobarbituric acid reactive substances (TBARS) for oxidative rancidity. If a sausage

product contains sugars, yellow chromogens are emitted; therefore, to measure TBA the distillation method or a method by Du and Bramlage (1992) must be used to prevent erroneous results (Vasavada & Cornforth, 2006). However, if a meat product does not contain sugar then the rapid, wet method can be used (AMSA, 2012). According to Wang, Pace, Dessai, Bovell-Benjamin, and Phillips (2002) the distillation method may not be exceptionally accurate because when the product is heated and distilled, the formation of additional TBARS can potentially form causing the reading of oxidation to be higher than in actuality. Additionally, error can occur in TBARS results of cured meats due to residual nitrite. According to Zipser and Watts (1962) this problem can be resolved by adding sulfanilamide; however, Shahidi, Rubin, Diosady, and Wood (1985) reported that sulfanilamide added to meat with 100 to 200 ppm nitrite resulted in larger TBARS values than without sulfanilamide.

Mielnik, Aaby, Rolfsen, Ellekjaer, and Nilsson (2002) completed an 18-wk study on frozen mechanically deboned poultry (MDP) sausages consisting of either vacuum packaged MDP or air packed skeleton that were deboned prior to production. They found that using meat from air packed skeleton detrimentally increased TBARS 0.313 mg/kg MDA more than vacuum packaged MDP sausage. Species of poultry used also affected TBARS. Turkey sausage had higher ( $P < 0.01$ ) TBARS than chicken sausage. Storage time of frozen MDP affected TBARS outcome as well. The 18-wk storage time had higher ( $P < 0.01$ ) TBARS than sausage stored for 6-wk. In a study where different levels of unsaturated fat content in fresh pork sausage frozen up to 12-wk was evaluated, Baer and Dilger (2014) found lipid oxidation to remain under 1 mg/kg MDA.

In a study that incorporated beef preblend into frankfurters, Abu-Bakar et al. (1982) found that storage time of a raw, 7 d preblend resulted in a higher ( $P < 0.05$ ) TBA value than a 0 d preblend. However, no differences in TBA were found past 7 d storage up to 28 d and TBA numbers remained below 1 mg/kg MDA. Contrary to those results, Waldman et al. (1974) found an increase above 1 mg/kg MDA in beef and pork frankfurters formulated with raw preblends that had been stored 2 d prior to manufacture. When evaluating the effect of MAP and vacuum packaging and temperature at 4° and 15°C on TBARS of pork Chinese-style sausage during 5 months storage, Wang, Jiang, and Lin (1995) observed MAP as well as a lower storage temperature to have lower ( $P < 0.05$ ) TBARS than vacuum packaging and the warmer storage temperature. By month 2, all treatments surpassed the 1 mg/kg MDA threshold of rancidity

detection. In a 10-wk study on vacuum packaged beef bologna, Brewer, McKeith, Martin, Dallmier, and Wu (1992) found inconsistent differences ( $P < 0.05$ ) in TBA values and they were all below 0.65 mg/kg MDA. Based on the literature, preblending hold time detrimentally affects TBARS of raw preblends held for longer than 2 d.

### ***Proximate Analysis***

In order to remain in accordance with law, sausage products must maintain fat and moisture percentages within a certain limit. According to CFR 319.180 (2015), cooked sausage shall not contain more than 30 percent fat and no more than 40 percent of a combination of fat and added water. Processors generally use the common methods of the Association of Official Analytical Chemists (AOAC) to monitor protein, fat and moisture content.

Meat is mostly comprised of water (75%), fat (5%), protein (20%), mineral (ash- 1%) and a minute amount of carbohydrates (1%) (Huff-Lonergan & Lonergan, 2005). If under the regulated amount for fat and added water, processors will typically add more of these ingredients to establish a functional, efficient and economical sausage product. Added water serves as a solute to dry ingredients and contributes to texture and juiciness of the final product. Processors can better predict end product composition by using approximate moisture and protein content as well as moisture-to-protein ratios of raw meat materials. Variation in raw materials can occur based on meat and fat condition (Romans et al., 2001).

There are many components that can affect the outcome of final product composition such as particle size, if product was dried and for how long along with type and amount of ingredients used. Frye (1990) found no differences ( $P > 0.05$ ) in moisture or fat percentages for fine-cut sausage, although, differences were discovered in coarse ground pork sausage. In this study, use of a lean preblend and the control treatment where phosphate was added at the batching step, moisture percentage was higher ( $P < 0.05$ ) by 1.6% and 0.5%, respectively, than it was for all other treatments. Sausage formulated with the lean preblend phosphate added treatment revealed a higher ( $P < 0.05$ ) final fat percentage than all other treatments.

### ***Cured Meat Color***

Cured meat color is only stable when oxygen and light are not present (AMSA, 2012). With the presence of oxygen and light, the cured color will eventually turn gray due to photooxidation. According to Munk, Huvaere, Van Bocxlaer, and Skibsted (2010), this

phenomenon is due to a two-step parallel reaction where there is formation of nitrosyldioxy-radical forms and the ferrous state transforms to ferric state within the heme cavity. Color change from pink to green can occur due to oxidation from heavy metals (iron, copper, chromium) and bacterial growth (Rust, 1975). Pink cured color is found to be appealing among consumers for cooked cured red meat but undesirable in cured poultry meat (Hui, 2012).

In a study done by Abu-Bakar et al. (1982), residual nitrite levels had no effect on L\* (lightness) and a\* (redness) values between prerigor and postrigor beef preblends. However, a difference in residual nitrite levels between prerigor and postrigor preblends was seen for b\* (yellowness) values of a beef frankfurter product. Moller et al. (2000) found that 0.1% or less residual oxygen was low enough to prevent discoloration of sliced, modified atmosphere packaged ham that was displayed under fluorescent lighting for 27 d of refrigerated storage.

### ***Instrumental Meat Color***

Meat color measured instrumentally is considered to be an objective method and is widely used within the meat industry. There are several important selections to determine prior to color measurement. First, an instrument must be selected and then within each instrument there are the following selections to consider: color systems (Hunter, CIE and tristimulus), illuminant, degree of observer and aperture size (Mancini & Hunt, 2005). According to AMSA (2012) there are two main instruments. Colorimeters measure L\* (lightness), a\* (red) and b\* (yellow) values while spectrophotometers are instruments that provide spectral analysis with intervals of 1 to 10 nm. When evaluating the most common illuminants (A, C and D<sub>65</sub>), the recommended choice for measuring meat color is Illuminant A as more emphasis is placed on red wavelength proportion. The remaining two common illuminants are used to evaluate other food product types. Brewer, Zhu, Bidner, Meisinger, and McKeith (2001) found results confirming that color measurements are impacted upon instrument and illuminant chosen and comparing data with a differing instrument and illuminant may not be valid. Also, there are multiple degrees of observers but the most common are 2° and 10° observers. Due to the ability of 10° observers to capture a greater portion of the scanned sample, it is the recommended choice for meat color measurement. However, Garcia-Esteban, Ansorena, Gimeno, and Astiasaran (2003) found lightness (L\*) of dry-cured ham provided the most reproducible results from CIE L\* a\* b\* and Hunter Lab systems. However, they found no differences for illuminants (D<sub>65</sub>, C and A) or various angles used (2° and 10°). Lastly, aperture size (8 mm to more than 3.18 cm)

needs to be chosen and this decision should be based off the size or area of the measurable sample and provided that at least 3 measurements can be taken of the sample (AMSA, 2012). Researchers should use caution when comparing color data as a difference in aperture size can result in erroneous comparisons. With the decrease in size, the percentage of reflectance also decreases, especially between 600 and 700 nm of red wavelengths (Yancey & Kropf, 2008).

When taking color readings, it is crucial to standardize the instrument to prevent unreliable data. If a meat product is covered with a packaging film, the instrument must also be standardized with the same film. The color measurement of a meat product that is at least 12 to 15 mm thick is also recommended to prevent light from passing through the sample resulting in an inaccurate measurement. Pillowing or the formation of a curved surface due to excess pressure of the instrument should be avoided as this too can skew color results.

Along with CIE  $L^*$ ,  $b^*$  and  $a^*$  values are saturation index, hue angle and  $a^*/b^*$  ratios. Saturation index (chroma) calculations are used to indicate the intensity of the product hue. Hue angle is useful for lengthy studies or shelf-life studies to determine if there are shifts in color and discoloration. Ratios for  $a^*/b^*$  that are larger reveal more meat product redness and less discoloration (Setser, 1984).

Extrinsic and intrinsic factors can impact final meat color. Guidi, Castigliero, Armani, Iannone, and Giafaldoni (2006) concluded that discoloration might be impacted by an increase in lipid oxidation and unsaturated fatty acids. This study agrees with the findings of Alderton, Faustman, Liebler, and Hill (2003) where aldehydes from lipid oxidation accelerate the oxidation of heme proteins resulting in discoloration. Another study by Brewer et al. (1992) reported that hue angle,  $L^*$  and  $b^*$  were not affected ( $P > 0.05$ ) by the addition of different sodium lactate levels to vacuum packaged beef bologna. However, 10-wk storage time inconsistently affected  $L^*$ , decreased ( $P < 0.05$ )  $a^*$  and increased ( $P < 0.05$ ) hue angle for all treatments. When comparing 10, 30, 50 and 70% of added MDPM added to smoked pork and beef sausage, there were differences in core color. For  $L^*$  values, the 70% added MDPM was darkest ( $P < 0.05$ ), 10% added MDPM had the reddest ( $P < 0.05$ )  $a^*$  values and no differences ( $P > 0.05$ ) between MDPM levels were seen for  $b^*$  or hue angle with the Hunter Lab system. Also, no differences ( $P > 0.05$ ) were found in color between conventional and preblending processing methods (Jantawat & Carpenter, 1989).

### ***Salt (NaCl)***

Salt is considered to be the most critical and functional ingredient in sausage production (Romans et al., 2001; Rust, 1975). However, salt also has negative connotations as well. Within salt remain impurities of trace amounts of heavy metals (iron, chromium and copper) causing salt to be a pro-oxidant and increasing lipid oxidation (Rust, 1975). A study done by Chen et al. (1984) found results confirming that salt alone increases lipid oxidation but that salt coated in Tenox 4 (BHA-citric acid-propylene glycol) and salt mixed with BHA and BHT were both effective as antioxidants in raw and cooked beef. Although the most commonly used salt is sodium chloride, alternative salts like potassium chloride and calcium chloride have been researched to help reduce sodium since sodium is linked to hypertension. However, there have been issues of bitterness with these salt alternatives, therefore, they have to be blended with NaCl.

Tobin, O'Sullivan, Hamill and Kerry (2012) found that with salt content levels at 1, 1.5, 2, 2.5 and 3% and fat levels at 10, 15, 20 and 25% in beef and pork frankfurters, consumers accepted 10 and 15% fat frankfurters only when salt content was at 2.5-3%. Puolanne and Terrell (1983) revealed that salt could be reduced from 2% to 1.5% without any affect on water binding capacity of cooked pork sausage. Another study by Puolanne et al. (2001) found 2.5% salt to be the optimum salt level for water holding capacity in cooked pork and beef sausage. They also found that when lowering salt content in cooked sausages the pH should be increased in order to achieve a more optimal water holding capacity. Hand et al. (1987) found that 20% fat beef and pork frankfurters with 1.5% salt had a softer texture than those with 2.0% and 2.5% salt. Additionally 30% fat frankfurters became more red ( $P < 0.05$ ) with the decrease in salt level.

### ***Water Holding Capacity***

Meats ability to maintain water within the muscle or added water during processing where water is retained with the application of force such as cutting, heating, pressing, grinding is referred to as water holding capacity (WHC) (Hamm, 1960). An understanding of WHC is crucial because it affects properties of meat like color, texture, juiciness and tenderness (Aberle et al., 2001). In addition, WHC affects meat quality following slaughter whether it is during storage, grinding, heating or freezing (Hamm, 1960). Many factors also influence WHC. Major physical and biochemical factors include: net charge effects, genetic factors, and steric effects of the muscle cell (Huff-Lonergan & Lonergan, 2005). In addition, there are many methods to measure product WHC. For instance, WHC can be based off amount of purge loss, cook loss,

total expressible fluid due to meat being pressed between plates and fluid loss via centrifugation (Hui, 2012; Hamm, 1986).

There are three ways in which water exists in muscle and these are bound, immobilized and free form. The bound form has the highest ability to be retained within muscle and the free form having the least ability to be retained. Water is considered polar and therefore associates with electrically charged reactive groups of proteins. An increase or decrease in pH can change the availability of reactive groups on proteins and essentially alters WHC. The lowest WHC occurs when pH is at the isoelectric point (pH 5.3-5.5), which is the pH where the number of positively charged groups equals the number of negatively charged groups. As a result, when pH is above or below the isoelectric point, WHC increases (Aberle et al., 2001). Another factor that helps to increase WHC are salts. Once muscle converts to meat, salts are able to migrate into the fibers and cause swelling or intake of water (Hamm, 1960).

Purge is a water-soluble protein or sarcoplasmic protein estimated to be about 34% of all muscle proteins; also within a milliliter of purge fluid there is approximately 112 mg of protein (Savage, Warriss, & Jolley, 1990; Hamm, 1960). Accumulation of purge in packaging is unattractive to consumers and can also result in a dryer and perceived tougher meat product (Aberle et al., 2001). Phosphates are generally known to increase WHC, juiciness, and cook yields, especially when they are alkaline and raise the pH (Whiting, 1988; Trout & Schmidt, 1983, 1986). However, this was not the case for Wang et al. (2009). When observing the effect of phosphate level on WHC in pork emulsion-type sausage, Wang et al. (2009) found that WHC could not be increased by phosphate use during 30 d of storage, however, pre-rigor meat was able to improve ( $P < 0.05$ ) WHC.

### ***Sensory Analysis***

Analysis of sensory attributes is used as a common and practical way to improve the quality and optimization of shelf life as well as the cost of processed meat products without detrimentally affecting consumer acceptability of products. According to AMSA (2015) there are three test methods in sensory analysis and these include consumer testing, descriptive analysis and discrimination tests. Consumer testing is a subjective measurement and should be completed in conjunction with marketing tests to augment a better understanding of acceptability of new or altered product (Ramirez, Hough, & Contarini, 2001). There are also objective ways of sensory

analysis, which involves descriptive analysis and the utilization of trained panelists. A trained panelist is described as someone who has been to at least 6 to 10 training sessions (AMSA, 2015). This matter of fact approach to sensory analysis aids in providing more reliable data for researchers to quantify the impact of particular attributes on consumer satisfaction (Hui, 2012). Discrimination tests help to determine if there are differences between samples and can be done subjectively or objectively (AMSA, 2015). The objectives and type of study conducted will help to determine whether a consumer panel or trained panel should be used. For instance, during a shelf life study, a trained panel is used to better understand how a product performs throughout its shelf life as well to determine if there are differences among treatments.

When analyzing a food product, panelists will distinguish attributes in the order of appearance, odor, texture and flavor (Meilgaard, Civille, & Carr, 2007). Among these attributes, texture is of primary importance in processed meat products; especially in deli meats since bind is necessary for thin slices and economical yield (Hui, 2012). When evaluating the effect of sodium lactate (SL) on a vacuum packaged, beef bologna, Brewer et al. (1992) found an increased ( $P < 0.05$ ) salty flavor as SL increased. Additionally, they found no differences in off-flavor for the treatment with 3% SL until week 10.

A consumer panel that examined varying salt and fat levels of frankfurters showed that 10 and 15% fat levels and 2.5-3% salt levels were most acceptable to consumers and a reduction in both fat and salt content were judged to be more tough, possessed greater cooking losses and were less juicy (Tobin et al., 2012). Another consumer panel was conducted on vacuum packaged low-fat (0%, 2% and 5% added fat) chicken sausage (Andres et al., 2006). They found the most acceptable sausage to be at 2% added fat. This fat content also had the highest likability for texture while the 5% added fat was most liked in flavor.

A trained panel evaluated Galician chorizo sausage during a 208 d storage period found 19 of the 29 variables that were tested differed over the storage period (Fernandez-Fernandez et al., 2002). These 29 variables measured odor, color, flavor and texture attributes. Olsen et al. (2005) showed that pork sausage developed different flavors in storage than chicken and that lean poultry sausage had less rancid flavor during an 11 month frozen storage study than higher-fat pork sausage due to more polyunsaturated fatty acids in pork. Mechanically deboned poultry meat is often used in cooked sausages. Mielnik et al. (2002) found with a trained panel that vacuum packaged sausages made from MDPM were affected mainly by storage time (6 and 18

weeks raw storage) and storage form (vacuum packed MDPM or air packed skeleton). The texture attribute “hardness” was mostly affected by storage time and species (chicken or turkey) while meat from air packed skeleton as well as turkey meat was found to have more graininess in sausage products.

## Chapter 2 - Shelf Life of Preblend Formulated Smoked Sausage Displayed Under Fluorescent Lighting

### Abstract

Pork preblends held for 0, 4 or 7 d were formulated into smoked sausages and analyzed for cook yield, instrumental external color, pH, salt content, proximate analysis, Warner-Bratzler shear force (WBSF), thiobarbituric acid reactive substances (TBARS), sensory analysis and purge percentage during 0, 110, 131 and 160 d display at an average 2.65 °C under fluorescent lighting.

One preblend × day of display interaction was found for b\* values. On display d 0, preblend d 7 was more yellow ( $P < 0.05$ ) than preblend d 0 and 4; however, no differences ( $P > 0.05$ ) were found for any preblends on d 110 or 160. On display d 131, preblend d 0 was more ( $P < 0.05$ ) yellow than preblend d 4 but similar ( $P > 0.05$ ) to preblend d 7. There was no preblend effect ( $P > 0.05$ ) on any of the other attributes measured. Display day did not affect ( $P > 0.05$ ) purge, pH, proximate analysis, WBSF, juiciness, saltiness or off-flavor. For color, a\* and saturation index values decreased ( $P < 0.05$ ) and L\* increased ( $P < 0.05$ ) between d 0 and 110 as well as d 110 and 131, while L\*, a\*, a\*/b\* ratio and saturation index values were similar ( $P > 0.05$ ) from d 131 to 160. Hue angle value decreased from d 0 to 110 but was similar for the remaining display. A reduction ( $P < 0.05$ ) in a\*/b\* ratio was shown from d 0 and 110 (average 0.85) to d 131 and 160 (average 0.78). There was a reduction in salt content by 0.43% and an increase in TBARS values by 0.46 mg malonaldehyde/100 g sample from d 0 compared to d 110, 131 and 160 ( $P < 0.05$ ). Inconsistent differences were found for sensory panel traits bite and flavor intensity and a reduction ( $P < 0.05$ ) in mouthfeel coating was found from d 0, 110 and 131 compared to 160. Therefore, preblending could be implemented without any detrimental outcome on quality or sensory attributes of skinless smoked sausage; however, as day of display increases product may become lighter, less red and more oxidized.

Key words: Extended shelflife, Fluorescent lighting, Mechanically separated turkey, Nitrite, Pork preblend, Precooked smoked sausage

## Introduction

Within the processed meat industry, preblending has become prominently known as a functional method to improve bind, texture, product color and cook yields while also providing a way to help manage product composition (Sindelar, 2015). Although this processing method has been used since the mid-1960s (Pearson & Gillett, 1996), research to best optimize the procedure for the product being made needs to be conducted. Also, with a change in processing can come risks in detrimentally affecting product shelf life. Therefore, quality and functional attributes should be examined prior to implementing a preblending process.

There are many variables to consider when implementing a preblend in a sausage formulation. One major factor that influences functionality is preblend holding time. Preblends held at the optimal time have been shown to improve functionality characteristics of various processed meat products. Hand et al. (1992) found an improvement in cook yields of Polish sausage formulated with pork and beef preblends held for up to 16 h compared to no preblend and preblends held from 24 to 240 h. They also found an increase in instrumental compression texture with preblending up to 16 h. Another study found an increase in water holding capacity for raw beef preblends with 3% salt held for 1 d (Ockerman & Crespo, 1982). Reagan et al. (1981) reported a 4.6% greater smokehouse yield for frankfurters formulated with beef preblends held for 14 d than preblends held for 7 d. Frye (1990) also found similar results where yields increased ( $P < 0.05$ ) when coarse-ground sausage was formulated with a preblend held up to 18-24 h and reduced with longer pork preblend holding times. Conversely, Abu-Bakar et al. (1982) discovered no differences in yield of frankfurters formulated with beef preblends held for 0, 7, 14, 21 or 28 d and Hand et al. (1987) found no differences ( $P > 0.05$ ) in texture between frankfurters formulated with preblending or nonpreblending treatments.

Literature has shown a preblending effect on product color. Hand et al. (1987) reported that frankfurters formulated with a pork and beef preblend held for 24 h were darker with a lower  $L^*$  value by 1.17 units than nonpreblended frankfurters. Similar to these findings, Abu-Bakar et al. (1982) found d 0 and 7 preblends had similar  $L^*$  values (average 53.47) but lower  $L^*$  values by 2.17 and 1.14 units, respectively, than preblends held for 28 d where the longer preblend holding time resulted in a lighter product.

In addition, preblending has been shown to affect lipid oxidation. A study by Abu-Bakar et al. (1982) found preblends held for 7, 14, 21 and 28 d had greater TBA values than d 0 with a difference of 0.59 mg/kg malonaldehyde (MDA) between d 0 and 28. Similar results were also shown in a study by Waldman et al. (1974) where a greater TBA value was found in pork and beef preblends held for 4 d than for d 0, 1 and 2. The authors reported d 0 to have a TBA value of 0.65 mg/kg MDA and d 4 showed 1.64 mg/kg MDA. Various levels of salt and the inclusion of phosphate can impact lipid oxidation. Choi (1986) found an increase in salt content of pork preblends resulted in greater TBA values but that the inclusion of mixed phosphates at 0.5% helped to reduce TBA values. According to Frye (1990), the inclusion of sodium tripolyphosphate (STPP) during the preblending phase for various lean and fat blends helped to reduce TBA values versus waiting until sausage formulation to add STPP. By week 6, a 50% lean / 50% fat preblend with STPP added prior to preblending was 0.1 mg/kg MDA lower than the preblend with STPP added after preblending.

Research has been conducted on preblend holding time and the affect of preblending on quality attributes. However, there is no research that has evaluated the effects of preblending on finished product characteristics held over a longer shelf life period. Therefore, the objectives of this study were to determine whether the addition of a preblend within a smoked sausage formulation affects quality characteristics of the final product in a refrigerated retail display case for a shelf life of 160 d and how an extension of shelf life to 160 d affects sausage quality.

## **Materials and Methods**

### ***Experimental Design***

A shelf life study was conducted on skinless, smoked sausage formulated to contain one of three preblends: 0 d served as the control, 4 d or 7 d. Sausages were analyzed on d 0, 110, 131 and 160 of refrigerated display under fluorescent lighting for a total of 12 preblend by display day treatment combinations. Days of display 110, 131 and 160 were 85%, 100% and 123% of the product shelf code, respectively. Cook yield, purge percentage, instrumental external color, pH, sodium chloride content, proximate analysis, Warner-Bratzler shear force (WBSF), thiobarbituric acid reactive substance (TBARS) and descriptive sensory analysis were measured on the smoked sausage for each experiment replication. Three replications of the experiment were conducted.

### ***Product Description and Preparation***

Materials to make 0 d, 4 d and 7 d preblends were obtained from a commercial facility (Smithfield Foods, Junction City, KS) and transported in coolers filled with frozen ice-packs to Kansas State University's Meat Lab. Proprietary preblends contained fresh 7 d postmortem pork picnic shoulder (72% lean), fresh 7 d postmortem pork fat trim (42% lean), cure mix (156 ppm sodium nitrite) and salt. To make the preblend, the meat ingredients were ground (Model 4732, Hobart, Troy, OH) through a 9.5 mm plate and then immediately reground through a 4.8 mm plate. The ground meat was then mixed with remaining preblend ingredients using a ribbon mixer (Model I200DA70, Leland Southwest, Fort Worth, TX) for 4.5 min, placed in a lug, covered with butcher paper and stored in a fluorescent lit cooler (KSU Meat Lab, Manhattan, KS) and held at 1-4°C for either 4 d or 7 d prior to making sausage. The 0 d preblend served as a control and was manufactured on the same day as sausage production.

Upon reaching the designated preblend treatment time, 0 d, 4 d and 7 d preblends were then used as an ingredient in a proprietary sausage formulation. Product ingredients to formulate all 72 packages (24 packages per each replication of experiment) of skinless smoked sausage were acquired from a commercial facility (Smithfield Foods, Junction City, KS). Skinless smoked sausage ingredients included: fresh 7 d postmortem pork picnic shoulder (72% lean), fresh 7 d postmortem pork fat trim (42% lean), fresh 6-14 d postmortem mechanically separated turkey (MST) that contained 156 ppm sodium nitrite and 1.68% salt, previously frozen beef fat trim, water, corn syrup, 2% or less of dextrose, flavorings, autolyzed yeast, modified food starch, mechanically separated chicken, monosodium glutamate, potassium and sodium lactate, salt, sodium diacetate, sodium nitrite, sodium phosphate and vitamin C (ascorbic acid).

Beef fat trim (25% lean) was ground using a 9.5 mm plate and then immediately reground through a 4.8 mm plate one day prior to sausage production to facilitate sausage processing on the following day. For each preblend treatment, preblend, ground beef trim and MST were weighed and mixed for 3 min using a ribbon mixer. Next, the remaining dry and wet nonmeat ingredients were added, the batter was mixed for an additional 4 min, transferred to a vacuum stuffer (Model VF608, Handtmann, Biberach, Germany) and stuffed in 32 mm cellulose casings (Viscofan, Navarra, Spain) to a sausage link length of 279.4 mm. Immediately following manufacture, linked sausage treatments were transported in coolers filled with several frozen ice packs to a commercial facility (Smithfield Foods, Junction City, KS) where sausages were

thermally processed in a proprietary continuous oven to an internal temperature of 72°C following USDA FSIS Appendix A (1999). Sausages were then cooled in a proprietary brine solution following USDA FSIS Appendix B (1999), machine peeled, subsequently vacuum packaged (2 links per package) with a light permeable and oxygen impermeable film (Curlam, Bemis Company, Oshkosh, WI). The film was 3.5 mm thick, had an oxygen transmission rate < 0.3 cc/64,516 mm<sup>2</sup>/24 h at 22.8°C, 0% relative humidity, 1 atm and a water vapor transmission rate of < 1.0 g/64,516 mm<sup>2</sup>/24 h at 37.8°C, 90% relative humidity, 1 atm. Packages of sausage treatments were then placed in cardboard boxes according to assigned preblend treatment and transported in coolers filled with several frozen ice packs to Kansas State University where they were labeled with preprinted labels and randomly placed on shelves in a fluorescent-lighted (FLS) retail display case. Packages were placed so the front label faced down on the retail display shelf so the sausage links were exposed to the fluorescent lighting 24 h/d. Also, packages were not rotated at all throughout the duration of the study. Lighting within the color study room remained off throughout the duration of the study.

### ***Retail Display Cases and Lighting Intensity***

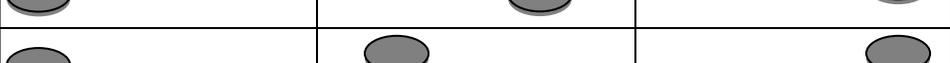
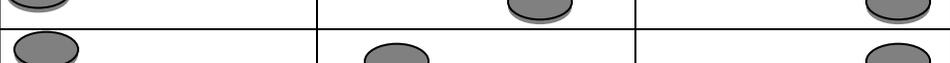
A Hussmann Ingersoll 2.44 meter M5X (Bridgeton, MO) refrigerated retail display case equipped with 5 shelves and FLS lighting (Sylvania Octron, F032/835/ECO, Danvers, MA) was used for the study. Every 6 h, a defrost cycle would occur in the display case. The top shelf width was 35.66 cm, shelf 2 was 40.64 cm, shelves 3 and 4 were 45.72 cm, and the bottom shelf was 72.39 cm wide. The display case was turned on one week prior to the start of the study. Out of 120 shelf locations available within the case, 72 spots were randomly assigned to product. The remaining shelf locations were occupied by 454 g plastic bags of water to simulate a full display and maintain case temperature. Additionally, plastic water bags replaced product as packages were removed for analysis during progression of the shelf life study. To help reduce temperature variation on the left side of the case, a 1.03 x 1.74 x 0.05 m piece of Owens Corning Formulator 150 insulation (Toledo, OH) was placed on the outside of the left side of the case.

Lighting intensity (lumens) was measured four hours after the retail case was powered on with an illumination meter (INS DX-200). Measurements were taken at each package location (72 packages total) within the case, 2.54-cm directly above the shelf to imitate location of greatest intensity on 2.54-cm diameter sausage links.

### *Case Temperature*

Case temperature was monitored every 4 h throughout the study using I-button ThermoChron (DS1921 G Maxim Direct, Sunnyvale, CA). The display case was equipped with a total of 30 I-buttons, with 6 on each shelf. Three I-buttons were placed on the front of each shelf on the far right, far left and center locations and on the back far right, far left and center locations (Figure 2.1).

**Figure 2.1 I-button temperature logger locations within fluorescent display case.**

FLS Display Case		
Shelf		
1, Top	Back	
	Front	
2	Back	
	Front	
3	Back	
	Front	
4	Back	
	Front	
5, Bottom	Back	
	Front	

### *Cook Yield*

The sausages were placed on a metal triangular stick to thermally process in a continuous oven. Before hanging the sausage, the weight of the triangular stick was weighed. Next, the combined weight of the metal stick and the sausages was obtained prior to thermal processing. Cooked sausage was then weighed on the stick immediately after cooking. Percentage cook yield

was calculated using the following equations: (stick weight – raw sausage weight) = raw weight and (stick weight – after brine chill cooked sausage weight) = cooked weight. Final cook yield percentage: [(cooked weight / raw weight) × 100].

### ***Instrumental External Color***

Two packages for each replicate of each shelf life day and preblend combination were evaluated for instrumental external color for a total of 24 packages per replicate of experiment. Sausage link color measurements were taken from the light exposed side through clear vacuum packaged film. The attributes measured were L\* (lightness), a\* (redness), and b\* (yellowness) Illuminant A with 10° observer values using a 1.27cm aperture Hunterlab MiniScan™ EZ (Model 4500L, Reston, VA). Three-color measurements were taken from each package and averages of the L\*, a\* and b\* were used to calculate a\*/b\* ratio, hue angle and saturation index (AMSA, 2012).

### ***Percent Purge Loss***

Percent purge was measured on two packages from each preblend treatment on d 110, 131 and 160. The weight of the package containing sausages was obtained. Sausage links were then removed from the vacuum package and the sausages were patted dry with paper towels. Blotted sausage links were then weighed together. The remaining empty package was dried and then weighed. Purge weight was calculated using the following formula: (initial package + sausage weight) – (sausage weight) – (empty package weight) = purge weight. Final purge percentage was calculated using the following formula: (purge weight / initial package + sausage weight) × 100.

### ***pH***

Each individual link within one package for each preblend and day of display combination was measured to determine pH. The pH of sausage was obtained by first slicing the sausage in half, widthwise. Then, a pH probe (Model H199163, Hanna Instruments, Woonsocket, RI) that was attached to a calibrated pH meter (Accumet Basic, Fisher Scientific Pittsburgh, PA) was inserted into the sample to obtain sausage pH.

### ***Sodium Chloride***

Salt content was analyzed on d 0, 110, 131 and 160 using Quantab (Hach Co., Loveland, CO) high range chloride titrate strips. Ten grams of sausage from one sausage link per preblend treatment was finely chopped with a knife and placed into 90 ml of distilled boiling water. Water had been heated to a boil using a microwave (Model Wes1130DM2BB, General Electric Co., Louisville, KY) for 1 min. A glass stir bar was used to blend chopped sausage in water for 30 s. Product rested in the hot water for 1.5 min and was then stirred again for an additional 30 s. Following stirring, the solution was held at room temperature for at least 30 min to allow the solution to cool. A piece of #42 110 mm Whatman<sup>®</sup> (Maidstone, England) filter paper was then immersed in the solution followed by the Quantab<sup>®</sup> strip being placed against the filter. Finally, the wick measurement on the test strip was recorded and calculated following the percent salt table on the back of the Quantab<sup>®</sup> container with a 1:10 dilution where %NaCl was multiplied by 10 (Boyle, ASI 777, 2014).

### ***Proximate Analysis***

Proximate analysis was measured on each treatment on d 0, 110, 131, and 160 of refrigerated display. Half of a link from each link within a package was used to determine proximate analysis. Sausage samples were prepared by first cubing the sausage manually into small pieces with a knife and then freezing the cubed samples by immersing in liquid nitrogen. Frozen samples were then homogenized using a blender (Model 33BL79, Waring Products, New Hartford, CT) and placed in 11.4 cm x 22.9 cm plastic labeled Whirl-Pak<sup>®</sup> bags (Fisher Scientific, Fair Lawn, NJ). The homogeneous sausage powder was stored at -80° C until used to determine proximate analysis and TBARS within 30 days.

The Association of Analytical Communities procedures (AOAC Official Method PVM-1:2003 MEAT) were used to analyze moisture and crude fat content by the SMART system 5 (CEM Corp., NC). Crude protein analysis was conducted according to the AOAC procedure (AOAC Official Method 990.03) using the LECO FP-2000 Protein/Nitrogen Analyzer (Model 602-600, LECO Corp., MI).

### ***Warner-Bratzler Shear Force***

To evaluate objective tenderness using Warner-Bratzler Shear Force (WBSF), one package from each preblend treatment and day of display combination was taken directly from the retail display case, placed in a refrigerator (Model MSR 23NM, Turbo Air, CA) and sheared at refrigerated temperature (2-4 °C). One half of both links within a package was used and sheared perpendicular to the circumference of the link using a Warner-Bratzler V-shaped blunt blade (G-R Manufacturing Co., Manhattan, KS) powered by an Instron Universal Testing Machine (Model 5569, Instron Corp., Norwood, MA). Each link within a package was sheared eight times with a shear every 1.25 cm and the average of the individual measurements from both links within a package was used for statistical analysis.

### ***Thiobarbituric Acid Reactive Substances (TBARS)***

Product samples were prepared similar to proximate analysis samples. Oxidative rancidity was conducted in triplicate and analyzed using a modified procedure following Tarladgis et al. (1960). A 10 g ± 0.2 sausage powder sample was placed in a 250 ml bottom round flask. Added to the flask was 97 ml of distilled water, 2 ml of hydrochloric acid (Fisher Scientific, Fair Lawn, NJ) solution, 1 ml of sulfanilamide (Alfa Aesar, Ward Hill, MA) solution, 2 boiling beads (Boileezers Fisher Scientific, Fair Lawn, NJ) and 5 drops of antifoam C emulsion (Sigma-Aldrich, St. Louis, MO) solution. The mixture was then distilled until 50 ml of distillate was obtained. Next, 5 ml of distillate and 5 ml of thiobarbituric acid (Tokyo Chemical Industry Co., LTD, Portland, OR) reagent was pipetted into a 30 ml screw top test tube. Test tubes were placed in a test tube rack and then held in a covered boiling hot water bath for 35 min. Following the hot water bath, test tubes were placed in a cold water bath for 10 minutes. Finally, 1 ml from each test tube solution was pipetted into a cuvette. Absorbance was read with a spectrophotometer (Eon, BioTek Instruments, Winooski, VT) at 532 nm where mg of malonaldehyde was calculated from absorbance reading. The formula to calculate TBAR number was:  $[(O.D. (Absorbance)_{532} - \text{blank})] \times 7.8 = \text{TBA number (mg malonaldehyde/100 g of sample)}$ .

### ***Sensory Evaluation***

Product samples were prepared by cooking whole sausage links from a single package for each preblend treatment and day of display combination to an internal temperature of 74° C in a

30.5 cm Oster electric skillet (Model CKSTSKFM12W-ECO, Sunbeam Products, Inc., Boca Raton, FL) containing two cups of simmering water. Links were then sliced into 1.3 cm pieces and held warm in double boilers until served to panelists where each panelist was given two pieces of sausage. A total of six samples (three treatments, each done in duplicate) per panel were randomly provided to each panelist. A minimum of six panelists were present for each panel. Panelists were composed of graduate students and faculty from Kansas State University, and were trained for evaluating bite, flavor intensity, saltiness, off flavor, and mouth feel/coating of cooked skinless smoked sausages. Panelists were trained by completing 3 orientations where references were established as well as an additional orientation in the middle of the study to get reacquainted with the sausage product. To provide anchors for panelists, a 0.64 cm thick slice of pork/beef summer sausage (Wimmer's Big N' Meaty, West Point, NE) was used for bite and had a consensus bite value of 6.5 on an 8-point scale. A 0.4% salt solution was used to provide an anchor of 5.5 for saltiness on an 8-point scale and room temperature cream cheese (Philadelphia Cream Cheese, Kraft Foods Group, Inc., Northfield, IL) was used to provide an anchor of 6.5 for mouthfeel coating and 1 for bite on an 8-point scale. Additional anchors for mouthfeel coating included 2% milk at a 2 and summer sausage warmed in a microwave for 10 seconds was referred to as a 6.5. The attribute scale was achieved using an 8-point scale and attributes that were measured included bite, juiciness, flavor intensity, saltiness, off-flavor and mouthfeel where 8 represented: extremely firm, extremely intense, extremely salty, extremely intense, and extremely heavy coating, respectively. The middle of the scale, 4, represented slightly soft, slightly bland, slightly unsalty, slight, and slight for attributes and a value of 1 on the scale represented extremely soft, extremely bland, not salty, none, and none, respectively. Additionally, panelists were provided unsalted saltine crackers and distilled water to cleanse their palates between samples. Furthermore, a thawed, previously frozen smoked sausage was used as a warm-up and panelists were given warm-ups on d 0, 110, 131 and 160.

### ***Statistical Analysis***

The smoked sausage study was analyzed as a randomized complete-block design with a split-plot arrangement of treatments where the whole plot was preblend treatment factor and the sub-plot was days of display. Replication was used as a blocking factor. The Kenward-Roger adjustment was used for degrees of freedom error. Model effects tested included preblend d (0, 4

and 7), shelf-life d (0, 110, 131 and 160) and preblend by shelf life. The LSMEANS statement was used to compute least squares means of the fixed effects: preblend and shelf life.

Temperature data of the retail display case were analyzed in a randomized complete-block design with day as a blocking factor. Data for both designs were analyzed using PROC MIXED in SAS 9.3 (Statistical Analysis System 9.3, SAS Institute Inc., Cary, NC).

## **Results and Discussion**

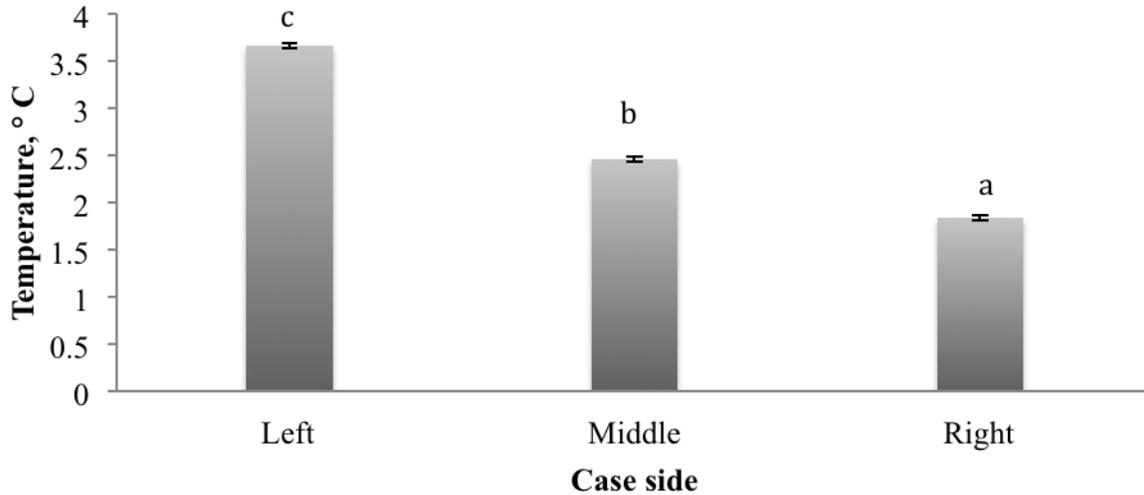
### ***Lighting Intensity***

Fluorescent lighting had a lighting intensity average of 1034 lm. The range for lighting intensity was 140 to 2300 lm (Appendix A Figure A.1).

### ***Case Temperatures***

The average retail display case temperature with fluorescent lighting throughout the duration of the study was 2.65 °C with a standard error of the mean (SEM) of 0.01 °C. Differences in case temperature were found between sides of case as shown in Figure 2.2. The left side of the case was warmer than the middle by 1.2 °C and 1.82 °C warmer than the right side. This is most likely due to a LED refrigerated retail case located on the right side of the fluorescent case operating during a majority of the current study. Conversely, Steele (2011) found the center of the same case used to be the coldest on average by 0.37-1.00 °C than the sides. Temperature differences were also found when comparing the front to the back of the case. The average temperature of the back locations of the five shelves were 2.06 °C colder than the average front shelf location temperatures (Figure 2.3). These findings agree were similar to Steele (2011) where the author found the backs of the shelves to be colder than the front by 1 °C ( $P < 0.05$ ).

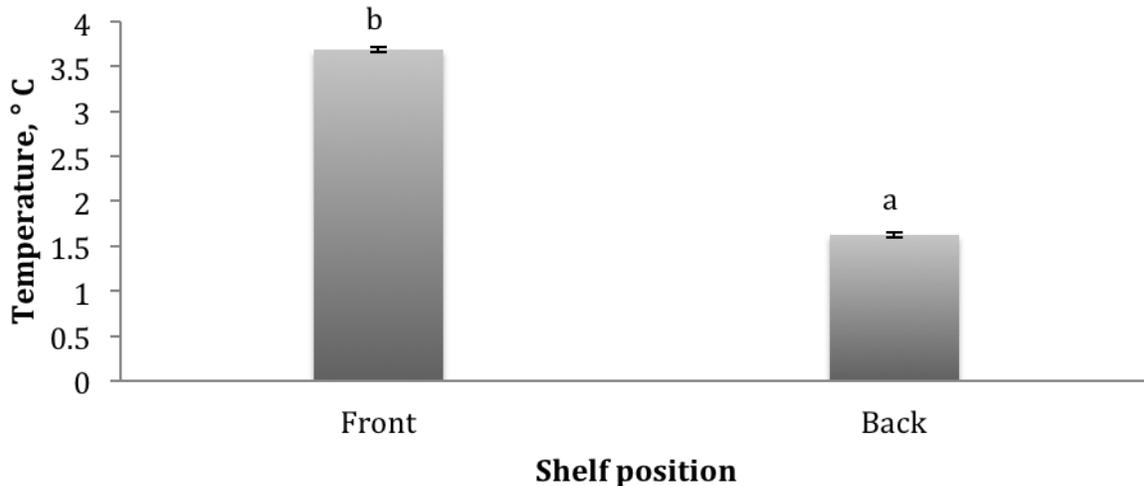
**Figure 2.2 Least squares means for case temperature<sup>1</sup> at three different sides in a refrigerated display case during 160 days of operation.**



<sup>abc</sup> Different superscript letters differ ( $P < 0.05$ ). Standard error of the mean = 0.03.

<sup>1</sup>Sides of case include: Left = front and back spots of all shelves on left side of case, Middle = front and back spots of all shelves on middle of case, Right = front and back spots of all shelves on right side of case.

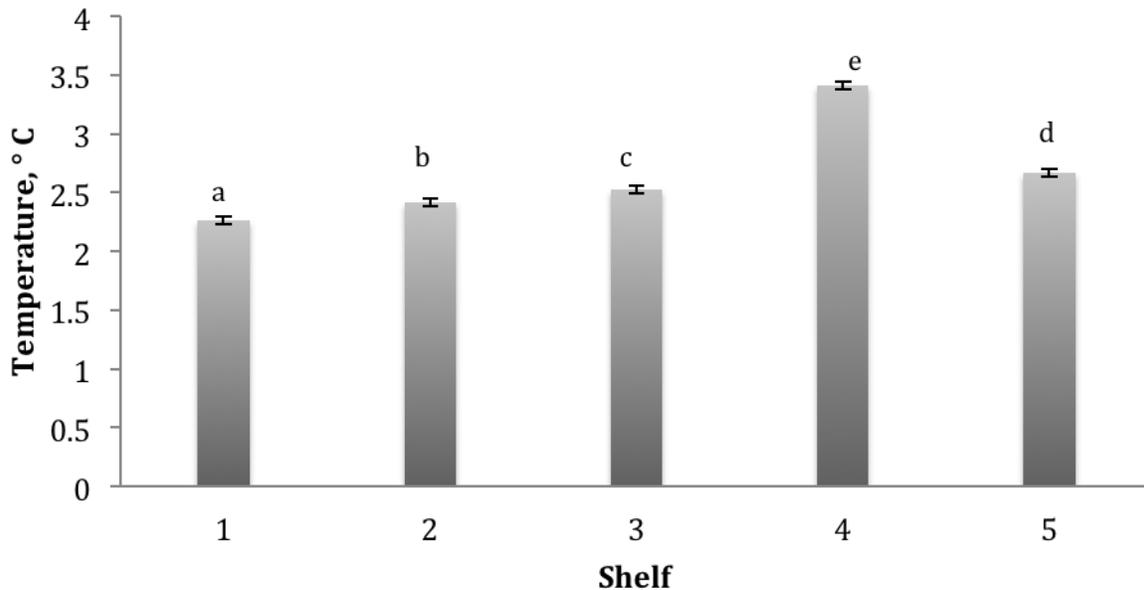
**Figure 2.3 Least squares means for case temperature<sup>1</sup> at two positions (Front and Back) within five shelves in a refrigerated display case during 160 days of operation.**



<sup>ab</sup> Different superscript letters differ ( $P < 0.05$ ). Standard error of the mean = 0.03.

<sup>1</sup>Positions within shelves of case include: Front = front spots of all shelves, Back = back spots of all shelves.

**Figure 2.4 Least squares means for case temperature<sup>1</sup> of five shelves (1, 2, 3, 4 and 5) in a refrigerated display case during 160 days of operation.**



<sup>abcde</sup> Different superscript letters differ ( $P < 0.05$ ). Standard error of the mean = 0.03.

<sup>1</sup> Shelves of case include: 1 = top of case, 3 = middle, 5 = bottom of case.

Average shelf temperatures for shelves 1, 2, 3, 4 and 5 where 1 represented the top of the case, 3 represented the middle of the case and 5 represented the bottom of the case, were 2.26, 2.42, 2.53, 3.41 and 2.67, respectively (Figure 2.4). Differences were found between all shelves ( $P < 0.05$ ). Shelves 4 and 5 were on average warmer than all other shelves, which were the bottom two shelves of the retail case. Shelves 1 and 2 were the coldest shelves on average compared to all other shelves, which were at the top of the case. In contrast, Steele (2011) found no differences ( $P < 0.05$ ) among shelves in a study where the same case was utilized. However, the Steele (2011) study was 7 d compared to the current 160 d study (216 d total over 3 replications), which explains why differences were found in the current study and not in the Steele study.

### ***Cook Yield***

No differences ( $P = 0.14$ ) were shown between the three preblend treatments for cook yield. The average for cook yield among preblend levels was 93.29% with a SEM of 1.66%, although, as preblends age increased, a decreasing trend was shown in cook yields (Appendix A Table A.1). Hand et al. (1992) studied the influence of pork and beef preblending time on cook

yield. With their study, an increase in cook yield was found with a shorter preblending time. The optimum cook yield was shown at a preblend hold time of 8 h and was followed by a rapid decrease in cook yield as preblend holding time continued. Hand et al. (1992) also found that longer preblending times (2-10 d) resulted in minimal change or a reduction in cook yield. They attributed the efficacy of shorter preblending time due to rapid activity of salt extracting proteins and noted few changes in the preblend were made beyond 16 hours. Additional results from Gumpen and Sørheim (1987) showed 24 h presalting time to be more effective in reducing cooking loss of coarsely comminuted pork sausage than nonpresalted pork.

### ***Instrumental External Color***

External color mean results are provided in Table 2.1. There were no preblend  $\times$  day of display interactions for any independent variables measures except  $b^*$  values. The interaction for  $b^*$  values is shown in Table 2.2. Initially on display d 0, similar ( $P > 0.05$ ) preblend treatments held for 0 and 4 d were both less ( $P < 0.05$ ) yellow than d 7 by 3.35 units. However, for d 110 no differences ( $P > 0.05$ ) were shown between preblend treatments for  $b^*$  values ranging from 24.82-25.77. On d 131, preblend d 0 was similar ( $P > 0.05$ ) to d 7 but more ( $P < 0.05$ ) yellow than d 4, which was 23.76. The d 131 difference shown between preblend treatments d 0 and d 4 was 1.39 units. Also on d 131, preblend treatment d 0 was the only treatment to advance in  $b^*$  values. By the end of the shelf life on d 160, no differences ( $P > 0.05$ ) in  $b^*$  were exhibited with values ranging from 23.38-24.57.

No differences ( $P > 0.05$ ) in  $L^*$ ,  $a^*$ ,  $b^*$ ,  $a^*/b^*$  ratio, saturation index or hue angle were found between preblend treatments formulated for 0, 4 and 7 d. This indicates that preblending for 0, 4 or 7 d did not affect product color. These results agree with Jantawat and Carpenter (1989) where they found no differences ( $P > 0.05$ ) in  $L^*$ ,  $a^*$ ,  $b^*$  and hue angle between 24-hour vacuum packaged preblends and nonpreblended smoked sausage formulated with mechanically deboned chicken meat. Additionally, Abu-Bakar et al. (1982) found there to be no differences in  $a^*$  or  $b^*$  in beef preblends that were vacuum packaged and stored for 0, 7, 14, 21 and 28 d prior to thermal processing. The product did increase in  $L^*$  values by d 28 and was shown to be lighter than d 0 and 7. Hand et al. (1987) observed slightly lower  $L^*$  values in frankfurters formulated with a 24-hour pork and beef preblend than in nonpreblended product.

All tested color attributes were influenced by the day of display. With progression in days of display from 0 to 110, changes were shown where  $L^*$  increased,  $a^*$  and saturation index was reduced, and an increase in hue angle ( $P < 0.05$ ) was revealed. As day increased from 0 to 131,  $L^*$  values of sausage product increased ( $P < 0.05$ ) and decreased ( $P < 0.05$ ) in  $a^*$  values, became less saturated, developed a greater hue and developed a smaller  $a^*/b^*$  ratio. The product became less intense of a red color and more discolored from d 0 to d 131. The product became lighter by 3.96 units and less red by 4.31 units, respectively. This may be a result of residual oxygen within vacuum packages causing oxidation and discoloration from the combination of fluorescent light and oxygen. Days of display also affected color between 110 to 131 where an increase in  $L^*$ , decrease in  $a^*$ , decrease in  $a^*/b^*$  ratio, and decrease in saturation ( $P < 0.05$ ) was exhibited. This indicated that during this progression of time, product became lighter, less red, more discolored and a less intense red. It should be acknowledged that during thermal processing replicates 2 and 3 had fattening occur; therefore, the addition of fat on the external surface of the sausage could contribute to myoglobin oxidation from the effect of lipid oxidation on cured meat color (AMSA, 2012). No differences ( $P > 0.05$ ) were found between d 131 and 160 products for any of the color traits. Similar results were found by Brewer et al. (1992) with vacuum packaged beef bologna. They reported that a 10 week storage time inconsistently affected  $L^*$ , decreased  $a^*$  and increased hue angle. Another study conducted on vacuum packaged dry-cured ham found an increase in  $L^*$ , no differences in  $a^*$  values and an increase in  $b^*$  values between 0 and 3 weeks (Garcia-Esteban et al., (2004). Between week 3 and 8 however, no differences were found in  $L^*$ ,  $a^*$  or  $b^*$ .

**Table 2.1 Least squares means (Lsmeans) for instrumental color attributes of exterior surface of smoked sausages formulated with 0, 4 or 7 d preblend treatments and displayed under refrigeration for up to 160 days under fluorescent lighting.**

Treatment	L*	a*	b*	a*/b* ratio	Saturation Index	Hue Angle
Preblend						
0 d	50.33	20.32	25.35	0.80	32.52	51.43
4 d	49.77	20.65	24.56	0.84	32.10	49.98
7 d	50.45	20.71	25.97	0.80	33.23	51.53
SEM <sup>1</sup>	1.03	0.82	0.68	0.02	0.97	0.82
<i>P</i> - value	0.79	0.80	0.26	0.37	0.37	0.39
Days of Display						
0	47.55 <sup>a</sup>	23.24 <sup>c</sup>	27.48	0.85 <sup>b</sup>	36.00 <sup>c</sup>	49.74 <sup>a</sup>
110	50.15 <sup>b</sup>	21.11 <sup>b</sup>	25.19	0.84 <sup>b</sup>	32.87 <sup>b</sup>	50.03 <sup>b</sup>
131	51.51 <sup>c</sup>	18.93 <sup>a</sup>	24.36	0.78 <sup>a</sup>	30.87 <sup>a</sup>	52.19 <sup>b</sup>
160	51.53 <sup>c</sup>	18.95 <sup>a</sup>	24.15	0.78 <sup>a</sup>	30.72 <sup>a</sup>	51.97 <sup>b</sup>
SEM <sup>1</sup>	0.93	0.81	0.58	0.02	0.93	0.63
<i>P</i> - value	< 0.01	< 0.01	-	< 0.01	< 0.01	< 0.01

<sup>1</sup> SEM is standard error of the mean.

<sup>a-c</sup> Least squares means in the same section of the same column without a common superscript indicate mean differences ( $P < 0.05$ ).

The current study results indicate that preblend holding time did not have an effect on instrumental external color. However, days of display detrimentally affected color by d 110 where product became lighter, had less intense redness, and formed greater discoloration. Figures of sausage images are provided in the appendix of the three replications and d 110, 131 and 160 (Figure A.2, A.3, A.4). Additionally, the b\* interaction between preblend holding time and days of display showed that the longer preblend holding time from d 0 to d 110 initially had more yellow color but also a faster rate of yellow fading. Once d 7 preblend holding time treatment reached 110 d of display, no differences were found among b\* values. For d 131, however, another difference was shown between d 0 and d 4 where d 0 was more yellow. Results by the end of shelf life showed all b\* values to be similar among preblend treatments.

**Table 2.2 Least squares means for instrumental color of b\* preblend × day interaction ( $P = 0.0079$ ) of external surface of smoked sausages formulated with 0, 4 or 7 day preblends and displayed under refrigeration for up to 160 days under fluorescent lighting.**

	Days of Display			
	0	110	131	160
Preblend				
0 d	26.93 <sup>d</sup>	24.82 <sup>abc</sup>	25.15 <sup>bcd</sup>	24.50 <sup>abc</sup>
4 d	26.08 <sup>cd</sup>	25.03 <sup>bcd</sup>	23.76 <sup>a</sup>	23.38 <sup>a</sup>
7 d	29.43 <sup>e</sup>	25.77 <sup>cd</sup>	24.16 <sup>ab</sup>	24.57 <sup>abc</sup>

<sup>a-c</sup> Different superscripts indicate mean differences within row and column ( $P < 0.05$ ).

Standard error of the mean is 0.77.

### ***Percent Purge Loss***

Results of mean purge percentages for preblend and day are provided in Table 2.3. Statistically, percent purge was not affected ( $P > 0.05$ ) by preblend treatments or days of display. A decreasing trend of purge percentage was observed as preblend holding time increased, albeit the difference was 0.6%. Logically, a longer preblend holding period would result in further protein extraction and consequentially in an increase in WHC, and subsequently less purge. This same trend was not observed between days of display. A study conducted by Andres et al. (2006) demonstrated that storage time of sausage does not affect purge loss; however, their study was conducted on chicken sausage and stored for only 45 days.

### ***pH***

Average sausage pH was 6.25 with a range from 6.18 to 6.33. The results for the effect of preblend and days of display on pH are shown in Table 2.3. No differences ( $P > 0.05$ ) were revealed between preblend treatments or the days of display (0, 110, 131 and 160). These results are similar to results shown by Waldman et al. (1974) where they found no differences between beef and pork preblends, which were held for 0, 1, 2, 3 or 4 d and the pH ranged from 5.88 to 5.94. In addition, similar results were found by Andres et al. (2006) where no effect ( $P > 0.08$ ) was shown for storage time (50 d) on pH of cooked, vacuum-packaged chicken sausages.

### ***Sodium Chloride***

Results for sodium chloride revealed no statistical differences ( $P < 0.05$ ) between preblend treatments d 0, 4 and 7 and ranged from 1.98% to 2.03% (Table 2.3). However, salt

content differences were observed between days. There was a decreasing trend in sausage salt content as time progressed from 2.29% on d 0 to 1.86% on d 160 and d 0 had a greater ( $P < 0.05$ ) amount of salt than all other days of display (110, 131 and 160). This could potentially be caused by human error in methodology due to inconsistent particle size of sausage upon chopping. Also, a decrease in salt content may result from sausage being used for analysis following towel blotting of purge loss calculation on d 110, 131 and 160 but not d 0. However, no purge was visually observed on d 0. No literature was found on reduction of salt content in cooked sausages over time.

### ***Proximate Analysis***

Moisture, fat and protein analyses revealed no differences ( $P > 0.05$ ) for any of the preblend treatments or days of display (Table 2.3). The mean moisture, fat and protein content was 52.61%, 22.95% and 10.64%, respectively. As preblend holding time progressed, however, an increasing trend in moisture content was shown. Between d 0 and d 7 preblend holding time, an increase of 1.67% moisture was determined. Reagan, Pirkle, Campion, and Carpenter (1981) found a smaller ( $P < 0.05$ ) percentage of moisture on preblend storage time d 7 (49.8%) than d 14 (52.3%) or d 21 (53.8%) for wieners formulated with a prerigor, beef preblend. It is possible that initially, preblend raw material may have had some variation in moisture and fat content. Another likelihood is the longer holding time which provides salt more time to solubilize protein, results in a greater percentage of moisture (Sindelar, 2015). As days of display advanced from d 0 to d 131, a declining trend of 1.15% in moisture was found. Logically, as days of display continue, the amount of free water is released as purge. However, a slight increase (0.27%) occurred between d 131 and 160. Fat percentage for the current study also revealed a trend in preblend holding time treatments where the amount of fat was reduced by 2.00% as preblend holding time increased from 0 to 7 days. Reagan et al. (1981) found with an increase in storage of preblends from d 7 to d 21, fat percentage decreased ( $P > 0.05$ ) from 32.6% to 28.7%. Since moisture had a tendency to increase as preblend hold time progressed, fat percentage decreased. In addition, as days of display continued, the trend was for fat percentage to increase by 1.60%, showing again an inverse relationship with moisture percent. No trends were observed between preblend treatments for protein percentage.

### ***Warner-Bratzler Shear Force***

Neither preblend treatments nor days of display exhibited an effect ( $P > 0.05$ ) on WBSF values (Table 2.3). The overall mean WBSF value was 1.30 kg. Results from Abu-Bakar et al. (1982) found no differences ( $P > 0.05$ ) in WBSF of frankfurters formulated with beef preblend stored raw for 0, 14, 21 or 28 days. Contrary to the current study, Reagan et al. (1981) were able to detect greater values in instrumental shears with a straight blade in frankfurters formulated with prerigor beef preblends held for 7 and 14 d than those held for 21 d. This was supported by Hand (1986) where beef and pork preblends held up to 16 h had greater ( $P > 0.05$ ) Instron textural results than no preblending in coarse ground sausage; however, Kramer shear force (kg) results showed no differences ( $P > 0.05$ ). Furthermore, Jantawat and Carpenter (1989) reported a 24 h preblend formulated with mechanically deboned poultry meat resulted in greater firmness and chewiness values in smoked sausage than a conventional (nonpreblend) formulation. Days of refrigerated display did not reveal any evidential trends in the current study.

### ***Thiobarbituric Acid Reactive Substances (TBARS)***

There was not a preblend treatment effect on TBARS ( $P = 0.09$ ) as shown in Table 2.3, which ranged from 0.58 to 0.78 mg malonaldehyde (MDA) / 100 g of sample. Day 7 of the preblend holding times revealed the smallest observed TBARS value by 0.2 mg MDA and d 4 preblend treatments had the greatest average TBARS value (0.78 mg MDA). It should be noted although, that one replication for d 4 preblends contained fat trim with visual oxidative issues, including fat discoloration and off odors. Off flavor sensory results also detected a trend of an increase in off flavor for preblends held for 4 d. However, no differences ( $P = 0.56$ ) were found in off flavor sensory results. Waldman et al. (1974) found similar results compared to the current study. For raw beef and pork preblends, they found preblend holding time d 0 to be smaller in TBA values than d 4 by 0.99 mg MDA. However, it should be noted the product analyzed for TBA was raw instead of cooked while finished cooked product was used to measure TBARS in this study. In a study conducted by Abu-Bakar et al. (1982), they found smaller TBA values ( $P < 0.05$ ) for d 0 of raw beef preblend holding time than at d 7, 14, 21 and 28 with the difference between d 0 and d 28 being 0.59 mg MDA. This also was raw product that was tested.

As expected, days of display had an effect on TBARS values ( $P < 0.01$ ), which ranged from 0.4 to 0.86 mg MDA. For days of display, d 0 exhibited a smaller ( $P < 0.05$ ) TBARS value

than all other days (110, 131 and 160). Although an upward trend in average TBARS values was observed between d 110, 131 and 160, no differences ( $P > 0.05$ ) were found between those days. The average TBARS value for d 110 was 0.66 mg MDA while d 160 was 0.86 mg MDA. Also, none of the average TBARS values measured during days of display were  $>1.0$  mg MDA/kg of sample, which is considered the threshold for consumers to notice rancidity (Greene & Cumuze, 1981). When comparing TBARS values to sensory off flavor results for days of display, no differences ( $P = 0.52$ ) were found in sensory. Brewer et al. (1992) found significant differences ( $P < 0.05$ ) for TBA values of sliced and vacuum packaged beef bologna held in dark storage for 2, 4, 6, 8 and 10 wk. Their values were inconsistent but remained below 0.65 mg throughout the storage period.

**Table 2.3 Least squares means (Lsmeans) for product composition and various functional traits of smoked sausages formulated with 0, 4 or 7 day preblends and displayed under refrigeration for up to 160 days under fluorescent lighting.**

Treatment	Purge, %	pH	Salt, %	Moisture, %	Fat, %	Protein, %	WBSF, kg	TBARs, mg MDA <sup>2</sup>
Preblend								
0 d	1.97	6.26	2.03	51.64	24.19	10.50	1.25	0.62
4 d	1.84	6.27	1.98	52.88	22.48	10.88	1.31	0.78
7 d	1.37	6.22	1.98	53.31	22.19	10.54	1.34	0.58
SEM <sup>1</sup>	0.54	0.04	0.08	0.91	0.98	0.23	0.12	0.17
<i>P</i> - value	0.51	0.63	0.77	0.38	0.35	0.47	0.83	0.09
Day								
0	–	6.25	2.29 <sup>b</sup>	53.21	21.98	11.00	1.30	0.40 <sup>a</sup>
110	1.60	6.25	1.95 <sup>a</sup>	52.83	22.69	10.47	1.41	0.66 <sup>b</sup>
131	1.89	6.18	1.87 <sup>a</sup>	52.06	23.56	10.57	1.24	0.73 <sup>b</sup>
160	1.68	6.33	1.86 <sup>a</sup>	52.33	23.58	10.52	1.24	0.86 <sup>b</sup>
SEM <sup>1</sup>	0.47	0.04	0.09	0.95	1.04	0.21	0.10	0.18
<i>P</i> - value	0.21	0.16	< 0.01	0.75	0.59	0.21	0.12	< 0.01

<sup>1</sup> SEM is standard error of the mean.

<sup>a-b</sup> Least squares means in the same section of the same column without a common superscript indicate mean differences ( $P < 0.05$ ).

<sup>2</sup> mg MDA = mg MDA/100 g sample.

## *Sensory Evaluation*

Results of mean sensory evaluation attributes for preblend treatments and days of display are provided in Table 2.4. There were no interactions between preblend treatments and days of display. When evaluating the effect of preblend treatment on sensory characteristics including bite, juiciness, flavor intensity, saltiness, off flavor and mouthfeel, no differences ( $P > 0.05$ ) were noted. The current study's results are similar to results by Abu-Bakar et al. (1982) who found no differences between beef preblend holding time d 0, 14, 21 and 28 for appearance, flavor, saltiness or overall desirability. However, they found inconsistent differences for juiciness and firmness traits. A study conducted on preblends formulated with mechanically deboned poultry meat (MDPM) in smoked sausage evaluated sensory traits using a trained panel (Jantawat & Carpenter, 1989). They observed no differences ( $P > 0.05$ ) between preblended and conventional (nonpreblended) smoked sausages in sensory firmness, cohesiveness, flavor or quality traits. However, instrumentally, the preblended sausage formulation was more firm than the conventional formulation by 5.7 N ( $P < 0.05$ ). Conventional sausage formulations were juicier by 0.4 units ( $P < 0.05$ ) than sausage formulated with a preblend on a 10-point scale. Another study reported similar results where frankfurters formulated with a 24 h beef and pork preblend was less juicy by 0.78 units on a 15 cm line scale than frankfurters without preblending ( $P < 0.05$ ) (Hand et al., 1987). Perhaps preblending has a stronger and greater bind of water and is then perceived as not releasing as much moisture during consumption.

Days of refrigerated display did not affect juiciness, saltiness or off flavor ( $P > 0.05$ ). Sensory attributes that were affected by days of display include bite ( $P < 0.01$ ), flavor intensity ( $P = 0.04$ ) and mouthfeel ( $P = 0.02$ ). Results for bite were inconsistent with d 0 and 160 having similar scores with a firmer bite at 3.57 and 3.61, respectively, while d 110 had the softest bite at 3.04. Flavor intensity initially declined from d 0 to d 110 by 0.29 points, which both were considered slightly intense. However, d 110, 131 and 160 were similar in flavor intensity with a mean score of 5.17 representing intense. For mouthfeel, on days of display 0, 110 and 131 no statistical differences ( $P > 0.05$ ) were found; however, d 160 had the least mouthfeel coating with a score of 3.27 that represented traces of mouthfeel ( $P < 0.05$ ). This could be the result of the moisture percentage having the trend to decline over time. However, fat percentage was shown as having a trend to increase as d progressed. Brewer et al. (1992) found a decrease in

beefy flavor intensity of vacuum packaged beef bologna during a 10 wk refrigerated, dark shelf life study. This decrease in flavor intensity is most likely attributed to an increase in lipid oxidation, which can mask desirable flavors, and also degradation of flavor compounds, thereby perceived as reduced flavor intensity with time progression (Olsen et al., 2005).

**Table 2.4 Least squares means (Lsmeans) for sensory analysis<sup>1</sup> of smoked sausages with 0, 4 or 7 day holding time preblends displayed under refrigeration for up to 160 days under fluorescent lighting.**

Treatment	Bite	Juiciness	Flavor Intensity	Saltiness	Off Flavor	Mouthfeel Coating
Preblend						
0 d	3.44	5.25	5.22	5.35	1.34	3.57
4 d	3.51	5.29	5.25	5.39	1.42	3.67
7 d	3.18	5.48	5.17	5.38	1.27	3.74
SEM <sup>2</sup>	0.09	0.16	0.07	0.10	0.12	0.16
<i>P</i> - value	0.09	0.32	0.75	0.89	0.56	0.53
Day						
0	3.57 <sup>c</sup>	5.25	5.34 <sup>b</sup>	5.24	1.21	3.83 <sup>b</sup>
110	3.04 <sup>a</sup>	5.36	5.05 <sup>a</sup>	5.37	1.32	3.81 <sup>b</sup>
131	3.29 <sup>b</sup>	5.35	5.22 <sup>ab</sup>	5.43	1.42	3.72 <sup>b</sup>
160	3.61 <sup>c</sup>	5.40	5.23 <sup>ab</sup>	5.46	1.43	3.27 <sup>a</sup>
SEM <sup>2</sup>	0.08	0.16	0.07	0.11	0.13	0.17
<i>P</i> - value	< 0.01	0.71	0.04	0.26	0.52	0.02

<sup>a-c</sup> Least squares means in the same section of the same column without a common superscript indicate mean differences ( $P < 0.05$ ).

<sup>1</sup> Scale: 8 = extremely firm, extremely juicy, extremely intense, extremely salty, extremely intense, and extremely heavy coating, 4 = slightly soft, slightly dry, slightly unsalty, slight, and slight, and 1 = extremely soft, extremely dry, extremely bland, not salty, none, and none.

<sup>2</sup> SEM is standard error of the mean.

## Summary

Smoked summer sausages formulated with preblends held for either 0, 4 and 7 d revealed no differences between treatments on cook yield, L\*, a\*, hue angle, saturation index, a\* to b\* ratio, purge percentage, pH, salt content, proximate analysis, WBSF, lipid oxidation or sensory characteristics. Additionally, days of display (d 0, 110, 131, and 160) on smoked sausage did not

have an effect on purge percentage, pH, proximate analysis, WBSF, and sensory traits of juiciness, saltiness and off flavor.

Nevertheless, as days of display (0, 110, 131 and 160) progressed, sausage product became lighter, less red, had a lower  $a^*/b^*$  ratio and were less saturated, had a greater hue angle, a reduced salt content, greater TBARS values, was inconsistent in bite, reduced and then leveled off in flavor intensity and decreased in mouthfeel. A preblend and days of display interaction was shown for  $b^*$  external color where 7 d preblend holding time was initially (d 0) the most yellow and then on d 131, preblend held for 0 d was the most yellow. No differences in  $b^*$  values were shown for preblend treatments on d 110 and 160.

## **Conclusions**

Overall, preblend formulated smoked sausages revealed no differences in any quality or sensory characteristics measured between preblend holding time treatments during 160 days of refrigerated display. However, reduced quality was shown consequentially from days of display. Regardless of preblend age, displaying vacuum packaged cooked dinner sausage under fluorescent light for up to 160 days makes sausage lighter, less red, less yellow and increases lipid oxidation to a detectable level. Extending the refrigerated shelf life from 131 to 160 days of precooked vacuum packaged sausage would not be detrimental to product quality other than sausage may be perceived to have a slightly firmer bite and less mouthfeel coating. Therefore, preblending could be implemented without any detrimental outcome on quality or sensory attributes of skinless smoked sausage; however, as day of display increases product may become lighter, less red and slightly more oxidized.

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## Appendix A - Figures and Tables

### Figures and Tables Within Appendices

**Table A.1 Least squares means (Lsmeans) for cook yield percentage by preblends held for 0, 4 or 7 d in cooked smoked sausages.**

	Preblend Hold Time			SEM <sup>1</sup>
	0 d	4 d	7 d	
Cook Yield, % <sup>a</sup>	95.91	92.60	91.36	1.97

<sup>1</sup> SEM is standard error of the mean.

<sup>a</sup> No differences found in means within row ( $P > 0.05$ ).

**Figure A.1 Lighting intensity (lumens) at specific locations on shelves within a refrigerated fluorescent retail display case with five shelves where shelf 1 is at the top of the case and shelf 5 is at the bottom. This figure shows 120 assigned package spots within the case; of these, 72 were used for package display. The lumens at each spot where a package was displayed during 160 d of display is shown in parenthesis with the lighting intensity provided: spot (lumens).**

Shelf	Left Side		Middle Left			Middle Right			Right Side	
1, Top	1	2	3	4	5	6	7	8	9	10
		(920)	(983)	(998)	(969)		(1009)	(1000)	(982)	(945)
Back	11	12	13	14	15	16	17	18	19	20
			(1266)			(1167)	(1248)	(1277)	(1191)	
2	21	22	23	24	25	26	27	28	29	30
	(335)		(420)	(460)		(309)	(336)	(345)	(390)	(267)
Back	31	32	33	34	35	36	37	38	39	40
	(1768)	(2300)	(2100)		(1980)	(1890)	(2190)	(2150)	(2080)	
3	41	42	43	44	45	46	47	48	49	50
	(165)			(140)	(152)		(172)		(208)	(140)
Back	51	52	53	54	55	56	57	58	59	60
		(2190)	(2250)	(2000)	(1839)	(2020)	(2230)	(2160)	(1817)	
4	61	62	63	64	65	66	67	68	69	70
			(205)	(180)	(188)	(143)			(212)	
Back	71	72	73	74	75	76	77	78	79	80
	(1332)	(1490)	(1519)			(932)	(1330)		(1490)	(1339)
5, Bottom	81	82	83	84	85	86	87	88	89	90
	(178)		(276)	(348)	(269)					
Back	91	92	93	94	95	96	97	98	99	100
	(417)		(557)					(650)	(453)	
5	101	102	103	104	105	106	107	108	109	110
			(1544)	(1740)	(1554)		(1548)			
Front	111	112	113	114	115	116	117	118	119	120
		(740)	(777)				(815)	(780)		(690)

Figure A.2 Images of replication 1 smoked sausage formulated with 0, 4 or 7 d preblends during 110, 131 or 160 days of display. Days of display 0 were not photographed.



Figure A.3 Images of replication 2 smoked sausage formulated with 0, 4 or 7 d preblends during 110, 131 or 160 days of display. Days of display 0 were not photographed.



Figure A.4 Images of replication 3 smoked sausage formulated with 0, 4 or 7 d preblends during 110, 131 or 160 days of display. Days of display 0 were not photographed.



## Appendix B - SAS Code

### Case Temperature

```
ods rtf file="C:\Users\Chris\Documents\KSU Consulting\Ashley_Collins\temp_output.doc";
title 'Analysis of Average Daily Temperature (ADT) by Shelf & Spot';
proc mixed data=sumstats plots=none;
  class shelf spot date;
  model adt=shelf|spot/ddfm=satterth;
  random date;
  lsmeans shelf*spot/slice=(shelf spot) adjust=SCHEFFE pdiff cl;
run;
```

### Cook Yield %

```
data ;
input rep PB CY;
datalines;
proc mixed;
class PB rep;
model CY = PB/ddfm = KR;
random rep;
lsmeans PB/pdiff;
estimate 'overall' int 3 PB 1 1 1/divisor=3;
run;
quit;
```

### Instrumental L\* External Color

```
data ;
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;
datalines;
proc mixed;
class PB day rep;
model L = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Instrumental a\* External Color

```
data ;  
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;  
datalines;  
proc mixed;  
class PB day rep;  
model a = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## Instrumental b\* External Color

```
data ;  
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;  
datalines;  
proc mixed;  
class PB day rep;  
model b = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## a\* to b\* Color Ratio

```
data ;  
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;  
datalines;  
proc mixed;  
class PB day rep;  
model ratio = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## Saturation Index

```
data ;
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;
datalines;
proc mixed;
class PB day rep;
model sat = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Hue Angle

```
data ;
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;
datalines;
proc mixed;
class PB day rep;
model hue = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Percent Purge

```
data ;
input rep PB day purge;
datalines;
proc mixed;
class PB day rep;
model purge = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## pH

```
data ;
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;
datalines;
proc mixed;
class PB day rep;
model pH = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Salt

```
data ;
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;
datalines;
proc mixed;
class PB day rep;
model salt = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
estimate 'overall' int 3 PB 1 1 1/divisor=3;
run;
quit;
```

## Percent Moisture

```
data ;
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;
datalines;
proc mixed;
class PB day rep;
model moisture = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Percent Fat

```
data ;  
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;  
datalines;  
proc mixed;  
class PB day rep;  
model fat = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## Percent Protein

```
data ;  
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;  
datalines;  
proc mixed;  
class PB day rep;  
model protein = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## Warner-Bratzler Shear Force

```
data ;  
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;  
datalines;  
proc mixed;  
class PB day rep;  
model kg = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## TBARS

```
data ;
input rep PB day moisture fat protein salt pH kg L a b hue sat ratio mgmal;
datalines;
proc mixed;
class PB day rep;
model mgmal = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Bite

```
input rep PB day bite juice FI salt OF MF;
datalines;
proc mixed;
class PB day rep;
model bite = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Juiciness

```
data ;
input rep PB day bite juice FI salt OF MF;
datalines;
proc mixed;
class PB day rep;
model juice = PB|day/ddfm = KR;
random rep rep*PB;
lsmeans PB day/pdiff;
run;
quit;
```

## Flavor Intensity

```
data ;  
input rep PB day bite juice FI salt OF MF;  
datalines;  
proc mixed;  
class PB day rep;  
model FI = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## Saltiness

```
data ;  
input rep PB day bite juice FI salt OF MF;  
datalines;  
proc mixed;  
class PB day rep;  
model salt = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## Off Flavor

```
data ;  
input rep PB day bite juice FI salt OF MF;  
datalines;  
proc mixed;  
class PB day rep;  
model OF = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```

## Mouthfeel

```
data ;  
input rep PB day bite juice FI salt OF MF;  
datalines;  
proc mixed;  
class PB day rep;  
model MF = PB|day/ddfm = KR;  
random rep rep*PB;  
lsmeans PB day/pdiff;  
run;  
quit;
```