NUTRITIONAL, SENSORY, AND QUALITY ATTRIBUTES OF HERITAGE BRED CHICKEN AND COMMERCIAL BROILER MEAT

by

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Abstract

Animal production factors can affect nutritional composition and quality of poultry meat. Quality attributes and fatty acid composition were evaluated on breast and thigh meat with skin from free range, heritage bred chickens (>116 day of age) (HB) and commercial broilers (<50 day of age) (CM). In addition, sensory and textural attributes were evaluated on breast and thigh meat of HB, and air or water chilled CM. Moisture and fat content was similar ($P>0.05$) between chicken types without skin. Thigh meat had at least 2.41% more fat ($P<0.05$) than breast meat; however, breast meat had at least 2.33% more moisture ($P<0.05$) regardless of skin inclusion or chicken type. Heritage meat with or without skin had a greater amount ($P<0.05$) of ω3 polyunsaturated fatty acids (PUFA) than CM regardless of chilling type and HB had a lower, more desirable ω6:ω3 ratio of 12.79 when compared to air or water chilled CM at 15.20 and 14.77, respectively. Heritage breast and thigh meat with skin contained 35.60 and 35.21% PUFA which was greater than ($P<0.05$) CM breast and thigh meat with skin at 20.96 and 20.45%, respectively. Whole carcass weight of CM, breast weight, and bone-in thigh weight was 71.30%, 148.0%, and 52.2% heavier ($P<0.05$), respectively, than HB weight. However, bone-in thigh yield was 2.1% higher ($P<0.05$) in HB.

Commercial broiler breast and thigh meat was more tender ($P<0.05$) with higher myofibrillar tenderness and overall tenderness values and having less connective tissue than HB breast and thigh meat. Thigh meat from HB also had the highest ($P<0.05$) peak force values for Warner-Bratzler (3.47 kgf) and Allo-Kramer (7.22 kgf/g sample) shear tests. Thigh meat was perceived to be more juicy ($P<0.05$) and have more chicken flavor intensity ($P<0.05$) than breast meat. Heritage meat showed advantages in fatty acid profiles while CM meat showed advantages in yields and tenderness attributes.

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Dedication

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Chapter 1 - Introduction

Broiler production is an important segment of the agricultural industry, particularly due to the rapid expansion in production that started in the 1960's through the utilization of integration and increased efficiencies (USDA NASS, 2012). Broiler meat production (pounds) has been greater than beef and pork since 1996 and is projected to have the highest rate of growth recorded in billions of pounds until at least 2018 because broilers are the highest, most efficient feed convertor (USDA ERS, 2007). Throughout history, niche markets have arose to add value to products especially when market prices are low. More recently, smaller animal production farms have been searching for ways to add value to their products as margins are typically lower for independent farmers due to lower production volume and efficiencies. By raising animals in a slightly different manner and incorporating claims on retail products, value is added to products (Abrams et al., 2010). Examples of alternative production systems include organic production, free-range, or using a slow growing breed such as a standard/heritage bred chicken recognized by the American Poultry Association or the Label Rouge program approved in France (Fanatico et al., 2007a; 2007b). These specialty programs support the use of renewable resources and conservation of the environment along with adding value (Bailey and Cosby, 2005; Oberholtzer et al., 2006).

Natural/organic labels are helpful in educating consumers about how food is raised. A recent Harris poll (Meat and Poultry Staff, 2013) described consumers' feelings about organic and green food. While 80% of consumers thought about being green, only 30% were willing to spend the extra money to purchase green products. In addition, consumers believed that products with natural and organic claims can have higher prices just so companies can raise their profit margin without adding tangible value. Another belief was that organic food is more flavorful than conventional products. Since natural, organic, and free-range claims can be confusing, promoting nutritional advantages and tangible benefits could help the public know when additional value has been added to a product.

Meat is an excellent source of protein in the diet as it contains all of the essential amino acids which are the building blocks for protein along with assisting in production of enzymes and many essential processes in the body (Pellett and Young, 1990). Chicken meat has been

promoted as a lean protein source as most of the fat is stored as subcutaneous fat and within the skin membrane making it easy to remove prior to cooking (Decker and Canton, 1992; Wang et al., 2010). In developing countries, poultry meat is an important staple as chickens grow quickly and have high feed efficiencies. Poultry meat provides energy and balanced protein in regions of the world where populations typically have these deficiencies (Farrell, 2009). In addition, since chickens have monogastric digestive systems, altering the lipid composition in meat can be as simple as supplementing their diet (Decker and Canton, 1992).

It was reported in 2010 by the USDA that "seventy-two percent of men and sixty-four percent of women in the U.S. are overweight or obese with about one-third of adults being obese and eleven percent of children ages two to nineteen being obese" (Flegal et al., 2010). The Dietary Guidelines of Americans (USDA and HHS, 2010) encourages a balanced diet of primarily nutrient-dense foods which includes the consumption of at least five ounces of protein per day based on a two thousand calorie diet. Variety in the protein sources is encouraged to keep consumption saturated fat content low and increase long chain (C:20) polyunsaturated fatty acid (PUFA) content. When assessing at animal sources of lipids, beef contains the highest percentage of saturated fats followed by pork, and then chicken (Aberle et al., 2001b). Chicken meat is relatively low in cholesterol (64 mg/100 g of meat), only 30% of the lipids are saturated, and the largest percent of lipids is stearic acid which has no effect on blood cholesterol levels (Lindshield). Altering fatty acid composition of chicken through feed supplementation during production would provide for a more optimal nutrient dense protein source (Decker and Canton, 1992).

Meat flavor comes from the combination of Maillard browning reactions between proteins and carbohydrates during cooking and the oxidation and degradation of lipid compounds (d'Acampora-Zellner, 2008). Flavor is described as the combination of taste, smell, and texture sensations within the mastication process. Flavor and color are commonly used to assess food spoilage while meat texture, including tenderness, juiciness, and chewiness, is used for assessing meat quality and is an important factor in repeat purchases (Braxton, 1996; Maltin, 2003; McKee et al., 2012). In addition, texture is readily affected by size and shape of the muscles cells along with the maturity of the connective tissue within and surrounding the muscles (Fletcher, 2002; McKee et al., 2012; Wang et al., 2013). As a general rule, connective tissue matures by gaining more cross-links as it ages thus becoming less tender (Fletcher, 2002). While these effects are

minimized with the modern broiler lines by harvesting at 40 to 50 days of age, the effects can still be present with slower growing birds as they are raised to at least 83 days prior to harvesting.

The objective of these studies was to evaluate nutritional and sensory attributes of conventional, fast growing commercial broilers and heritage, slow growing, free-range chickens. In the first experiment, meat with skin from both types of chickens was evaluated for nutrient composition, instrumental color of skin and meat, and product yield. A second experiment compared sensory properties including tenderness, juiciness, and flavor of meat from both types of chickens. The purpose of these two studies was to characterize conventional and heritage chicken products currently available to consumers.

Chapter 2 - Review of Literature

Poultry Meat Industry

History and Economic Influences

Broilers are defined as chickens that are typically 7 weeks of age but must be under 13 weeks of age at harvest (Cochran, 2011; UDSA FSIS, 2012). Broiler production is an important segment of the agricultural industry, particularly due to the rapid expansion in production that started in the 1960's. Current annual broiler production is almost five times the volume produced in 1970 (USDA NASS, 2012); however, the growth in production has begun to slow since the mid-1990's. The growth since the 1970's was due to the unique use of integration which is still practiced by the broiler industry. Integration is when broiler production is under contract from the broiler processor who typically supplies the birds, feed, veterinary care, and labor for transportation of the birds, whereas, the farmers supply the facilities and labor to grow the chickens (MacDonald, 2008). In 2006, most growers participated in the contract system, and only 1.4% of growers were independent according a survey completed by the Agricultural Resource Management Survey (ARMS) in 2007. In addition, only 1.4% of broilers processed in the U.S. are certified organic and 0.7% of production farms are free-range (MacDonald, 2008). The U.S. poultry industry produces over 43 billion pounds annually. Of this, $4/5^{th}$ of poultry production is the result of broiler production which generated $45 billion in 2010. The U.S. is the largest producer in the world and second largest broiler exporter (USDA ERS, 2009, 2012).

When compared with other livestock species, broiler meat production has been greater than beef and pork since 1996. Broilers are projected to have the highest rate of growth recorded in billions of pounds until at least 2018 because of the high feed conversion rates. In addition, per capita consumption of poultry shows increases as well. Beef production is projected to remain stagnant and increase only after recovery from the current drought and high grain prices, while pork is projected to increase in production but at a slower rate than the broiler industry (USDA ERS, 2007). Besides increase in productivity, increase in chicken size, and use of integration in the industry, increase in poultry production and demand for broiler meat is based on new product innovation both in domestic consumption and exports (MacDonald, 2008).

Natural/ Niche Markets

Throughout history, niche markets have arose to add value to products especially when market prices are low. More recently, smaller farms have been searching for ways to add value to their products as margins are typically lower for independent farmers due to lower production volume and efficiencies. By raising animals in a slightly different manner and incorporating claims on retail products, value is added to products which help the independent farmer cover the additional production cost and improve profit margins (Abrams et al., 2010). To a consumer, labeling claims placed on food products such as organic, free-range, or natural can be confusing and unclear. With each passing generation, consumers become more removed from the farm and potentially need additional education on animal husbandry to understand the different types of production practices.

The United Stated Department of Agriculture (USDA) defines free-range as poultry having access to an outside environment, while "natural" on a label refers to processing of the meat after harvest. The definition of natural is "Product containing no artificial ingredient or added color and is only minimally processed. Minimal processing means that the product was processed in a manner that does not fundamentally alter the product" (USDA FSIS, 2011). Product labels are also required to provide a better description of why products have a natural claim such as "minimally processed" or "no artificial ingredients." Finally, organic poultry can bear the USDA organic label after being verified through a government approved certifying agency that the animals were raised on feed grown with no synthetic fertilizers, pesticides, bioengineering, or irradiation, that the feed was organic, no antibiotics were used, and poultry had access to the outdoors (USDA ERS, 2012). This is in place to help support the use of renewable resources and conservation of the environment (Bailey and Cosby, 2005; Oberholtzer et al., 2006).

The organic program was started by USDA in 2002, and organic and niche markets have seen 20% per year increases since that time with organic food now making up 3% of total food sales. Vegetables and fruits have seen the largest growth in the organic market, but meat and poultry sales have also been increasing (Oberholtzer et al., 2006; USDA ERS, 2012). In 2011, organic broiler sales were reported at $115 million dollars (USDA NASS, 2012). In addition, USDA Agricultural Marketing Services (2009) introduced a voluntary program allowing

producers to claim "naturally raised" on products coming from animals that are raised entirely without the use of growth promotants and antibiotics and have never been fed animal products.

These natural/organic labels are helpful in allowing consumers to know more about how food is raised, but can create negative connotations associated with conventional production systems because consumers may believe that one system is "better" than the other system. While the U.S. government believes these claims were not intended to differentiate food safety, the labeling system may be interpreted in such a manner by consumers because they typically rely on federal regulations to differentiate safe and unsafe food (Klonsky, 1998). A study by Abrams et al. (2010) was conducted to evaluate consumers' perceptions about products labeled as organic or all-natural. Several round table discussions with consumers discussed how these labels affected their perception of pork. Some of the common themes viewed with all-natural claims were: doubt in the claims themselves; an idea that all-natural means "no" such as no antibiotics or growth promotants; and the idea of better welfare. Organic claims were more associated with produce and consumers felt it described a healthier and more expensive product.

A recent Harris poll (Meat and Poultry Staff, 2013) described consumers' feelings about organic and green food. While 80% of consumers thought about being green, only 30% were willing to spend the extra money to purchase green products. In addition, consumers believed that products with natural and organic claims have higher prices just so companies can get more money, even though the higher prices really aren't justified. Another belief was that organic food is more flavorful than conventional products. Since there can be confusion about natural, organic, and free-range claims, additional claims promoting nutritional advantages would help the public differentiate between conventional and smaller farm produced products.

Nutrients

Protein, fats, and carbohydrates are three macronutrients that are required by the body, but must be consumed in moderation and in balance to provide for a healthy lifestyle. Meat is an excellent source of protein in the diet as it contains all of the essential amino acids which are the building blocks for protein in the body along with assisting in production of enzymes (Pellett and Young, 1990). Meat is also inherently low in carbohydrates and can be low in fat depending on the type of meat being consumed. Chicken meat has been promoted as a lean protein source as most of the fat is stored as subcutaneous fat and within the skin membrane making it easy to

remove prior to cooking (Decker and Canton, 1992). In developing countries, poultry meat is an important staple as chickens grow quickly and have great feed efficiency. Poultry meat provides energy and balanced protein in regions where populations typically lack both (Farrell, 2009). Since chickens have monogastric digestive systems, altering the lipid composition of chicken meat can be as simple as supplementing their diet (Decker and Canton, 1992). The typical make-up of chicken breast meat with skin is 69.5% water, 20.9% protein, and 9.25% lipids with 28.7% of the lipids being saturated, 41.3% monounsaturated (MUFA), and 21.2% polyunsaturated (PUFA). There are approximately 64 g of cholesterol/100 g breast meat and skin along with a good source of micronutrients such as calcium, iron, magnesium, potassium, and zinc (USDA ARS, 2012). When skin is removed from breast meat, protein remains similar at 21.0%, moisture content increases to 75.8%, and lipid content decreases by 71% to a lipid content of 2.6% with saturated, MUFA, and PUFA content each decreasing by about 6%. The composition of dark meat (thigh meat with skin) averages 16.2% protein, 66.6% moisture, and 16.6% lipids. The content of saturated, MUFA, and PUFA long chain fatty acids are similar to white meat with skin (USDA ARS, 2012).

Human Dietary Health Concerns

It was reported in 2010 by USDA that "seventy-two percent of men and sixty-four percent of women in the U.S. are overweight or obese with about one-third of adults being obese and eleven percent of children ages two to nineteen being obese" (Flegal et al., 2010; Ogden et al., 2010). With weight issues and poor nutrient balance are associated risks of diseases such as cardiovascular disease, diabetes, coronary heart disease, and cancer. The Dietary Guidelines of Americans (USDA and HHS, 2010) encourages a balanced diet of primarily nutrient-dense foods which would provide all of the essential nutrients without the use of supplements. Included in the dietary guidelines is the guideline to consume five ounces of protein based on a two thousand calorie diet. Variety in protein sources is encouraged to keep saturated fat content low and increase long chain (C:20) PUFA content. Since meat is an animal product it contains a higher percentage of saturated fats than other plant fat sources. Saturated fats have been found to increase low density lipoprotein which moves cholesterol and fatty acids from the liver into the blood stream, increasing the risk of cardiovascular disease by promoting the formation of artery-clogging fatty deposits (Lindshield). Meat also contains cholesterol which is essential to

processes in the body, but synthesized by the body so only low quantities are needed. It is recommended by the dietary guidelines (USDA and HHS, 2010) to consume less than 300 mg of cholesterol per day and saturated fats should provide less than ten percent of daily calories. When looking at animal sources of lipids, beef contains the highest percentage of saturated fats followed by pork, and then chicken (Aberle et al., 2001b). Chicken meat is relatively low in cholesterol (64 mg/100 g of meat), only 30% of the lipids are saturated, and the largest percent of lipids is stearic acid which has no effect on blood cholesterol levels (Lindshield).

Long chain PUFA (greater than 20 carbon chain) are encouraged as they have anti-inflammatory properties and are most commonly divided into two groups depending on the location of the first double bond from the methylated end (Omega, ω) (Decker and Canton, 1992; Aberle et al., 2001b; Kris-Etherton et al., 2003; Simopoulos, 2008; Harris et al., 2009). Omega-3 fatty acids (ω3) create a stronger inflammatory response than omega-6 fatty acids (ω6), thus increased consumption of ω3 fatty acids has been promoted since the 1990's. The most frequent dietary guideline of consumption of fatty acids is a ω6:ω3 ratio. Early nomads consumed a ω6:ω3 of approximately 1:1 whereas current western diets are close to 15-20:1 (Simopoulos, 2008). Most nutritional organizations recommend increasing consumption of foods with a ω6:ω3 of 4:1; however, the American Heart Association emphasize the continued consumption ω6 PUFA's as they also have minimal inflammatory response (Kris-Etherton et al., 2003; Harris et al., 2009).

Seafood has a high long chain PUFA content; however, due to sensory preferences, an alternative source of essential and beneficial long chain fatty acids needs to be found (Hargis and Van Elswyk, 1993). In an effort to find another viable source of ω3 fatty acids which are beneficial long chain fatty acids, several studies have evaluated strategies to increase ω3 fatty acids in chicken meat (Hargis and Van Elswyk, 1993; Nielsen, 2003; Azcona et al., 2008). Enhancement of chicken meat was successful when chickens were supplemented with fish oils or meals during production which significantly increased 20-carbon ω3 fatty acids (eicosapentaenoic acid (EPA), decosahexanoic acid (DHA)), but not without the development of off-flavors (Hargis and Van Elswyk, 1993). This same study found that plant sources could also be used to increase ω3 fatty acid content, but linoleic acid increased the most which isn't as beneficial as the 20-carbon ω3 fatty acids in inflammatory response. There was very limited off-flavor in the end product. Another study (Azcona et al., 2008) used a variety of plant sources that

were successful in increasing ω3 fatty acids in chicken meat, including 20-carbon fatty acids, thus improving ω6:ω3 ratios and decreasing saturated fatty acid content. However, when flaxseed was used, negative effects were seen on feed conversion ability.

Factors Influencing Chicken Meat Quality

Meat quality encompasses many different attributes which are important as they can affect many sensory attributes. The first and arguably most important meat quality factor is appearance because consumers use appearance as the basis for retail purchases. When evaluating appearance, several factors are involved including color, firmness/texture, and water holding capacity. All of these factors can be affected by intrinsic characteristics of meat including meat pH, structure, fiber type, and chemical composition (Aberle et al., 2001a). These intrinsic properties also affect yield, aroma, and palatability. If any of these attributes are below the expected experience of the consumer, repeat purchases may not be made for a chicken meat product, and possibly an entire brand.

Color

The majority of consumers agree that color is important when making purchase decisions for meat products (Lynch et al.,1986). When understanding poultry product color, it is important to consider skin color for products sold as whole chickens and meat color for products sold as skinless pieces. The color of chicken skin ranges from an opaque white to yellow color with consumers from different regions of the world having variable preferences on skin color. Skin color is primarily dependant on the grains harvested in regions and in turn fed to chickens (Fletcher, 2002; Sirr et al., 2010). When corn is a primary grain source, skin color tends to be more yellow due to pigments inherent in the corn. Skin color of retail products not only depends on the diet being fed during production, but also genetics because some chicken breeds, especially those of European decent, lack the ability to deposit carotenoid pigments in the skin creating a white skinned chicken (Fletcher, 2002).

Environment during growth can impact skin color. Chickens with access to pasture have a tendency to have more yellow skin color due to the pigments, commonly xanthophylls and chlorophyll, found in edible vegetation (Perez-Alvarez and Fernandez-Lopez, 2012). Finally, processing during harvest can affect the saturation of skin color in chickens as they are typically scalded to aid the plucking process. Too high of water temperature will fade the skin color so it

is recommended to soft scald (<48°C) (reduced water temperature) to keep a more pronounced, fresh color in the skin (Fletcher, 2002; Sirri et al., 2010).

The color of meat develops from several inherent factors such as muscle type, structure, and myoglobin content. In comparison to red meat products, poultry meat is highly variable in colorimeter values, especially L* and a* values, and has the lightest meat color (*pectoralis major*) with the exception of fish meat. Lighter colors values (higher L*) and lower red hues (lower a*) have been associated with a decrease in myoglobin. The light color associated with breast meat from young broilers is due to a lack of myoglobin (0.01 mg myoglobin/g meat) compared with 0.30 mg myoglobin/g meat in young pork and 4.60 mg/g in young beef (Fletcher, 2002). The chemical state of myoglobin (metmyoglobin, oxymyoglobin, or deoxymyoglobin) also effects the observed color in meat, but has limited effect in chicken breast meat due to the lack of myoglobin (Aberle et al., 2001a). Extrinsic properties that can affect poultry meat color include stress on the bird prior to harvest, type of stunning, scalding time and temperature, along with rate and method of chilling (Fletcher, 2002). During the biochemical reaction of turning muscle to meat, rate and extent of pH decline has a negative correlation with lightness of meat color (Aberle et al., 2001a; Fletcher, 2002).

Meat color can be measured objectively through the use of chemical pigment extraction, physical methods measuring reflectance and absorbance values with the use of a colorimeter or spectrophotometer, or subjectively through the use of a human visual panel. Colorimetry is a non-invasive, relatively quick method that can be run on multiple samples. Spectrophotometry is another method that measures values of reflectance at each individual wavelength (AMSA, 2012). Objective measurements are reproducible and precise on the condition that all variables are recorded and replicated. When using a colorimeter, illuminates A, C, D_{65}, and F, can be changed to best fit the objective of the study (AMSA, 2012). The most frequently used illuminate in fresh meat is "A" as it is the most sensitive to changes in red wavelengths. The degree of the observer (2° and 10°) and aperture size can be altered and should be recorded as they affect the recorded color values.

Objective measurement results are displayed using one of several different systems: Hunter L, a, b; Munsell (hue, lightness, and chroma), Commission Internationale de I'Eclairage (CIE) or Minolta values (AMSA, 2012). Colorimeters measure only in trismulus values of CIE which can be recorded on an XYZ or CIE LAB scale, including L* measuring from 0 (black) –

100 (white), a* (green, -a*; red, +a*), and b*, reported in a similar manner to a* except from blue (-) to yellow (+). These measurements are based off of how the human eye perceives color through the use of rod and cone receptors (McKee et al., 2012). Color measurements assist in a better understanding of the intrinsic properties of meat and predicting poultry quality, such as pale, soft, and exudative (PSE), without destroying the sample.

pH

An intrinsic property of meat that affects most other meat quality attributes is pH, the measure of hydrogen ions. When animals are still alive, blood and muscle have a pH near neutral (pH of 7), but during the formation of rigor mortis, glycolysis occurs in the muscle which lowers pH from the production of lactic acid. This pH decline is one of the most significant postmortem changes ultimately affecting all other quality attributes (Aberle et al., 2001a; Maltin, 2003). If there is a lack of lactic acid production, a higher pH of meat will result, and the meat is recognized as having a darker color, firmer texture, and drier appearance due to its capacity to hold more water. When considering chicken breast meat, a darker color is typically perceived as not common and customers might avoid this product. Another phenomenon occurring during processing is PSE characteristics where body temperature is too high, inducing a more rapid pH decline, thus lowering the functional properties of the meat (Aberle et al., 2001a; Maltin, 2003). Lower pH values are also associated with lighter colors (Fletcher, 1999, 2002) and create an acidic environment which can deactivate the enzymes responsible for postmortem tenderization lending to tougher product (Maltin, 2003). By monitoring meat pH, variation within the samples may be explained, especially if low quality is present.

Yield

In the current integrated poultry industry, increased breast size is the main focus of genetic selection as it provides a lean meat source with minimal connective tissue which is ideal for further processed products. Highly efficient commercial chicken lines present better feed efficiency, shortening the time from hatchery to harvest (Schmidt et al., 2009). In order to appeal to commercial markets, efficiency of chicken production is an important characteristic to monitor. Yields can display this information by presenting a ratio between poultry part and the whole carcass weight. When comparing fast (FG) and slow (SG) growing genotypes, Fanatico et al. (2008) found that FG chickens had increased ($P<0.05$) body weight and breast yield even

though they were grown for four weeks fewer than SG chickens. When given outdoor access, feed intake of FG chickens increased leading to decreased feed efficiency as there was no difference ($P>0.05$) in end breast weight. In addition, SG chickens showed a greater increase in leg yields when outdoor access was allowed.

Cook loss is another beneficial measurement as it relates back to the water holding capacity of the muscle. Water is held within the muscle as free, immobilized, or bound water. Free water is readily available and can easily be lost through handling and processing including evaporation during heating (Aberle et al., 2001a). Bound water makes up about 5% of meat and is readily bound with the muscle cells so that it is not being removed with even the most extreme cooking. Immobilized water is held stronger than free water but can be removed with some effort so that after proper cooking some immobilized water will still be in the muscle. Juiciness is an important sensory characteristic which has been found to positively correlate with tenderness, thus it is important for a piece of meat to have a greater amount of bound and immobilized water to increase sensory properties even after cooking (McKee et al., 2012). Cook loss, calculated by dividing the difference between raw and cooked weight by raw weight multiplied times 100, describes the structure and water holding capacity of the meat by determining the amount of water and water soluble proteins lost during cooking.

Water holding capacity is readily affected by the structure of a muscle fiber. A muscle fiber can hold more water when it has a more open structure. The isoelectric point of a muscle cell is at a pH value 5.1 (Aberle et al., 2001a) and is when the positive and negative charges in a cell are equal, allowing the muscle structure to collapse on itself. The typical muscle structure will have repulsive charges as the pH moves away from the isoelectric point in either direction which will keep the fibers open to hold more water. Low pH, associated with PSE qualities, is close to the isoelectric point, and limits the water holding capacity of a muscle fiber. The type of muscle fibers in a muscle has been related to the potential quality of meat (Maltin, 2003). A muscle with a greater amount of fast twitch fibers has a greater glycolytic potential as it completes anaerobic metabolism, creating more lactic acid, and thus lowers muscle pH. A lower pH affects water holding capacity, instrumental color, sensory properties, and instrumental texture.

Sensory Attributes of Chicken Meat

When evaluating food, consumers use all five senses: sight, smell, touch, taste, and hearing, to perceive the quality or lack thereof within a food product. As discussed earlier, color or visual appearance is typically used first by consumers when purchasing meat products from the store. Once a product is in the kitchen, the rest of the senses become very important for evaluating raw product safety, aromas while cooking, and the taste, texture, and aroma while eating the meat product. As reported by Maltin et al. (2003), the most common source of customer complaints and failure to repeat purchase a meat product is due to eating qualities.

Meat flavor comes from the combination of Maillard browning reactions between proteins and carbohydrates while cooking along with the oxidation and degradation of lipid compounds (d'Acampora-Zellner, 2008). Flavor is described as a combination of sensations from taste, smell, and toughness within the mastication process. Meat flavor as determined through gas chromatography mass spectrometry (GC-MS) and sensory panels (d'Acampora-Zellner, 2008; McKee et al., 2012), consists of both sulfur containing and lipid oxidation factors with sulfur compounds giving the meaty flavor through Maillard reactions in cooked meat (Miller, 1994) and lipid degradation providing the species flavor from the changes in fatty acid content. Chicken flavor has a unique species flavor as it contains a greater amount of unsaturated fatty acids than red meat species resulting in a greater amount of lipid oxidation (McKee et al., 2012) which produces more volatiles for flavor. Whereas, flavor from within the species depends on diet, production environments, and breed. Most importantly, the amino acids, carbohydrates, and lipids must be in combination for complete poultry meat flavor.

Meat texture, including tenderness, juiciness, and chewiness, is used for the assessment of meat quality and argued to be the most important factor in repeat purchases (Braxton, 1996; Maltin, 2003; McKee et al., 2012). Tenderness can be measured instrumentally through the use of shear tests measuring peak force or energy used while shearing a sample. Perceived meat texture is made up of more than just peak force, but also juiciness and chewiness which is best evaluated by the use of subjective measurements such as a sensory panel, because all of these perceptions in the brain are too complicated for instrumental analysis. Instrumental measurements and sensory analysis of the same products work well together to verify overall meat texture.

Subjective Measurements

As defined by Stone and Sidel (2004), sensory evaluation is "a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing". While it is a scientific measurement, sensory measurements are subjective because panelist perception depends on their senses which can be affected by panelist wellness, experiences, and daily diet. Sensory panelists are variable over time and among themselves, along with being prone to bias so it is important to correctly design a study with enough panelists, repetitions, and procedures to limit variability and bias effects (Meilgaard et al., 2007). There are three main types of sensory tests: discrimination, description, and affective (Lawless and Heymann, 2010). It is important to start by determining the goal of the sensory test which will determine the type of test needed. Affective testing is conducted using an untrained panel in which the panelists describe how much they like the product and is commonly used in industry prior to launching a new product. Whereas, discrimination and descriptive testing are analytical measurements judged by a trained panel to either differentiate traits or determine specific sensory attributes. While conducting analytical sensory tests, as much bias as possible must be removed. When working with a meat panel, it is key to have the same size of sample, colored lights to mask the doneness or species, use a room free of extraneous noises or smells, and the panelists should receive an individual booth to not be influenced by the group (Meilgaard et al., 2007; Lawless and Heymann, 2010). In addition, panelists for analytical measurements should undergo training to become familiar with the product and to the reference scales being used in the test. By aligning panelists all on one scale, variation between the panelists should be limited.

Objective Measurements

Sensory panels are very helpful but can be time consuming, expensive, and have large variation, thus instrumental measurements are commonly paired with or used in the place of sensory panels. Instrumental measurements continually measure the force applied to shear or deform a sample. Many factors can affect tenderness or shear force values so to remove bias, every treatment is normally treated the same. It is more common to shear cooked samples but unrealistic to test hot samples as they will be softer with an increased temperature. Cores are normally brought to room temperature (20°C) prior to shearing.

The most common method for shearing meat is Warner-Bratzler shear force (WB), developed by Warner (1928) and tested by Bratzler (1932). Warner-Bratzler shear force uses an upside down "V" blade to shear through a meat core. In addition, the poultry industry uses Allo-Kramer shear force for tenderness measurement which is a series of multiple blunt blades used to shear across the muscle fibers of samples with similar dimensions (typically 40 mm X 20 mm). Recording the weight of each sample allows the peak force to be reported as kilograms of peak force/gram of sample. Kramer (1951) developed the method which was originally manufactured by the Lee Corporation (Washington, DC), thus calling it Lee-Kramer shear force. Later, the rights were acquired by Allo Precision Metals Engineering (Rockville, Maryland) changing the name to the now known, Allo-Kramer shear force (Bourne, 2002; Miller and Alvarado, 2013). In a study by Lyon and Lyon (1991), WB values were correlated to sensory tenderness values to create a relationship between peak force values and perceived tenderness through sensory evaluation (Table 2-1).

Table 2-1. Correlation determined between Warner-Bratzler and single blade Allo-Kramer shear force and sensory tenderness categories, adapted from Lyon and Lyon (1998).

Sensory Tenderness, Shear Apparatus[1]	Objective Value Corresponding to Sensory Category
Very Tender	
SB-AK	<8.11
I-WB	<3.62
Moderately to slightly tender	
SB-AK	8.11 to 14.82
I-WB	3.62 to 6.61
Slightly tender to slightly tough	
SB-AK	14.83 to 21.53
I-WB	6.62 to 12.60
Slightly to moderately tough	
SB-AK	21.54 to 28.24
I-WB	9.61 to 12.60
Very tough	
SB-AK	>28.25
I-WB	>12.60

[1]SB-AK = single blade Allo-Kramer apparatus; I-WB = Instron Warner-Bratzler apparatus.

Previous Natural versus Commercial Studies

While studies have been completed looking at organic production system and its' effect on chicken meat quality, limited studies have compared slow growing breed types to conventional broiler lines. Fanatico et al. (2005, 2007a, b, 2008) completed several studies to observe the impact of genotype, type of production (whether conventional or free range), and diet (conventional or low-nutrient) on meat quality, sensory attributes, growth performance, and carcass yields. Berri et al. (2001) investigated the effect of an experimental broiler line, a commercial broiler line, and an unselected broiler line on meat quality characteristics such as pH, color, and meat composition. Smith et al. (2012) completed a study looking at meat quality attributes from conventionally raised broilers and Label Rouge-type broilers. Another study was completed comparing organic, free-range, and conventional broilers as available in retail markets for meat quality attributes such as yields, pH color, composition, tenderness, and sensory panels (Husak et al., 2008).

Fanatico et al. (2007a) found that type of diet had little impact on meat quality attributes while genotype and production system differences were seen. Birds raised with access to pasture had a greater amount of protein while slow growing birds (regardless of environment during growth) had a greater amount of protein in the breast meat than fast growing broilers. In addition, Husak et al. (2008) reported increased protein content in raw breast and thigh meat from alterative production systems compared to conventional retail markets whereas Smith et al. (2012) reported no nutritional differences between conventional and the French alternative production system (Label Rouge) which restricts early harvesting and must be free-range but does not guarantee use of a slow growing genotype.

Overall bird and breast weights were always greater along with increased yields in the conventional genotype since this is what they had been bred for; however, the slower growing genotype leg portion was always a larger portion of the overall carcass yield (Berri et al., 2001; Fanatico et al., 2005; Husak et al., 2008; Schmidt et al., 2009; Sirri et al., 2010; Smith et al., 2012). It was reported by Fanatico et al. (2007a) that no differences were seen within a descriptive sensory panel for basic tastes between different genotypes but differences were observed in meat from poultry with outdoor access producing more cohesive breast meat and slow growing meat tasting less salty then meat from fast growing genotypes. Consumer panels picked up no differences between genotypes and production systems. This is consistent with

findings by Smith et al. (2012) where no differences were seen between conventional and Label Rouge production systems within a sensory panel. Whereas the only sensory differences reported by Husak et al. (2008) was that conventional thigh meat was more tender and less chewy than alterative production system thigh meat.

Chapter 3 - Preliminary Nutritional Comparison between Heritage Chicken and Commercial Broiler Meat and Skin

Introduction

Fanatico et al. (2007b) found that meat from a slower growing breed of chicken has more protein and less fat compared with faster growing birds and one of their trial groups was to determine whole bird measurements. The object of this preliminary trial was to compare the fat, moisture, protein, and fatty acid composition including omega 3 and omega 6 fatty acids for meat with skin (combination of light and dark) from heritage bred and commercial broilers while evaluating the chilling methods.

Materials and Methods:

Experimental Design

For this preliminary trial, three types of chickens were evaluated. The three types of chicken were: 1) heritage bred, jersey giant fresh chicken (Good Shepherd Poultry Ranch, Lindsborg, KS - Free range, greater than 16 weeks of age, all natural-minimally processed, air chilled, and no water added) (HB); 2) air chilled commercial broiler (Young Whole Chicken; Smart Chicken, Tecumseh Poultry LLC, Waverly, NE.) (CMAC); and 3) water chilled commercial broiler, (Fresh Young Chicken with neck and giblets; Hy-Vee, Inc., West Des Moines, IA, 100% Natural with less than 7% water retained) (CMWC). The HB were air chilled, whereas commercial broilers are commonly water chilled thus potentially increasing the moisture content in the meat as they are allowed to retain up to seven percent of chill brine. Only one chicken was processed for each chicken type in an attempt to collect preliminary data so no statistical analyses were run on preliminary results.

Fabrication

All birds were purchased from local retailers on the same day and placed in a darkened cooler (approximately 3°C) until processing the following day. For fabrication, all meat and skin were manually deboned from the carcass, excluding the giblets (if included) and necks. Yields were recorded by measuring weights of the whole carcass divided by the weight of recovered

meat and skin. The meat and skin was slightly frozen at -20.0°C and then chopped in a 14-cup food processor (Model DFP-14BCN, Cuisinart, East Windsor, NJ) to make a paste. From this paste, three representative samples (150 g for each sample) from each treatment were collected and frozen in a pre-labeled whirlpak bag (14 X 23cm, Fisherbrand, Waltham, MA) at -80°C for not longer than 7 days until proximate measurements were taken.

Nutritional Measurements

Just prior to analytical measurements, samples were pulverized by freezing in liquid nitrogen and then blending in a table top blender (model 33bl79; Waring Products, New Hartford, CT). Moisture and crude fat content were measured using the SMART system 5 (CEM Corp., Matthews, NC) procedure (AOAC Official Method PVM-1:2003 MEAT). Crude protein was measured using the LECO FP-2000 Protein/Nitrogen Analyzer (AOAC 990.03) by Midwest Laboratories, INC. (Omaha, NE). Total fatty acid composition was determined through extraction using the procedure from Sukhija and Palmquist (1988) from the pulverized samples.

Results

Yields

Both commercial samples had greater meat and skin yields than HB which would be expected because they are raised to produce a high amount of meat deposition in a short period of time (Table 3-1). The CMWC chicken had a 2.33% higher meat and skin yield than CMAC chicken most likely due to being able to retain up to seven percent water through immersion chilling. While all packages had purge when opened, none of the remaining purge was included in any of the weight measurements as it would not typically be used by the consumer. The HB bred chickens had the smaller yields at only 55.79% which can be expected as they grow have not had the genetic selection for fast growth rates and have slower and lower growth curves.

Table 3-1. Yield and weight means for commercial air chilled, commercial water chilled, and heritage bred chicken meat with skin.

	CMAC[1]	CMWC[1]	HB[1]
Bird Weight[2] (g)	1965.82	1693.42	1443.72
Meat Weight[2] (g)	1382.43	1230.34	805.40
Meat Yield[2] (%)	70.32	72.65	55.79

[1]CMAC = Commercial air chilled broiler, CMWC = Commercial water chilled broiler, HB = Heritage bred chicken.
[2]n=1.

Macro-component Analysis

Protein content was greatest for HB samples having 20.57% of the meat and skin combination being protein (Table 3-2). Commercial water-chilled samples closely followed at 20.37% while CMAC samples were almost 1% lower than the standard bred bird at 19.63% protein. These preliminary results are consistent with results presented by Fanatico et al. (2007a). The HB sample had the highest moisture content (70.22%) which could lead to a perceived juicier product compared to CMWC at 68.27% and CMAC at 67.11% moisture. However, the HB fat level is low enough that it is able to balance out the difference of the higher contents of protein and moisture. Overall, fat content was lowest in the HB (6.86%) followed by CMWC (10.61%), and CMAC meat and skin having the highest fat content at 11.91%. It is typical that CMAC samples are higher in fat content as the CMWC would have added water which would dilute out its' fat portion of the overall sample composition.

Fatty Acid Analysis

Through extraction and GC-MS analysis, the HB sample had the highest quantity of omega 3 (ω3) fatty acids at 2.58% of extractable fatty acids (Table 3-2). Commercial water chilled samples closely followed at 2.09%, and CMAC samples had only 1.53 % ω3 polyunsaturated fatty acids (PUFA) as a percentage of extractable fatty acids. When looking into the less healthy omega fatty acids, the HB had the most omega 6 fatty acids (ω6) (Table 3-2) with 30.75% ω6 followed by the CMAC at 26.99% and CMWC chicken containing the lowest amount of ω6 fatty acids at 26.07%. When these numbers are translated into the ω6:ω3 ratio (Table 3-2), the HB birds have the most preferred ratio at 11.77, followed by CMWC at 12.38,

and 17.65 for the CMAC samples. The HB and CMWC ratio is close to the current levels of both ω6 and ω3 fatty acids in industry chicken meat and consistent with results from Husak et al. (2008). However, all samples are above the more optimal ratio of 4:1 for ω6 and ω3 which leads to a more balanced diet (Harris et al., 2009; Simopoulos, 2008).

Heritage bred chicken meat with skin showed the best nutritional profile having the highest protein and moisture content, least amount of total fat, and the more optimal omega fatty acid ratio. All of these measurements were closely followed by the water-chilled commercial sample. The air-chilled commercial sample had the least desirable nutritional profile with the least amount of protein and water, the highest fat content, and much greater omega fatty acid ratio. However, no replications were completed in this preliminary trial thus no variation or differences could be calculated for a true comparison between the treatment types.

Table 3-2. Nutritional composition means for commercial air chilled, commercial water chilled, and heritage bred chicken meat with skin.

	CMAC	CMWC	HB
Proximate Analysis[2]			
Protein	19.63	20.37	20.57
Moisture	67.11	68.27	70.22
Fat	11.91	10.61	6.86
Fatty Acid Analysis[3,]			
Total ω3 PUFA[4]	1.53	2.09	2.58
Total ω6 PUFA[4]	26.99	26.07	30.75
ω6:ω3[4]	17.65	12.50	11.94
Total MUFA[4]	40.10	41.41	36.85
Total PUFA[4]	28.52	28.16	33.32
Total SFA[4]	30.78	29.89	29.11

[1]CMAC = Commercial air chilled broiler, CMWC = Commercial water chilled broiler, HB = Heritage bred chicken.

[2] Reported as a percent of overall sample; n=1.

[3] Reported as percent of extractable fatty acid content.

[4] SFA=saturated fatty acids, MUFA= monounsaturated fatty acid, PUFA=polyunsaturated fatty acid, ω6 = omega 6 PUFA, ω3=omega 3 PUFA.

Chapter 4 - Nutritional Composition and Color Comparison of Heritage Bred Chickens and Commercial Broiler Meat with Skin Included

Introduction

Within the last century, growth of production animals has become more efficient through diet, genetics, and management. Commercial broiler reach harvest size in 6-7 weeks compared with the approximately 16 weeks it took chickens to reach harvest weight in the early 1900's (Schmidt et al., 2009). Increased production efficiency was needed to improve profitability and provide a highly bio-available protein source to an increasing world population. The U.S. Department of Health and Human Services encourages consumers to monitor food intake due to increased obesity rates (USDA and HHS, 2010). One recommendation when choosing a protein source is to seek low fat sources high in omega 3 (ω3) fatty acids which have been shown to increase high density lipoprotein (HDL), lower triglycerides, and help immunity and brain function. Chicken meat is commonly believed to be a good protein source because skinless white meat is very low in fat (USDA ARS, 2012). Wang et al. (2009) compared the composition of poultry raised under current production systems versus the recorded composition of birds from the late 1800's. Results from Wang et al. (2009) suggest that the fat:protein energy ratio collected from an 1870 chicken trial was much lower at 0.4 than compared to current trials at 3.2. This suggests that the emphasis on production efficiency has resulted in chicken becoming fatter and less desirable compositionally.

A study by Fanatico et al. (2007a) found that meat from a slower growing breed of chicken had more protein and less fat compared with faster growing birds. Environmental conditions were changed in this study and slower growing birds had an increase in protein and α-tocopherol when permitted access to an outdoor, pasture environment. On the other hand, there was little improvement in composition of faster growing birds raised with outdoor access. Fatty acid composition was not evaluated nor was breed type specified, limiting the ability to make comparisons between breeds. The objective of this study was to investigate nutritional and meat

quality characteristics of a slow growing, heritage breed, and a conventional, fast growing breed of chicken that are readily available to consumers in retail markets.

Materials and Methods

Experimental Design

Twenty chickens each for heritage bred chicken (HB) and commercially bred broilers (CM) were purchased from retailers. Breast (*pectoralis major* and *minor*) and thigh (*quadriceps femoris*) meat with appropriate amounts of skin were evaluated for skin and meat color, pH, proximate analysis (moisture, fat, and protein), and fatty acid composition. Each bird was a replication (n=20) for an individual type of chicken. The design was a modified split-plot design comparing breast versus thigh meat within each type of chicken. Samples were processed in random order within a type of chicken with HB processed one week before CM.

Raw Materials

Twenty commercial broilers (Fresh Young Chicken with neck and giblets, HyVee, Inc., West Des Moines, IA, 100% Natural with less than 7% water retained), were purchased from a local retail store in groups of ten on two consecutive days. All carcasses were transported to Kansas State University and directly placed into a walk-in cooler kept at 2 to 4°C until fabrication and analysis on the same day of being purchased from the store. Twenty Heritage chickens (Barred Rock Standard Chicken, Good Shepherd Poultry Ranch, Lindsborg, KS, Free Range, All Natural, Air Chilled, and No Water Added) were delivered to Kansas State University immediately after harvesting, processing and chilling at a United States Department of Agriculture (USDA) inspected facility. Upon delivery, chickens were directly placed in a walk-in cooler kept at 2 to 4°C until fabrication. These chickens were processed over a span of three days, fabricating five on the first day, nine on the second day, and the remaining six chickens on the last morning. Some of the chickens were partially frozen because the USDA Food Safety and Inspection Service (FSIS) fresh poultry labeling rule permits poultry carcasses to be kept as cool as -3°C (26°F) and still be labeled “fresh” (USDA FSIS, 2011). Chickens were removed from the cooler just prior to fabrication. If a chicken was still slightly frozen, it was briefly held under warm running water so the body cavity could be opened for neck and giblet removal.

Fabrication

After removal of accessory organs, the whole chicken was weighed. Skin color measurements were taken in triplicate for the breast and thigh region prior to deboning into parts, allowing the skin to lie in its' natural position. Next, fabrication of the breast and thigh was conducted by removing the wing and leg. Then, a cut was made directly proximal to the femur bone to remove the dark meat and appropriate amount of skin with the thigh. Bone-in thigh weight was determined. Breast meat was removed from the carcass by cutting along the clavical, corucoid, and sternum, and the boneless breast weight was determined. The skin was then peeled back on both breast and thigh to expose the meat for color measurements. After color measurements were taken, the thigh was deboned and re-weighed. The pH was determined on deboned meat. After all color, weight, and pH measurements were taken, the entire breast with approximate amounts of natural breast skin from each carcass was chopped in a 14-cup food processor (Model DFP-14BCN Cuisinart, East Windsor, NJ) to make a paste. Approximately 100 g of paste was placed in a pre-labeled whirlpak bag (14 X 23 cm, Fisherbrand, Waltham, MA) and frozen in a -80°F freezer prior to pulverizing the sample. The same process was used to prepare thigh portions. Remaining paste was frozen separately in labeled vacuum bags (3 mil cast nylon, PrimeSource, Bunzl Processor Division, Koch Supplies, Kansas City, MO; oxygen transmission rate of 4.5 cc/100^2/24 h and a moisture vapor transmission rate of 0.6 g/100^2/24 h at -20°C). These samples were homogenized prior to proximate and fatty acid compositions.

Instrumental Color

A HunterLab MiniScan™ EZ colorimeter (Model 4500; Reston, VA) was used to analyze for CIE L*, a*, and b* using Illuminant A, an aperture of 31.8 mm, and the 10° observer which allowed for determination of a/b ratio, hue angle, and saturation index for each sample. One piece of clear film (Ribeye Paper, Shield Manufacturing Corp. Oklahoma City, OK) per chicken was used and placed in between the skin or meat and the lens to keep the lens clean. Skin color measurements were collected in triplicate from the breast and thigh with skin lying naturally over the muscle of each carcass prior to any fabrication. Meat color measurements were taken in triplicate by peeling back the skin after the appropriate part was removed from the carcass and deboned. Thigh meat color measurements were taken after removal from the carcass, but prior to deboning so the thigh would remain in its natural form. The three readings were averaged for

individual parts and used to calculate saturation index (higher values indicate more intense red) calculated using the equation, $SI=[(a*2)+(b*2)]^{1/2}$ (AMSA, 2012).

pH

The pH was measured in triplicate on whole intact raw breast and thigh meat directly after deboning by placing a pH probe (Hanna Instruments, H199163, Woonsocket, RI) attached to an Accumet Basic pH Meter (Fischer Scientific, Pittsburgh, PA) directly into the appropriate muscle.

Proximate Analysis

The 100 g of meat paste sample was partially thawed at room temperature, approximately 20.0°C, until it could be finely chopped. It was then frozen using liquid nitrogen, and pulverized with a table top blender (Model 33BL79, Waring Products, New Hartford, CT). Samples were stored in sterile whirlpak sampling bags at -80°C until analysis. Moisture and crude fat content were measured using the SMART system 5 (CEM Corp., Matthews, NC) procedure (AOAC Official Method PVM-1:2003 MEAT). Crude protein was measured using the LECO FP-2000 Protein/Nitrogen Analyzer (Model 602-600; LECO Corp.; MI) procedure (AOAC Official Method 990.03). Total fatty acid content and composition was determined by extraction on the pulverized samples using the procedure from Sukhija and Palmquist (1988).

Statistical Analysis

A modified split-plot with a completely randomized design for the whole plots with the whole plot factor being type of chicken (TYPE) with two levels (HB or CM) and the subplot factor being poultry part (PART) with two levels (breast or thigh) was used. Analysis of variance (ANOVA) was performed by fitting a mixed model using the PROC MIXED procedure of SAS 9.2 (SAS Inst. Inc., Cary, NC) where TYPE, PART, and TYPE by PART interaction were fixed effects and chicken nested within TYPE was treated as a random effect. Least square means were calculated for each whole-plot and subplot variable. The Satterthwaite approximation to the degrees of freedom was used in the comparisons of the least squares means with each pairwise comparison declared significant when $P<0.05$.

Results and Discussion

Raw Material pH

All products visibly appeared free of any major blemishes. An interaction for pH was present within HB and CM breast and thigh meat, with CM thigh having the highest ($P<0.05$) pH and HB breast having the lowest ($P<0.05$) pH and differences between CM breast and HB thigh pH (Tables 4-1 and A-1). Also, thigh parts had a higher pH than breast meat, regardless of chicken type. Similarly, Berri et al. (2001) investigated the effects of selection on meat quality attributes such as color, pH, and composition. They found that selected lines, for increased growth rates, had less postmortem pH decline similar to the results found in this study with end pH values ranging from 5.75 to 6.08.

In contrast, Husak et al. (2008) found that organic breast and thigh meat had a significantly higher end pH than respective parts from free-range and conventional broilers with no difference being found between the free-range and conventional broilers within similar parts. It was found that thigh pH was always higher than breast pH. The difference between HB and CM seen in this study may be the result of CM being processed through a more efficient system allowing for more rapid chilling, whereas HB chickens were processed through a smaller, multi-species plant that may have lower efficiency leading to increased time to chill the carcasses. With more rapid chilling, the pH decline ends earlier, resulting in a higher final pH. This may also be due to a rapid chilling as the thigh parts are located more lateral and are smaller than breast meat allowing them to chill more quickly(Fletcher, 2002; Savell et al., 2005).

Another reason for differences in end point pH may be due to the type of muscle fibers within the muscle. Thigh meat's dark color would imply a greater portion of type I fibers which are more aerobic thus having less glycolytic potential. Less glycogen would result in less lactic acid production in the transfer of muscle to meat resulting in a higher endpoint pH. This could also explain some differences between chicken types, but further studies would have to be investigated to determine muscle fiber types for both treatments (Dransfield and Sosnicki, 1999). Overall, all treatment LSmeans were above 5.6, typical of final poultry meat pH with normal quality.

Table 4-1. Least square means (LSmeans) of pH measurements for heritage bred (HB) and commercial (CM) broiler breast and thigh meat.

	HB		CM		
	Breast[1]	**Thigh**[1]	**Breast**[1]	**Thigh**[1]	**SEM**[2]
pH	5.74[c]	5.95[b]	5.96[b]	6.40[a]	0.04

[abc] LSmeans within a row having different superscripts differ (P<0.05).
[1] n=40
[2] ± Standard error of the mean.

Instrumental Color Evaluation

Instrumental color data are composed of three measurements, lightness (L*), redness (a*) and yellowness (b*). Mathematical combinations of a* and b* are useful because they combine the two "color" components (a* and b*) rather than relying on redness values alone with an increase in a*/b* indicating a more red surface and less discoloration. Higher saturation index indicates a more vivid, intense color previously described by the L*, a*, and b* values (AMSA, 2012). Probability values for all measurements for chicken type, part, and type by part interaction are shown in Table A-1.

Skin Color

There was a significant (P<0.05) chicken type by part interaction for skin lightness (L*) and yellowness (b*) (Table 4-2 and A-1). Commercial broiler breast and thigh skin L* color was similar (P>0.05) and lighter (P>0.05) than both skin covering the HB breast and thigh. Heritage skin covering the breast was darkest and had the lowest (P<0.05) L* value. The CM thigh had a lower b* value indicating a less yellow color. There was an interaction for b* values with HB breast and thigh skin and CM breast skin having similar (P>0.05) b* (yellowness) values. This color difference is most likely due to the diet change between the treatments as it was not held constant and skin color can be more yellow with a higher concentration of vegetation in the diet (Sirri et al., 2010). Saturation index, describing the intensity of red/ yellow color, had interaction effects with commercial skin having a more intense red/green color suggesting a thinner skin layer, allowing more of the meat color to show through the skin.

Table 4-2. Least square means (LSmeans) for breast and thigh skin instrumental color measurements of heritage bred (HB) and commercial broilers (CM).

	HB		CM		
Color Attribute	**Breast[1]**	**Thigh[1]**	**Breast[1]**	**Thigh[1]**	**SEM[2]**
Skin					
Lightness, L*	70.02[c]	71.65[b]	74.94[a]	74.09[a]	0.47
Yellowness, b*	14.28[a]	13.66[a]	14.38[a]	11.69[b]	0.83
	Chicken Type			**Chicken Part**	
	HB[3]	**CM[3]**	**SEM[2]**	**Breast[3]**	**Thigh[3]**	**SEM[2]**
Skin						
a*	7.68[b]	9.15[a]	0.25	8.61	8.22	0.21
Saturation Index[4]	16.75	15.18	0.75	16.77[a]	15.17[b]	0.59

[abcd] LSmeans within a row with different superscripts differ (P<0.05).
[1] n=20
[2] SEM=Standard error of the mean.
[3] n=40
[4] Saturation Index = $(a^{*2} + b^{*2})^{1/2}$.

There was a main effect for chicken type within a* skin values (Tables 4-2 and A-1). Heritage bred skin was less red (P<0.05) than CM skin. Consumers might perceive brighter, lighter skin to be fresher than darker skin colors, but this is variable due to regional differences found by consumers from different areas (Sirri et al., 2010). In addition, it is generally accepted that the human eye can't perceive differences until 1-2 units of change. This suggests that CM skin might appear lighter and more red to the human eye compared with HB skin color. However, Husak et al. (2008) found no differences between organic, free-range, and convention broiler lightness and redness colors of skin, but did find that conventional skin had a less yellow appearance which could be perceived by the human eye.

Meat Color

An interaction for chicken type by part (Table A-1) found breast meat color was lighter (L*) (P<0.05) than thigh meat which would expected as thigh meat is visually darker due to higher concentration of myoglobin in the muscle. Breast and thigh meat from CM broilers was lighter (P<0.05) than breast and thigh meat from HB chickens (Table 4-3). The amount of redness (a*) for meat color was similar (P>0.05) between breed types (Table 4-3). Typically characteristic of poultry meat, thigh meat was redder (a*) (P<0.05) than breast meat. Based on b* values, meat from CM broilers was more yellow (P<0.05) than meat from HB chickens. Breast meat color was more yellow (P<0.05) than thigh meat color, regardless of chicken type. Husak et al. (2008) found no differences between meat color of conventional and free-range products;

however, just because a bird is free-range, does not mean it is of slow growing genotype. Thus, genetic influences may have more of an effect on muscle color than other factors.

Table 4-3. Least square means (LSmeans) for breast and thigh meat instrumental color measurements for heritage bred (HB) and commercial (CM) broilers.

	HB		CM		
Color Attribute	**Breast[1]**	**Thigh[1]**	**Breast[1]**	**Thigh[1]**	**SEM[2]**
Lightness, L*	63.54[b]	57.50[d]	65.61[a]	61.70[c]	0.502
Saturation Index[3]	16.93[b]	16.36[b]	19.19[a]	17.14[b]	0.450
	Chicken Type			**Chicken Part**	
	HB[4]	**CM[4]**	**SEM[2]**	**Breast[4]**	**Thigh[4]**	**SEM[2]**
Redness, a*	12.16	11.91	0.22	10.98[b]	13.09[a]	0.19
Yellowness, b*	11.06[b]	13.51[a]	0.41	14.29[a]	10.29[b]	0.33

[abcd]LSmeans within a row with different superscripts differ (P<0.05).
[1] n=20.
[2]SEM=Standard error of the mean.
[3]Saturation Index = $(a^{*2} + b^{*2})^{1/2}$.
[4] n=40.

Yields

Weights for HB and CM chickens and breast and thigh yields are shown in Tables 4-4 and A.1. Whole carcass weight of CM was 71% heavier (P<0.05) than HB carcass weight. As a result, breast and bone-in thigh weight was heavier (P<0.05) in CM than for HB. While CM breast weight was 148% heavier than HB breast weight, breast meat yield was only 9% higher (P<0.05) in CM when compared to HB chickens. Commercial broiler bone-in thigh weight was 52% higher (P<0.05) than HB bone-in thigh weight; however, when evaluated as a proportion of the total carcass weight, HB bone-in thigh yield was 2% higher (P<0.05) than CM. Similar results were found by Smith et al. (2012) when comparing conventional and Label-Rouge-type broiler breeds and they found no differences in cook yield which was not investigated in this study. In addition, Fanatico et al. (2005) found that weight gain was similar between slow and fast going birds; however, the breast comprised a much greater carcass portion of fast growing broilers whereas the slow growing broilers had a more balanced body with legs making up a larger portion of the carcass as expected as no genetic selection had taken place to increase muscle production at a faster rate. There was 5% more thigh waste (P<0.05) when the femur was removed from HB than from CM.

Table 4-4. Least square means (LSmeans)[1] of main effects of whole chicken, breast, and thigh weight along with yields for heritage bred (HB) chickens and commercial (CM) broilers main effects.

	Chicken Type	
	HB[2]	**CM[2]**
Weights		
Whole Bird (g)	$1167.25^{b} \pm 53.53$	$1999.82^{a} \pm 54.92$
Breast (g)	$244.18^{b} \pm 19.64$	$605.38^{a} \pm 20.70$
Thigh Bone-in (g)	$222.80^{b} \pm 10.90$	$339.17^{a} \pm 10.90$
Yields		
Breast Yield[3] (%)	$20.65^{b} \pm 0.50$	$30.33^{a} \pm 0.52$
Thigh Yield[4] (%)	$18.95^{a} \pm 0.22$	$16.89^{b} \pm 0.23$
Thigh Waste[5] (%)	$23.58^{a} \pm 0.64$	$19.37^{b} \pm 0 .64$

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] ± Standard error of the mean.
[2] n=20.
[3] Breast yield = (whole bird weight-breast weight)/whole bird weight*100.
[4] Thigh yield = (whole bird weight-thigh bone-in weight)/whole bird weight*100.
[5] Thigh waste = (thigh bone-in weight – thigh boneless weight)/thigh bone-in weight*100.

Proximate Analysis and Fatty Acid Content

An interaction between chicken type and part (Table A-1) showed that fat content of thigh meat with skin was almost 2.50% higher (P<0.05) in CM compared to HB, while fat content was similar (P>0.05) in breast meat with skin between the chicken types (Table 4-5). There was a main effect for chicken part moisture and protein content (Tables 4-6 and A-1). Breast meat had (P<0.05) 4.25% more moisture and 4.28% more protein content than thigh meat, regardless of chicken type. Meat from HB chickens had 1.7% more protein (P>0.05) than meat from CM broilers. Similarly, Fanatico et al. (2007a) found that slow growing breeds had greater protein content than fast growing breeds along with chickens with outdoor access having an increase in protein compared with indoor production systems. However, it was also found that chickens fed a conventional diet produced chickens with a higher protein content than chickens fed a low energy diet. In addition, fast growing breeds had about 3.0% greater fat content in breast meat than slow growing breeds' breast meat with no difference from environment during growth. Heritage bred and CM breast meat with skin showed no differences in fat content. Protein content was slightly lower than the levels presented by Berri et al. (2001) which can be expected as they were analyzing just meat. Diet and genetics have been found to have effects on

composition. Heritage bred chicken meat with skin appears to have a higher protein content and lower fat percentages than reported by USDA, ARS (2012).

Table 4-5. Least square means (LSmeans) for interaction effects of fat content[1] of heritage (HB) and commercial (CM) breast and thigh meat with skin.

	HB		CM		
Composition	**Breast[2]**	**Thigh[2]**	**Breast[2]**	**Thigh[2]**	**SEM[3]**
Crude Fat (%)	4.73[c]	12.35[b]	5.30[c]	14.80[a]	0.570

[ab]LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of sample.
[2] n=20.
[3] SEM=Standard error of the mean.

Table 4-6. Least square means (LSmeans) for main effect of protein and moisture content[1] heritage and commercial chicken breast and thigh meat with skin.

	Chicken Type			Chicken Part		
Composition	**Heritage[2]**	**Commercial[2]**	**SEM**	**Breast[2]**	**Thigh[2]**	**SEM[3]**
Protein (%)	20.50[a]	18.81[b]	0.153	21.80[a]	17.52[b]	0.142
Moisture (%)	70.39	69.81	0.396	72.22[a]	67.97[b]	0.3259

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of sample.
[2] n=40.
[3] SEM = Standard error of the mean.

Interactions for fatty acid content for chicken type by part effects (Table A-2) of HB and CM chickens are shown in Table 4-7 and main effects for chicken type or chicken part are displayed in Table 4-8. Heritage chickens had a higher (P<0.05) percentage of total extractable PUFA content at 35.60 and 35.21% for thigh and breast parts, compared to 20.96 and 20.45% found in breast and thigh parts of CM chickens (Table 4-7). Heritage chicken meat had a higher (P<0.05) percent of ω3 fatty acids content at 3.33% than CM broiler meat with 1.47%, regardless of part, and breast meat (2.59%) was 0.38% higher in ω3 fatty acid content than thigh meat regardless of chicken type (Table 4-8). Similarly, ω3 fatty acids content increased from conventional to free-range poultry with meat from organic production containing the greatest ω3 fatty acids amount (Husak et al., 2008). Heritage thigh and breast meat with skin had a greater (P<0.05) amount of ω6 fatty acids at 32.46 and 31.69% of extractable fatty acids than CM breast and thigh meat at 19.31 and 19.16%, respectively (Table 4-7).

In a healthy diet, it is preferable to have a lower ω6:ω3 ratio from all meat consumed, with exact ratio depending upon the health agency (USDA and HHS, 2010). The lowest (P<0.05) ratios were found in breast and thigh meat from HB chickens which had 9.11 and 10.45,

respectively. The ratio in breast and thigh meat from CM broilers was 11.83 and 14.94, respectively, resulting in HB breast and thigh meat having a more desirable ω6:ω3 ratio which is similar to the findings by Siri et al. (2010) when comparing 3 growth rate levels, fast, medium, and slow. The U.S. Department of Agriculture and Department of Health and Human Services (2010) recommends that less than 10% of a persons' calories come from saturated fats as they have been related to increased cases of cardiovascular disease. Heritage meat with skin had a lower ($P<0.05$) total content of saturated fatty acids (SFA) at 27.75 and 26.78% for breast and thigh meat and skin compared to 31.56% and 31.66% SFA in CM (Table 4-7). Heritage thigh meat with skin contained the lowest amount of SFA. Similar results were report by Sirri et al. (2010) and Husak et al. (2008) with slow growing breeds and alternative production chicken meat. As a result, slow growing and alternative production chicken meat has a more optimal fatty acid profile which could be incorporated into a healthy diet program.

Table 4-7. Least square means (LSmeans) for interactions of fatty acid content[1] for heritage bred (HB) and commercial broiler (CM) breast and thigh meat with skin.

		HB		CM		
Fatty Acid (%)[1]	**Common Names**	**Breast[2]**	**Thigh[2]**	**Breast[2]**	**Thigh[2]**	**SEM[3]**
C16:0	Palmitic acid	19.14^{c}	18.55^{d}	24.39^{b}	24.63^{a}	0.24
C17:0	Margaric acid	0.28	0.25	0.18	0.17	0.01
C18:0	Stearic acid	7.72	7.37	6.39	6.06	0.13
C20:0	Arachidic acid	0.19^{a}	0.19^{a}	0.11^{b}	0.09^{b}	0.01
Total SFA[4]		27.75^{b}	26.78^{c}	31.66^{a}	31.56^{a}	0.29
C16:1	Palmitoleic acid	2.90^{d}	3.22^{c}	7.12^{b}	7.23^{a}	0.17
C18:1n9	Oleic acid	30.09^{d}	30.74^{c}	35.11^{b}	36.41^{a}	0.50
C18:1n7		2.41^{b}	2.25^{c}	2.77^{a}	2.49^{b}	0.07
C20:1	Eicosenoic acid	0.33^{b}	0.32^{b}	0.34b	0.39^{a}	0.01
Total MUFA[4]		35.73	36.53	45.39	46.47	0.62
C18:2ω6	Linoleic acid	31.06^{b}	31.97^{a}	18.44^{c}	18.28^{c}	0.58
C18:3ω6	γ-linoenic acid	0.32	0.27	0.41	0.35	0.003
C20:3ω6		0.26^{bc}	0.19^{c}	0.59^{a}	0.34^{b}	0.03
C20:4ω6	Arachidonic acid (AA)	0.05	0.04	0.04	0.03	0.005
Total ω6 PUFA[4]		31.69^{b}	32.46^{a}	19.31^{c}	19.16^{c}	0.59
C18:3ω3	α-linolenic acid (ALA)	2.43^{b}	2.51^{a}	0.99^{c}	0.95^{c}	0.07
C20:5ω3	Eicosapentaenoic acid (EPA)	0.10	0.04	0.05	0.03	0.01
C22:5ω3	Docosapentaenoic acid (DPA)	0.48	0.27	0.49	0.26	0.03
C22:6ω3	Docosahexaenoic acid DHA	0.51^{a}	0.30^{b}	0.12	0.05^{d}	0.02
Total ω3 PUFA[4]		3.52	3.13	1.65	1.29	0.06
Total PUFA		35.21^{b}	35.60^{a}	20.96^{c}	20.45^{d}	0.67
Total Other		1.31^{c}	1.10^{d}	1.52^{b}	1.99^{a}	0.06
ω6:ω3 Ratio		10.45^{d}	9.11^{c}	14.94^{a}	11.83^{b}	0.22

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of extractable fatty acid content.
[2] n=20.
[3] SEM=Standard error of the mean.
[4] SFA=saturated fatty acids, MUFA= monounsaturated fatty acid, PUFA=polyunsaturated fatty acid, ω6 = omega 6 PUFA, ω3=omega 3 PUFA.

Table 4-8. Least square means (LSmeans) for main effects of fatty acid content[1] for heritage bred (HB) and commercial (CM) broiler breast and thigh meat with skin.

		Chicken Type			Chicken Part		
Fatty Acid (%)[1]	**Common Names**	**Heritage[2]**	**Commercial[2]**	**SEM[3]**	**Breast[2]**	**Thigh[2]**	**SEM[3]**
C16:0	Palmitic acid	24.51[a]	18.85[b]	0.24	21.77[a]	21.59[b]	0.17
C17:0	Margaric acid	0.26[a]	0.17[b]	0.01	0.23[a]	0.21[b]	0.01
C18:0	Stearic acid	7.54[a]	6.22[b]	0.12	7.05[a]	6.71[b]	0.09
C20:0	Arachidic acid	0.10[a]	0.18[b]	0.01	0.14	0.14	0.01
Total SFA[4]		31.61[a]	27.26[b]	0.29	29.70[a]	29.17[b]	0.20
C16:1	Palmitoleic acid	7.17[a]	3.05[b]	0.17	5.01[b]	5.22[a]	0.12
C18:1n9	Oleic acid	35.76[a]	30.41[b]	0.49	32.60[b]	33.57[a]	0.35
C18:1n7		2.63[a]	2.33[b]	0.05	2.59[a]	2.37[b]	0.04
C20:1	Eicosenoic acid	0.37a	0.33b	0.01	0.36a	0.33b	0.01
Total MUFA[4]		36.13[b]	45.93[a]	0.61	40.56[b]	41.50[a]	0.44
C18:2ω6	Linoleic acid	18.36b	31.51a	0.57	24.67b	25.20a	0.41
C18:3ω6	γ-linolenic acid	0.30[b]	0.38[a]	0.03	0.36[a]	0.31[b]	0.02
C20:3ω6		0.47[a]	0.23[b]	0.03	0.43[a]	0.26[b]	0.02
C20:4ω6	Arachidonic acid (AA)	0.04	0.04	0.003	0.04	0.03	0.003
Total ω6 PUFA[4]		19.24[b]	32.08[a]	0.59	25.50	25.81	0.42
C18:3ω3	α-linolenic acid (ALA)	0.97[b]	2.47[a]	0.06	1.71	1.73	0.05
C20:5ω3	Eicosapentaenoic acid (EPA)	0.04[b]	0.07[a]	0.01	0.08[a]	0.04[b]	0.009
C22:5ω3	Docosapentaenoic acid (DPA)	0.37	0.38	0.03	0.48[a]	0.27[b]	0.02
C22:6ω3	Docosahexaenoic acid DHA	0.09[b]	0.40[a]	0.02	0.31[a]	0.18[b]	0.02
Total ω3 PUFA[4]		3.33[a]	1.47[b]	0.09	2.59[a]	2.21[b]	0.06
Total PUFA		20.71[b]	35.41[a]	0.67	28.09	28.03	0.47
Total Other		1.75[a]	1.20[b]	0.05	1.65[a]	1.31[b]	0.05
n-6:n-3 Ratio		13.38[a]	9.78[b]	0.18	10.47[b]	12.69[a]	0.15

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of extractable fatty acid content.
[2] n=40.
[3] SEM=Standard error of the mean.
[4] SFA=saturated fatty acids, MUFA= monounsaturated fatty acid, PUFA=polyunsaturated fatty acid, ω6 = omega 6 PUFA, ω3=omega 3 PUFA.

Chapter 5 - Sensory and Textural Properties of Heritage Bred and Commercial Broiler Meat

Introduction

Meat quality encompasses many different attributes which are important as they can affect many sensory attributes. When evaluating food, consumers use all five senses: sight, smell, touch, taste, and hearing, to perceive the quality or lack thereof within a food product. These senses are also important for evaluating spoilage of a raw product, to perceive aromas while cooking, and for taste, texture, and aroma while eating. As reported by Maltin et al. (2003), the most common source of customer complaints and failure in repeat purchasing a meat product is due to eating qualities.

Flavor is described as the sensation of a combination between taste, smell, and texture within the mastication process. Meat flavor is the combination of Maillard browning reactions between proteins and carbohydrates while cooking and the oxidation and degradation reaction of lipid compounds (d'Acampora-Zellner, 2008). While flavor and color are used to detect food spoilage, meat texture, including tenderness, juiciness, and chewiness, is used for the assessment of meat eating quality and thus argued to be the most important factor in repeat purchases (Braxton, 1996; Maltin, 2003; McKee et al., 2012).

In addition, texture is readily affected by size and shape of the muscles cells along with the maturity of the connective tissue within and surrounding the muscles (Fletcher, 2002; McKee et al., 2012; Wang et al., 2013). As a general rule, connective tissue matures by gaining more cross-links as it ages causing meat to be less tender (Fletcher, 2002). While these effects are minimized with modern broiler lines harvested at ages around 40 to 50 days of age, the effects can still be present with slower growing chickens as they are raised to at least 83 days prior to harvesting. The objective of this study was to evaluate sensory and texture attributes of breast and thigh meat from heritage bred slow growing chickens and commercial broilers that were chilled by water immersion chilling or air chilling.

Materials and Methods

Experimental Design

This experiment was a modified split plot design. The whole-plot design was a randomized complete block design with the whole-plot factor being the type of chicken (TYPE), blocking factor being the day a replicate was run (DAY) and the subplot factor being the part of chicken (PART). Five replications were performed with all replications being completed within one week resulting in five blocks. The whole plot factor TYPE had three levels including: 1) Heritage Bred Cornish Chicken (HB) that were harvested at more than 116 days of age, certified standard breed by the American Poultry Association, and labeled "Free Range, All Natural, Air Chilled, No Artificial Ingredients, No Antibiotics, All-Natural-Minimally Processed, and No Water-Added" (Good Shepherd Poultry Ranch, Lindsborg, KS); 2) Commercial Water Chilled broiler (CMWC) that were harvested at approximately 42 days of age and labeled as "Fresh Young Chicken with Neck and Giblets, 100% natural with less than 7% water retained, No Artificial Ingredients, Minimally Processed, No Added Hormones, and No Added Steroids" (HyVee, Inc., West Des Moines, IA); and 3) Commercial air chilled broilers (CMAC) that were harvested at approximately 42 days of age and labeled "Young Whole Chicken, No Tips or Giblets, All Natural, Grain Fed, Raised Without Antibiotics, Minimally Processed, and No Artificial Ingredients" (Smart Chicken, Tecumseh Poultry LLC, Waverly, NE 68462).The subplot factor PART had two levels including breast meat (*pectoralis major*) and thigh meat (*quadriceps femoris*). Sensory analysis, instrumental shear force measurements, pH, proximate analysis, and fatty acid composition were measured for each type of bird and part without skin in each replication.

Product Preparation

Twenty-five whole chickens were purchased for each type of chicken from local retail markets (Manhattan, KS). The chickens were purchased within ten days of one another and placed in -29°C freezer for at least seven days and no longer than 20 days at the KSU Meat lab until analyses were ran. Prior to being frozen, all carcasses of one type were pooled, randomly assigned into one of five groups each containing five carcasses, given a date for sampling, and then boxed according to replication to allow for ease of thawing.

Approximately 72 h prior to fabrication, carcasses were placed in an upright refrigerator (McCall Refrigeration model 4-4070, Irvington , NJ) at 2.69°C ± 1.29°C to allow for thawing. On the morning of fabrication and analyses, carcasses still in their original shrink wrapping were immersed in a sink of cold water for approximately 30 min to finish thawing if needed. Whole carcass weights (with skin) were collected for raw part yields using a table top scale (Explorer Pro model EP2102C, Ohaus, Parsippany, NJ). The carcasses were fabricated with the ventral most portion facing up and the tail directed towards the processor. Breast and thigh meat was manually deboned, skin was removed from these pieces, and meat portions were individually bagged in vacuum packages (3 mil cast nylon, PrimeSource, Bunzl Processor Division, Koch Supplies, Kansas City, MO, oxygen transmission rate of 4.5 cc/100^2/24 h and a moisture vapor transmission rate of 0.6 g/100^2/24 h at -20°C). Right breast and thigh portions were reserved for sensory panel measurements and respective left portions were designated for instrumental measurements. Prior to bagging individual parts, weights were obtained for raw yield measurements using a table top scale. Commercial breast meat was thicker than breast from HB and this would result in increased cook time and a sample that would be too thick for sensory analysis. To standardize the thickness, these breast samples were trimmed with a knife by hand to a similar thickness as HB breasts by removing the dorsal/ back side of the breast fillet. Raw weight of trimmed breast fillets was collected after trimming to allow for calculation of cook loss. One of the five carcasses for each type of chicken per replication was not trimmed to a similar breast depth; instead it was reserved for pH measurement and proximate analysis.

Breast and thigh portions were placed in vacuum packages (3 mil cast nylon, PrimeSource, Bunzl Processor Division, Koch Supplies, Kansas City, MO, oxygen transmission rate of 4.5 cc/100^2/24 h and a moisture vapor transmission rate of 0.6 g/100^2/24 h at -20°C) able to withstand cooking temperatures. Excess air was manually removed and the packages were heat sealed with a 50.8 cm Impulse Sealer (model # H-1029, Uline, Pleasant Prairie, WI). The thickest sample of breast from each treatment was probed using a thermocouple (thirty gauge copper and constantan, Omega Engineering, Stamford, CT) to monitor temperature using a Doric Minitrend 205 (VAS Engineering, San Francisco, CA). These packages were then heat sealed. Samples for instrumental measurements were cooked separate from sensory samples using two water baths heated to a target temperature of 85°C in a food warmer (model 1001, Vollrath Co. LLC, Sheboygan, WI) without the inset warming dish. Treatments were heated to an internal end

point temperature of 76°C (Cavitt et al., 2005) which was reached within 15-20 min. Samples for instrumental measurements were allowed to reach room (approximately 20°C) temperature in the bag (at least two h) prior to being weighed and used for instrumental texture determination. Sensory samples were cooked following the same procedure, except no after-cook weight was obtained.

pH

The pH was measured on whole intact raw breast and thigh meat directly after deboning by placing a pH probe (Hanna Instruments; H199163; Woonsocket, RI) attached to an Accumet Basic pH Meter (Fischer Scientific, Pittsburgh, PA) directly into the meat of one chicken per type within each replication. After pH measurements were recorded, two breast pieces from the same carcass were frozen at -20°C in vacuum bags (3 mil cast nylon, PrimeSource, Bunzl Processor Division, Koch Supplies, Kansas City, MO, oxygen transmission rate of 4.5 $cc/100^2/24$ h and a moisture vapor transmission rate of 0.6 $g/100^2/24$ h at -20°C) for less than 10 days until being prepared for proximate and fatty acid analysis.

Proximate Analysis

Frozen parts were partially thawed at 20°C until able to be chopped, frozen in liquid nitrogen, and pulverized with a table top blender (model 33BL79; Waring Products, New Hartford, CT) to achieve a homogenous mixture. Samples were stored in whirl pak bags (14 X 23 cm, Fisherbrand, Waltham, MA) at -80°C until analysis. Approximately 5 g of the sample was separated and packaged in whirl pak bags (118.3 cc, Nasco, Ft. Atkinson, WI) for crude protein analysis which was measured at the Soils Testing Lab in the Department of Agronomy at Kansas State University using the LECO TruSpec CN (LECO Corp.; MI) procedure (AOAC Official Method 990.03). Protein results were not reported in this thesis. Moisture and crude fat content were measured using the SMART system 5 (CEM Corp., Matthews, NC) procedure (AOAC Official Method PVM-1:2003 MEAT). Total fatty acid content and composition was determined using the procedure from Sukhija and Palmquist (1988).

Instrumental Texture Measurements

After samples cooled to room temperature (20°C), packages were opened, purge was drained, and weights were recorded for the meat only, for calculation of cook yields. The

samples were then individually sampled for Warner-Bratzler shear force (WB) and Allo-Kramer shear force (AK) tenderness measurements. For breast and thigh, WB strips were taken by cutting two 19 mm width strips parallel to muscle fiber orientation (Lyon and Lyon, 1990). For AK cores, 40x20 mm rectangle strips were cut parallel to muscle fiber orientation (Lyon and Lyon, 1990) (two for breast and one for thigh parts due to limited parallel surface area). To remove potential location bias, WB and AK strips were rotated from ventral to posterior location within the breast muscle thus rotating whether the samples were near the edge or the center of the sample. The WB strip was placed in an Instron Universal Testing Machine (Model 5569, Instron Corporation, Canton, MA) with a 100 kg load cell and descending at a rate of 4.2 mm/s so that the V-blade cut perpendicular to the fiber orientation. Two measurements were taken on each strip during separate descents and peak force results were reported in kg. Strips for AK were placed in a multi-blade attachment (Kramer Shear Cell, model 2830-018, Instron Corporations, Canton, MA) on the Instron and connected to a 100 kg load cell descending at 3.3 mm/s so that the blades cut across the fibers. Allo-Kramer measurement results were reported as kg of force per g of sample (Lyon and Lyon, 1990).

Sensory Analysis

After cooking individual parts, samples rested in the bag for approximately five min prior to package being opened and draining the fluid at ambient temperature (approximately 20°C). Breast and thigh parts were cut into 1.9 cm cubes for sensory analysis using a high density polyethylene (HDPE) template (G-R Manufacturing, Manhattan, KS). Two pieces were randomly placed into a sampling cup (Portion Cups Plastic Translucent 60 cc rolled rim with lids, Model # 7790239, Sysco Corporation, Houston, TX) and covered with a plastic lid bearing a code. Samples were keep warm using a food warmer (Vollrath, model 1001, Vollrath Co. LLC, Sheboygan, WI) with chafing dishes inside to keep the samples at 48.8°C until presented to panelists, less than 30 min but variable as panelists received samples in a variable order.

A sensory panel comprised of graduate students and faculty members at Kansas State University underwent screening following the American Society for Testing and Materials guidelines (Anonymous, 1981) to participate on the panel. Next, panelists were oriented to whole muscle chicken sampling by attending at least 2 out of 5 training sessions using a ballet containing seven attributes on an eight-point descriptive attribute scale. The samples presented to

panelists during orientation were the same samples to be evaluated except for a wild duck sample that was included to orient panelists to a wild/gamey flavor and low, tough, texture attribute scores. Samples for orientation were served in a round table format with each panelist receiving the same sample in a cup with a lid to allow for orthogonal aroma evaluation. Panelists were then asked to place a sample between the molars and chew while evaluating for myofibrillar tenderness, juiciness, chicken flavor intensity, connective tissue content, overall tenderness, , and off flavor (Table A-4). Each of these attributes were ranked to the nearest 0.5 increment using the respective eight point scales: 8 = extremely intense aroma, extremely tender, extremely juicy, extremely intense, none connective tissue, extremely tender, and none off flavor to 1 = no aroma, extremely tough, extremely dry, extremely bland, abundant, extremely tough, and abundant off flavor examples including gamey, feathery, rancid, metallic, livery, organy, and bloody. For the actual panel, at least six panels were present and each panelist evaluated six samples and one warm-up in one session. The panel was blocked and repeated by day for five days.

Statistical Analysis

Analysis of variance (ANOVA) was performed by fitting a mixed model using the PROC MIXED procedure of SAS 9.2 (SAS Inst. Inc., Cary, NC) where TYPE, PART and TYPE by PART interaction were fixed effects and DAY and DAY by TYPE were treated as random effects. One panel was competed per day. Least square means were calculated for each whole-plot and subplot variable. The Satterthwaite approximation to the degrees of freedom was used in the comparison of least squares means with each pairwise comparison declared significant when $P < 0.05$. Regression analysis was considered between instrumental measurements and sensory terms, but because of the split-plot design, analysis would be confounded and was not conducted.

Results and Discussion

pH

All products visibly appeared free of defects except for a few blood splash spots on the edge of breast muscles for CMWC in the second replication which were trimmed from muscles prior to processing. No interaction effect ($P>0.05$) was seen within pH measurements of raw meat (Table A-4). Main effects ($P<0.05$) were present within type and part (Table 5-1).

Commercial meat, regardless of the type of chilling, had higher (P<0.05) pH values than HB meat by at least 0.26 units. Similarly, Berri et al. (2001) investigated the effects of genetic selection on meat quality attributes such as color, pH, and composition. They found that selected lines for increased growth rates had a slower and lower pH decline, resulting in a higher ending pH from 5.75 to 6.08 for breast meat. In contrast, Husak et al. (2008) found that organic breast and thigh meat had a significantly higher end pH than respective parts from free-range and convention broiler with no difference being found between the free-range and conventional broilers within similar parts. It was found that thigh pH was always higher than breast pH (Aberle et al., 2001a).

The variation of pH between types of chickens may be due to capacity of the processing plants as the commercial chickens may be processed more efficiently than HB which were processed at a small processing facility. Breast meat, regardless of the type of chicken, had a lower pH by 0.38 units than thigh meat which may also be due to variation in the concentrations of different muscle fiber types as white fibers have a higher glycolytic potential resulting in a lower pH. However, all pH values are in an acceptable range (Wilkins, 2000) and would not be associated with negative attributes such as dark, firm, and dry (DFD) or pale, soft, and excudative (PSE) meat.

Table 5-1. Least squares means (LSmeans) main effects for raw meat pH of commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) chicken breast and thigh meat.

	Chicken Type				Chicken Part		
	CMAC[1]	CMWC[1]	HB[1]	SEM[2]	Breast[3]	Thigh[3]	SEM[2]
pH	6.48[a]	6.42[a]	6.16[b]	0.048	6.15[b]	6.53[a]	0.036

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] n=5.
[2] SEM=Standard error of the mean.
[3] n=15

Proximate Analysis

There were no interactions for moisture and fat content between type of chicken and part of chicken (Table A-4). Main effects were only found between parts regardless of chicken type. Protein results are not presented. Thigh meat had a greater amount of fat at 7.40% when compared to breast meat at 0.55%, respectively (Table 5-2). Breast meat was moister than thigh meat by 2.33%. The lack of significant differences between genotypes types is inconsistent with

results presented by Husak et al. (2008) and Sirri et al. (2010); however, the preliminary (Chapter 3) and nutritional studies (Chapter 4) with meat and skin found differences in fat percentage. This shows the significance of incorporating skin in the analysis as the majority of the fat content is included in the skin.

Table 5-2. Least squares means (LSmeans) [1] for main effects for proximate analysis of commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) chicken breast and thigh meat.

	Chicken Type				Chicken Part		
Component	CMAC[2]	CMWC[2]	HB[2]	SEM[3]	Breast[2]	Thigh[2]	SEM[3]
Moisture (%)	72.67	72.73	72.05	0.32	73.65[a]	71.32[b]	0.26
Fat (%)	3.53	4.82	3.57	0.39	0.55[b]	7.40[a]	0.32

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of part.
[2] n=16.
[3] SEM=Standard error of the mean.

Fatty Acid Composition

Interactions between chicken type and part (P<0.05) are found in Table A-3 and were found for palmitic acid, total saturated fatty acid content, and linoleic acid (Table 5-3). Palmitic acid was more than twice the concentration of stearic acid in the percentage of total extractible acid. Linoleic acid was highest in HB thigh meat followed by HB breast and CMAC thigh meat with CMAC breast and CMWC breast and thigh meat having the lowest content. Linoleic acid is an ω6 PUFA, so while it is essential to the diet, it has been stated by the American Heart Association that a more optimal diet would lower these PUFA in the diet as well as lowering SFA intake (USDA and HHS, 2010). Total saturated fatty acid content was highest (P<0.05) in CMAC breast meat followed by HB breast and CMAC thigh meat. CMWC had the lowest or most desirable SFA content at 28.85%. While significant differences were seen, the range of SFA content was fairly small only ranging from 28.85 -33.27%, all within 5% change of one another. Sirri et al. (2010) found no differences between the genetic lines for SFA content whereas Cortinas et al. (2004) found that SFA increased with an increase in PUFA in the diet.

Main effects for type of bird (P<0.05) was seen in palmitoleic, margaric, and stearic acids along with α – linolenic acid (ALA), arachidonic acid (AA), ω3-docosapentaenoic acid (DPA), docosahexaenoic acid (DHA), total MUFA, ω6 PUFA, ω3 PUFA, total PUFA, and ω6:ω3 ratio (Tables 5-4 and A-3) which are similar to results presented by Sirri et al. (2010) and Husak et al. (2008). It is recommended by multiple health agencies that the American diet needs to increase

in ω3 fatty acid content (USDA and HHS, 2010; Simopoulos 2008; Kris-Etherton, Harris, and Appel, 2003). The greatest amount of ω3 fatty acids ($P<0.05$) was found in HB that had a total ω3 content at 2.52% of extractable fatty acid content with ALA at 1.08%, DPA at 0.60%, and DHA at 0.78%. Both commercial chicken types had ($P<0.05$) lower amounts of all ω3 fatty acids compared to HB (Table 5-4). Health professionals have also suggested an increase in ω3 PUFA with a decrease in ω6 PUFA content resulting in health benefits from a food item with a lower ratio of ω6:ω3 and the FAO suggested an increase in foods below a ratio of ω6:ω3 4:1 (Harris et al., 2009; Kris-Etherton et al., 2003; Simopoulos, 2008). Heritage bred meat had a lower ($P<0.05$) ω6:ω3 ratio than CMWC or CMAC, although it was still higher than the recommended 4:1 ω6:ω3 ratio. As a result, HB meat does have a nutritional advantage over CM broiler meat based on genotype of the chicken. This difference could be increased with additional PUFA being added to the diet during production as evidenced in a study by Cortinas et al. (2004).

Chicken part main effects and total fatty acid content are shown in Table 5-5. Breast meat, regardless of chicken type, contained a greater amount of ω6 PUFA, ω3 PUFA, and total PUFA than thigh meat. Breast meat also had a lower ($P<0.05$), more optimal ω6:ω3 ratio at 11.37, compared with 17.14 for thigh meat. In addition, thigh meat contained a greater amount of total MUFA at 42.63% compared to 35.51% in breast meat which is beneficial since MUFA are considered neutral fats and have yet to be associated with increasing the risk of cardiovascular disease (CVD) or heart disease (USDA and HHS, 2010). Few studies have made a composition comparison between chicken parts (white and dark meat) thus continued research would be beneficial in aiding consumers with decisions when trying to achieve a healthier diet.

Table 5-3. Least squares means (LSmeans) for interactions of fatty acid content[1] for commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) chicken breast and thigh meat.

		CMAC		CMWC		HB		
Fatty Acid	**Common Names**	**Breast[2]**	**Thigh[2]**	**Breast[2]**	**Thigh[2]**	**Breast[2]**	**Thigh[2]**	**SEM[3]**
C14:0	Mystric acid	0.44	0.51	0.45	0.51	0.48	0.56	0.027
C16:0	Palmitic acid	22.09^{bc}	23.56^{a}	21.38b^{c}	22.32^{b}	21.49^{bc}	21.12^{c}	0.39
C17:0	Margaric acid	0.16	0.14	0.14	0.12	0.18	0.18	0.010
C18:0	Stearic acid	10.58	7.65	8.95	5.88	10.18	7.98	0.46
Total SFA[4]		33.27^{a}	31.87^{b}	30.93^{c}	28.85^{e}	32.33^{b}	29.85^{d}	0.30
C16:1	Palmitoleic acid	3.22	4.58	4.08	5.91	2.40	3.99	0.41
C18:1		31.44	37.17	35.54	41.98	28.79	33.25	0.83
C20:1	Eicosenoic acid	0.36^{ab}	0.34^{ab}.	0.40^{a}	0.34^{ab}	0.27^{c}	0.33^{ab}	0.02
Total MUFA[4]		35.02	42.10	40.02	48.23	31.47	37.57	1.08
C18:2ω6	Linoleic acid	19.12^{c}	21.44^{b}	17.95^{c}	19.20^{c}	21.95^{b}	26.39^{a}	0.52
C18:3 ω6	γ –linolenic acid	0.29	0.22	0.20	0.21	0.21	0.23	0.01
C20:3 ω6		1.35	0.42	1.28	0.36	0.77	0.36	0.12
C20:4 ω6	Arachidonic acid (AA)	6.19	1.51	5.06	1.05	8.13	2.51	0.54
Total ω6 PUFA[4]		26.86	23.59	24.50	20.82	31.06	29.49	0.65
C18:3 ω3	α – linolenic acid (ALA)	0.72	1.02	0.68	0.90	0.93	1.23	0.05
C20:5 ω3	Eicosapentaenoc acid (EPA)	0.24^{a}	0.051^{a}	0.23^{b}	0.040^{b}	0.074^{b}	0.030^{b}	0.023
C22:5 ω3	Docosapentaenoic acid (DPA)	0.70	0.17	0.65	0.12	0.91	0.30	0.061
C22:6 ω3	Docosahexaenoc acid (DHA)	0.64	0.10	0.50	0.076	1.21	0.36	0.11
Total ω3 PUFA[4]		2.29	1.34	2.05	1.14	3.12	1.91	0.15
Total PUFA[4]		29.15	24.93	26.55	21.97	34.18	31.40	0.77
Total Other[4]		2.56	1.10	2.50	0.96	2.02	1.18	0.18
ω6:ω3 ratio		11.95	17.59	12.08	18.32	10.07	15.52	0.58

[abcde] LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of extractable fatty acid content.
[2] n=4.
[3] SEM=Standard error of the mean.
[4] SFA=saturated fatty acids, MUFA= monounsaturated fatty acid, PUFA=polyunsaturated fatty acid, ω6 = omega 6 PUFA, ω3=omega 3 PUFA.

Table 5-4. Least squares means (LSmeans) main effect for fatty acid composition[1] of commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) meat.

		Chicken Type			
Fatty Acid	**Common Name**	**CMAC[2]**	**CMWC[2]**	**HB[2]**	**SEM[3]**
14:0	Mystric acid	0.47	0.48	0.52	0.02
16:0	Palmitic acid	22.83[a]	21.85[b]	21.30[b]	0.32
C17:0	Margaric acid	0.15[b]	0.13[b]	0.18[a]	0.009
C18:0	Stearic acid	9.12[a]	7.42[b]	9.08[a]	0.38
Total SFA		32.57[a]	29.89[c]	31.09[b]	0.28
C16:1	Palmitoleic acid	3.90[b]	5.00[a]	3.20[b]	0.39
C18:1		34.30[b]	38.76[a]	31.02[c]	0.62
C20:1	Eicosenoic acid	0.35	0.37	0.30	0.02
Total MUFA		38.56[b]	44.12[a]	34.52[c]	0.85
C18:2ω6	Linoleic acid	20.28[b]	18.58[c]	24.17[a]	0.44
C18:3 ω6	γ –linolenic acid	0.21	0.21	0.22	0.02
C20:3 ω6		0.89	0.82	0.57	0.08
C20:4ω6	Arachidonic acid (AA)	3.85[b]	3.09[b]	5.32[a]	0.38
Total ω6 PUFA[4]		25.23[b]	22.66[c]	30.28[a]	0.52
C18:3ω3	α – linolenic acid (ALA)	0.87[b]	0.79[c]	1.08[a]	0.04
C20:5ω3	Eicosapentaenoc acid (EPA)	0.14[a]	0.13[a]	0.05[b]	0.017
C22:5ω3	ω3-docosapentaenoic acid (DPA)	0.43[b]	0.38[b]	0.60[a]	0.043
C22:6ω3	Docosahexaenoic acid (DHA)	0.37[b]	0.29[b]	0.78[a]	0.077
Total ω3 PUFA[4]		1.82[b]	1.60[b]	2.52[a]	0.10
Total PUFA[4]		27.04[b]	24.26[c]	32.79[a]	0.59
ω6:ω3 ratio		15.20[a]	14.77[a]	12.79[b]	0.41

[abc] LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of extractable fatty acid content.
[2] n=16.
[3] SEM=Standard error of the mean.
[4] SFA=saturated fatty acids, MUFA= monounsaturated fatty acid, PUFA=polyunsaturated fatty acid, ω 6 = omega 6 PUFA, ω3=omega 3 PUFA.

Table 5-5. Least squares means (LSmeans) main effects for fatty acid composition[1] of breast and thigh meat from commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) chickens.

		Chicken Part		
Fatty Acid	**Common Name**	**Breast[2]**	**Thigh[2]**	**SEM[3]**
C14:0	Mystric acid	0.46[b]	0.53[a]	0.02
C16:0	Palmitic acid	21.65[b]	22.34[a]	0.28
C17:0	Margaric acid	0.162[a]	0.143[b]	0.01
C18:0	Stearic acid	9.90[a]	7.17[b]	0.32
Total SFA		32.18[a]	30.19[b]	0.17
C16:1	Palmitoleic acid	3.24[b]	4.83[a]	0.32
C18:1		31.92[b]	37.47[a]	0.51
C20:1	Eicosenoic acid	0.34	0.34	0.01
Total MUFA[4]		35.51[b]	42.63[a]	0.70
C18:2ω6	Linoleic acid	19.68[b]	22.35[a]	0.32
C18:3ω6	γ –linolenic acid	0.20[b]	0.22[a]	0.01
C20:3ω6		1.14[a]	0.38[b]	0.07
C20:4ω6	Arachidonic acid (AA)	6.46[a]	1.69[b]	0.31
Total ω6 PUFA[4]		27.47[a]	24.64[b]	0.44
C18:3ω3	α – linolenic acid (ALA)	0.78[b]	1.05[a]	0.03
C20:5ω3	Eicosapentaenoic acid (EPA)	0.18[a]	0.04[b]	0.01
C22:5ω3	ω3 docosapentaenoic acid (DPA)	0.75[a]	0.19[b]	0.04
C22:6ω3	Docosahexaenoic Acid (DHA)	0.78[a]	0.18[b]	0.07
Total ω3 PUFA[4]		2.49[a]	1.46[b]	0.09
Total PUFA[4]		29.96[a]	26.10[b]	0.51
Total Other		2.36[a]	1.08[b]	0.11
ω6:ω3 ratio[4]		11.37[b]	17.14[a]	0.34

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] Reported as percent of extractable fatty acid content.
[2] n=16.
[3] SEM=Standard error of the mean.
[4] SFA=saturated fatty acids, MUFA= monounsaturated fatty acid, PUFA=polyunsaturated fatty acid, ω6=omega 6 PUFA, ω3=omega 3 PUFA.

Instrumental Texture Measurements

There were interactions between chicken type and part for instrumental measurements evaluating tenderness values for breast and thigh meat from HB, CMAC, and CMWC (Table A-4). Results for Warner-Bratzler (WB) and Allo-Kramer (AK) shear force are shown in Table 5-6. All products were found to be very tender based on the research developed by Lyon and Lyon (1991) where a scale was developed that compared sensory panel tenderness with shear force measurements (Table 2-1). Heritage bred thigh meat was the least tender which could be expected because HB chickens are raised nearly three times longer than commercial chickens, permitting development of a greater amount of connective tissue and potential cross linking within the connective tissue (An et al., 2010).

The WB and AK values found for HB thigh meat were at the tougher end of the very tender category so some customers may note it to be slightly less tender. Similar results were found from Smith et al. (2012) where Label-Rouge-type meat had higher shear measurements than conventional products and Husak et al. (2008) found organic and free-range meat to be less tender than conventional samples. On the other hand, CMWC and CMAC thigh meat was more tender with the lowest WB at 1.48 and 1.49 kgf and the lowest AK values at 2.75 followed by 3.40 kgf/g of sample. No direct correlations can be made between sensory texture analyses and instrumental analyses due to project design.

Table 5-6. Least squares means (LSmeans) interactions for instrumental texture measurements of commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) breast and thigh meat.

	CMAC		CMWC		HB		
Shear Force	**Breast[1]**	**Thigh[1]**	**Breast[1]**	**Thigh[1]**	**Breast[1]**	**Thigh[1]**	**SEM[2]**
Warner Bratzler (kgf)	2.24[b]	1.48[c]	2.28[b]	1.49[c]	2.20[b]	3.47[a]	0.11
Allo-Kramer (kgf/g)	3.88[c]	3.40[d]	3.90[c]	2.75[e]	4.64[b]	7.22[a]	0.17

[abcd] LSmeans within a row with different superscripts differ (P<0.05).
[1] n=5.
[2] SEM=Standard error of the mean.

Sensory Panel

There was chicken type by part interactions for sensory textural attributes (Tables 5-7 and A-4). Main effects for sensory values are shown in Table 5-8. Chicken aroma intensity was not affected (P>0.05) by chicken type or part. All attributes including chicken aroma (8 = Extremely

Intense to 1 = None) myofibrillar tenderness(8=Extremely Tender to 1=Extremely Tough), juiciness (8=Extremely Juicy to 1=Extremely Dry), chicken flavor intensity (8=Extremely Intense to 1=Extremely Bland), connective tissue amount (8=None to 1=Abundant), overall tenderness (8=Extremely Tender to 1=Extremely Tough), and off flavor intensity (8=None to 1=Abundant) were ranked to the nearest 0.5 increment using the respective eight-point scales with higher values being more desirable for all attributes. Off flavor examples included gamey, feathery, rancid, metallic, livery, organy, and bloody.

All of the textural sensory attributes had interaction effects (P<0.05) between chicken type and part with CMAC breast and CMWC breast having higher, more tender myofibrillar tenderness, lower connective tissue amount, and more tender overall. Heritage bred thigh meat had the lowest (P<0.05) tenderness attribute values of 5.79 for myofibrillar tenderness, 5.61 for connective tissue amount, and 5.44 for overall tenderness values although these values were still on the tender side of the scale. In addition, HB thigh had the highest (P<0.05) peak force values for both WB (kgf) and AK (kgf/g sample) at 3.47 kgf and 7.22 kgf/ g of sample, respectively, supporting the sensory panel results (Table 5-7).

Table 5-7. Least squares means (LSmeans) interactions for textural sensory observations of commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) breast and thigh meat.

Attribute	CMAC		CMWC		HB		
	Breast[1]	Thigh[1]	Breast[1]	Thigh[1]	Breast[1]	Thigh[1]	SEM[2]
Myofibrillar Tenderness[3]	7.23[a]	7.02[c]	7.33[a]	7.48[a]	7.09[bc]	5.79[d]	0.10
Connective Tissue Amount[4]	7.80a	7.34[c]	7.87[a]	7.46b[c]	7.71[ab]	5.61[d]	0.11
Overall Tenderness[3]	7.31[a]	6.98[b]	7.41[a]	7.33[a]	7.25[a]	5.44[c]	0.11

[abcd] LSmeans within a row with different superscripts differ (P<0.05).
[1] n=5.
[2] SEM=Standard error of the mean.
[3]Myofibrillar and Overall Tenderness Scale: 8=Extremely Tender, 5=Slightly Tender, 4=Slightly Tough, 1=Extremely Tough.
[4]Connective Tissue Amount: 8=None, 5=Slight, 4=Moderate, 1=Abundant.

There were chicken part main effects for juiciness, chicken flavor intensity, and off flavor with thigh meat being more juicy (P<0.05) and having a higher (P<0.05) chicken flavor intensity than breast meat with breast meat being on the dry side of the scale. Thigh meat was expected to be perceived as more juicy and potential for more intense fatty/chicken intensity flavor as it contained a substantially higher percentage of fat than breast meat. Thigh meat contained less

(P<0.05) saturated fatty acid (SFA), more (P<0.05) monounsaturated fatty acid (MUFA), but had a significantly less desirable (P<0.05) ω6:ω3 fatty acid ratio than breast meat.

Several prior studies looked at the effect of genotype and environment on sensory attributes (Farmer et al., 1997; Fanatico et al. 2007a; Husak et al., 2008; Smith et al., 2012). No differences were found in any sensory attributes between breast meat of conventional and Label Rouge-type breeds. However, thigh meat of alternative broilers (Label Rouge) had higher, more optimal scores for appearance, tenderness, juiciness, and likeness of appearance (Smith et al., 2012). On the other hand, Farmer et al. (1997) found that Label Rouge type broilers had breast meat that was more tender and moist as determined by a trained sensory panel. Organic and free-range thigh meat was found to be less tender and more chewy by a sensory panel with products purchased from a retail grocery store (Husak et al., 2008). No differences were detected between the breast meat from organic, free-range, and conventional broilers.

Breast meat from chickens raised with outdoor access was found to be more cohesive as determined by descriptive panel (Fanatico et al., 2007a); however, there were no differences for most basic tastes. It was found that fast growing birds, with or without outdoor access, had a saltier taste when compared with slow growing broiler meat. A consumer panel was also completed and no significant differences were found for overall liking, appearance, texture, and flavor between slow and fast growing broiler meat with or without access to the outdoors for breast or thigh meat. In conclusion, descriptive and trained sensory panels are able to distinguish differences between convention and alternatively grown chicken meat for texture and flavor attributes especially within thigh meat. However, these differences have yet to be distinguished by consumer panels.

Table 5-8. Least squares means (LSmeans) main effects for chicken aroma, juiciness, chicken flavor intensity, and off-flavor intensity of commercial air chilled (CMAC), commercial water chilled (CMWC), and heritage bred (HB) chicken breast and thigh meat.

	Chicken Type				Chicken Part		
	CMAC[1]	CMWC[1]	HB[1]	SEM[2]	Breast[1]	Thigh[1]	SEM[2]
Attribute							
Chicken Aroma	5.09	5.20	5.15	0.15	5.17	5.13	0.14
Juiciness[3]	5.07	5.16	4.99	0.11	4.85[b]	5.29[a]	0.092
Chicken Flavor[4]	4.91	4.89	4.83	0.11	4.66[b]	5.10[a]	0.096
Off Flavor[5]	7.61[a]	7.50[a]	7.07[b]	0.086	7.64[a]	7.15[b]	0.07

[ab] LSmeans within a row with different superscripts differ (P<0.05).
[1] n=5.
[2] SEM=Standard error of the mean.
[3]Juiciness: 8=Extremely Juicy, 5=Slightly Juicy, 4=Slightly Dry, 1=Extremely Dry.
[4] Chicken Flavor: 8=Extremely Intense, 5=Slightly Intense, 4=Slightly Bland, 1=Extremely Bland.
[5]Off Flavor Intensity: 8=None, 5=Slight, 4=Moderate, 1=Abundant.

Chapter 6 - Conclusions

Some poultry producers are beginning to use alternative production methods such as free-range or Label Rouge which decrease feed efficiencies due to increased activity from access to the outdoors/pasture and thus require the growth period to be longer in an effort to add value to their products and be more environmentally conscious as perceived by consumers. This study compared nutritional, sensory, and quality attributes in heritage bred (HB) chickens and commercial (CM) broilers purchased from retail vendors. Heritage bred chicken meat had an increased protein content and decreased fat content with a more optimal (lower) ω6:ω3 ratio which could provide health advantages over conventional broilers. These health advantages were small, less than available in fish, but an alternative for consumers whom won't consume fish.

Differences between the breeds were seen in meat color that could be distinguished by the human eye; however, preferences within poultry meat and skin color depend on the geographical region and personal background so either breed would be considered acceptable. Commercial broiler skin was lighter and more red but similar to HB skin in yellowness. In addition, breast meat was always lighter and less red than thigh meat, and CM meat was lighter in color than the similar part in HB. Finally, differences were noted in sensory measurements from a trained panel especially with HB thigh meat being tougher and having some noted off flavors, but all response values were still in the acceptable range. Also, thigh meat was juicier and had a stronger chicken flavor intensity than breast meat. Differences between the heritage, slow-growing, and commercial, fast growing broilers were minor, but value could be added to the HB especially if producers look at additional value adding techniques such as merchandising breast, legs, thighs, or half of a chicken. The consumer will have to weigh the price difference against personal beliefs and diet plan when deciding which to purchase, but additional processing of the fresh chicken may validate the additional cost associated with the heritage bred chicken.

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Appendix A - Probability Value Tables

Table A-1. Probability values for ANOVA analysis of heritage and commercial meat with skin for color values, yields, and proximate analysis.

	Type[3]	Part[4]	Type* Part
Skin Color[1]			
L*	<0.0001	0.3640	0.0056
a*	0.0002	0.1029	.2836
b*	0.3874	0.0016	0.0392
Saturation Index	0.1496	0.0032	0.0573
Meat Color[1]			
L*	<.0001	<.0001	0.0221
a*	0.4316	<.0001	0.0808
b*	0.0001	<.0001	0.3360
Saturation Index	<.0001	0.0002	0.0279
pH	<.0001	<.0001	<.0001
Yields			
Whole Bird Weight	<.0001	-	-
Breast Weight	<.0001	-	-
Thigh Bone-in Weight	<.0001	-	-
Breast Yield	<.0001	-	-
Thigh Yield	<.0001	-	-
Thigh Waste Yield	<.0001	-	-
Proximate Analysis[2]			
Moisture	0.3091	<.0001	0.2250
Protein	<.0001	<.0001	0.0972
Fat	0.0395	<.0001	0.0268

[1] L* = lightness, a*=redness, b*=yellowness, and saturation index=$[(a*2)+(b*2)]^{1/2}$.
[2] Reported as percent of sample.
[3]Type = heritage bred versus commercial broilers.
[4]Part= thigh versus breast.

Table A-2. Probability values for ANOVA analysis of heritage and commercial meat with skin for fatty acid composition.

	Type[2]	Part[3]	Type* Part
C16:0	<0.0001	0.0001	<0.0001
C17:0	<0.0001	0.0011	0.1045
C18:0	<0.0001	<0.0001	0.7234
C20:0	<0.0001	0.7039	0.0361
Total SFA[1]	<0.0001	<0.0001	<0.0001
C16:1	<0.0001	<0.0001	0.0010
C18:1n9	<0.0001	<0.0001	0.0002
C18:1n7	0.0001	<0.0001	0.0007
C20:1	0.0018	0.0021	0.0348
Total MUFA[1]	<0.0001	<0.0001	0.1103
C18:2ω6	<0.001	<0.0001	<0.0001
C18:3ω6	0.0375	0.0014	0.6497
C20:3ω6	<0.0001	<0.0001	0.0113
C20:4ω6	0.2108	0.1234	0.2733
Total ω6 PUFA[1]	<0.0001	0.0001	<0.0001
C18:3ω3	<0.0001	0.1414	0.0003
C20:5ω3	0.0189	0.0010	0.2123
C22:5ω3	0.8704	<0.0001	0.7243
C22:6ω3	<0.0001	<0.0001	0.0008
Total ω3 PUFA[1]	<0.0001	<0.0001	0.6818
Total PUFA[1]	<0.0001	0.2587	<0.0001
Total Other	<0.0001	<0.0001	0.0202
ω6:ω3Ratio	<0.0001	<0.0001	<0.0001

[1] SFA=saturated fatty acids, MUFA= monosaturated fatty acid, PUFA=polyunsaturated fatty acid, ω6=omega 6 PUFA, ω3=omega 3 PUFA.
[2]Type = heritage bred versus commercial broilers.
[3]Part= thigh versus breast.

Table A-3. Probability values for ANOVA analysis of heritage, commercial air chilled, commercial water chilled breast and thigh meat for fatty acid composition.

	Type[2]	Part[3]	Type* Part
C14:0	0.4006	0.0002	0.7177
C16:0	0.5402	0.0200	0.0325
C17:0	0.0151	0.0127	0.5080
C18:0	0.0125	<0.0001	0.4754
SFA[1]	0.0014	<0.0001	0.0292
C16:1	0.0102	<0.0001	0.5055
C18:1	0.003	<0.0001	0.4685
C20:1	0.0797	0.5284	0.0030
MUFA[1]	0.0003	<0.0001	0.5612
C18:2ω6	0.0002	<0.0001	0.0091
C18:3ω6	0.8892	0.0067	0.6548
C20:3ω6	0.0619	<0.0001	0.0705
C20:4ω6	0.0156	<0.001	0.3665
Total ω6 PUFA[1]	<0.0001	0.0002	0.1982
C18:3ω3	0.0061	<0.0001	0.4356
C20:5ω3	0.0150	<0.0001	0.0173
C22:5ω3	0.0250	<0.0001	0.7172
C22:6ω3	0.0061	<0.0001	0.1537
Total ω3 PUFA[1]	0.0019	<0.0001	0.5654
Total PUFA[1]	<0.0001	<0.0001	0.4214
Total Other	0.4982	<0.0001	0.1712
ω6:ω3Ratio	0.0131	<0.0001	0.7848

[1] SFA=saturated fatty acids, MUFA= monosaturated fatty acid, PUFA=polyunsaturated fatty acid, ω6=omega 6 PUFA, ω3=omega 3 PUFA.
[2]Type = heritage bred versus commercial broilers.
[3]Part= thigh versus breast.

Table A-4. Probability values for ANOVA analysis of heritage, commercial air chilled, commercial water chilled breast and thigh meat for quality measurements.

Quality Measurements	Type[7]	Part[8]	Type*Part
pH	0.0063	<0.0001	0.1849
Yields			
Raw Yields	0.0858	<0.0001	0.0694
Cook Loss	0.4020	0.0945	0.6371
Proximate Analysis			
Moisture	0.3085	<0.0001	0.2793
Fat	0.0509	<0.0001	0.0991
Instrumental			
Warner Bratzler (kgf)	<0.0001	0.2405	<0.0001
Allo-Kramer (kgf/g)	<0.0001	0.0225	<0.0001
Sensory			
Chicken Aroma[1]	0.7432	0.7132	0.9502
Myofibrillar[2]	<0.0001	<0.0001	<0.0001
Juiciness[3]	0.4921	0.0011	0.6637
Chicken Flavor[4]	0.8064	0.0014	0.7193
Connective Tissue[5]	<0.0001	<0.0001	<0.0001
Overall Tenderness[2]	<0.0001	<0.0001	<0.0001
Off Flavor[6]	0.0050	0.0003	0.2681

[1]Chicken Aroma: 8=Extremely Intense, 5=Slightly Intense, 4=Slight, 1=None
[2] Myofibrillar and Overall Tenderness Scale: 8=Extremely Tender, 5=Slightly Tender, 4=Slightly Tough, 1=Extremely Tough.
[3] Juiciness: 8=Extremely Juicy, 5=Slightly Juicy, 4=Slightly Dry, 1=Extremely Dry.
[4] Chicken Flavor: 8=Extremely Intense, 5=Slightly Intense, 4=Slightly Bland, 1=Extremely Bland.
[5]Connective Tissue Amount: 8=None, 5=Slight, 4=Moderate, 1=Abundant.
[6]Off Flavor Intensity: 8=None, 5=Slight, 4=Moderate, 1=Abundant.
[7]Type = heritage bred versus commercial broilers.
[8]Part= thigh versus breast.

Appendix B - Sensory Panelist Ballot

Kansas State University - Sensory Panel Evaluation

Study:_____

Name: Date: Time:

SAMPLE	CHICKEN AROMA	MYOFIBRILLAR TENDERNESS	JUICINESS	CHICKEN FLAVOR INTENSITY	CONNECTIVE TISSUE AMOUNT	OVERALL TENDERNESS	OFF FLAVOR INTENSITY	OFF FLAVOR DESCRIPTOR
WU								
A								
B								
C								
D								
E								
F								
	8. Extremely Intense	8. Extremely tender	8. Extremely juicy	8. Extremely intense	8. None	8. Extremely tender	8. None	**Off Flavor Examples**
	7. Very Intense	7.Very tender	7. Very juicy	7. Very intense	7. Practically none	7.Very tender	7. Practically none	**Gamey**
	6. Moderately Intense	6. Moderately tender	6. Moderately juicy	6. Moderately intense	6. Traces	6. Moderately tender	6. Traces	**Feathery**
	5. Slightly Intense	5. Slightly tender	5. Slightly juicy	5. Slightly intense	5. Slight	5. Slightly tender	5. Slight	**Rancid**
	4. Slight	4. Slightly tough	4. Slightly dry	4. Slightly bland	4. Moderate	4. Slightly tough	4. Moderate	**Metallic**
	3. Traces	3. Moderately tough	3. Moderately dry	3. Moderately bland	3. Slightly abundant	3. Moderately tough	3. Slightly abundant	**Livery/ Organy**
	2. Practically None	2. Very tough	2. Very dry	2. Very bland	2. Moderately abundant	2. Very tough	2. Moderately abundant	**Bloody**
	1. None	1. Extremely tough	1. Extremely dry	1. Extremely bland	1. Abundant	1. Extremely tough	1. Abundant	**Ect..**

Appendix C - Statistical Codes

Statistical Code in SAS for all measurements within Chapter 4.

Instrumental Color Analysis for both Meat and Skin

```
data skin;
input Bird Trt$  Part$ L     a     b     ratio angle index;
      Data entered here;

proc mixed;
title 'skin';
class bird trt part;
model L = trt part trt*part/ddfm = satterth;
random bird(trt);
LSmeans trt part trt*part/pdiff;
      run;
```

Proximate Analysis for Meat with Skin

```
data Proximate;
input Bird Trt$  Part$ Moisture   Protein    Crude_fat  Total_Fat_acid
      O3_Fat_acid     O6_Fat_acid     O6_O3;
      datalines;

proc mixed;
title 'proximate';
class bird trt part;
model Moisture = trt part trt*part/ddfm = satterth;
random bird(trt);
LSmeans trt part trt*part/pdiff;
      run;
```

Yield Analyses

```
data yields;
input Bird Trt$  Part$ pH    Whole_Wt   Breast_wt  Thigh_bone_in_wt
      Breast_yield    Thigh_yield     Thigh_Waste;
      datalines;


proc mixed;
title 'yields';
class bird trt part;
model pH = trt part trt*part/ddfm = satterth;
random bird(trt);
LSmeans trt part trt*part/pdiff;
      run;
```

Fatty Acid Composition Analyses

```
data FA;
input Bird Trt$  Part$ C16_0 C17_0 C18_0 C20_0 SFA   C16_1 C18_1n9c
      C18_1n7    C20_1 MUFA  C18_2n6    C18_3n6    C20_3n6    C20_4n6
      n6_PUFA    C18_3n3    C20_5n3    C22_5n3    C22_6n3    n3_PUFA
      n6_n3 Total_PUFA Total_Other;
      datalines;


proc mixed;
title 'FA';
class bird trt part;
model C16_0 = trt part trt*part/ddfm = satterth;
random bird(trt);
LSmeans trt part trt*part/pdiff;
      run;
```

Statistical Code in SAS for all measurements within Chapter 5.

pH Analyses

```
data S_pH;
input Rep Type$ Part$ pH;
datalines;

proc mixed;
title 'S_pH';
class Rep Type Part;
model pH = Type part Type*part/ddfm = satterth;
random rep rep*Type;
LSmeans Type part Type*part/pdiff;
run;
```

Proximate Analyses

```
data S_MacroNutrients;
input Rep Type$ Part$ Moisture Fat Protein;
datalines;

proc mixed;
title 'S_MacroNutrients';
class Rep Type Part;
model Moisture = Type part Type*part/ddfm = satterth;
random rep rep*Type;
LSmeans Type part Type*part/pdiff;
run;
```

Fatty Acid Composition Analyses

```
data S_Fatty_Acids;
```

```
input Rep       Type$   Part$   C14_0   C16_0   C17_0   C18_0   C21_0   SFA
        C16_1   C18_1   C20_1   MUFA    C18_2n6 C18_3n6 C20_2n6 C20_4n6 n6PUFA
        ALA     EPA     DPA     DHA     n3PUFA  Total_PUFA      Other   n6_n3;
datalines;


proc mixed;
title 'S_Fatty_Acids';
class Rep Type Part;
model C14_0 = Type part Type*part/ddfm = satterth;
random rep rep*Type;
LSmeans Type part Type*part/pdiff;
run;
```

Instrumental Texture Analyses

```
data S_Instrumental;
input Rep       Type$   Part$   WB      LK;
datalines;


proc mixed;
title 'S_Instrumental';
class Rep Type Part;
model WB = Type part Type*part/ddfm = satterth;
random rep rep*Type;
LSmeans Type part Type*part/pdiff;
run;
```

Sensory Panel Analyses

```
data S_Sensory;
input Rep       Type$   Part$   Chicken_Aroma   Myofibrillar    Juiciness
Chicken_Flavor CT       Tenderness      OffFlavor;
datalines;

proc mixed;
title 'S_Sensory';
class Rep Type Part;
model Chicken_Aroma = Type part Type*part/ddfm = satterth;
random rep rep*Type;
LSmeans Type part Type*part/pdiff;
run;
```